# PROSES KORESPONDENSI

AGRONOMIC CHARACTERS AND QUALITY OF FRUIT OF SOME
CULTIVARS SALAK GULAPASIR PLANTED IN DIFFERENT AGRO-ECOSYSTEMS IN BALI

1. Sebelum Terbit Di Jurnal JJBS, Artikel Ini Diterima Sebagai Presenter pada tanggal 4 Juli 2021, Pada Intenational Conference on Bio-energy and Environmentally Sustainable Agriculture Technolocy July, 28-29th 2021, at Rayz Hotel, University of Muhammadiyah Malang, Indonesia (bukti Letter of Acceptance terlampir dan draft artikel terlampir).
2. Sambil menunggu publikasi ((apakah akan terbit di Prosiding atau ke jurnal ) maka pada tanggal 22 Oktober 2022 ada surat pemberitahuan dari panitia No :003/ICON-BEAT/X/2022 bahwa judul artikel di atas Rekomendasi **Publish di Jordan Journal of Biological Sciences (JJBS), Terindek Scopus Q3.** Bukti surat terlampir.
3. Melengkapi dokumen antara lain a) Draft jurnal seperti tempelate JJBS, b) melengkapi surat pernyataan dari panitia, c) Menambahkan minimal satu co author dari luar negeri, d) Mengusulkan kandidat reviewer di utamakan dari luar negeri sebanyak 6 orang.(Terlampir)
4. Proses perbaikan/revisi artikel sebelum di submit ke JJBBS Nopember-Akhir Desember 2022 (terlampir)
5. Artikel di submit Januari 2023 dan Proses Revisi sampai awal Maret 2023.(bukti kegiatan terlampir)
6. Artikel dinyatakan diterima oleh JJBS pada tanggal 4 April 2023 (terlampir).
7. Pemberitahuan Tahap Galley proof tanggal 5 Mei 2023 dan prose perbaikan dikirim 17 Mei 2023 (Terlampir).
8. Terbit pada JJBS Volume 16, Number 2, bulan June 2023: Pages 207 – 221 https://doi.org/10.54319/jjbs/160205 (terlampir)

**Tahap 1: Intenational Conference**

# 2nd ICON BEAT 2021

Intenational Conference on Bio-energy and Environmentally Sustainable Agriculture Technolocy
July, 28-29th 2021, at Rayz Hotel, University of Muhammadiyah Malang, Indonesia

Juli 4th, 2021

## Letter of Acceptance

Dear Authors : I Ketut Sumantra and I Ketut Widnyana

We are pleased to inform you that your fullpaper (IC2-001, Oral Presentation), entitled:

**AGRONOMIC CHARACTERS AND QUALITY OF FRUIT OF SOMECULTIVARS SALAK GULAPASIR PLANTED IN DIFFERENT AGRO- ECOSYSTEMS IN BALI**

has been accepted to be presented at 2nd ICON BEAT 2021 conference to be held on July, 28-29th2021 in Malang, Indonesia.

We cordially invite you to attend our conference and present your research described in thefullpaper.

About publication fees, it must be paid with registration code. E.g. if your registration number is IC2-001, you should be paid IDR 2.500.001 for publication fee. All bank charges and commissions must be paid by the participants. Please inform your payment about this, **only through** the website (http://icon-beat.umm.ac.id/ click registration, resubmitted is allowed).

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Best regards,

**Dr. Ir. Damat, MP., IPM.**
2nd ICON BEAT 2021 Chairperson

Artikel yang diseminar

# AGRONOMIC CHARACTERS AND QUALITY OF FRUIT OF SOME CULTIVARS SALAK GULAPASIR PLANTED IN DIFFERENT AGRO-ECOSYSTEMS IN BALI

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**Abstract.** Salak Gulapasir (*Salacca zalacca* var. Amboinensis) is a tropical fruit preferred by consumers due to the specific fruit flesh taste. The research objective was to obtain superior of some Salak Gulapasir cultivars both in production and fruit quality. The research using a Randomized Block Design with three replications. The non-independent variable was the three cultivars of Salak Gulapasir: Nangka, Nenas, Gondok, and six sites, namely Karangasem (low, medium and highlands) and Tabanan (low, medium, and highlands). Observations were made on the agronomic characters and fruit quality. Data were analyzed using variance analysis, and if the planting location and cultivars show a difference, then it is followed by the LSD test at the 5% level. The results showed that different cultivars caused different fruit weights, fruit bunches, TSS, and the total acid ratio. In Tabanan (in the low, medium, and highlands), the three cultivars showed lower fruit weight and fruit quality than the salak originating from Karangasem. The Nangka cultivar in Karangasem showed higher fruit weight, vitamin C content, and TSS/total acid ratio, while the Nanas salak cultivar showed the highest number of fruits bunches$^{-1}$ in six locations.

**Keywords:** Salak, agronomy, fruit quality, agro-ecosystem.

## 1 Introduction

Balinese salak cultivar (*Salacca zalacca* var. Amboinensis) is a unique tropical palm that bears fruit, botanically known as drupes. The skin of the salak fruit is scaly like snake skin.The nutrition of salak fruit is comparable to well-known fruits such as mango, and apple, because of the rich antioxidants, phenolics, vitamins, and minerals they contain [1]. Despite its incredible food and medicinal benefits, salak fruit is still underutilized and unknown globally. So that the market can accept the Balinese salak fruit, it is necessary to select superior salak to meet market demand and fulfill community nutrition. Salak Bali is quite a lot, based on the shape, aroma, taste, and skin color of the location where the plants are cultivated [2]. Under the Decree of the Minister of Agriculture of the Republic of Indonesia in 1994, Balinese zalacca was grouped into two superior zalacca: Salak Bali [3] and Salak Gulapasir [4]. From the second, the salak Gulapasir is the most superior zalacca because of its sweet fruit taste; even though the age of the fruit is still young, thick fruit flesh and seeds are not attached to the fruit flesh [5, 6]. The nature of this fruit is ideal for meeting market demands for both the domestic and export markets. Salak Gulapasir is monoecious, so that crossing does not need human help [7], and can quickly develop using seeds [8]. Another advantage of zalacca plants in Indonesia compared to other fruits is harvest fruit 2-3 times a year if management is good [9]. The expansion of Gulapasir salak planting causes variations in phenotypic diversity. You can find 2-3 types of salak plants with a marker, fruit shape, aroma, flesh color, and fruit weight [10]. The results of this study mean that the emergence of plant diversity due to plant propagation is done by seeds so that new varieties of salak Gulapasir appear, as reported by Sumantra and Martiningsih (2016). Based on the marker that can be used as a differentiator, salak farmers give it the name of Salak Gulapasir Nenas, Gondok, and Nangka. The three cultivars have not yet identified their advantages in meeting market needs in line with the results of research [11] that each cultivar of salak has adaptation to an elevation closely related to plant tolerance to temperature. The performance and produce are influenced by environmental factors, particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status, and growth hormone [12; 13]. Climate affects almost all aspects of farming activities. The need for accurate climate information is getting more strategic to support agricultural activities. Therefore, one way of handling salak quality is by undertaking severe studies for factors such as land and climate and adjusting agricultural patterns according to local climate conditions. The success of each species to occupy the environment of an area is influenced by its ability to adapt optimally to all physical environmental factors (temperature, light, soil structure, humidity), biotic factors (interaction between species, competition, parasitism), and chemical factors including the availability of water, oxygen: pH, and nutrients [14]. Moreover, a broad genetic variability would lead to wide phenotypic variability due to the effect of genetic-environment interaction [15]. The research objective was to obtain superior Salak Gulapasir cultivars in production and fruit quality in six different locations in Bali.

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## 2 Material and methods

The study was conducted in six different locations, three in Karangasem and three in the district in Tabanan. Locations in Karangasem are lowlands (<560 m asl) which include several places, namely Telaga, Dukuh, and Karanganyar. Karangasem in the moderate plains (560-650 m asl) has several areas, namely Kecing and Kutabali. c(Fig. 1). The research location is in Tabanan in the lowlands (<560 m asl), including Wanagiri, Sari Buana, and Mundeh Kauh. Tabanan in the medium lands (560-650 m asl) includes several places, namely Pajahan, Kebon Jero, and Blatungan. Tabanan in the highlands (> 650 m asl), namely Munduk Temu, Pempatan, and Batungsel. (Fig. 1).

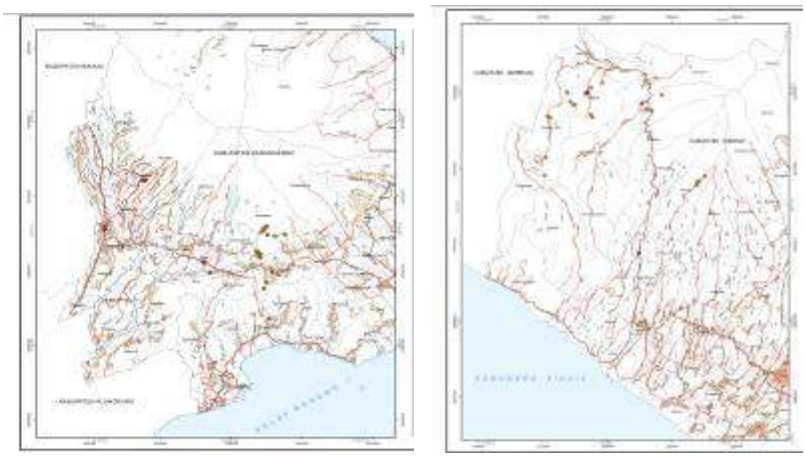

Fig 1. Research map and sampling point in Karangasem (Left) and Tabanan (Right)

The salak Gulapasir plant was used with consistent growth, has been fruitful, and has an average age of 8 years. The study used a Randomized Block Design (RCBD) are repeated at several locations with the model [16] as follows:

$$Yjk = u + L\,i + \delta\,ik + Pj + (LP)\,ij + \varepsilon\,ijk$$

Where:

Yijk = The observation value of the treatment (j) in the group (k), which is repeated at the location (i).
u = the actual average value
Li = additive effect from location i
δ ik = the error effect in group k at location i
Pj = additive effect of the next treatment
(LP) ij = the effect of treatmen (j) at the location (i)
Ɛ ijk = the effect of error from the treatment (j) in the group (k) which was carried out at the location (i).

As the non-independent variable was the three cultivars of Salak Gulapasir, namely: Nangka, Nenas, Gondok, and six sites, namely Karangasem (lowlands, medium, and highlands) and Tabanan (lowlands, medium, and highlands). Repetition was carried out three times with the number of samples plants in each location, and cultivars were seven plants.

Gulapasir zalacca plant used as the object of research was a plant that has been fruitful, with the uniform on morphological, age of plants and cultivation action. The intentional practice is that the plant only receives treatment in the midrib, tillers, and weed cleaning. In this study, the plants were not fertilized. The provision of water was only from rainfall following the habits applied by zalacca farmers. The sample plant maintains by trimming unproductive leaf midribs and removing young shoots. Observations and measurements of agronomic and quality performance were (1) fruit weight$^{-1}$, and the number of fruits bunch$^{-1}$; (2) Quality of fruit included parts of edible fruit and thick fruit flesh; (3) sugar content (TSS), acidity, sugar-acid ratio, and levels of vitamin C. The data were analyzed using ANOVA; if ANOVA is significant, then analysis continued using the least significant difference (LSD) at the level of 5%.

## 3 Results and discussion

The results of the variance analysis showed that the interaction between planting locations and cultivars of salak were affected by the weight of fruit tree$^{-1}$, fruit weight$^{-1}$, the number of fruit per bunch, ratio of sugar content/total acid and vitamin C content (Table 1).

Table 1. Recapitulation of the effects of cultivars and growing locations on several agro-ecosystems.

| No. | Character agronomic and fruits quality | Planting location | Cultivars | Cultivars x Location |
|---|---|---|---|---|
| 1 | Thick fruit flesh | ** | ** | NS. |
| 2 | Number of fruit bunches $^{-1}$ | ** | ** | * |
| 3 | Fruit tree weight $^{-1}$ | ** | ** | * |
| 4 | Fruit weight $^{-1}$ | ** | ** | * |
| 5 | TSS ratio and total acid | ** | ** | ** |
| 6 | Vitamin C | Ns. | Ns. | * |
| 7 | Tanin | Ns. | Ns. | Ns. |

Notes: *) significant P <0.05, **) very significant P <0.01 and Ns) not significantly different P> 0.05

The differences in salak cultivars on the fruit$^{-1}$ and fruit weight tree$^{-1}$ in each location different. In Tabanan both, in the low, medium, and highlands, all three cultivars show fruit weight tree$^{-1}$ and fruit weight fruit$^{-1}$ lower than the weight of fruit from Karangasem. In line with the results of this study, several researchers stated that environmental factors that affect fruit yield and quality could come from the level of altitude [17], water content, and soil nutrients [18]. Salak Nangka cultivar shows the highest fruit weight (1.62 kg tree$^{-1}$), while the highest yield of Gondok and Nenas cultivars is obtained in Karangasem <550 m. In the two locations (Tabanan and Karangasem), increasing the area altitude of growth above 550 m and 570 m asl caused fruit weight fruit$^{-1}$ and fruit weight tree$^{-1}$ to decrease in all three cultivars (Table 2). The height of the place increases, causing the weight of the fruit to fall. The increase in altitude causes the rainfall to rise, but the air temperature decreases [19]. High rainfall affects the percentage of pollinated flowers [20]. In addition, the wet flowers easily attach to the fungus, and the flowers become rotten [10].

Table 2. Fruit weight of Nangka, Gondok, and Nenas cultivars (CV) in six locations

| Location (asl) | CV. Nangka | | CV. Gondok | | CV. Nenas | | Average location | |
|---|---|---|---|---|---|---|---|---|
| | Fruit$^{1}$ (g) | Tree$^{-1}$ (kg) | Fruit-$^{1}$ (g) | Tree$^{-1}$ (kg) | Fruit$^{-1}$ (g) | Tree$^{-1}$ (kg) | Frui$^{-1}$ (g) | Tree$^{-1}$ (kg) |
| Lowlands Tabanan (< 550 m) | 45.32 c a | 1.19 d a | 40.14 b b | 1.11 b a | 39.0 ab b | 1.14 b a | 41.49 | 1.14 |
| Medium Tabanan (550-650m) | 48.56 bc a | 1.29cd a | 38.67 b b | 1.09 b b | 37.79 b b | 1.13 b b | 41.67 | 1.17 |
| Highlands Tabanan (>650 m) | 38.22 d a | 1.03 e a | 32.95 c b | 0.93 c a | 32.12 c b | 0.94 c a | 34.43 | 0.97 |
| Lowland Karangasem (<550m) | 55.84 a a | 1.48 b a | 44.22 a b | 1.27 a b | 41.80 a b | 1.36 a ab | 47.29 | 1.37 |
| Medium Karangasem (550- 650m) | 59.43 a a | 1.62 a a | 38.20 b b | 1.16 ab b | 36.57 b b | 1.18 b b | 44.73 | 1.32 |
| Highlands Karangasem (>650m) | 49.40 b a | 1.34 c a | 36.20 bc b | 1.07 b b | 37.10 b b | 1.11 b b | 40.90 | 1.17 |
| Average cultivar | 49.46 | 1.33 | 38.40 | 1.11 | 37.40 | 1.14 | - | - |

Notes: The number followed by the same letter in the row, column, and the same parameter shows a non-significant difference in LSD 5%.

The interaction between cultivars and altitude significantly affected TSS/total acid and vitamin C ratio. The three cultivars are grown in Tabanan (low, mid, and highland) showed a lower TSS/total acid ratio. The fruit flavor planted in three locations in Tabanan is sourer than the three locations in Karangasem. Sugar content is greatly affected by the geographical. The geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity, and rainfall [15]. Table 4 also shows that the increase in height from 550 m to 700 m asl in Tabanan and addition in altitude from550 to 650 m asl in Karangasem causes the TSS/total acid ratio to decrease in all three cultivars, and the lowest TSS/acid value occurs in cultivars Nenas in all locations. Each salak cultivar has an adaptation to an elevation closely related to plant tolerance to temperature [10]. Many factors influence fruit quality, but the most dominant are climate factors, especially temperature and rainfall. High rainfall and low air temperature during the fruit ripening phase can cause the dissolved solids in the fruit to become watery so that the TSS value is low [21].

Zalacca fruits from three different cultivars grown in low lands in Karangasem (Telaga and Kecing) showed the highest vitamin C content and were significantly different from the three cultivars when planted in other locations. In both areas, a high increase in place caused vitamin C to decrease, and cultivars of Nangka and Gondok showed higher levels of vitamin C (Table 4).

Table 4. TSS / total acid ratio and levels of vitamin C of Nangka, Gondok, and Nenas cultivars in six locations.

| Location (asl) | Nangka | | Gondok | | Nenas | | Average location | |
|---|---|---|---|---|---|---|---|---|
| | TSS / T. acid | Vit. C (mg /100g) | TSS / T. acid | Vit. C (mg / 100g) | TSS/ T.acid | Vit. C (mg / 100g) | TSS / T.acid | Vit. C (mg / 100g) |
| Lowlands Tabanan (< 550 m) | 56.20ab A | 27.50 ab A | 34.88c A | 25.50 bc A | 31.50b B | 26.71 a A | 40.86 | 26.57 |
| Medium Tabanan (550-650m) | 59.18a A | 25.45 bc A | 34.80c B | 25.75 bc A | 30.44b B | 25.88 ab A | 41.48 | 25.69 |
| Highlands Tabanan (>650 m) | 37.89d A | 22.52 d A | 30.24c A | 23.34 c A | 26.13b B | 23.65 bc A | 31.42 | 23.17 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lowland Karangasem (<550m) | 51.41bc A | 27.74 ab B | 51.28b A | 30.31 a A | 53.73a A | 24.42 abc C | 52.14 | 27.49 |
| Medium Karangasem (550-650m) | 53.52abc a | 29.61 a a | 58.44a a | 27.63 b A | 52.63a a | 22.82 c B | 54.86 | 26.68 |
| Highlands Karangasem (>650m) | 47.76c a | 24.25 cd a | 53.04a a | 25.07 c A | 47.60a a | 25.16 abc A | 49.46 | 24.83 |
| Average Cultivar | 50.99 | 26.18 | 43.78 | 26.27 | 40.34 | 24.77 | - | - |

Note: The number followed by the same letter in the row, column, and the same parameter shows a non-significant difference in LSD 5%.

There was no interaction between cultivar and altitude to the flesh thickness, edible fruit portion, and fruit sugar content. The single treatment of salak cultivars, Nangka cultivars, showed fruit quality, including TSS, edible parts of the fruit, and higher flesh thickness (Table 5). Salak grown in Karangasem both from the lowlands and the middle lands produces fruit thickness, and the edible portion of fruits is higher than plants in the highlands. This study indicates that the ideal growing place for salak plants is between 450-650 m asl. This study is in line with several previous studies which explained that altitude affects the flowering process and fruit enlargement [15].

Table 5. The effect of a single factor of cultivars and planting location on TSS, the portion of edible flesh, and thickness of salak fruit

| Cultivar | TSS ($^{o}$Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| Nangka | 16.59a | 72.50a | 0.63a |
| Gondok | 16.42a | 70.66ab | 0.59b |
| Nenas | 15.64b | 69.22b | 0.52c |
| LSD 5% | 0.60 | 3. 1 | 0.039 |
| Plant locations (asl) | TSS (◦ Brix) | Edible portion(%) | Meat thickness (cm) |
| Lowlands Tabanan (< 550 m) | 16.28a | 73.13a | 0.54c |
| Medium Tabanan (550-650m) | 16.27a | 69.89a | 0.58bc |
| Highlands Tabanan (>650 m) | 16.14a | 63.87b | 0.49d |
| Lowland Karangasem (<550m) | 16.81a | 73.15a | 0.61b |
| Medium Karangasem(550-650m) | 16.11a | 72.29a | 0.66a |
| Highlands Karangasem (>650m) | 15.69 | 72.44a | 0.61b |
| LSD 5% | ns. | 3.85 | 0.04 |

Notes: The number followed by the same letter in the same column shows a non-significant difference in LSD 5%.

## 4 Conclusion

Different cultivars caused different fruit weights, fruit bunches, and the TSS/total acid ratio at various locations. The three cultivars showed lower fruit weight and fruit quality in Tabanan (low, medium, and highlands) than the salak originating from Karangasem. The Nangka cultivar in Karangasem showed higher fruit weight, vitamin C content, and TSS/total acid ratio, while the Nanas salak cultivar showed the highest number of fruits bunches$^{-1}$ in six locations. Jackfruit cultivars are very suitable to be planted at an altitude of 450 m-570 m above sea level. In contrast, the Pineapple and Gondok cultivars are developed naturally at 450 m above sea level.

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Tahap 2. Surat rekomendasi untuk diterbitkan di JJBS dan kelengpan lainnya

# 2nd ICON BEAT 2021

**Intenational Conference on Bio-energy and Environmentally Sustainable Agriculture Technolocy**
**University of Muhammadiyah Malang, Indonesia**

Nomor : 003/ICON-BEAT/X/2022
Lamp. :
Perihal : **Rekomendasi Publish di Jordan Journal of Biological Sciences (JJBS), Terindek Scopus Q2**

Kepada Yth
1. Bapak Fefria Tanbar
2. Ibu Meiri Triani
3. Bapak I Ketut Sumantra

Assalammu'alaikum wr.wb.

Bersama ini disampaikan bahwa artikel Bapak Ibu terpilih untuk publish di **Jordan Jurnal of Biological Sciences (JJBS),** ISSN 1995-6673**.** Sejak awal tahun 2022 ini, jurnal tersebut sudah naik kelas dari terindek Scopus Q3 ke Q2, dengan SJR=0,29.

Untuk itu disampaikan beberapa hal sebagai berikut:

1. Bapak ibu dimohon mengisi surat pernyataan sebagaimana terlampir dan mengirim kembali ke pak Roy: hendroko@umm.ac.id dan cc ke: damatumm@gmail.com, paling lambat hari **Rabu, tanggal 26 Oktober 2022**.
2. Merevisi artikel yang sudah dikirim dengan ketentuan sebagai berikut:
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   b. Menambahkan minimal satu co author dari luar negeri.
   c. Mengusulkan kandidat reviewer dari luar negeri sebanyak 6 orang.
   d. Membayar tambahan biaya publikasi, sebesar **Rp 5.500.000**,- (Lima juta lima ratus ribu rupiah) mohon ditransfer Bank BNI, an. **Panitia ICON BEAT UMM Pendidikan**, Nomor Rekening: **1939594444.** Bukti transfer dikirim ke Bendahara ICON-BEAT sdr. Ismi Ummu Muslimah, S.TP Mobil phone: 0812-3496-6789
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3. Ketentuan lainnya tentang publikasi di JJBS dapat dibaca di lampiran surat ini.
4. Apabila ada hal-hal yang belum jelas terkait konten draft artikel dapat ditanyakan langsung ke pak Roy, mobil phone: 0815-9555-028, sedangkan pertanyaan yang terkait administrasi, dapat langsung WA saya.
5. Apabila sampai tanggal yang sudah kami tentukan bapak ibu belum mengembalikan surat pernyataan dan melakukan revisi sesuai dengan waktu yang ditentukan, kami anggap bapak ibu mengundurkan diri sebagai kandidat publikasi artikel di JJBS.

Demikian, atas perhatian dan kerjasamanya disampaikan terima kasih.

Wassalammu'alaikum wr.wb.

Malang, 22 Oktober 2022

Hormat kami,

**Dr. Ir. Damat, MP., IPM.**

2nd ICON BEAT 2021 Chairperson

# SURAT PERNYATAAN

Yang bertanda tangan di bawah ini saya:

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# STRUKTUR IMRAD

- **Introduction** - Mengapa studi tersebut dilakukan? Apa pertanyaan penelitian, hipotesis atau tujuan penelitian?
- **Methods** - Kapan, di mana, dan bagaimana studi tersebut dilakukan? Bahan apa yang digunakan atau siapa yang tercakup dalam kelompok studi (pasien, dsb)?
- **Results** - Apa jawaban yang ditemukan terhadap pertanyaan riset; apa yang ditemukan dalam studi tersebut? Apakah hipotesis yang diuji benar?
- **and**
- **Discussion** - Apa makna dari jawaban yang ditemukan dan mengapa hal itu terjadi? Bagaimana hal itu sesuai dengan apa yang ditemukan oleh peneliti-peneliti lain? Apa perpektifnya untuk penelitian yang akan datang?

<u>The IMRAD Format: What goes where?</u>

(IMRAD = Introduction, Methods, Research and Discussion)

| Section | Purpose | Verb Tense | Elements |
|---|---|---|---|
| Abstract | Mini-version of the paper | Simple past - refers to work done | ✓ Principal objectives<br>✓ Methods used<br>✓ Principal results<br>✓ Main conclusions |
| Introduction | Provides rationale for the study | Present — refers to established knowledge in the literature | ✓ Nature and scope of problem<br>✓ Review of relevant literature<br>✓ Your hypothesis<br>✓ Your approach used in this study (& justification for this approach)<br>✓ Principal results<br>✓ Main conclusions |
| Methods & Materials | Describes what was done -- experiment, model, or field study | Simple past - refers to work done | ✓ Description of materials<br>✓ Description of procedure in a logical order, e.g., chronological order or by experiment<br>✓ Sufficient detail so that procedure can be reproduced |

| | | | |
|---|---|---|---|
| Results | Presents the data, the facts -- what you found, calculated, discovered, observed | Simple past - refers to what was found, observed | ✓ Your results<br>✓ Your observations during experiments/field work<br>✓ Your observations about the results (e.g., compare and contrast between experiments/model runs)<br>✓ Results of any calculations using the data, like rates or error |
| Discussion | • Shows the relationships among the facts<br>• Puts your results in context of previous research | Present - emphasis on established knowledge, present results | ✓ Trends, relationships, generalizations shown by the results<br>✓ Any exceptions, outlying data (and WHY)<br>✓ How your results agree/disagree with previous studies and WHY |
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Nama Lengkap : Dr.Ir.I Ketut Sumantra, MP

Judul artikel : AGRONOMIC CHARACTERS AND QUALITY OF FRUIT OF SOME CULTIVARS SALAK GULAPASIR PLANTED IN DIFFERENT AGRO-ECOSYSTEMS IN BALI

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Agronomic Characters and Quality of Fruit of Some Cultivars Salak Gulapasir Planted in Different Agro-Ecosystems

**Keywords:**

Agronomic Characters, Yield Quality, *Salacca-zalacca* var. Amboinensis, Cultivar, Altitude, Agro-ecosystem

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# Agronomic Characters and Quality of Fruit of Some Cultivars Salak Gulapasir Planted in Different Agro-Ecosystems

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**ABSTRACT**

Salak Gula pasir (*Salacca zalacca* var. Amboinensis) is a tropical fruit preferred by consumers due to its specific fruit flesh taste. The research objective was to obtain the superior of some Salak Gulapasir cultivars both in production and fruit quality. The research used a Randomized Block Design with three replications. The non-independent variable was the three cultivars of Salak Gulapasir: Nangka, Nenas, Gondok, and six sites, namely Karangasem (low, medium and highlands) and Tabanan (low, medium, and highlands). Observations were made on the agronomic characters and fruit quality. Data were analyzed using variance analysis, and if the planting location and cultivars show a difference, then it is followed by the LSD test at the 5% level. The results showed that different cultivars caused different fruit weights, fruit bunches, TSS, and total acid ratio. In Tabanan (in the low, medium, and highlands), the three cultivars showed lower fruit weight and fruit quality than the salak originating from Karangasem. The Nangka cultivar in Karangasem showed higher fruit weight, vitamin C content, and TSS/total acid ratio, while the pineapple salak cultivar showed the highest number of fruit bunches-1 in six locations.

**Keywords :** Agronomic Characters, Yield Quality, Salacca-zalacca var. Amboinensis, Cultivar, Altitude, Agro-ecosystem.

## 1. Introduction

Salak (*Zalacca salacca*) is one of the important fruits in Indonesia and the plant can be found in most regions of Indonesia (Rai et al. 2016; Ritonga et al., 2018). The Snake fruit belong to the family Palmae or Arecaceae, and are native to the Indonesian-Malaysian region (Zumaidar et al., 2014; Hakim et al., 2019). One of the extraordinary strengths of this fruit commodity for Indonesia is the possession of high genetic diversity (Budiyanti et al., 2019). Also, the nutrition of salak fruit is rich in antioxidants, phenolics, vitamins, and minerals (Mazumdar et al., 2019; Cepkova et a.l., 2021). The fruit flesh and peel have shown some tremendous anti-inflammatory, anticancer and antidiabetic (Saleh et al., 2018), and anti-ageing agents (Girsang et al., 2019). Antioxidants are chemical compounds that play an essential role in protecting cells due to attacks against free radicals-induced damage to biomolecules (Puspitasari and Ningsih, 2016; Setyobudi et al., 2019; Setyobudi et al., 2022). Despite its incredible food and medicinal benefits, salak fruit is still underutilized and unknown globally. So that this underutilized fruit remains an issue for future sustainable utilization and commercial value enhancement market (Mazumdar et al., 2019). Fruit quality is an important issue, especially for products that are consumed raw and fresh One of the problems is the lack of fruit quality because of inadequate information about superior salak (Herawati et al., 2018; Budiyanti et al., 2019). Therefore, it is necessary to select superior salak to meet market demand and fulfil community nutrition.

Salak Bali is quite a lot, based on the shape, aroma, taste, and skin colour of the location where the plants are cultivated (Sumantra et al., 2014; Sumantra et al.,2012; Sumantra and.Martiningsih, 2016). Under the Decree of the Minister of Agriculture of the Republic of Indonesia in 1994, Balinese zalacca was grouped into two superior zalacca: Salak Bali (Decree No.584) and Salak Gulapasir (Decree No.585). The second type, the salak Gulapasir is the most superior zalacca because of its sweet fruit taste; even though the age of the fruit is still young, thick fruit flesh and seeds are not attached to the fruit flesh (Sumantra et al., 2016; Rai et al., 2014). The nature of this fruit is ideal for meeting market demands for both the domestic and export markets (Martiningsih et al., 2018). Salak Bali is monoecious, so crossing does not need human help (Herawati et al., 2018), and can quickly develop using seeds (Sumantra and Martiningsih, 2016). Another advantage of zalacca plants in Indonesia compared to other fruits is harvest fruit 2-3 times a year if management is good (Rai et al., 2016; Warnita et al., 2019). The expansion of Gulapasir salak planting causes variations in phenotypic diversity. People can find 2-3 types of salak plants with a marker, fruit shape, aroma, flesh colour, and fruit weight (Martiningsih et al., 2018). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seeds so that new varieties of salak Gulapasir appear, as reported by Sumantra and Martiningsih (2016). Based on the marker that can be used as a differentiator, salak farmers give it the name of Salak Gulapasir Nenas, Gondok, and Nangka. The three cultivars have not yet identified their advantages in meeting market needs in line with the results of research (Sumantra and Martiningsih, 2016). The performance and produce are influenced by the characteristics of the agricultural ecosystem, particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status (Kinet et al., 1985; Adelina et al., 2021), and growth hormone (Rai et al., 2016; Prihastanti and Haryanti. 2022 Bernier, 1981 ).

The Salak Gula Pasir plantation in the District of Bebandem is the main producer of Salak Gula Pasir in Bali is located in the southern part of Mount Agung with an altitude of 450-700 m above sea level. The effect of altitude on plant growth and production is related to plant adaptation to temperature (Sumantra, et al., 2014), full sunlight (Sukawijaya et al., 2009), water status and soil quality (Rai et al., 2014; Raharjo et al., 2022; Ritonga et al., 2018). Salak plants are not resistant to full sun but 50-70% enough, therefore it is necessary to have shade plants (Sumantra et al., 2012; Sukawijaya et al., 2009). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech et al., 2019). Water status and soil quality really determine the fruit set on the salak Gulapasir. Low rainfall reduces leaf RWC, leaf chlorophyll content, and plant nutrient uptake (Rai et al., 2014). soil quality included the suitability of the physical, chemical and biological properties (Raharjo et al., 2022). Nuary et al. (2019) stated that the distribution of the Salak Pondoh plantation area in Sleman was greatly influenced by temperature and rainfall. The contribution of temperature in the modelling reached

38.6% while the rainfall was 27.8%. Furthermore, taking into account the probability of the temperature variable, the average temperature ranges from 17.41 to 25.65 °C, and the ideal month's rainfall ranges from 385.24 to 505.01 mm.

Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech et al., 2019). Therefore, cultivar differences may depend on growing requirements and cultivation techniques. Likewise, Puspitasari et al. (2017) stated that tannin content, fruit size and flesh colour of salak fruit are strongly influenced by where it grows. Other studies also explain that Gula pasir salacca cultivar *nangka* which is grown 570 m asl, would result in a higher quality of fruit that includes thickness of the mesocarpium, edible portion of fruit then compared to above and below 570 m asl (Sumantra et al., 2014; Sumantra and Martiningsih, 2016). Meanwhile, fruit weight and fruit quality of *gondok* and *nenas* cultivars have not been reported. Therefore, one way of handling salak quality is by undertaking severe studies for factors such as land and climate and adjusting agricultural patterns according to local climate conditions (Gliessman, 2000). The success of each species to occupy the environment of an area is influenced by its ability to adapt optimally to all physical environmental factors (temperature, light, soil structure, humidity), biotic factors (interaction between species, competition, parasitism), and chemical factors including the availability of water, oxygen: pH, and nutrients (Gliessman, 2000; Widyastuti et al., 2022). Moreover, a broad genetic variability would lead to wide phenotypic variability due to the effect of genetic-environment interaction (Ritonga et al., 2018). The research objective was to obtain the superior of some salak Gula pasir cultivars both in production and fruit quality (sugar and acid ratio, vitamin C and tannin) in six different agricultural ecosystems in Bali.

## 2. Materials and Methods

### *2.1 Experimental Site*

The study was carried out in six different locations, three sites in Karangasem Regency and three sites in the district of Tabanan. Locations in Karangasem are lowlands (K<560 m asl) which include several places, namely Telaga, Dukuh, and Karanganyar. Karangasem in the moderate plains (K.560-650 m asl) has several areas, namely Kecing and Kutabali and highlands (K> 650 m asl), namely Tanah Apo and Kresek (Fig. 1).

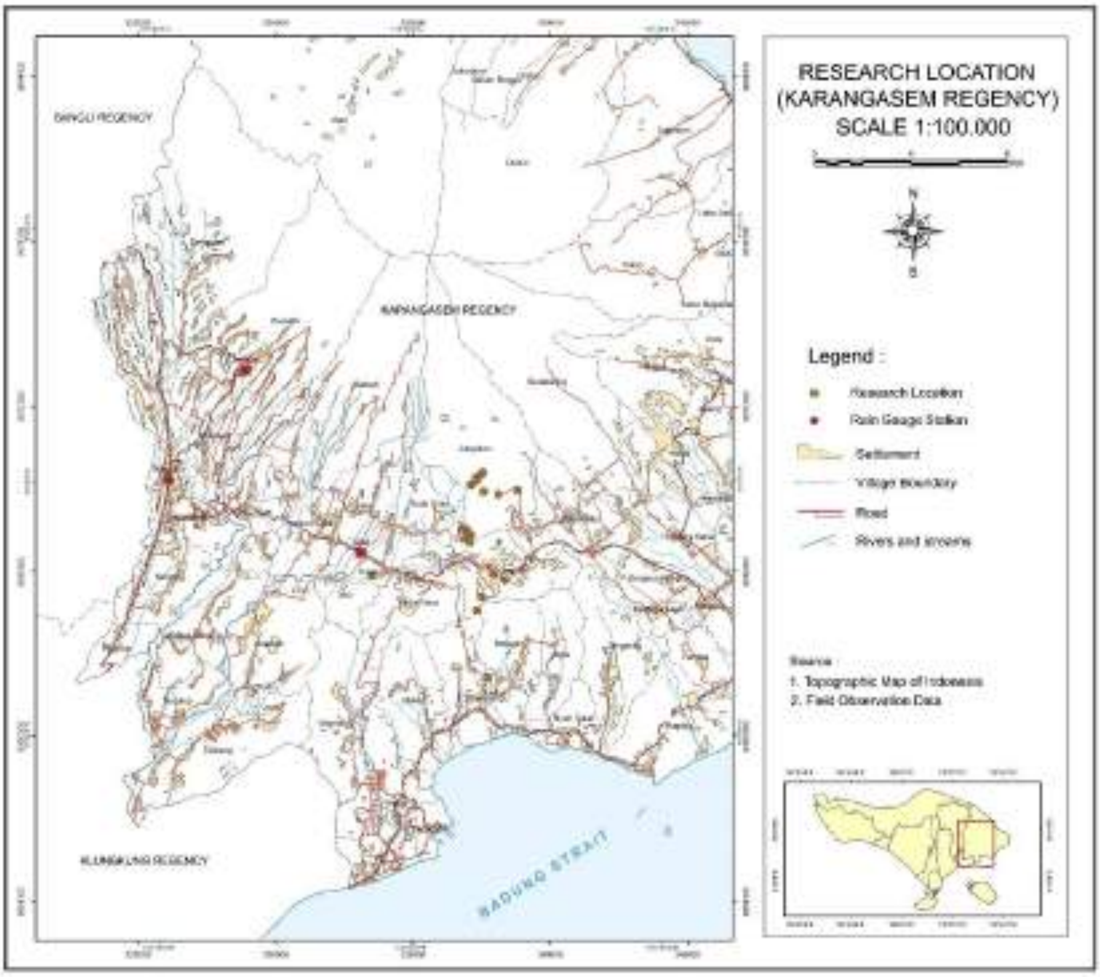


**Fig 1.** Research map and sampling point in Karangasem

The research location is in Tabanan in the lowlands (T<560 m asl), including Wanagiri, Sari Buana, and Mundeh Kauh. Tabanan in the medium lands (T560-650 m asl) includes several places, namely Pajahan, Kebon Jero, and Angseri. Tabanan in the highlands (T> 650 m asl), namely Munduk Temu, Pempatan, and Batungsel. (Fig. 2).

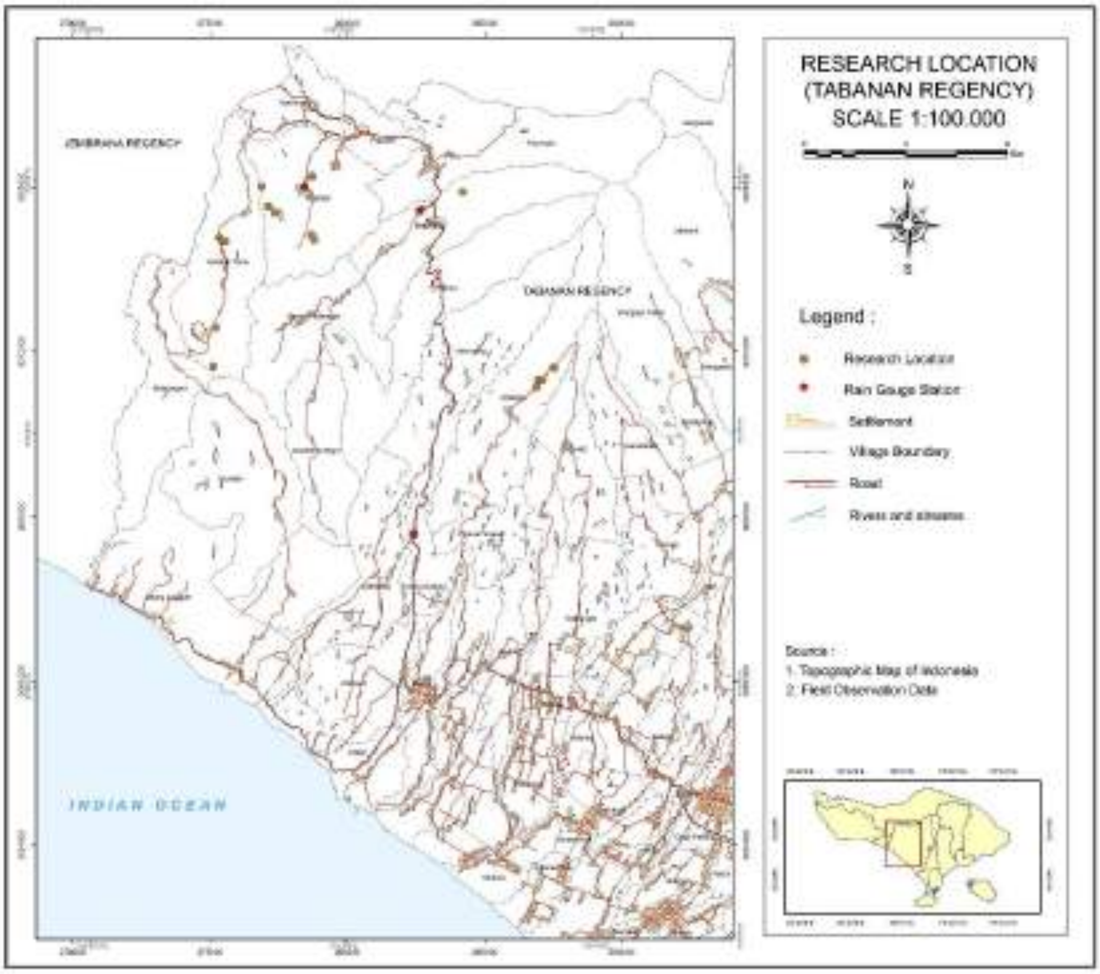


**Fig 2.** Research map and sampling point in Tabanan

As the non-independent variable was the three cultivars of salak Gula pasir, namely: Nangka, Nenas, Gondok, and six sites, namely Karangasem (K-lowlands, K-medium, and K-highlands) and Tabanan (T-lowlands, T-medium, and T-highlands). Repetition was carried out three times with the number of sample plants in each location, and cultivars were seven plants. Thus the treatment tested is as shown in Table 1

Table 1 Treatment of plant location and type of Gulapasir salak

| No | Treatment | Explanation |
|---|---|---|
| 1 | NT< 560 m asl | Salak GP.var. *Nangka* Tabanan < 560 m asl. |
| 2 | NT 560-650 m asl | Salak GP.var. *Nangka* Tabanan 560-650 m asl. |

| | | |
|---|---|---|
| 3 | NT > 650 m asl. | Salak GP.var. *Nangka* Tabanan > 650 m asl. |
| 4 | NK < 560 m asl. | Salak GP.var. *Nangka* Karangasem < 560 m asl. |
| 5 | NK 560-650 m asl | Salak GP.var. *Nangka* Karangasem 560 -650m asl. |
| 6 | NK > 650 m asl. | Salak GP.var. *Nangka* Karangasem > 650 m asl. |
| 7 | GT<560 m asl | Salak GP var. *Gondok* Tabanan < 560 m asl. |
| 8 | GT.560-650 m asl | Salak GP var. *Gondok* Tabanan 560 - 650 m asl. |
| 9 | GT>650 m asl | Salak GP var. *Gondok* Tabanan > 650 m asl. |
| 10 | GK.<560 m asl | Salak GP var. *Gondok* Karangasem < 560 m asl. |
| 11 | GK 560 - 650 m asl | Salak GP var. *Gondok* Karangasem 560 – 650 m asl. |
| 12 | GK >650 m asl | Salak GP var. *Gondok* Karangasem > 650 m asl. |
| 13 | NST <560 m asl | Salak GP var. Nenas Tabanan < 560 m asl. |
| 14 | NST.560 - 650 m asl | Salak GP var. *Nenas* Tabanan 560 – 650 m asl. |
| 15 | NST >650 m asl | Salak GP var. *Nenas* Tabanan > 650 m asl. |
| 16 | NSK .<560 m asl | Salak GP var. *Nenas* Karangasem < 560 m asl. |
| 17 | NSK 560 - 650 m asl | Salak GP var. *Nenas* Karangasem 560 – 650 m asl.. |
| 18 | NSK >650 m asl | Salak GP var. *Nenas* Karangasem > 650 m asl. |

The study used a Composite Analysis of Variance (Andinurani, 2016) with the model determined using Equation (1) below:

$$Yjk = u + L\,i + \delta\,ik + Pj + (LP)\,ij + \mathcal{E}\,ijk \qquad (1)$$

Where:

Yijk = The observation value of the treatment (j) in the group (k), which is repeated at the location (i).

u = the actual average value

Li = additive effect from location i

$\delta$ ik = the error effect in group k at location i

Pj = additive effect of the next treatment

(LP) ij = the effect of treatment (j) at the location (i)

Ɛ ijk = the effect of error from the treatment (j) in the group (k) which was carried out at the location (i).

*2.2 Preparation of study materials*

The material used is the Gulapasir salak plant with uniform growth, plants have been fruitful with uniform on morphological, age of plants and cultivation action. The intentional practice is that the plant only receives treatment in the midrib, tillers, and weed cleaning. In this study, the plants were not fertilized. The provision of water was only from rainfall following the habits applied by salak farmers. The sample plant maintains by trimming unproductive leaf midribs and removing young shoots. Plant material was taken from the salak development centre in six locations, namely at the centre of salak development in the Bebandem sub-districts, Karangasem district (K-lowland <560 m asl, K-medium 560-650 m asl and K-highland >650 m asl), Bajre, West Slemadeg and Pupuan sub-districts, Tabanan district (T-lowland <560 m asl, T-medium 560-650 m asl and T-highland >650 m asl).

2.*3 Analysis of physicochemical properties of soil sample*

Soil analysis was carried out to determine the physical and chemical properties of the soil. Soil sampling was carried out under sample plant trees, carried out in a composite manner at a depth of 0-40 cm. Chemical analysis was carried out on total N (Kjeldahl method), available P by Bray I method and $K_2O$ by the Bray I method, organic C, pH, Soil physical properties in the form of texture by pipette method.

*2.4 Observation of fruit and fruit quality*

Salak fruit can be harvested when it is ready for consumption. Consumable ripe fruit is a fruit that is ready to be consumed, characterized by a change in skin colour from dark brown to light brown, the thorns on the skin have reduced and are not sharp, and in general, at this stage, the fruit easily falls when shaken.

Observation and measurement of agronomic characters follow the method that has been done by Sumantra et al (2014) including fruit weight, number of fruit bunches, the thickness of fruit flesh and fruit shape. The fruit characters from these six-observed locations include the numbers of fruits per bunch, which is calculated manually on the formed fruits. The fruit weight per fruit and the fruit weight per tree is weighed after the fruits were removed from the bunch. The thickness of the mesocarpium is obtained by measuring the mesocarpium after it is cut vertically. The shape of the salak fruit is measured by calculating the length and diameter of the fruit.

While fruit quality includes sugar content, tannins, titrated acid, sugar content and vitamin C. Titrated acid was analyzed by titration (Rengana, 1997). The fruit was weighed 10 g of sample was added to 100 ml of distilled water, then was homogenized using a slow spin blender, and filtered using an aseptic filter. The filtrate obtained was taken as much as 25 ml, then titrated with 0.1 N NaOH solution with phenolphthalein indicator until red in colour appeared. The results obtained are calculated as the percentage tartaric acid is determined using Equation (2) below :

$$A = \frac{\text{ml NaOH} \times \text{N NaOH} \times P \times BM}{Y \times 1000 \times 2} \times 100\% \qquad (2)$$

where:

A = percentage of total acid

P = amount of dilution

BM = molecular weight of tartaric acid

Y = sample weight (g).

Tannis content was analyzed as done by Thakur et al. (2021) 100 mg of the sample was homogenized by 2ml of methanol. Centrifuged for 10 minutes at 10,000 rpm and collected the supernatant. 1 ml of supernatant mixed with 0.5 ml Folin's phenol reagent and 35% $Na_2CO_3$ of 5ml added and the mixture was kept at room temperature for 5 minutes. The blue colour of the reaction mixture was observed at 640 nm by UV/visible spectrophotometer. The content of tannin was calculated by calibration curve equation and determined using Equation (3) below « :

$$Y=0.0073x-0.0071 : R^2 = 0.9973 \quad (3)$$

Vitamin C was determined by titration like the method used by Asamara (2016). The material is weighed as much as 10 g and crushed in mortal. Then put into a 250 ml volumetric flask, set to the mark and filtered. Take 25 ml of the filtrate and titrate with 0.01 N Yod solution equivalent to 0.88 mg of ascorbic acid. The calculation of ascorbic acid content per 100 g of material is determined using Equation (4) below:

$$A = \frac{\text{ml Yod } 0.01 \text{ N} \times 0.88 \times P \times 100}{Y} \quad (4)$$

where: A = mg of ascorbic acid per 100 g of material

P = amount of dilution

Y = gram sample weight

Sugar content as TSS is calculated using a hand refractometer (Bellingham and Stanley Ltd., London) at 20 $^{o}$C.

The ratio of sugar content (TSS) and total acid is calculated by the sugar content divided by the acid content multiplied by 100 percent.

*2.5 Study design*

This study used a randomized block design with the data analyzed using a Composite Analysis of Variance. If the variance test is significantly different, then it is continued with a different test with LSD at the 5% level. Data analysis was performed using SPSS-IBM 18 (Adinurani, 2016) Each experimental treatment was repeated three times.

## 3. Results and Discussion

### *3.1 Agroclimate characteristic*

The low production level and quality of salak fruit are caused by environmental factors that do not support growth or because the physiological processes of the plant are not optimal due to insufficient nutrients and water. The suitability of climatic and soil conditions at six locations of the centres for the development of the Gulapasir salak was evaluated. The evaluation results show that the air temperature decreases as the altitude increases. The average air temperature at the Gulapasir salak plantation in Tabanan is 22.90$^{o}$C, while the air temperature at the Karangasem salak plantation is around 23.24$^{o}$C.

Likewise, monthly rainfall shows an increasing trend in line with the increase in altitude (Table 1). Based on the growing requirements of salak plants, rainfall and air temperature in the six locations evaluated were in the very suitable range to support plant growth and development. A good air temperature for the growth of salak plants is between 20 - 30°C and an average rainfall of 200 - 400 mm/month (Nuary et al., 2019).

Soil C-organic content in six planting sites was in the moderate to high range. Availability of N and P nutrients in salak plantations in Tabanan in the lowlands, medium and highlands in low to very low conditions. Salak planting land in Karangasem, both in the lowlands, medium and highlands, these two nutrients are available in moderate conditions (Table 1). The nutrient content of potassium available in the six planting locations that have been evaluated shows a very low value. The results of this study indicate that the cultivation techniques carried out by farmers are very low, farmers do not apply fertilizers that only rely on litter from the pruning of salak midrib as reported by Rai et al (2014) and Warnita et al. (2019).

**Table 1.** Soil and climate characteristics of the research site in Tabanan and Karangasem in three subzones

| Parameter | Tabanan | | | Karangasem | | |
|---|---|---|---|---|---|---|
| | Lowlands (<560m asl) | Moderate (560-650 m asl) | Highlands (> 650 m asl) | Lowlands (<560m asl) | Moderate (560-650 m asl) | Highlands (> 650 m asl) |
| Temp. ($^oC$) | 23.82 | 22.75 | 22.12 | 24.29 | 23.35 | 22.09 |
| Rainfall (mm/month) | 247.20 | 263.63 | 340.25 | 205,55 | 213,74 | 240.65 |
| Soil Texture | loamy clay | loamy clay | loamy clay | clay | clay | sandy loam |
| pH ($H^2O$) | 5.64(sa) | 5.75 (sa) | 5.84 (sa) | 6.08 (sa) | 6.05 (sa) | 6.03(sa) |
| C- organic (%) | 3.07(h) | 4.40 (h) | 5.90(h) | 3.93 (m) | 3.63 (h) | 4.79 (h) |
| Nutrients available | | | | | | |
| N total (%) | 0.18 (l) | 0.16 (l) | 0.18 (l) | 0.24(m) | 0.23 (m) | 0.29 (m) |
| $P_2O_5$ (ppm) | 9.38 (vl) | 9.12 (vl) | 13.50 (l) | 22.55 (m) | 24.18 (m) | 23.04 (m) |
| K2O (ppm) | 18.47 (vl) | 22.05 (vl) | 17.23 (vl) | 24.17 (vl) | 19.93 ( vl ) | 18.37 ( vl ) |

Notes: sa: slightly acidic; h: high; m: medium; l: low; vh: very high; h: high; asl: above sea level (The assessment criteria refer to Soil Research Center, Bogor 1983).

### *3.2 Kharacteristics of Salak Gula Pasir Cultivars*

The salak gula pasir his monoecius plant, namely male and female flowers arranged on the same bunches, the shape of the bunches is compound, and the position of the flower is on the back of the midrib. The salak gula pasir is classified as special because of its sweet fruit taste and the price per unit weight is 4 times more expensive than the salak Bali (Sumantra et al., 2012; Rai et al., 2014). The expansion of the cultivation of the salak gula pasir from its area of origin, Sibetan, Karangasem, has resulted in phenotypic diversity with a phenotypic similarity level of 58.62% - 93.10% (Sumantra and Martiningsih, 2016). In one garden one can find at least three different types of characters, located in fruit shape, aroma, fruit flesh colour and fruit weight (Sumantra and Martiningsih, 2016). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seed, so new variants of salak gula pasir appear with local names such as *salak gula pasir nenas, salak gula pasir*

*Gondok* and *salak gula pasir nangka*. The striking difference between these three cultivars lies in the shape and flesh of the fruit. The number of fruit branches of *Salak Gula pasir nangka*, 1-2 fruit, *Salak Gula pasir nenas* cultivar 2-4 and *Salak Gula pasir gondok* cultivar not branched. Salak Gula pasir, which is ready to harvest, has fruit flesh attached to the seed, and the fruit flesh is 0.63 cm thick. Meanwhile, the flesh of the *Salak Gula pasir nenas* is the thinnest, and the seeds are attached to the flesh. Meanwhile, when the *Salak Gula pasir gondok* cultivar is ready to harvest, the seeds make a sound when shaken.


**Figure.1** The form of the fruit from 3 cultivar. **Figure.2 & 3** The shape of the bunch and the thickness of the cv *nangka* flesh


**Figure. 4 & 5** The shape of the bunches and the thickness of the fruit flesh gondok cv; **Figure.6&7** The shape of the bunch and the thick flesh of the nenas cv.

*3.3* Agronomic characteristics of salacca cultivar

Analysis of variance showed that the interaction between planting locations and salak cultivars had significant effect on the number of fruits per bunch, fruit weight per tree, fruit weight per fruit, number of fruits per bunch, the ratio of sugar and acid and vitamin C content. Meanwhile, the thick fruit flesh and tannin content was not significant (Table 2)

**Table 2.** Recapitulation of the effects of cultivars and growing locations on agronomic and fruits quality of salak Gulapasir

| No. | Character agronomic and fruits quality | Planting location | Cultivars | Cultivars x Location |
|---|---|---|---|---|
| 1 | Number of fruit bunches $^{-1}$ | ** | ** | * |
| 2 | Fruit tree weight $^{-1}$ | ** | ** | * |
| 3 | Fruit weight $^{-1}$ | ** | ** | * |
| 4 | TSS ratio and total acid | ** | ** | ** |
| 5 | Thick fruit flesh | ** | ** | NS. |
| 6 | Vitamin C | Ns. | Ns. | * |
| 7 | Tanin | Ns. | Ns. | Ns. |
| 8 | Edible portion | ** | ** | Ns |

Notes: *) significant P <0.05, **) very significant P <0.01 and Ns) not significantly different P> 0.05

The interaction of cultivar and planting location had a significant effect on the length of the flower sheath and the number of fruit bunches $^{-1}$. *Nenas* cultivars grown in Tabanan (T<560, T560-650, and T>650 ) and Karangasem (K<560, K560-650, and K>650) showed higher sheath length and a number of fruit bunches $^{-1}$ than with Nangka and Gondok cultivars (Table 3). Tabanan (T 560-650) and Karangasem (K<560 m asl) are ideal conditions for flower sheath development and fruit development of *Nenas* cv. (Table 3)

**Table 3.** Flower sheath length (cm) and a number of fruit bunches $^{-1}$ (fruit) of var.Nangka, var. Gondok and var. *Nenas* at six locations.

| | Sheath length (cm) | Amount fruit bunches $^{-1}$ |
|---|---|---|
| NT< 560 | 27.50 ± 0.34 bcd | 19.55 ± 0.82 hij |
| NT 560-650 | 28.83 ± 1.31 b | 20.39 ± 1.00 g |
| NT > 650 | 27.17 ± 0.96 cde | 19.02 ± 0.82 j |
| NK < 560 | 26.00 ± 0.82 e | 21.13 ± 0.82 ef |
| NK 560-650 | 27.17 ± 0.14 cde | 22.28± 2.45 c |
| NK > 650 | 26.67 ± 1.36 cde | 21.13 ± 0.74 ef |
| GT<560 | 26.67 ± 2.18 cde | 20.22 ± 0.31 gh |
| GT.560-650 | 27.50 ± 1.22 bcd | 20.55 ± 0.62 fg |
| GT>650 | 27.70 ± 1.98 bc | 19.22 ± 0.74 ij |
| GK<560 | 25.83 ± 1.41 e | 21.89 ± 0.82 cd |
| GK 560 - 650 | 26.83 ± 0.75 cde | 20.5 ± 1.63 fg |
| GK >650 | 27.5 ± 0.82 bcd | 21.28 ± 0.78 def |

| | | |
|---|---|---|
| NST <560 | 27.5 ± 0.82 bcd | 21.41 ± 0.91 de |
| NST560 - 650 | 27.67 ± 0.82 bc | 22 ± 1.56 cd |
| NST >650 | 26.17 ± 2.16 de | 19.91 ± 1.36 ghi |
| NSK <560 | 32.00 ± 1.63 a | 25.27± 1.41 a |
| NSK 560 - 650 | 30.9 ± 2.10 a | 24 ± 0.82 b |
| NSK >650 | 27.00 ± 1.47 cde | 21.86 ± 0.82 cde |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in BNT 5 percent.

From Table 3 above, it can be explained that at K<560, Nenas cv. produced the highest number of fruits per bunch (25.27 pieces) compared to the other five locations. In Tabanan, the high number of the fruit of *Nenas* cv is ideal for growth at an altitude of 560 - 650 m and produces the second highest number of fruits after K<560. Nangka cv is ideal at K 560-650, while in Tabanan it is very good when it's planted at a height of 560-650 although the number of fruits shows a significant difference. Likewise, the ideal of Gondok cv is at T 560-650 and K<560 although the number of fruits did not show any difference with K 560-650 nor K>650. The results of this study are in line with the findings of Sumantra and Martiningsih (2016) that the Gulapasir salacca cv. *Nenas* produces the highest number of fruits both in the on season (*gadu* season) and -off-season (*sela* season).

The interaction of cultivar and planting location had a significant effect on the fruit weigh (fruit tree$^{-1}$ and fruit$^{-1}$). Nangka cultivars grown in Tabanan (T<560, T560-650, and T>650) and Karangasem (K<560, K560-650, and K>650) showed higher of weight of fruit tree$^{-1}$ and fruit-$^{1}$ than with Nenas and Gondok cultivars (Table 3). Tabanan (T 560-650) and Karangasem (K560-650 m asl) are ideal conditions for fruit development of Nangka cv. (Table 3). Whereas var. Godok cv and Nenas cv are ideal at heights <550, both planted in Tabanan and Karangasem, although these two species show no difference from nangka cv at the same height. Nenas and Gondok cultivars showed a trend of decreasing fruit weight in line with increasing altitude, both planted in Karangasem and Tabanan. The reverse occurred in the salak nangka cultivar, an increase in altitude from 550 m asl to 550-650 m asl caused an increase in fruit weight and after that the fruit weight decreased when planted at altitudes > 650 m asl. This finding is in line with the results of research that has been reported by Sumantra et al. (2014). However, for the salak gondok cultivar, and nenas cultivars, this is a new finding. (Table 4)

**Table 4**. Fruit weight of var.Nangka, var.Gondok, and var. Nenas in six locations

| | **Fruit$^{-1}$ (g)** | **Fruit tree$^{-1}$ (kg)** |
|---|---|---|
| NT< 560 | 45.32 ± 1.08 cd | 1.19 ± 0.08 def |
| NT 560-650 | 48.56 ± 0.71 c | 1.29 ± 0.07 cd |
| NT > 650 | 38.22 ± 0.46 ef | 1.03 ± 0.06 ghi |
| NK < 560 | 55.84 ± 1.37 a | 1.48 ± 0.02 b |
| NK 560-650 | 59.43 ± 0.71 a | 1.62 ± 0.07 a |
| NK > 650 | 49.4 ±1.65 b | 1.34 ± 0.05 c |
| GT<560 | 40.14 ± 0.11 e | 1.11± 0.09 fg |
| GT.560-650 | 38.67 ± 0.55 ef | 1.09 ± 0.07 fg |
| GT>650 | 32.95 ± 0.73 gh | 0.93 ± 0.10 i |
| GK<560 | 44.22 ± 0.18 d | 1.27 ± 0.06 cde |
| GK 560 - 650 | 38.20 ± 0.78 ef | 1.16 ± 0.05 defg |
| GK >650 | 36.20 ± 0.75 fg | 1.07 ± 0.11 fgh |
| NST <560 | 39.00 ± 1.07 ef | 1.14 ± 0.11 efg |
| NST560 - 650 | 37.79 ± 0.65 f | 1.13 ± 0.06 g |
| NST >650 | 32.12 ± 0.11 h | 0.94 ± 0.10 hi |
| NSK <560 | 41.80 ± 0.65 de | 1.36 ± 0.08 bc |
| NSK 560 - 650 | 36.57 ± 0.80 fg | 1.18 ± 0.09 def |
| NSK >650 | 37.10 ± 0.23 f | 1.11 ± 0.07 fg |

Notes: The number followed by the same letter in the row, column, and the same parameter shows a non-significant difference in LSD 5percent.

Apart from being influenced by environmental factors, the production of Salak Gula Pasir fruit is also influenced by internal plant factors (Lestari et al. 2011). Altitude is related to plant tolerance to temperature and rainfall (Ritonga et al., 2018). Altitude increases, the average daily air temperature decreases and monthly rainfall increases (Table 1). Nuary et al. (2019) stated that the distribution and adaptation of zalacca plants is strongly influenced by temperature and rainfall. It was further stated, the contribution of daily temperature accounts for nearly 38.6% while rainfall is 27.8%. Kanzaria et al. (2015) reported that mango plants planted at an altitude of 229 m flowered slower than those at an altitude of 148 m and 81 m asl. The temperature regime at higher altitudes is colder than at lower altitudes. Lower temperatures accumulate less GDD and may result in late flowering. Table 4 shows that the salak gula pasir planted in Karangasem produced a higher fruit weight in the three salak cultivars tested. This is related to the level of soil fertility and soil type. The results of soil analysis showed that the nutrient content of Potassium was very low, the pH of the soil was slightly acidic, the N and P content was very low to moderate (Table 1). Therefore, improving soil fertility through fertilization and calcium is highly recommended.

*3.4 Quality characteristics of salacca cultivar*

The interaction between cultivars and altitude significantly affected sugar/total acid and vitamin C content. The three cultivars grown in Tabanan (low, mid, and highland) showed a lower TSS/acid ratio. The fruit flavour planted in three locations in Tabanan is sourer than the three locations in Karangasem. Sugar content is greatly affected by the geographical. The geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity, and rainfall (Ritonga et al., 2018). Table 4 also shows that the increase in height from 550 m to 700 m asl in Tabanan and the addition in altitude from 550 to 650 m asl in Karangasem causes the sugar/acid ratio decrease in all three cultivars, and the lowest sugar/acid value occurs in cultivars Nenas in all locations. Each salak cultivar has an adaptation to an elevation closely related to plant tolerance to temperature (Sumantra and Martiningsih, 2016). Many factors influence fruit quality, but the most dominant are climate factors, especially temperature and rainfall. High rainfall and low air temperature during the fruit ripening phase can cause the dissolved solids in the fruit to become watery so that the TSS value is low (Singh et al., 2011).

Zalacca fruits from three different cultivars grown in low lands in Karangasem showed the highest vitamin C content and were significantly different from the three cultivars when planted in other locations. In both areas land increased by>650 effects to vitamin C decrease, and cultivars of Nangka and Gondok showed higher levels of vitamin C between <550 m - <650 m asl. (Table 5).

**Table 5.** TSS/acid ratio and levels of vitamin C of Nangka, Gondok, and Nenas cultivars in six locations.

| | **TSS/T.Acid** | **Vit. C (mg /100g)** |
|---|---|---|
| NT< 560 | 56.20 ± 0.16 abc | 27.5 ± 0.41 bde |
| NT 560-650 | 59.18 ± 0.82 a | 25.45 ± 0.37 defgh |
| NT > 650 | 37.89 ± 0.91 f | 22.52 ± 0.39 j |
| NK < 560 | 51.41 ± 0.33 cde | 27.74 ± 0.47 bd |
| NK 560-650 | 53.52± 0.82 abcd | 29.61 ± 0.50 ab |
| NK > 650 | 47.76 ± 0.11 de | 24.25 ± 0.20 fghij |
| GT<560 | 34.88± 0.72 fg | 25.50 ± 0.41 defgh |
| GT.560-650 | 34.80 ± 0.65 fg | 25.75 ± 0.20 defgh |
| GT>650 | 30.24 ± 0.20 gh | 23.34 ± 0.28 hij |
| GK<560 | 51.28 ± 0.23 cde | 30.31 ± 0.25 a |
| GK 560 - 650 | 58.44 ± 0.36 ab | 27.63 ± 0.30 bd |
| GK >650 | 53.04 ± 0.82 bcde | 25.07 ± 0.33 efghi |
| NST <560 | 31.50 ±0.41 gh | 26.71± 0.21 cdef |
| NST560 - 650 | 30.44 ± 0.36 gh | 25.88 ± 0.41 defg |
| NST >650 | 26.13 ± 0.11 h | 23.65 ± 0.29 ghij |
| NSK <560 | 53.73 ± 0.60 abc | 24.42 ± 0.34 fghij |
| NSK 560 - 650 | 52.63 ± 0.51 bcde | 22.82 ± 0.15 ij |
| NSK >650 | 47.60 ± 0.49 e | 25.16 ± 0.13 efghi |
| BNT 5 percent | 28.54 | 22.41 |

Note: The number followed by the same letter in the row, column, and the same parameter shows a non-significant difference in LSD 5%.

The results showed that the cultivar of the Gulapasir zalacca needs different environmental requirements to optimize yields. Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech et al., 2019). Therefore, cultivar differences may depend on growing requirements and cultivation techniques. Vitamin C in the Gulapasir zalacca cultivar is strongly influenced by the altitude of the land. To produce high levels of vitamin C, the Nangka and Gondok cultivars are ideal for planting at an altitude of 560-650 m asl while the

Nenas cultivar is ideal at a land altitude of <560 m asl. However, changes in ascorbate levels during fruit ripening are species-dependent and environmental factors (Fenech et al., 2019).

There was no interaction between cultivar and altitude to the flesh thickness, edible fruit portion, and fruit sugar content. The single treatment of salak cultivars, Nangka cultivars, showed fruit quality, including TSS, edible parts of the fruit, and higher flesh thickness (Table 6). Salak grown in Karangasem both from the lowlands and the middle lands produces fruit thickness, and the edible portion of fruits is higher than plants in the highlands. This study indicates that the ideal growing place for salak plants is between 450-650 m asl. This study is in line with several previous studies which explained that altitude affects the flowering process and fruit enlargement [15].

**Table 5.** The effect of a single factor of cultivars and planting location on TSS, the portion of edible flesh, and the thickness of salak fruit

| Cultivar | TSS ($^{o}$Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| Nangka | 16.59a | 72.50a | 0.63a |
| Gondok | 16.42a | 70.66ab | 0.59b |
| Nenas | 15.64b | 69.22b | 0.52c |
| LSD 5% | 0.60 | 3. 1 | 0.039 |
| Planting locations (m asl) | TSS ( $^{o}$Brix) | Edible portion (%) | Flesh thickness (cm) |
| T< 550 | 16.28a | 73.13a | 0.54c |
| T550-650 | 16.27a | 69.89a | 0.58bc |
| T >650 | 16.14a | 63.87b | 0.49d |
| K550 | 16.81a | 73.15a | 0.61b |
| K550-650 | 16.11a | 72.29a | 0.66a |
| K>650 | 15.69 a | 72.44a | 0.61b |
| LSD 5% | ns. | 3.85 | 0.04 |

Notes: The number followed by the same letter in the same column shows a non-significant difference in LSD 5%.

## 4. Conclusion and Recommendation

Different cultivars caused different fruit weights, fruit bunches, and the sugar/acid ratio at various locations. The three cultivars showed lower fruit weight and fruit quality in Tabanan (low, medium, and highlands) than the salak originating from Karangasem. The Nangka cultivar in Karangasem showed higher fruit weight, vitamin C content, and sugar/ acid ratio, while the Nanas salak cultivar showed the highest number of fruit bunches$^{-1}$ in six locations. Nangka cultivars are very suitable to be planted at an altitude of 550- 650 m above sea level. In contrast, the Nanas cv and Gondok cv are developed naturally at low altitudes < 550 above sea level. In order for all cultivars to be able to produce optimally, efforts to improve the cultivation system are needed through fertilization and the provision of calcium is highly recommended.

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**Tahap 4 . Proses perbaikan/revisi artikel sebelum di submit ke JJBBS dan Bulan Nopember 2022- Akhir Desember 2022**

**Title:**

Agronomic Characters and Quality of Fruit of Some Cultivars Salak Gulapasir Planted in Different Agro-Ecosystems

**Running Title:**

Agronomic Characters and Quality of Fruit of Some Cultivars Salak Gulapasir Planted in Different Agro-Ecosystems

**Keywords:**

Agronomic Characters, Yield Quality, *Salacca-zalacca* var. Amboinensis, Cultivar, Altitude, Agro-ecosystem

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**Agronomic Characters and Quality of Fruit of Salak (*Salacca zalacca* var.amboinensis cv.Gulapasir Planted in Different Agro-Ecosystems**

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*Corresponding author :ketut.sumantra@unmas.ac.id

**ABSTRACT**

Salak Gula Pasir (*Salacca zalacca* var. amboinensis) is a tropical fruit preferred by consumers due to its specific fruit flesh taste. The fruit flavor is sweet from a young age, the flesh is thick and not astringent and the flesh is not sticking to the seeds. The research objective was to obtain the superior of some Salak Gulapasir cultivars both in production and fruit quality. The research used a Randomized Block Design with three replications. The non-independent variable was the three of Salak Gulapasir: Nangka cv., Nenas cv., Gondok cv., and six sites, namely Karangasem (low, medium and highlands) and Tabanan (low, medium, and highlands). Observations were made on the agronomic characters and fruit quality. Data were analyzed using variance analysis, and if the planting location and cultivars show a difference, then it is followed by the LSD test at the 5 percent % level. The results showed that different cultivars caused different fruit weights, fruit bunches, TSS, and total acid ratio. In Tabanan (in the low, medium, and highlands), the three cultivars showed lower fruit weight and fruit quality than the salak originating from Karangasem. The Nangka cultivar in Karangasem showed higher fruit weight, vitamin C content, and TSS/total acid ratio, while the pineapple salak cultivar showed the highest number of fruit bunches-1 in six locations.

**Keywords :** Agronomic Characters, Yield Quality, Salacca-zalacca var. Amboinensis, Cultivar, Altitude, Agro-ecosystem.

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## 1. Introduction

Salak (*Zalacca salacca*) is one of the important fruits in Indonesia and the plant can be found in most regions of Indonesia (Rai *et al.* 2016; Ritonga *et al*. 2018). The Snake fruit belong to the family Palmae or Arecaceae, and are native to the Indonesian-Malaysian region (Zumaidar et al., 2014; Hakim et al., 2019). One of the extraordinary strengths of this fruit commodity for Indonesia is the possession of high genetic diversity (Budiyanti et al., 2019). Also, the nutrition of salak fruit is rich in antioxidants, phenolics, vitamins, and minerals (Mazumdar et al., 2019; Cepkova et a.l., 2021). The fruit flesh and peel have shown some tremendous anti-inflammatory, anticancer and antidiabetic (Saleh et al., 2018), and anti-ageing agents (Girsang et al., 2019). Antioxidants are chemical compounds that play an essential role in protecting cells due to attacks against free radicals-induced damage to biomolecules (Puspitasari and Ningsih, 2016; Setyobudi et al., 2019; Setyobudi et al., 2022). Despite its incredible food and medicinal benefits, salak fruit is still underutilized and unknown globally. So that this underutilized fruit remains an issue for future sustainable utilization and commercial value enhancement market (Mazumdar et al., 2019). Fruit quality is an important issue, especially for products that are consumed raw and fresh One of the problems is the lack of fruit quality because of inadequate information about superior salak (Herawati et al., 2018; Budiyanti et al., 2019). Therefore, it is necessary to select superior salak to meet market demand and fulfil community nutrition.

Salak Bali is quite a lot, based on the shape, aroma, taste, and skin colour of the location where the plants are cultivated (Sumantra et al., 2014; Sumantra et al.,2012; Sumantra and.Martiningsih, 2016). Under the Decree of the Minister of Agriculture of the Republic of Indonesia in 1994, Balinese zalacca was grouped into two superior zalacca: Salak Bali (Decree No.584) and Salak Gulapasir (Decree No.585). The second type, the salak Gulapasir is the most superior zalacca because of its sweet fruit taste; even though the age of the fruit is still young, thick fruit flesh and seeds are not attached to the fruit flesh (Sumantra et al., 2016;

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Rai et al., 2014). The nature of this fruit is ideal for meeting market demands for both the domestic and export markets (Martiningsih et al., 2018). Salak Bali is monoecious, so crossing does not need human help (Herawati et al., 2018), and can quickly develop using seeds (Sumantra and Martiningsih, 2016). Another advantage of zalacca plants in Indonesia compared to other fruits is harvest fruit 2-3 times a year if management is good (Rai et al., 2016; Warnita et al., 2019). The expansion of Gulapasir salak planting causes variations in phenotypic diversity. People can find 2-3 types of salak plants with a marker, fruit shape, aroma, flesh colour, and fruit weight (Martiningsih et al., 2018). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seeds so that new varieties of salak Gulapasir appear, as reported by Sumantra and Martiningsih (2016). Based on the marker that can be used as a differentiator, salak farmers give it the name of Salak Gulapasir Nenas, Gondok, and Nangka. The three cultivars have not yet identified their advantages in meeting market needs in line with the results of research (Sumantra and Martiningsih, 2016). The performance and produce are influenced by the characteristics of the agricultural ecosystem, particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status (Kinet et al., 1985; Adelina et al., 2021), and growth hormone (Rai et al., 2016; Prihastanti and Haryanti. 2022 Bernier, 1981).

The Salak Gula Pasir plantation in the District of Bebandem is the main producer of Salak Gula Pasir in Bali is located in the southern part of Mount Agung with an altitude of 450-700 m above sea level. The effect of altitude on plant growth and production is related to plant adaptation to temperature (Sumantra, et al., 2014), full sunlight (Sukawijaya et al., 2009), water status and soil quality (Rai et al., 2014; Raharjo et al., 2022; Ritonga et al., 2018). Salak plants are not resistant to full sun but 50-70% enough, therefore it is necessary to have shade plants (Sumantra et al., 2012; Sukawijaya et al., 2009). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech

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**Commented [R29]:** Ini didepan krn urut abjad et al., 2019). Water status and soil quality really determine the fruit set on the salak Gulapasir. Low rainfall reduces leaf RWC, leaf chlorophyll content, and plant nutrient uptake (Rai et al., 2014). soil quality included the suitability of the physical, chemical and biological properties (Raharjo et al., 2022). Nuary et al. (2019) stated that the distribution of the Salak Pondoh plantation area in Sleman was greatly influenced by temperature and rainfall. The contribution of temperature in the modelling reached 38.6% while the rainfall was 27.8%. Furthermore, taking into account the probability of the temperature variable, the average temperature ranges from 17.41 to 25.65 °C, and the ideal month's rainfall ranges from 385.24 to 505.01 mm.

Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech et al., 2019). Therefore, cultivar differences may depend on growing requirements and cultivation techniques. Likewise, Puspitasari et al. (2017) stated that tannin content, fruit size and flesh colour of salak fruit are strongly influenced by where it grows. Other studies also explain that Gula pasir salacca cultivar *nangka* which is grown 570 m asl, would result in a higher quality of fruit that includes thickness of the mesocarpium, edible portion of fruit then compared to above and below 570 m asl (Sumantra et al., 2014; Sumantra and Martiningsih, 2016). Meanwhile, fruit weight and fruit quality of *gondok* and *nenas* cultivars have not been reported. Therefore, one way of handling salak quality is by undertaking severe studies for factors such as land and climate and adjusting agricultural patterns according to local climate conditions (Gliessman, 2000). The success of each species to occupy the environment of an area is influenced by its ability to adapt optimally to all physical environmental factors (temperature, light, soil structure, humidity), biotic factors (interaction between species, competition, parasitism), and chemical factors including the availability of water, oxygen: pH, and nutrients (Gliessman, 2000; Widyastuti et al., 2022). Moreover, a broad genetic variability would lead to wide phenotypic variability due to the effect of genetic-environment interaction (Ritonga et al., 2018). The research objective was to obtain

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## 2. Materials and Methods

*2.1 Experimental Site*

The study was carried out in six different locations, three sites in Karangasem Regency and three sites in the district of Tabanan. Locations in Karangasem are lowlands (K<560 m asl) which include several places, namely Telaga, Dukuh, and Karanganyar. Karangasem in the moderate plains (K.560-650 m asl) has several areas, namely Kecing and Kutabali and highlands (K> 650 m asl), namely Tanah Apo and Kresek (Fig. 1). The research location is in Tabanan in the lowlands (T<560 m asl), including Wanagiri, Sari Buana, and Mundeh Kauh. Tabanan in the medium lands (T560-650 m asl) includes several places, namely Pajahan, Kebon Jero, and Angseri. Tabanan in the highlands (T> 650 m asl), namely Munduk Temu, Pempatan, and Batungsel. (Fig. 1).

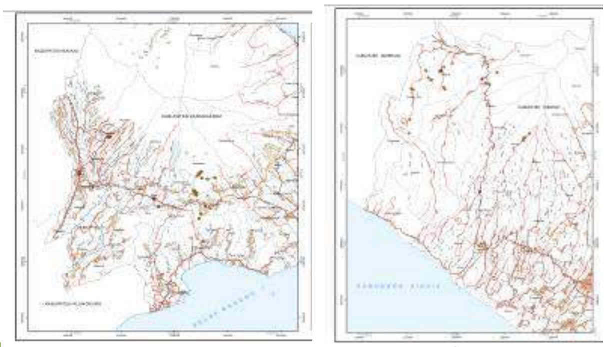

**Fig 1.** Research map and sampling point in Karangasem (Left) and Tabanan (Right)

The study used a Composite Analysis of Variance (Gaspersz, 1991) with the model determined using Equation (1) below:

$$Yjk = u + L\,i + \delta\,ik + Pj + (LP)\,ij + \varepsilon\,ijk \quad (1)$$

Where:

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Yijk = The observation value of the treatment (j) in the group (k), which is repeated at the location (i).

u = the actual average value

Li = additive effect from location i

δ ik = the error effect in group k at location i

Pj = additive effect of the next treatment

(LP) ij = the effect of treatment (j) at the location (i)

Ɛ ijk = the effect of error from the treatment (j) in the group (k) which was carried out at the location (i).

As the non-independent variable was the three cultivars of salak Gula pasir, namely: Nangka, Nenas, Gondok, and six sites, namely Karangasem (K-lowlands, K-medium, and K-highlands) and Tabanan (T-lowlands, T-medium, and T-highlands). Repetition was carried out three times with the number of sample plants in each location, and cultivars were seven plants.

*2.2 Preparation of study materials*

The material used is the Gulapasir zalacca plant with uniform growth, plants have been fruitful with uniform on morphological, age of plants and cultivation action. The intentional practice is that the plant only receives treatment in the midrib, tillers, and weed cleaning. In this study, the plants were not fertilized. The provision of water was only from rainfall following the habits applied by zalacca farmers. The sample plant maintains by trimming unproductive leaf midribs and removing young shoots. Plant material was taken from the salak development centre in six locations, namely at the centre of salak development in the Bebandem sub-districts, Karangasem district (K-lowland <560 m asl, K-medium 560-650 m asl and K-highland >650 m asl), Bajre, West

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Slemadeg and Pupuan sub-districts, Tabanan district (T-lowland <560 m asl, T-medium 560-650 m asl and T-highland >650 m asl).

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2.*3 Analysis of physicochemical properties of soil sample*

Soil analysis was carried out to determine the physical and chemical properties of the soil. Soil sampling was carried out under sample plant trees, carried out in a composite manner at a depth of 0-40 cm. Chemical analysis was carried out on total N (Kjeldahl method), available P by Bray I method and $K_2O$ by the Bray I method, organic C, pH, Soil physical properties in the form of texture by pipette method.

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*2.4 Observation of fruit and fruit quality*

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Salak fruit can be harvested when it is ready for consumption. Consumable ripe fruit is a fruit that is ready to be consumed, characterized by a change in skin colour from dark brown to light brown, the thorns on the skin have reduced and are not sharp, and in general, at this stage, the fruit easily falls when shaken.

Observation and measurement of agronomic characters follow the method that has been done by Sumantra et al (2014) including fruit weight, number of fruit bunches, the thickness of fruit flesh and fruit shape. The fruit characters from these six-observed locations include the numbers of fruits per bunch, which is calculated manually on the formed fruits. The fruit weight per fruit and the fruit weight per tree is weighed after the fruits were removed from the bunch. The thickness of the mesocarpium is obtained by measuring the mesocarpium after it is cut vertically. The shape of the salak fruit is measured by calculating the length and diameter of the fruit.

While fruit quality includes sugar content, tannins, titrated acid, sugar content and vitamin C. Titrated acid was analyzed by titration (Rengana, 1997). The fruit was weighed 10 g of sample was added to 100 ml of distilled water, then was homogenized using a slow spin blender, and filtered using an aseptic filter. The filtrate obtained was taken as much as 25 ml, then titrated with 0.1 N NaOH solution with phenolphthalein indicator until red in colour appeared. The results obtained are calculated as the percentage tartaric acid is determined using Equation (2) below :

$$A = \frac{\text{ml NaOH} \times \text{N NaOH} \times P \times BM}{Y \times 1000 \times 2} \times 100\% \qquad (2)$$

where:

A = percentage of total acid

P = amount of dilution

BM = molecular weight of tartaric acid

Y = sample weight (g).

Tannis content was analyzed as done by Thakur et al. (2021)……  100 mg of the sample was homogenized by 2ml of methanol. Centrifuged for 10 minutes at 10,000 rpm and collected the supernatant. 1 ml of supernatant mixed with 0.5 ml Folin's phenol reagent and 35% Na2CO3 of 5ml added and the mixture was kept at room temperature for 5 minutes. The blue colour of the reaction mixture was observed at 640 nm by UV/visible spectrophotometer. The content of tannin was calculated by calibration curve equation and determined using Equation (3) below « :

$$Y=0.0073x-0.0071 : R^2 = 0.9973 \qquad (3)$$

Vitamin C was determined by titration like the method used by Asamara (2016). The material is weighed as much as 10 g and crushed in mortal. Then put into a 250 ml volumetric flask, set to the mark and filtered. Take 25 ml of the filtrate and titrate with 0.01 N Yod solution equivalent to 0.88 mg of ascorbic acid. The calculation of ascorbic acid content per 100 g of material is determined using Equation (4) below:

ml Yod 0.01 N x 0.88 x P x 100

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A = ------------------------------------------------ (4)

Y

where: A = mg of ascorbic acid per 100 g of material

P = amount of dilution

Y = gram sample weight

Sugar content as TSS is calculated using a hand refractometer (Bellingham and Stanley Ltd., London) at 20 $^{o}$C.

The ratio of sugar content (TSS) and total acid is calculated by the sugar content divided by the acid content multiplied by 100 percent.

…………………….

*2.5 Study design*

This study used a randomized block design with the data analyzed using a Composite Analysis of Variance. If the variance test is significantly different, then it is continued with a different test with LSD at the 5% level. Data analysis was performed using SPSS-IBM 18 (Adinurani, 2016, 2022) Each experimental treatment was repeated three times.

**3. Results and Discussion**

*3.1 Agroclimate characteristic*

The low production level and quality of salak fruit are caused by environmental factors that do not support growth or because the physiological processes of the plant are not optimal due to insufficient nutrients and water. The suitability of climatic and soil conditions at six locations of the centres for the development of the Gulapasir salak was evaluated. The evaluation results show that the air temperature decreases as the altitude increases. The average air temperature at the Gulapasir salak plantation in Tabanan is 22.90$^{o}$C, while the air temperature at the Karangasem salak plantation is around 23.24$^{o}$C.

Likewise, monthly rainfall shows an increasing trend in line with the increase in altitude (Table 1). Based on the growing requirements of salak plants, rainfall and air

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temperature in the six locations evaluated were in the very suitable range to support plant growth and development. A good air temperature for the growth of salak plants is between 20 - 30°C and an average rainfall of 200 - 400 mm/month (Nuary et al., 2019).

Soil C-organic content in six planting sites was in the moderate to high range. Availability of N and P nutrients in salak plantations in Tabanan in the lowlands, medium and highlands in low to very low conditions. Salak planting land in Karangasem, both in the lowlands, medium and highlands, these two nutrients are available in moderate conditions (Table 1). The nutrient content of potassium available in the six planting locations that have been evaluated shows a very low value. The results of this study indicate that the cultivation techniques carried out by farmers are very low, farmers do not apply fertilizers that only rely on litter from the pruning of salak midrib as reported by Rai et al (2014) and Warnita et al. (2019).

**Table 1.** Soil and climate characteristics of the research site in Tabanan and Karangasem in three subzones

| **Parameter** | **Tabanan** | | | **Karangasem** | | |
|---|---|---|---|---|---|---|
| | Lowlands (<560m asl) | Moderate (560-650 m asl) | Highlands (> 650 m asl) | Lowlands (<560m asl) | Moderate (560-650 m asl) | Highlands (> 650 m asl) |
| Temp. (°C) | 23.82 | 22.75 | 22.12 | 24.29 | 23.35 | 22.09 |
| Rainfall (mm/month) | 247.20 | 263.63 | 340.25 | 205,55 | 213,74 | 240.65 |
| Soil Texture | loamy clay | loamy clay | loamy clay | clay | clay | sandy loam |
| pH ($H^2O$) | 5.64(sa) | 5.75 (sa) | 5.84 (sa) | 6.08 (sa) | 6.05 (sa) | 6.03(sa) |
| C- organic (%) | 3.07(h) | 4.40 (h) | 5.90(h) | 3.93 (m) | 3.63 (h) | 4.79 (h) |
| Nutrients available | | | | | | |
| N total (%) | 0.18 (l) | 0.16 (l) | 0.18 (l) | 0.24(m) | 0.23 (m) | 0.29 (m) |
| $P_2O_5$ (ppm) | 9.38 (vl) | 9.12 (vl) | 13.50 (l) | 22.55 (m) | 24.18 (m) | 23.04 (m) |
| K2O (ppm) | 18.47 (vl) | 22.05 (vl) | 17.23 (vl) | 24.17 (vl) | 19.93 ( vl ) | 18.37 ( vl ) |

Notes: sa: slightly acidic; h: high; m: medium; l: low; vh: very high; h: high; asl: above sea level (The assessment criteria refer to Soil Research Center, Bogor 1983).

*3.2 Kharacteristics of Salak Gula Pasir Cultivars*

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The salak gula pasir  his monoecius plant, namely male and female flowers arranged on the same bunches, the shape of the bunches is compound, and the position of the flower is on the back of the midrib. The salak gula pasir is classified as special because of its sweet fruit taste and the price per unit weight is 4 times more expensive than the salak Bali (Sumantra et al., 2012; Rai et al., 2014). The expansion of the cultivation of the salak gula pasir from its area of origin, Sibetan, Karangasem, has resulted in phenotypic diversity with a phenotypic similarity level of 58.62% - 93.10% (Sumantra and Martiningsih,  2016). In one garden one can find at least three different types of characters, located in fruit shape, aroma, fruit flesh colour and fruit weight (Sumantra and Martiningsih, 2016). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seed, so new variants of salak gula pasir appear with local names such as *salak gula pasir nenas*, *salak gula pasir Gondok* and *salak gula pasir nangka*. The striking difference between these three cultivars lies in the shape and flesh of the fruit. The number of fruit branches of *Salak Gula pasir nangka*, 1-2 fruit, *Salak Gula pasir nenas* cultivar 2-4 and *Salak Gula pasir gondok* cultivar not branched. Salak Gula pasir, which is ready to harvest, has fruit flesh attached to the seed, and the fruit flesh is 0.63 cm thick. Meanwhile, the flesh of the *Salak Gula pasir nenas* is the thinnest, and the seeds are attached to the flesh. Meanwhile, when the *Salak Gula pasir gondok* cultivar is ready to harvest, the seeds make a sound when shaken.

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**Figure.1** The form of the fruit from 3 cultivar. **Figure.2 & 3** The shape of the bunch and the thickness of the cv *nangka* flesh

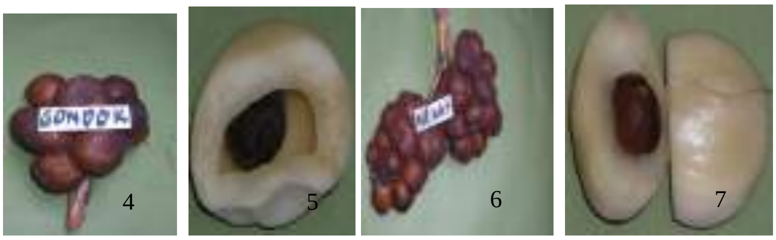


**Figure. 4 & 5** The shape of the bunches and the thickness of the fruit flesh gondok cv; **Figure.6&7** The shape of the bunch and the thick flesh of the nenas cv.

*3.3* Agronomic characteristics of salacca cultivar

Analysis of variance showed that the interaction between planting locations and salak cultivars had significant effect on the number of fruits per bunch, fruit weight per tree, fruit weight per fruit, number of fruits per bunch, the ratio of sugar and acid and vitamin C content. Meanwhile, the thick fruit flesh and tannin content was not significant (Table 2)

**Table 2.** Recapitulation of the effects of cultivars and growing locations on agronomic and fruits quality of salak Gulapasir

| No. | Character agronomic and fruits quality | Planting location | Cultivars | Cultivars x Location |
|---|---|---|---|---|
| 1 | Number of fruit bunches $^{-1}$ | ** | ** | * |
| 2 | Fruit tree weight $^{-1}$ | ** | ** | * |
| 3 | Fruit weight $^{-1}$ | ** | ** | * |
| 4 | TSS ratio and total acid | ** | ** | ** |
| 5 | Thick fruit flesh | ** | ** | NS. |
| 6 | Vitamin C | Ns. | Ns. | * |
| 7 | Tanin | Ns. | Ns. | Ns. |
| 8 | Edible portion | ** | ** | Ns |

Notes: *) significant P <0.05, **) very significant P <0.01 and Ns) not significantly different P> 0.05

The interaction of cultivar and planting location had a significant effect on the length of the flower sheath and the number of fruit bunches $^{-1}$. *Nenas* cultivars grown in Tabanan

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(T<560, T560-650, and T>650 ) and Karangasem (K<560, K560-650, and K>650) showed higher sheath length and a number of fruit bunches $^{-1}$ than with Nangka and Gondok cultivars (Table 3). Tabanan (T 560-650) and Karangasem (K<560 m asl) are ideal conditions for flower sheath development and fruit development of *Nenas* cv. (Table 3)

**Table 3.** Flower sheath length (cm) and a number of fruit bunches $^{-1}$ (fruit) of Nangka, Gondok and *Nenas* cultivars at six locations.

| Location (Original m) | Nangka cv | | Gondok cv | | Nenas cv | | Average Location | |
|---|---|---|---|---|---|---|---|---|
| | Sheath length (cm) | Amount fruit bunches $^{-1}$ | Sheath length (cm) | Amount fruit bunches $^{-1}$ | Sheath length (cm) | Amount fruit bunches $^{-1}$ | sheath length (cm) | Amount fruit bunches $^{-1}$ |
| T<560 | 27.50ab A | 19.55 d B | 26.67ab a | 20.22cd b | 27.50bc a | 21.41c a | 27.22 | 20.39 |
| T.560-650 | 28.83a A | 20.39 c B | 27.50a a | 20.55bc b | 27.67b a | 22.00c a | 28.00 | 20.98 |
| T>650 | 27.17bc Ab | 19.02 d B | 27.70a a | 19.22d a | 26.17c b | 19.91d a | 27.01 | 19.38 |
| K.<560 | 26.00c B | 21.13 b B | 25.83b b | 21.89a b | 32.00a a | 25.27a a | 27.94 | 22.76 |
| K 560-650 | 27.17bc B | 22.28 a B | 26.83ab b | 10.50a b | 30.90a a | 24.00b a | 28.30 | 22.93 |
| K>650 | 26.67bc A | 21.13 b A | 27.50a a | 21.28ab a | 27.00bc a | 21.86c a | 27.06 | 21.42 |
| Average cultivar | 27.22 | 20.58 | 27.01 | 20.94 | 28.54 | 22.41 | - | - |

Remarks : Numbers followed by the same letter in the same row, column and parameter indicate a non-significant difference in BNT 5%.

From Table 3 above, it can be explained that at K<560, Nenas cv. produced the highest number of fruits per bunch (25.27 pieces) compared to the other five locations. In Tabanan, the high number of the fruit of *Nenas* cv is ideal for growth at an altitude of 560 - 650 m and produces the second highest number of fruits after K<560. Nangka cv is ideal at K 560-650, while in Tabanan it is very good when it's planted at a height of 560-650 although the number of fruits shows a significant difference. Likewise, the ideal of Gondok cv is at T 560-650 and K<560 although the number of fruits did not show any difference with K 560-650 nor K>650. The results of this study are in line with the findings of Sumantra and Martiningsih (2016) that the Gulapasir salacca cv. *Nenas*

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The interaction of cultivar and planting location had a significant effect on the fruit weigh (fruit tree$^{-1}$ and fruit$^{-1}$). Nangka cultivars grown in Tabanan (T<560, T560-650, and T>650) and Karangasem (K<560, K560-650, and K>650) showed higher of weight of fruit tree$^{-1}$ and fruit-$^{1}$ than with Nenas and Gondok cultivars (Table 3). Tabanan (T 560-650) and Karangasem (K560-650 m asl) are ideal conditions for fruit development of Nangka cv. (Table 3). Whereas Godok cv and Nenas cv are ideal at heights <550, both planted in Tabanan and Karangasem, although these two species show no difference from nangka cv at the same height. Nenas and Gondok cultivars showed a trend of decreasing fruit weight in line with increasing altitude, both planted in Karangasem and Tabanan. The reverse occurred in the salak nangka cultivar, an increase in altitude from 550 m asl to 550-650 m asl caused an increase in fruit weight and after that the fruit weight decreased when planted at altitudes > 650 m asl. This finding is in line with the results of research that has been reported by Sumantra et al. (2014). However, for the salak gondok cultivar, and nenas cultivars, this is a new finding. (Table 4)

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**Table 4**. Fruit weight of Nangka, Gondok, and Nenas cultivars (cv) in six locations

| Location (m asl) | CV. Nangka | | CV. Gondok | | CV. Nenas | | Average location | |
|---|---|---|---|---|---|---|---|---|
| | Fruit$^{-1}$ (g) | Tree$^{-1}$ (kg) | Fruit-$^{1}$ (g) | Tree$^{-1}$ (kg) | Fruit$^{-1}$ (g) | Tree$^{-1}$ (kg) | Frui$^{-1}$ (g) | Tree$^{-1}$ (kg) |
| T< 550 | 45.32 c A | 1.19 d a | 40.14 b b | 1.11 b a | 39.0 ab b | 1.14 b a | 41.49 | 1.14 |
| T 550-650 | 48.56 bc a | 1.29 cd a | 38.67 b b | 1.09 b b | 37.79 b b | 1.13 b b | 41.67 | 1.17 |
| T>650 | 38.22 d a | 1.03 e a | 32.95 c b | 0.93 c a | 32.12 c b | 0.94 c a | 34.43 | 0.97 |
| K<550 | 55.84 a a | 1.48 b a | 44.22 a b | 1.27 a b | 41.80 a b | 1.36 a ab | 47.29 | 1.37 |
| K 550- 650 | 59.43 a a | 1.62 a a | 38.20 b b | 1.16 ab b | 36.57 b b | 1.18 b b | 44.73 | 1.32 |
| K >650m | 49.40 b a | 1.34 c a | 36.20 bc b | 1.07 b b | 37.10 b b | 1.11 b b | 40.90 | 1.17 |
| Average cultivar | 49.46 | 1.33 | 38.40 | 1.11 | 37.40 | 1.14 | - | - |

Notes: The number followed by the same letter in the row, column, and the same parameter shows a non-significant difference in LSD 5%.

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Apart from being influenced by environmental factors, the production of Salak Gula Pasir fruit is also influenced by internal plant factors (Lestari et al. 2011). Altitude is related to plant tolerance to temperature and rainfall (Ritonga et al., 2018). Altitude increases, the average daily air temperature decreases and monthly rainfall increases (Table 1). Nuary et al. (2019) stated that the distribution and adaptation of zalacca plants is strongly influenced by temperature and rainfall. It was further stated, the contribution of daily temperature accounts for nearly 38.6% while rainfall is 27.8%. Kanzaria et al. (2015) reported that mango plants planted at an altitude of 229 m flowered slower than those at an altitude of 148 m and 81 m asl. The temperature regime at higher altitudes is colder than at lower altitudes. Lower temperatures accumulate less GDD and may result in late flowering. Table 4 shows that the salak gula pasir planted in Karangasem produced a higher fruit weight in the three salak cultivars tested. This is related to the level of soil fertility and soil type. The results of soil analysis showed that the nutrient content of Potassium was very low, the pH of the soil was slightly acidic, the N and P content was very low to moderate (Table 1). Therefore, improving soil fertility through fertilization and calcium is highly recommended.

*3.4 Quality characteristics of salacca cultivar*

The interaction between cultivars and altitude significantly affected sugar/total acid and vitamin C content. The three cultivars grown in Tabanan (low, mid, and highland) showed a lower TSS/acid ratio. The fruit flavour planted in three locations in Tabanan is sourer than the three locations in Karangasem. Sugar content is greatly affected by the geographical. The geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity, and rainfall (Ritonga et al., 2018). Table 4 also shows that the increase in height from 550 m to 700 m asl in Tabanan and the addition in altitude from 550 to 650 m asl in Karangasem causes the sugar/acid ratio

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Zalacca fruits from three different cultivars grown in low lands in Karangasem showed the highest vitamin C content and were significantly different from the three cultivars when planted in other locations. In both areas land increased by>650 effects to vitamin C decrease, and cultivars of Nangka and Gondok showed higher levels of vitamin C between <550 m -<650 m asl. (Table 5).

**Table 5.** TSS / acid ratio and levels of vitamin C of Nangka, Gondok, and Nenas cultivars in six locations.

| Location (m asl) | Nangka cv | | Gondok cv | | Nenas cv | | Average location | |
|---|---|---|---|---|---|---|---|---|
| | TSS / T. acid | Vit. C (mg /100g) | TSS / T.acid | Vit. C (mg / 100g) | TSS/ T.acid | Vit. C (mg / 100g) | TSS / T.acid | Vit. C (mg / 100g) |
| T< 550 | 56.20ab a | 27.50 ab a | 34.88c a | 25.50 bc a | 31.50b b | 26.71 a a | 40.86 | 26.57 |
| T 550-650 | 59.18a a | 25.45 bc a | 34.80c b | 25.75 bc a | 30.44b B | 25.88 ab a | 41.48 | 25.69 |
| T>650 | 37.89d a | 22.52 d a | 30.24c a | 23.34 c a | 26.13b B | 23.65 bc a | 31.42 | 23.17 |
| K<550 | 51.41bc a | 27.74 ab b | 51.28b a | 30.31 a a | 53.73a A | 24.42 abc c | 52.14 | 27.49 |
| K 550- 650 | 53.52abc a | 29.61 a a | 58.44a a | 27.63 b a | 52.63a a | 22.82 c b | 54.86 | 26.68 |
| K >650m | 47.76c a | 24.25 cd a | 53.04a a | 25.07 c a | 47.60a a | 25.16 abc a | 49.46 | 24.83 |
| Average cultivar | 50.99 | 26.18 | 43.78 | 26.27 | 40.34 | 24.77 | - | - |

Note: The number followed by the same letter in the row, column, and the same parameter shows a non-significant difference in LSD 5%.

The results showed that the cultivar of the Gulapasir zalacca needs different environmental requirements to optimize yields. Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech et al., 2019). Therefore, cultivar differences may depend on growing requirements and cultivation techniques. Vitamin C in the Gulapasir zalacca cultivar is strongly influenced by the altitude of the land. To produce high levels of vitamin C, the Nangka and Gondok cultivars are ideal for planting at an altitude of 560-650 m asl while the Nenas cultivar is ideal at a land altitude of <560 m asl. However, changes in ascorbate levels during fruit ripening are species-dependent and environmental factors (Fenech et al., 2019).

There was no interaction between cultivar and altitude to the flesh thickness, edible fruit portion, and fruit sugar content. The single treatment of salak cultivars, Nangka cultivars, showed fruit quality, including TSS, edible parts of the fruit, and higher flesh thickness (Table 6). Salak grown in Karangasem both from the lowlands and the middle lands produces fruit thickness, and the edible portion of fruits is higher than plants in the highlands. This study indicates that the ideal growing place for salak plants is between 450-650 m asl. This study is in line with several previous studies which explained that altitude affects the flowering process and fruit enlargement [15].

**Table 5.** The effect of a single factor of cultivars and planting location on TSS, the portion of edible flesh, and the thickness of salak fruit

| Cultivar | TSS ($^o$Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| Nangka | 16.59a | 72.50a | 0.63a |
| Gondok | 16.42a | 70.66ab | 0.59b |
| Nenas | 15.64b | 69.22b | 0.52c |
| LSD 5% | 0.60 | 3. 1 | 0.039 |
| Planting locations (m asl) | TSS ( $^o$Brix) | Edible portion (%) | Flesh thickness (cm) |
| T< 550 | 16.28a | 73.13a | 0.54c |
| T550-650 | 16.27a | 69.89a | 0.58bc |
| T >650 | 16.14a | 63.87b | 0.49d |
| K550 | 16.81a | 73.15a | 0.61b |
| K550-650 | 16.11a | 72.29a | 0.66a |
| K>650 | 15.69 | 72.44a | 0.61b |
| LSD 5% | ns. | 3.85 | 0.04 |

Notes: The number followed by the same letter in the same column shows a non-significant difference in LSD 5%.

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### 4. Conclusion and Recommendation

Different cultivars caused different fruit weights, fruit bunches, and the sugar/acid ratio at various locations. The three cultivars showed lower fruit weight and fruit quality in Tabanan (low, medium, and highlands) than the salak originating from Karangasem. The Nangka cultivar in Karangasem showed higher fruit weight, vitamin C content, and sugar/ acid ratio, while the Nanas salak cultivar showed the highest number of fruit bunches$^{-1}$ in six locations. Nangka cultivars are very suitable to be planted at an altitude of 550- 650 m above sea level. In contrast, the Nanas cv and Gondok cv are developed naturally at low altitudes < 550 above sea level. In order for all cultivars to be able to produce optimally, efforts to improve the cultivation system are needed through fertilization and the provision of calcium is highly recommended.

### Acknowledgements

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**Title:**

Agronomic Characters and Quality of Fruit of Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis) cv. Gulapasir Planted in Different Agro-Ecosystems

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**Running Title:**

Agronomic Characters and Quality of Fruit of Salak [Salacca zalacca (Gaertn.) Voss] var. amboinensis) cv. Gulapasir Planted in Different Agro-Ecosystems

**Keywords:**

Agronomic Characters, Yield Quality, *Salacca-zalacca* var. Amboinensis, Altitude, Agro-ecosystem, Tropical fruit.

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*ORCID ID 0000-0003-0669-7745*

# Agronomic Characters and Quality of Fruit of Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis) cv. Gulapasir Planted in Different Agro-Ecosystems

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## ABSTRACT

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Salak [Salacca zalacca (Gaertn.) Voss] var. amboinensis) cv. Gulapasir has been officially released by the Minister of Agriculture of the Republic of Indonesia since 1994. Salak Gulapasir is one of five types of fruit that have been designated as the superior fruit of the Bali Province. Salak Gulapasir preferred by consumers due to its specific fruit flesh taste. Salak Gula Pasir was propagated using seeds so that a new types of salak emerged. However, the characters of this new type of salak Gulapasir is not yet known. The research objective was to obtain the superior of some Salak Gulapasir both in production and fruit quality. The research used a Randomized Block Design with three replications. The non-independent variable was the three of Salak Gulapasir (SGP): SGP var.*Nangka (N)*, SGP var. *Nenas (N)*, SGP var.*Gondok (G)*, and six sites, namely Karangasem (K) : (K <560 m asl, K 560-650 m asl, and K >650 m asl) and Tabanan (T) : (T <560 m asl, T 560-650 m asl, T >650 m asl). Observations were made on the agronomic characters and fruit quality. Data were analyzed using variance analysis, and if the planting location and cultivars show a difference, then it is followed by the LSD test at the 5 % level. The results showed that different cultivars caused different fruit weights, fruit bunches, TSS, and total acid ratio. In Tabanan (in the low, medium, and highlands), the three t varieties showed lower fruit weight and fruit quality than the salak originating from Karangasem. The SGP var.*Nangka* in Karangasem showed higher fruit weight, vitamin C content, and TSS/total acid ratio, while the SGP var. *Nenas* showed the highest number of fruit bunches$^{-1}$ in six locations.

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**Ke ywords :** Agronomic Characters, Yield Quality, Salacca-zalacca var. Amboinensis, Altitude, Agro-ecosystem, Tropical fruit. .

## 1. Introduction

) Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis) cv. Gulapasir is one of the important fruits in Indonesia and the plant can be found in most regions of Indonesia (Rai *et al*. 2016; Ritonga *et al*., 2018). The salak fruit belong to the family Palmae or Arecaceae, and are native to the Indonesian-Malaysian region (Hakim *et al.*, 2019; (Zumaidar *et al.*, 2014).). One of the extraordinary strengths of this fruit commodity for Indonesia is the possession of high genetic diversity (Budiyanti *et al*., 2019). Also, the nutrition of salak fruit is rich in antioxidants, phenolics, vitamins, and minerals (Cepkova *et al.*, 2021; Mazumdar *et al*., 2019). The fruit flesh and peel have shown some tremendous anti-inflammatory, anticancer and antidiabetic (Saleh *et al*., 2018), and anti-ageing agents (Girsang *et al*., 2019). Antioxidants are chemical compounds that play an essential role in protecting cells due to attacks against free radicals-induced damage to biomolecules (Puspitasari and Ningsih, 2016; Setyobudi *et al*., 2019, 2022). Despite its incredible food and medicinal benefits, salak fruit is still underutilized and unknown globally. So that this underutilized fruit remains an issue for future sustainable utilization and commercial value enhancement market (Mazumdar *et al*., 2019). Fruit quality is an important issue, especially for products that are consumed raw and fresh. One of the problems is the lack of fruit quality because of inadequate information about superior salak (Budiyanti *et al*., 2019; Herawati *et al*., 2018). Therefore, it is necessary to select superior salak to meet market demand and fulfil community nutrition.

Salak Bali is quite a lot, based on the shape, aroma, taste, and skin colour of the location where the plants are cultivated (Sumantra *et al*., 2012, 2014; Sumantra and.Martiningsih, 2016, 2018). Under the Decree of the Minister of Agriculture of the Republic of Indonesia in 1994, Balinese zalacca was grouped into two superior zalacca: Salak Bali (Decree No.584)

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and Salak Gulapasir (Decree No.585). The second type, the salak Gulapasir (SGP) is the most superior salak because of its sweet fruit taste; even though the age of the fruit is still young, thick fruit flesh and seeds are not attached to the fruit flesh (Rai *et al*., 2014; Sumantra *et al*., 2016 ). The nature of this fruit is ideal for meeting market demands for both the domestic and export markets (Martiningsih *et al*., 2018). Salak Bali is monoecious, so crossing does not need human help (Herawati *et al*., 2018), and can quickly develop using seeds (Sumantra and Martiningsih, 2016). Another advantage of zalacca plants in Indonesia compared to other fruits is harvest fruit 2 to 3 times a year if management is good (Rai *et al*., 2016; Warnita *et al*., 2019). The expansion of Gulapasir salak planting causes variations in phenotypic diversity. People can find 2 to 3 types of salak plants with a marker, fruit shape, aroma, flesh colour, and fruit weight (Martiningsih *et al*., 2018). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seeds so that new varieties of salak Gulapasir appear, as reported by Sumantra and Martiningsih (2016). Based on the marker that can be used as a differentiator, salak farmers give it the name of SGP var. *Nenas*, SGP var.*Gondok*, and SGP var. *Nangka*. The three varieties varieties have not yet identified their advantages in meeting market needs in line with the results of research (Sumantra and Martiningsih, 2016). The performance and produce are influenced by the characteristics of the agricultural ecosystem, particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status (Adelina *et al*., 2021; Kumar *et al*., 2020 , and growth hormone (Prihastanti and Haryanti. 2022; Rai *et al*., 2016).

The Salak Gulapasir plantation in the District of Bebandem is the main producer of Salak Gulapasir in Bali is located in the southern part of Mount Agung with an altitude of 450 to- 700 m above sea level. The effect of altitude on plant growth and production is related to plant adaptation to temperature (Sumantra, *et al*., 2014), full sunlight (Sukawijaya *et al*., 2009), water status and soil quality (Raharjo *et al*., 2022; Rai *et al*., 2014; Raharjo Ritonga *et al*.,

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2018). Salak plants are not resistant to full sun but 50 to 70 % enough, therefore it is necessary to have shade plants (Sukawijaya *et al*., 2009; Sumantra *et al*., 2012 ). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019). Water status and soil quality really determine the fruit set on the salak Gulapasir. Low rainfall reduces the Relative Water Content in leaves (RWC), RWC, leaf chlorophyll content, and plant nutrient uptake (Rai *et al*., 2014). soil quality included the suitability of the physical, chemical and biological properties (Raharjo *et al*., 2022). Nuary *et al*. (2019) stated that the distribution of the Salak Pondoh plantation area in Sleman was greatly influenced by temperature and rainfall. The contribution of temperature in the modelling reached 38.6 % while the rainfall was 27.8 %. Furthermore, taking into account the probability of the temperature variable, the average temperature ranges from 17.41 to 25.65 °C, and the ideal month's rainfall ranges from 385.24 to 505.01 millimetre (mm).

Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019). Therefore, varieties differences may depend on growing requirements and cultivation techniques. Likewise, Puspitasari *et al*. (2017) stated that tannin content, fruit size and flesh colour of salak fruit are strongly influenced by where it grows. Other studies also explain that Gulapasir salak var. *nangka* which is grown 570 m asl, would result in a higher quality of fruit that includes thickness of the mesocarpium, edible portion of fruit then compared to above and below 570 m asl (Sumantra *et al*., 2014; Sumantra and Martiningsih, 2016). Meanwhile, fruit weight and fruit quality of *Gondok* and *Nenas* varieties have not been reported. Therefore, one way of handling salak quality is by undertaking severe studies for factors such as land and climate and adjusting agricultural patterns according to local climate conditions (Nassar *et al*., 2018). The success of each species to occupy the environment of an area is influenced by its ability to adapt optimally to all physical

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environmental factors (temperature, light, soil structure, humidity), biotic factors (interaction between species, competition, parasitism), and chemical factors including the availability of water, oxygen: pH, and nutrients (Nassar *et al*., 2018 ; Widyastuti *et al*., 2022). Moreover, a broad genetic variability would lead to wide phenotypic variability due to the effect of genetic-environment interaction (Ritonga *et al*., 2018). The research objective was to obtain the superior of some salak Gulapasir varieties both in production and fruit quality (sugar and acid ratio, vitamin C and tannin) in six different agricultural ecosystems in Bali.

## 2. Materials and Methods

### *2.1 Experimental Site*

The study was carried out in six different locations, three sites in Karangasem Regency and three sites in the district of Tabanan. Locations in Karangasem (K) are lowlands (K < 560 m asl) which include several places, namely Telaga, Dukuh, and Karanganyar. Karangasem in the moderate plains (K.560 to -650 m asl) has several areas, namely Kecing and Kutabali and highlands (K > 650 m asl), namely Tanah Apo and Kresek (Fig. 1).

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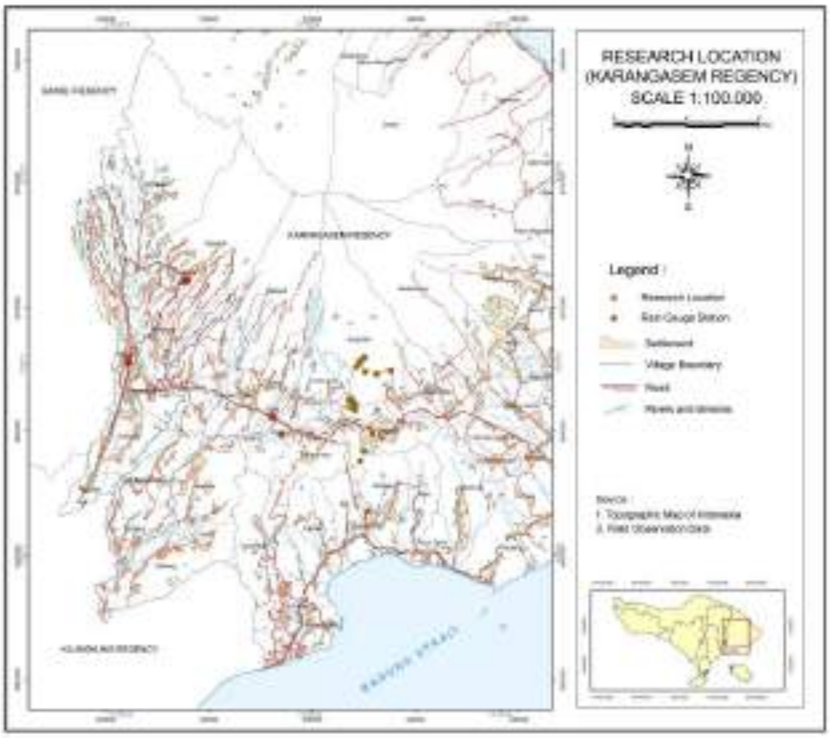


**Fig 1.** Research map and sampling point in Karangasem (K)

The research location is in Tabanan (T) in the lowlands (T < 560 m asl), including Wanagiri, Sari Buana, and Mundeh Kauh. Tabanan in the medium lands (T 560 to 650 m asl) includes several places, namely Pajahan, Kebon Jero, and Angseri. Tabanan in the highlands (T> 650 m asl), namely Munduk Temu, Pempatan, and Batungsel. (Fig. 2).

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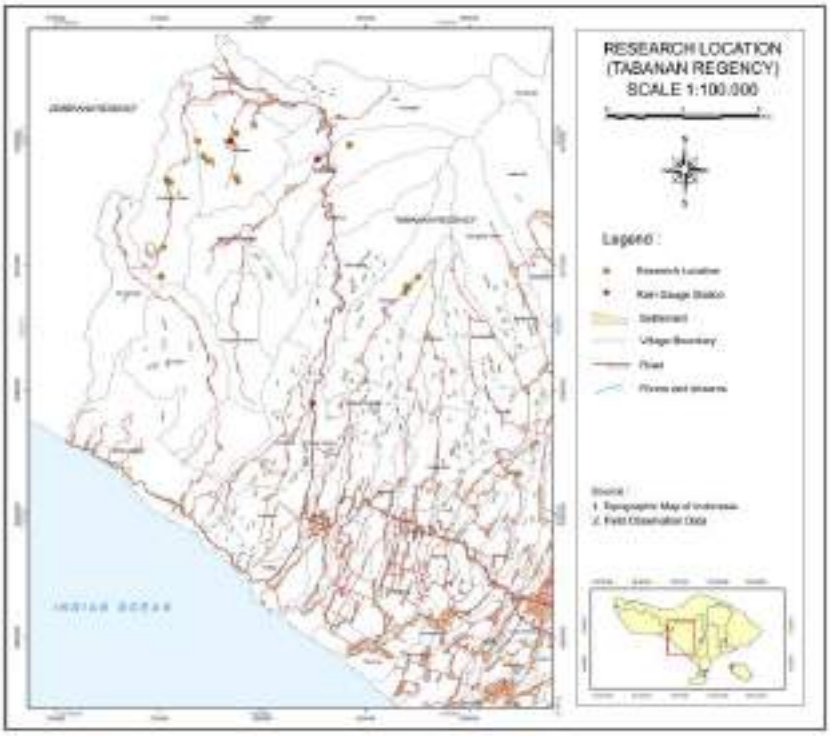


**Fig 2.** Research map and sampling point in Tabanan (T)

The non-independent variable was the three varieties of Salak Gulapasir (SGP): SGP var.*Nangka* (N), SGP var. *Nenas* (NS), SGP.var.*Gondok* (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560-650 m asl, and K > 650 m asl) and Tabanan (T) : (T < 560 m asl, T 560-650 m asl, T > 650 m) Repetition was carried out three times with the number of sample plants in each location, and cultivars were seven plants. The treatment tested is as shown in Table 1

**Table 1**. Treatment of plant location and three varieties of Gulapasir salak

| No | Treatment | Explanation |
|---|---|---|
| 1 | NT< 560 m asl | Salak GP.var. *Nangka* Tabanan < 560 m asl. |

| | | |
|---|---|---|
| 2 | NT 560-650 m asl | Salak GP.var. *Nangka* Tabanan 560-650 m asl. |
| 3 | NT > 650 m asl. | Salak GP.var. *Nangka* Tabanan > 650 m asl. |
| 4 | NK < 560 m asl. | Salak GP.var. *Nangka* Karangasem < 560 m asl. |
| 5 | NK 560-650 m asl | Salak GP.var. *Nangka* Karangasem 560 -650m asl. |
| 6 | NK > 650 m asl. | Salak GP.var. *Nangka* Karangasem > 650 m asl. |
| 7 | GT<560 m asl | Salak GP var. *Gondok* Tabanan < 560 m asl. |
| 8 | GT.560-650 m asl | Salak GP var. *Gondok* Tabanan 560 - 650 m asl. |
| 9 | GT>650 m asl | Salak GP var. *Gondok* Tabanan > 650 m asl. |
| 10 | GK.<560 m asl | Salak GP var. *Gondok* Karangasem < 560 m asl. |
| 11 | GK 560 - 650 m asl | Salak GP var. *Gondok* Karangasem 560 – 650 m asl. |
| 12 | GK >650 m asl | Salak GP var. *Gondok* Karangasem > 650 m asl. |
| 13 | NST <560 m asl | Salak GP var. Nenas Tabanan < 560 m asl. |
| 14 | NST.560 - 650 m asl | Salak GP var. *Nenas* Tabanan 560 – 650 m asl. |
| 15 | NST >650 m asl | Salak GP var. *Nenas* Tabanan > 650 m asl. |
| 16 | NSK .<560 m asl | Salak GP var. *Nenas* Karangasem < 560 m asl. |
| 17 | NSK 560 - 650 m asl | Salak GP var. *Nenas* Karangasem 560 – 650 m asl.. |
| 18 | NSK >650 m asl | Salak GP var. *Nenas* Karangasem > 650 m asl. |

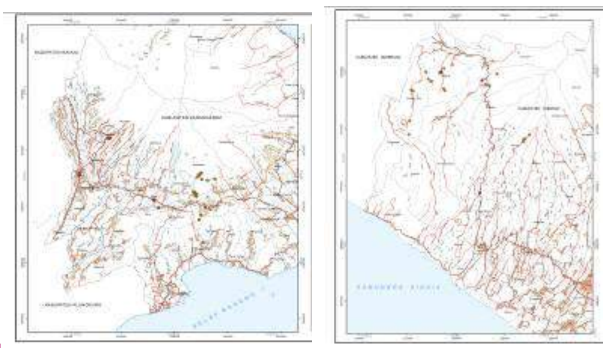

**Fig 1.** Research map and sampling point in Karangasem (Left) and Tabanan (Right)

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The study used a Composite Analysis of Variance (Andinurani, 2016) 1991) with the model determined using Equation (1) below:

$$Yjk = u + L\,i + \delta\,ik + Pj + (LP)\,ij + \varepsilon\,ijk \qquad (1)$$

Where:

Yijk = The observation value of the treatment (j) in the group (k), which is repeated at the location (i).

u = the actual average value

Li = additive effect from location i

δ ik = the error effect in group k at location i

Pj = additive effect of the next treatment

(LP) ij = the effect of treatment (j) at the location (i)

Ɛ ijk = the effect of error from the treatment (j) in the group (k) which was carried out at the location (i).

*2.2 Preparation of study materials*

The material used is the Gulapasir salak plant with uniform growth, plants have been fruitful with uniform on morphological, age of plants and cultivation action. The intentional practice is that the plant only receives treatment in the midrib, tillers, and weed cleaning. In this study, the plants were not fertilized. The provision of water was only from rainfall following the habits applied by salak farmers. The sample plant maintains by trimming unproductive leaf midribs and removing young shoots. Plant material was taken from the salak development centre in six locations, namely at the centre of salak development in the Bebandem sub-districts, Karangasem district (K-lowland <560 m asl, K-medium 560 to 650 m asl and K-highland >650 m asl), Bajre, West Slemadeg and Pupuan sub-districts, Tabanan district (T-lowland <560 m asl, T-medium 560 to 650 m asl and T-highland >650 m asl).

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2.*3 Analysis of physicochemical properties of soil sample* and climate

Soil analysis was carried out to determine the physical and chemical properties of the soil. Soil sampling was carried out under sample plant trees, carried out in a composite manner at a depth of 0 to 40 cm. Chemical analysis was carried out on total N (Kjeldahl method), available P by Bray I method and $K_2O$ by the Bray I method, organic C, pH, Soil physical properties in the form of texture by pipette method.

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Rainfall data was taken for five years from 2015 to 2019. by collecting data from the six stations closest to the research site (Table 2). Daily temperature data obtained from the Denpasar Meteorology Climatology Agency.

**Table 2**. Research locations and place of climatology stations

| Research Locations | Climate observation station | Latitude and altitude |
|---|---|---|
| Tabanan Lowlands (<560m asl) | Ampadan, Tiyinggading No.St. 439 m | $8^o$13'00"S/ $115^o$1500"E; 400 m asl. |
| Tabanan Moderate (56 0 to 650 m asl) | Coffee Breeding Center, Sai Pupuan No. St. 439 h | $08^o$20'08.6"S/$114^o$ 59'17.4" E; 580 m asl. |
| Tabanan Highlands (> 650 m asl) | Agricultural Extension Center, Pupuan. No St.441 h | $08^o$20'38.1" S/$115^o$01'35.2" E; 750 m asl. |
| Karangasem Lowlands (<560m asl) | Agricultural Extension Center, Selat. No. St. 444 d | $08^o$26’25” S /$115^o$29’02” E; 450 m asl. |
| Karangasem Moderate (560 to 650 m asl) | Horticulture Seed Center, Singerata No.St. 442 | $08^o$24’57”S /$115^o$25’14”E; 580 m asl. |
| Karangasem Highlands | Besakih Station. No.St.442 a | $08^o$22’49”S /$115^o$26’47”E; |

| | |
|---|---|
| (> 650 m asl) | 800 m asl. |

*2.4 Observation of fruit and fruit quality*

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Salak fruit can be harvested when it is ready for consumption. Consumable ripe fruit is a fruit that is ready to be consumed, characterized by a change in skin colour from dark brown to light brown, the thorns on the skin have reduced and are not sharp, and in general, at this stage, the fruit easily falls when shaken.

Observation and measurement of agronomic characters follow the method that has been done by Sumantra *et al*. (2014) including fruit weight, number of fruit bunches, the thickness of fruit flesh and fruit shape. The fruit characters from six-observed locations include the numbers of fruits per bunch, which is calculated manually on the formed fruits. The fruit weight per fruit and the fruit weight per tree is weighed after the fruits were removed from the bunch. The thickness of the mesocarpium is obtained by measuring the mesocarpium after it is cut vertically. The length of the flower sheath is measured on the stem of the sheath from the base to the tip of the sheath.

While fruit quality includes sugar content, tannins, titrated acid, sugar content and vitamin C. Titrated acid was analyzed by titration (Rengana, 1997). The fruit was weighed 10 g of sample was added to 100 mL of distilled water, then was homogenized using a slow spin blender, and filtered using an aseptic filter. The filtrate obtained was taken as much as 25 mL, then titrated with 0.1 N NaOH solution with phenolphthalein indicator until red in colour appeared. The results obtained are calculated as the percentage tartaric acid is determined using Equation (2) below :

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mL NaOH X N NaOH X P X BM

**Commented [R63]:** mL

A = ---------------------------------------------------- X 100 % (2)

Y X 1000 X 2

where:

A = percentage of total acid

P = amount of dilution

BM = molecular weight of tartaric acid

Y = sample weight (g).

Tannis content was analyzed as done by Thakur *et al*. (2021). Amount of 100 mg of the sample was homogenized by 2 mL of methanol. Centrifuged for 10' (min) minutes at 10,000 revolutions per minute (rpm ) and collected the supernatant. Amount of 1 mL of supernatant mixed with 0.5 mL Folin's phenol reagent and 35 % $Na_2CO_3$ of 5 mL added and the mixture was kept at room temperature for 5 minutes. The blue colour of the reaction mixture was observed at 640 nm by UV/visible spectrophotometer (Shimadzu UV-1800). The content of tannin was calculated by calibration curve equation and determined using Equation (3) below:

$$Y = 0.0073x-0.0071 : R^2 = 0.9973 \qquad (3)$$

Vitamin C was determined by titration like the method used by Asamara (2016). The material is weighed as much as 10 g and crushed in mortal. Then put into a 250 mL volumetric flask, set to the mark and filtered. Take 25 mL of the filtrate and titrate with 0.01 N Yod solution equivalent to 0.88 mg of ascorbic acid. The calculation of ascorbic acid content per 100 g of material is determined using Equation (4) below:

$$A = \frac{\text{mL Yod } 0.01 \text{ N X } 0.88 \text{ X P x } 100}{Y} \qquad (4)$$

where: A = mg of ascorbic acid per 100 g of material

P = amount of dilution

Y = gram sample weight

Sugar content as TSS is calculated using a hand refractometer (Bellingham and Stanley Ltd., London) at 20 °C.

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The ratio of sugar content (TSS) and total acid is calculated by the sugar content divided by the acid content multiplied by 100 percent.

The materials used in this study were Folin-Ciocalteu reagent (Pro Analytic, Merck), NaOH (Pro Analytic, Merck), $Na_2CO_3$ (Pro Analytic, Merck), Phenolphereagent ascorbic acid (Pro Analytic, Merck), Phosphoric Acid (Pro Analytic, Merck), Sodium Phosphate (Pro Analytic, Merck) and Ammonium Molybdate (Pro Analytic, Merck).

The tools used in this study were analytical balances (Shimadzu ATY224), centrifuge tubes, Erlenmeyer flasks (pyrex), dropper pipettes (pyrex), volume pipettes (pyrex), vortex (Maxi Mix II Type 367000), measuring flask (pyrex), water bath (Memmert), blender (Miyako), and centrifuge (Damon /IEC Division). Whatman filter paper No 1 (Sigma – Aldrich, USA), measuring cup (Pyrex, USA), micropipette (Dragon Lab, Indonesia), spectrophotometer (Biochromsn 133467, UK), test tube (Pyrex¸ USA), vortex (Barnsteadl Thermolyne Type 37600 Mixer, USA), aluminum foil (Klin Pak, Indonesia). …………

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*2.5 Study design*

This study used a randomized block design with the data analyzed using a Composite Analysis of Variance. If the variance test is significantly different, then it is continued with a different test with LSD at the 5 % level. Data analysis was performed using SPSS-IBM 18 (Adinurani, 2022) Each experimental treatment was repeated three times.

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**Commented [R82]:** Adinurani, PG. 2022. Agrotechnology Applied Statistics (compiled according to the semester learning plan). Deepublish, Yogyakarta, Indonesia.

**3. Results and Discussion**

*3.1 Agroclimate characteristic*

The low production level and quality of salak fruit are caused by environmental factors that do not support growth or because the physiological processes of the plant are not optimal due to insufficient nutrients and water. The suitability of climatic and soil conditions at six locations of the centres for the development of the Gulapasir salak was evaluated. The evaluation results show that the air temperature decreases as the altitude increases. The average air temperature at the Gulapasir salak plantation in Tabanan is 22.90 °C, while the air temperature at the Karangasem salak plantation is around 23.24 °C. (Tabel 2)

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Likewise, monthly rainfall and the average rainfall over the five years is presented in Table 2 and 3.

**Table 2.** Soil and climate characteristics of the research site in Tabanan and Karangasem in three subzones

| Parameter | Tabanan (T) | | | Karangasem (K) | | |
|---|---|---|---|---|---|---|
| | Lowlands (<560m asl) | Moderate (560 to 650 m asl) | Highlands (> 650 m asl) | Lowlands (<560m asl) | Moderate (560 to 650 m asl) | Highlands (> 650 m asl) |
| Temp. (° C) | 23.82 | 22.75 | 22.12 | 24.29 | 23.35 | 22.09 |
| Rainfall (mm/month) | 188.24 | 199.91 | 231.008 | 237.242 | 254.183 | 289.216 |
| Soil Texture | loamy clay | loamy clay | loamy clay | clay | Clay | sandy loam |
| pH ($H_2O$) | 5.64(sa) | 5.75 (sa) | 5.84 (sa) | 6.08 (sa) | 6.05 (sa) | 6.03(sa) |
| C- organic (%) | 3.07(h) | 4.40 (h) | 5.90(h) | 3.93 (m) | 3.63 (h) | 4.79 (h) |
| Nutrients available | | | | | | |
| N total (%) | 0.18 (l) | 0.16 (l) | 0.18 (l) | 0.24(m) | 0.23 (m) | 0.29 (m) |
| $P_2O_5$ (mg/g) | 9.38 (vl) | 9.12 (vl) | 13.50 (l) | 22.55 (m) | 24.18 (m) | 23.04 (m) |
| $K_2O$ (mg/g)) | 18.47 (vl) | 22.05 (vl) | 17.23 (vl) | 24.17 (vl) | 19.93 ( vl ) | 18.37 ( vl ) |

Notes: sa: slightly acidic; h: high; m: medium; l: low; vh: very high; h: high; asl: above sea level (The assessment criteria refer to Soil Research Center, Bogor 1983).

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Annual rainfall in Tabanan (T < 560, T 560-650 and T > 650) is lower with an average of 2515.05 mm while in Karangasem (K < 560, K 560-650 and K > 650) it is 3122.05 mm. However, the six locations show a trend of increasing rainfall as altitude increases. The salak plantation area in Karangasem is in the southern part of Mount Agung. Meanwhile in Tabanan, the dominant salak plantation area is behind Mount Batukaru with a lower elevation than Mount Agung. Mount Agung with an altitude of 3,142 m asl (Andaru and Rau, 2019), while the Batukaru mountains area with an elevation 2250 m asl (Asmiwyati et al., 2015). Mount Batukaru as a barrier, causing this area to be a rain shadow. Enyew & Steenveld (2014) state that rainfall in an area is influenced by topographical factors and mountain ranges. Decreasing the height of the mountains, provides a reduction in the maximum level of rainfall over the mountains and foothills by 50% (Flesch & Reuter, 2012). Topographical factors and regional weather systems have an important role in the amount and spatial pattern of rainfall in an area (Enyew & Steenveld, 2014).

**Table 3.** The annual rainfall in the six study sites (Year 2015 to 2019)

| Year | Tabanan : T (mm year $^{-1}$) | | | Karangasem : K (mm year $^{-1}$) | | |
|---|---|---|---|---|---|---|
| | T < 560 | T 560-650 | T > 650 | K < 560 | K 560-650 | K > 650 |
| 2015 | 2001.0 | 2462.7 | 2633.0 | 2470.5 | 2714.0 | 3291.0 |
| 2016 | 2095.0 | 2453.5 | 3049.5 | 2659.0 | 2885.0 | 3800.0 |
| 2017 | 1958.0 | 2152.5 | 2135.0 | 2903.0 | 3173.0 | 3500.0 |
| 2018 | 2335.5 | 2463.9 | 2955.0 | 3002.0 | 3057.0 | 3200.0 |
| 2019 | 2905.0 | 2462.0 | 3088.0 | 3200.0 | 3422. | 3562.0 |
| Average | 2258.9 | 2398.92 | 2772.1 | 2846.9 | 3050.2 | 3470.6 |

Based on the growing requirements of salak plants, rainfall and air temperature in the six locations evaluated were in the very suitable range to support plant growth and development. A good air temperature for the growth of salak plants is between 20 to 30 °C and an average rainfall of 200 to 400 mm/month (Nuary *et al*., 2019).

Soil C-organic content in six planting sites was in the moderate to high range. Availability of N and P nutrients in salak plantations in Tabanan in the lowlands, medium and highlands in low to very low conditions. Salak planting land in Karangasem, both in the lowlands, medium and highlands, these two nutrients are available in moderate conditions (Table 2). The nutrient content of potassium available in the six planting locations that have been evaluated shows a very low value. The results of this study indicate that the cultivation techniques carried out by farmers are very low, farmers do not apply fertilizers that only rely on litter from the pruning of salak midrib as reported by Rai *et al.* (2014), Warnita *et al.* (2019) and Ilmiah *et al*. (2021).

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**Commented [R90]:** SI

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**Commented [KS92R90]:** Data curah 5 tahun ditampilkan Tabel 3

*3.2 Kharacteristics of Salak Gulapasir Varieties*

The salak Gulapasir his monoecius plant, namely male and female flowers arranged on the same bunches, the shape of the bunches is compound, and the position of the flower is on the back of the midrib. The salak Gulapasir is classified as special because of its sweet fruit taste and the price per unit weight is four times more expensive than the salak Bali (Sumantra *et al*., 2012; Rai *et al*., 2014). The expansion of the cultivation of the salak Gulapasir from its area of origin, Sibetan, Karangasem, has resulted in phenotypic diversity with a phenotypic similarity level of 58.62 % to 93.10 % (Sumantra and Martiningsih, 2016). In the same garden, you can find at least two to three different varieties of Gulapasir salak, depending on fruit shape, aroma, color of fruit flesh and fruit weight (Sumantra and Martiningsih, 2016) The results of this study mean that the emergence of plant diversity due to plant propagation is done by seed, so new variants of salak Gulapasir appear with local names such as salak Gulapasir *Nenas*, salak Gulapasir *Gondok* and salak Gulapasir *Nangka*. The striking difference between these three varieties lies in the shape and flesh of the fruit. The number of fruit branches of salak Gulapasir *Nangka*, 1 to 2 fruit, salak Gulapasir *Nenas* cultivar 2 to 4 and salak Gulapasir *Gondok* not branched. Salak Gulapasir, which is ready to harvest, has fruit flesh attached to the seed, and the fruit flesh is 0.63 cm thick. Meanwhile, the flesh of the salak Gulapasir *Nenas* is the thinnest and the seeds are attached to the flesh (Fig.3). Meanwhile, when the salak Gulapasir *Gondok* is ready to harvest, the seeds make a sound when shaken (Fig.4).

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**Fig.3** The shape and the thickness of the fruit flesh of SGP.var.*Nenas*

**Fig.4** The shape and the thickness of the fruit flesh of SGP.var.*Gondok*

**Fig.5** The shape  and the thickness of the fruit flesh of SGP.var.*Nangka*


**Fig.1** The form of the fruit from three cultivar

**Fig. 2** The  shape  and the thickness of the flesh of *Gondok Nenas,*   and  *Nangka* varieties

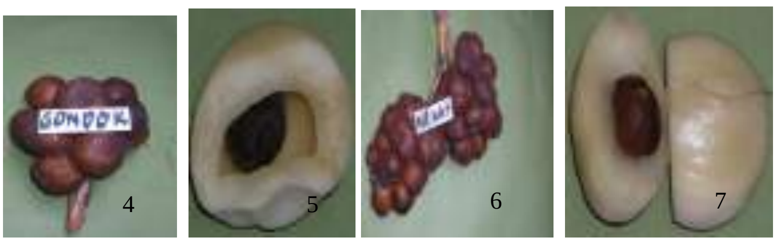


**Figure. 4 & 5** The shape of the bunches and the thickness of the fruit flesh gondok cv;

**Figure.6&7** The shape of the bunch and the thick flesh of the nenas cv.

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*3.3* Agronomic characteristics of Gulapasir Salak

Analysis of variance showed that the interaction between planting locations and varieties of Gulapasir salak  had significant effect on the number of fruits per bunch, fruit weight per tree, fruit weight per fruit, number of fruits per bunch, the ratio of sugar and acid and vitamin C content. Meanwhile, the thick fruit flesh and tannin content was not significant (Table 4)

**Table 4.** Recapitulation of the effects of varieties and growing locations on agronomic and fruits quality of Gulapasir salak

| No. | Character agronomic and fruits quality | Planting location | Varieties | Varieties x Location |
|---|---|---|---|---|
| 1 | Length of the flower sheath | ** | ** | * |
| 2 | Number of fruit bunches $^{-1}$ | ** | ** | * |
| 3 | Fruit tree weight $^{-1}$ | ** | ** | * |
| 4 | Fruit weight $^{-1}$ | ** | ** | * |
| 5 | TSS ratio and total acid | ** | ** | ** |
| 6 | Thick fruit flesh | ** | ** | Ns |
| 7 | Vitamin C | Ns | Ns | * |
| 8 | Tanin | Ns | Ns | Ns |
| 9 | Edible portion | ** | ** | Ns |

Notes: *) significant P < 0.05, **) very significant P < 0.01 and Ns) not significantly different P > 0.05

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The interaction of varieties and planting location had a significant effect on the length of the flower sheath and the number of fruit bunches $^{-1}$. *Nenas* variety  grown in Tabanan (T < 560, T 560 to 650, and T > 650 ) and Karangasem (K < 560, K560 to 650, and K > 650) showed higher sheath length and a number of fruit bunches $^{-1}$ than with *Nangka* and *Gondok* varieties  (Table 5). Tabanan (T 560-650) and  Karangasem (K<560 m asl) are ideal conditions for flower sheath development and fruit development of *Nenas*.

**Table 5.** Flower sheath length (cm) and a number of fruit bunches $^{-1}$ (fruit) of *Nangka*, *Gondok* and *Nenas* varieties  at six locations.

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| Treatment | Sheath length (cm) | Amount fruit bunches $^{-1}$ |
|---|---|---|
| NT< 560 | 27.50 ± 0.34 bcd | 19.55 ± 0.82 hij |
| NT 560-650 | 28.83 ± 1.31 b | 20.39 ± 1.00 g |
| NT > 650 | 27.17 ± 0.96 cde | 19.02 ± 0.82 j |
| NK < 560 | 26.00 ± 0.82 e | 21.13 ± 0.82 ef |
| NK 560-650 | 27.17 ± 0.14 cde | 22.28± 2.45 c |
| NK > 650 | 26.67 ± 1.36 cde | 21.13 ± 0.74 ef |

| | | |
|---|---|---|
| GT<560 | 26.67 + 2.18 cde | 20.22 + 0.31 gh |
| GT.560-650 | 27.50 + 1.22 bcd | 20.55 + 0.62 fg |
| GT>650 | 27.70 + 1.98 bc | 19.22 + 0.74 ij |
| GK<560 | 25.83 + 1.41 e | 21.89 + 0.82 cd |
| GK 560 - 650 | 26.83 + 0.75 cde | 20.5 + 1.63 fg |
| GK >650 | 27.5 + 0.82 bcd | 21.28 + 0.78 def |
| NST <560 | 27.5 + 0.82 bcd | 21.41 + 0.91 de |
| NST560 - 650 | 27.67 + 0.82 bc | 22.00 + 1.56 cd |
| NST >650 | 26.17 + 2.16 de | 19.91 + 1.36 ghi |
| NSK <560 | 32.00 + 1.63 a | 25.27+ 1.41 a |
| NSK 560 - 650 | 30.90 + 2.10 a | 24.00 + 0.82 b |
| NSK >650 | 27.00 + 1.47 cde | 21.86 + 0.82 cde |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

| Location (Original m) | *Nangka* var | | *Gondok* var | | *Nenas* cv | | Average Location | |
|---|---|---|---|---|---|---|---|---|
| | Sheath length (cm) | Amount fruit bunches $^{-1}$ | Sheath length (cm) | Amount fruit bunches $^{-1}$ | Sheath length (cm) | Amount fruit bunches $^{-1}$ | sheath length (cm) | Amount fruit bunches $^{-1}$ |
| T<560 | 27.50ab A | 19.55 d b | 26.67ab A | 20.22cd B | 27.50bc A | 21.41c A | 27.22 | 20.39 |
| T.560-650 | 28.83a A | 20.39 c b | 27.50a A | 20.55bc B | 27.67b A | 22.00c A | 28.00 | 20.98 |
| T>650 | 27.17bc Ab | 19.02 d b | 27.70a A | 19.22d A | 26.17c B | 19.91d A | 27.01 | 19.38 |
| K.<560 | 26.00c B | 21.13 b b | 25.83b B | 21.89a B | 32.00a A | 25.27a A | 27.94 | 22.76 |
| K 560-650 | 27.17bc B | 22.28 a b | 26.83ab B | 10.50a B | 30.90a A | 24.00b A | 28.30 | 22.93 |
| K>650 | 26.67bc A | 21.13 b a | 27.50a A | 21.28ab A | 27.00bc A | 21.86c A | 27.06 | 21.42 |
| Average cultivar | 27.22 | 20.58 | 27.01 | 20.94 | 28.54 | 22.41 | - | - |

Remarks : Numbers followed by the same letter in the same row, column and parameter indicate a non-significant difference in BNT 5%.

From Table 5 above it can be explained that the three varieties planted in six locations produced a number of fruits between 19.02 to 25.27 fruits per bunch. *Nenas* variety planted in Karangasem at an altitude of < 560 m asl (NSK < 560) produced the highest number of fruits of 25.27 per bunch, followed by NSK 560 - 650 and NST 560 - 650 with 24.00 and 22.00 fruits per bunch. In order for the salak plants to bear much fruit,

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**Commented [MOU106R105]:** Sajian data diperbaiki seperti saran Bpk (di Tabel 5)
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the *Nangka* variety is ideal in Karangasem 560 to 650 m asl (NK 560 - 650), while the Gondok variety is very good when planted below 560 m asl (GK < 560) although the number of fruits is not significantly different from the same altitude  for NT 560 - 650 and GT < 560. The results of this study are in line with the findings of Sumantra and Martiningsih (2016) that the Gulapasir salak var. *Nenas* produces the highest number of fruits both in the on season (*gadu* season) and -off-season (*sela* season).

The interaction of varieties and planting location had a significant effect on the fruit weigh (fruit tree$^{-1}$ and fruit$^{-1}$). *Nangka* variety grown in Tabanan (T<560, T560-650, and T>650) and Karangasem (K<560, K560-650, and K>650) showed higher of weight of fruit tree$^{-1}$ and fruit-$^{1}$ than with *Nenas* and *Gondok* varities (Table 6).

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**Table 6**. Fruit weight of *Nangka*, *Gondok*, and *Nenas* varieties in six locations

| Treatment | Fruit$^{-1}$ (g) | Fruit tree-$^{1}$ (kg) |
|---|---|---|
| NT < 560 | 45.32 ± 1.08 cd | 1.19 ± 0.08 def |
| NT 560-650 | 48.56 ± 0.71 c | 1.29 ± 0.07 cd |
| NT > 650 | 38.22 ± 0.46 ef | 1.03 ± 0.06 ghi |
| NK < 560 | 55.84 ± 1.37 a | 1.48 ± 0.02 b |
| NK 560-650 | 59.43 ± 0.71 a | 1.62 ± 0.07 a |
| NK > 650 | 49.4 ±1.65 b | 1.34 ± 0.05 c |
| GT <560 | 40.14 ± 0.11 e | 1.11± 0.09 fg |
| GT.560-650 | 38.67 ± 0.55 ef | 1.09 ± 0.07 fg |
| GT >650 | 32.95 ± 0.73 gh | 0.93 ± 0.10 i |
| GK <560 | 44.22 ± 0.18 d | 1.27 ± 0.06 cde |
| GK 560 – 650 | 38.20 ± 0.78 ef | 1.16 ± 0.05 defg |
| GK >650 | 36.20 ± 0.75 fg | 1.07 ± 0.11 fgh |
| NST <560 | 39.00 ± 1.07 ef | 1.14 ± 0.11 efg |
| NST560 – 650 | 37.79 ± 0.65 f | 1.13 ± 0.06 g |
| NST >650 | 32.12 ± 0.11 h | 0.94 ± 0.10 hi |
| NSK <560 | 41.80 ± 0.65 de | 1.36 ± 0.08 bc |
| NSK 560 - 650 | 36.57 ± 0.80 fg | 1.18 ± 0.09 def |
| NSK >650 | 37.10 ± 0.23 f | 1.11 ± 0.07 fg |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

From Table 6 it can be explained that the three varieties grown in six locations produced fruit weight per tree between 0.93 kg and 1.62 kg. The salak *Nangka* variety planted in Karangasem at an altitude of 560-650 m asl (NK 560-650) produced the heaviest fruit weight of 1.62 kg per tree, followed by NK < 560 and NT 560-650 with fruit weights of 1.48 and 1.29 kg. While the *Nenas* variety produces the best fruit at altitudes <560 m asl (NSK <560 and NT <560). Salak Gulapasir var. *Gondok* is ideal when planted at altitudes < 560 m asl (GK < 560 and GT < 560), although the two growing locations showed a different yields.

*Nenas* and *Gondok* varieties showed a trend of decreasing fruit weight in line with increasing altitude, both planted in Karangasem and Tabanan. The reverse occurred in the salak nangka cultivar, an increase in altitude from 550 m asl to 550-650 m asl caused an increase in fruit weight and after that the fruit weight decreased when planted at altitudes > 650 m asl. This finding is in line with the results of research that has been reported by Sumantra *et al*. (2014). However, for the *Gondok* and *Nenas* varieties, this is a new finding.

**Table 4**. Fruit weight of Nangka, Gondok, and Nenas cultivars (cv) in six locations

| Location (m asl) | CV. Nangka | | CV. Gondok | | CV. Nenas | | Average location | |
|---|---|---|---|---|---|---|---|---|
| | Fruit$^{-1}$ (g) | Tree$^{-1}$ (kg) | Fruit-$^{1}$ (g) | Tree$^{-1}$ (kg) | Fruit$^{-1}$ (g) | Tree$^{-1}$ (kg) | Frui$^{-1}$ (g) | Tree$^{-1}$ (kg) |
| T< 550 | 45.32 c A | 1.19 d A | 40.14 b B | 1.11 b a | 39.0 ab B | 1.14 b A | 41.49 | 1.14 |
| T 550-650 | 48.56 bc A | 1.29 cd A | 38.67 b B | 1.09 b b | 37.79 b B | 1.13 b B | 41.67 | 1.17 |
| T>650 | 38.22 d A | 1.03 e A | 32.95 c B | 0.93 c a | 32.12 c B | 0.94 c A | 34.43 | 0.97 |
| K<550 | 55.84 a A | 1.48 b A | 44.22 a B | 1.27 a b | 41.80 a B | 1.36 a Ab | 47.29 | 1.37 |
| K 550- 650 | 59.43 a A | 1.62 a A | 38.20 b B | 1.16 ab b | 36.57 b B | 1.18 b B | 44.73 | 1.32 |
| K >650m | 49.40 b A | 1.34 c A | 36.20 bc B | 1.07 b b | 37.10 b B | 1.11 b B | 40.90 | 1.17 |
| Average Cultivar | 49.46 | 1.33 | 38.40 | 1.11 | 37.40 | 1.14 | - | - |

Notes: The number followed by the same letter in the row, column, and the same parameter shows a non-significant difference in LSD 5%.

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Apart from being influenced by environmental factors, the production of Salak Gulapasir fruit is also influenced by internal plant factors (Lestari *et al*. 2011). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech et al., 2019), and rainfall (Ritonga *et al*., 2018). Altitude increases, the average daily air temperature decreases and monthly rainfall increases (Table 2,3). Nuary *et al.* (2019) stated that the distribution and adaptation of salak plants is strongly influenced by temperature and rainfall. It was further stated, the contribution of daily temperature accounts for nearly 38.6% while rainfall is 27.8%. Kanzaria *et al.* (2015) reported that mango plants planted at an altitude of 229 m flowered slower than those at an altitude of 148 m and 81 m asl. The temperature regime at higher altitudes is colder than at lower altitudes. Lower temperatures accumulate less GDD and may result in late flowering. Table 6 shows that the Gulapasir salak planted in Karangasem produced a higher fruit weight in the three salak varieties tested. This is related to the level of soil fertility and soil type. The results of soil analysis showed that the nutrient content of Potassium was very low, the pH of the soil was slightly acidic, the N and P content was very low to moderate (Table 2). Therefore, improving soil fertility through fertilization and calcium is highly recommended.

*3.4 Quality characteristics of salak varieties*

The interaction between varieties and altitude significantly affected sugar/total acid and vitamin C content. The three varieties grown in Tabanan (T < 560, T 560 to 650 and T > 650) showed a lower TSS/acid ratio. The fruit flavour planted in three locations in Tabanan is sourer than the three locations in Karangasem. Sugar content is greatly affected by the geographical. The geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity, and rainfall (Ritonga *et al*., 2018). Table 7 also shows that the increase in altitude from 550 m to 700 m asl in Tabanan and the addition in altitude from 550 to 650 m asl in Karangasem causes the sugar/acid ratio decrease in all three varieties, and the lowest sugar/acid value occurs in

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*Nenas* variety in all locations. Each salak variety has an adaptation to an elevation closely related to plant tolerance to temperature (Sumantra and Martiningsih, 2016; 2018). Many factors influence fruit quality, but the most dominant are climate factors, especially temperature and rainfall. High rainfall and low air temperature during the fruit ripening phase can cause the dissolved solids in the fruit to become watery so that the TSS value is low (Singh *et al*., 2011).

Salak fruits from three different varieties grown in low lands in Karangasem (K < 560 m asl) showed the highest vitamin C content and were significantly different from the three cultivars when planted in other locations. In both areas land increased by > 650 m asl effects to vitamin C decrease, *Nangka* and *Gondok* varieties showed higher levels of vitamin C between < 550 m to < 650 m asl. (Table 7).

**Table 7.** TSS/acid ratio and levels of vitamin C of *Nangka*, *Gondok*, and *Nenas* varieties in six locations.

| Treatment | TSS/T.Acid | Vit. C (mg /100g) |
|---|---|---|
| NT< 560 | 56.20 ± 0.16 abc | 27.50 ± 0.41 bde |
| NT 560-650 | 59.18 ± 0.82 a | 25.45 ± 0.37 defgh |
| NT > 650 | 37.89 ± 0.91 f | 22.52 ± 0.39 j |
| NK < 560 | 51.41 ± 0.33 cde | 27.74 ± 0.47 bd |
| NK 560-650 | 53.52± 0.82 abcd | 29.61 ± 0.50 ab |
| NK > 650 | 47.76 ± 0.11 de | 24.25 ± 0.20 fghij |
| GT<560 | 34.88± 0.72 fg | 25.50 ± 0.41 defgh |
| GT.560-650 | 34.80 ± 0.65 fg | 25.75 ± 0.20 defgh |
| GT>650 | 30.24 ± 0.20 gh | 23.34 ± 0.28 hij |
| GK<560 | 51.28 ± 0.23 cde | 30.31 ± 0.25 a |
| GK 560 - 650 | 58.44 ± 0.36 ab | 27.63 ± 0.30 bd |
| GK >650 | 53.04 ± 0.82 bcde | 25.07 ± 0.33 efghi |
| NST <560 | 31.50 ± 0.41 gh | 26.71± 0.21 cdef |
| NST560 - 650 | 30.44 ± 0.36 gh | 25.88 ± 0.41 defg |
| NST >650 | 26.13 ± 0.11 h | 23.65 ± 0.29 ghij |
| NSK <560 | 53.73 ± 0.60 abc | 24.42 ± 0.34 fghij |
| NSK 560 - 650 | 52.63 ± 0.51 bcde | 22.82 ± 0.15 ij |
| NSK >650 | 47.60 ± 0.49 e | 25.16 ± 0.13 efghi |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

**Table 5.** TSS / acid ratio and levels of vitamin C of Nangka, Gondok, and Nenas cultivars in six locations.

| Location (m asl) | Nangka cv | | Gondok cv | | Nenas cv | | Average location | |
|---|---|---|---|---|---|---|---|---|
| | TSS / T. acid | Vit. C (mg /100g) | TSS / T.acid | Vit. C (mg / 100g) | TSS/ T.acid | Vit. C (mg / 100g) | TSS / T.acid | Vit. C (mg / 100g) |
| T< 550 | 56.20ab a | 27.50 ab a | 34.88c a | 25.50 bc a | 31.50b b | 26.71 a A | 40.86 | 26.57 |
| T 550-650 | 59.18a a | 25.45 bc a | 34.80c b | 25.75 bc a | 30.44b B | 25.88 ab A | 41.48 | 25.69 |
| T>650 | 37.89d a | 22.52 d a | 30.24c a | 23.34 c a | 26.13b B | 23.65 bc A | 31.42 | 23.17 |
| K<550 | 51.41bc a | 27.74 ab b | 51.28b a | 30.31 a a | 53.73a A | 24.42 abc C | 52.14 | 27.49 |
| K 550- 650 | 53.52abc a | 29.61 a a | 58.44a a | 27.63 b a | 52.63a a | 22.82 c B | 54.86 | 26.68 |
| K >650m | 47.76c a | 24.25 cd a | 53.04a a | 25.07 c a | 47.60a a | 25.16 abc A | 49.46 | 24.83 |
| Average cultivar | 50.99 | 26.18 | 43.78 | 26.27 | 40.34 | 24.77 | - | - |

Note: The number followed by the same letter in the row, column, and the same parameter shows a non-significant difference in LSD 5%.

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The results showed that the varieties of the Gulapasir salak needs different environmental requirements to optimize yields. Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019). Therefore, variety differences may depend on growing requirements and cultivation techniques. Vitamin C in the Gulapasir salak is strongly influenced by the altitude of the land. To produce high levels of vitamin C, the *Nangka* and *Gondok* varieties are ideal for planting at an altitude of 560 to 650 m asl, while the *Nenas* variety is ideal at a land altitude of < 560 m asl. However, changes in ascorbate levels during fruit ripening are species-dependent and environmental factors especially temperature and light (Fenech *et al*., 2019).

There was no interaction between varieties and altitude to the flesh thickness, edible fruit portion, and fruit sugar content. The *Nangka* salak variety showed fruit quality, including TSS, edible parts of the fruit, and higher flesh thickness (Table 8).

**Table 8.** The effect of a single factor of varieties on TSS, the portion of edible flesh, and the thickness of salak fruits

| Varieties | TSS (°Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| *Nangka* | 16.59a | 72.50a | 0.63a |
| *Gondok* | 16.42a | 70.66ab | 0.59b |
| *Nenas* | 15.64b | 69.22b | 0.52c |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Salak grown in Karangasem both from the lowlands and the middle lands produces fruit thickness, and the edible portion of fruits is higher than plants in the highlands. This study indicates that the ideal growing place for salak plants is between 450 to 650 m asl. This study is in line with several previous studies which explained that altitude affects the flowering process and fruit enlargement (Sophie *at al*., 2017; Spinardi *et al*., 2019; Widyastut *et al*., 2022).

**Table 9.** The effect of a single factor of planting location on TSS, the portion of edible flesh, and the thickness of salak fruits

| Planting locations (m asl) | TSS ( °Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| T< 550 | 16.28a | 73.13a | 0.54c |
| T550-650 | 16.27a | 69.89a | 0.58bc |
| T >650 | 16.14a | 63.87b | 0.49d |
| K550 | 16.81a | 73.15a | 0.61b |
| K550-650 | 16.11a | 72.29a | 0.66a |
| K>650 | 15.69 | 72.44a | 0.61b |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

**4. Conclusion and Recommendation**

Different cultivars caused different fruit weights, fruit bunches, and the sugar/acid ratio at various locations. The three varieties showed lower fruit weight and fruit quality in Tabanan (low, medium, and highlands) than the salak originating from Karangasem. The

*Nangka* variety in Karangasem showed higher fruit weight, vitamin C content, and sugar/ acid ratio, while the *Nanas* salak showed the highest number of fruit bunches$^{-1}$ in six locations. *Nangka* salak are very suitable to be planted at an altitude of 550- 650 m asl. In contrast, the *Nanas* and *Gondok* varieties are developed naturally at low altitudes < 550 m asl. In order for all cultivars to be able to produce optimally, efforts to improve the cultivation system are needed through fertilization and the provision of calcium is highly recommended.

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**Title:**

Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Different Agro-Ecosystems

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**Running Title:**

Agronomic Characters and Quality of Fruit of Salak Planted in Different Agro-Ecosystems

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# Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Different Agro-Ecosystems

## ABSTRACT

Salak [Salacca zalacca (Gaertn.) Voss] var. amboinensis cv. Gulapasir has been officially released by the Minister of Agriculture of the Republic of Indonesia since 1994. Salak 'Gulapasir' is one of five types of fruit that have been designated as the superior fruit of the Bali Province. Salak 'Gulapasir' preferred by consumers due to its specific fruit flesh taste. Salak 'Gulapasir' was propagated using seeds so that a new types of salak emerged. However, the characters of this new type of salak 'Gulapasir' is not yet known. The research objective was to obtain the superior of some Salak 'Gulapasir' both in production and fruit quality. The research used a Randomized Block Design with three replications. The non-independent variable was the three of Salak 'Gulapasir' (SGP): SGP var. nangka (N), SGP var. nenas (N), SGP var. gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 to 650 m asl, and K > 650 m asl) and Tabanan (T) : (T < 560 m asl, T 560 to 650 m asl, T > 650 m asl). Observations were made on the agronomic characters and fruit quality. Data were analyzed using variance analysis, and if the planting location and cultivars show a difference, then it is followed by the LSD test at the 5 % level. The results showed that different cultivars caused different fruit weights, fruit bunches, TSS, and total acid ratio. In Tabanan (in the low, medium, and highlands), the three varieties showed lower fruit weight and fruit quality than the salak originating from Karangasem. The SGP var. nangka in Karangasem showed higher fruit weight, vitamin C content, and TSS/total acid ratio, while the SGP var. nenas showed the highest number of fruit bunches$^{-1}$ in six locations.

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**Ke ywords :** Agro-ecosystem, Altitude, *Salacca zalacca* (Gaertn.) Voss, Snake fruit, Tropical fruit

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## 1. Introduction

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir is one of the important fruits in Indonesia and the plant can be found in most regions of Indonesia (Rai *et al*. 2016; Ritonga *et al*., 2018). The salak fruit belong to the family Palmae or Arecaceae, and are native to the Indonesian-Malaysian region (Hakim *et al.,* 2019; Zumaidar *et al*., 2014). One of the extraordinary strengths of this fruit commodity for Indonesia is the possession of high genetic diversity (Budiyanti *et al*., 2019). Also, the nutrition of salak fruit is rich in antioxidants, phenolics, vitamins, and minerals (Cepkova *et al.,* 2021; Mazumdar *et al*., 2019). The fruit flesh and peel have shown some tremendous anti-inflammatory, anticancer and antidiabetic (Saleh *et al*., 2018), and anti-ageing agents (Girsang *et al*., 2019). Antioxidants are chemical compounds that play an essential role in protecting cells due to attacks against free radicals-induced damage to biomolecules (Puspitasari and Ningsih, 2016; Setyobudi *et al*., 2019, 2022). Despite its incredible food and medicinal benefits, salak fruit is still underutilized and unknown globally. So that this underutilized fruit remains an issue for future sustainable utilization and commercial value enhancement market (Mazumdar *et al*., 2019). Fruit quality is an important issue, especially for products that are consumed raw and fresh. One of the problems is the lack of fruit quality because of inadequate information about superior salak (Budiyanti *et al*., 2019; Herawati *et al*., 2018). Therefore, it is necessary to select superior salak to meet market demand and fulfil community nutrition.

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Salak 'Bali' is quite a lot, based on the shape, aroma, taste, and skin colour of the location where the plants are cultivated (Sumantra *et al*., 2012, 2014; Sumantra and Martiningsih, 2016, 2018). Under the Decree of the Minister of Agriculture of the Republic of Indonesia in 1994, Balinese zalacca was grouped into two superior zalacca: Salak 'Bali' (Decree No.584)

Commented [R9]: Sy perbaiki. Demikian juga di kalimat yang lain and Salak ‘Gulapasir’ (Decree No.585). The second type, the salak Gulapasir (SGP) is the most superior salak because of its sweet fruit taste; even though the age of the fruit is still young, thick fruit flesh and seeds are not attached to the fruit flesh (Rai *et al*., 2014; Sumantra *et al*., 2016). The nature of this fruit is ideal for meeting market demands for both the domestic and export markets (Martiningsih *et al*., 2018). Salak ‘Bali’ is monoecious, so crossing does not need human help (Herawati *et al*., 2018), and can quickly develop using seeds (Sumantra and Martiningsih, 2016). Another advantage of zalacca plants in Indonesia compared to other fruits is harvest fruit 2 to 3 times a year if management is good (Rai *et al*., 2016; Warnita *et al.*, 2019). The expansion of salak ‘Gulapasir’ planting causes variations in phenotypic diversity. People can find 2 to 3 types of salak plants with a marker, fruit shape, aroma, flesh colour, and fruit weight (Martiningsih *et al*., 2018). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seeds so that new varieties of salak ‘Gulapasir’ appear, as reported by Sumantra and Martiningsih (2016). Based on the marker that can be used as a differentiator, salak farmers give it the name of SGP var. nenas, SGP var. gondok, and SGP var. nangka. The three varieties varieties have not yet identified their advantages in meeting market needs in line with the results of research (Sumantra and Martiningsih, 2016). The performance and produce are influenced by the characteristics of the agricultural ecosystem, particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status (Adelina *et al.*, 2021; Kumar *et al*., 2020) and growth hormone (Prihastanti and Haryanti. 2022; Rai *et al.*, 2016).

The salak ‘Gulapasir’ plantation in the District of Bebandem is the main producer of salak ‘Gulapasir’ in Bali is located in the southern part of Mount Agung with an altitude of 450 m to 700 m above sea level (m asl). The effect of altitude on plant growth and production is related to plant adaptation to temperature (Sumantra, *et al*., 2014), full sunlight (Sukawijaya *et al*., 2009), water status and soil quality (Raharjo *et al.*, 2022; Rai *et al*., 2014; Raharjo

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Ritonga *et al.,* 2018). Salak plants are not resistant to full sun but 50 % to 70 % enough, therefore it is necessary to have shade plants (Sukawijaya *et al*., 2009; Sumantra *et al*., 2012). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019). Water status and soil quality really determine the fruit set on the salak 'Gulapasir'. Low rainfall reduces the Relative Water Content in leaves (RWC), leaf chlorophyll content, and plant nutrient uptake (Rai *et al*., 2014). soil quality included the suitability of the physical, chemical and biological properties (Raharjo *et al*., 2022). Nuary *et al*. (2019) stated that the distribution of the salak 'Pondoh' plantation area in Sleman (Yogyakarta, Special Region) was greatly influenced by temperature and rainfall. The contribution of temperature in the modelling reached 38.6 % while the rainfall was 27.8 %. Furthermore, taking into account the probability of the temperature variable, the average temperature ranges from 17.41 °C to 25.65 °C, and the ideal month's rainfall ranges from 385.24 mm to 505.01 mm.

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Commented [R13]: Mhn SI
Commented [R14R13]: Sy perbaiki
Commented [R15]: Sy perbaiki

Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019). Therefore, varieties differences may depend on growing requirements and cultivation techniques. Likewise, Puspitasari *et al*. (2017) stated that tannin content, fruit size and flesh colour of salak fruit are strongly influenced by where it grows. Other studies also explain that salak 'Gulapasir' var. nangka which is grown 570 m asl, would result in a higher quality of fruit that includes thickness of the mesocarpium, edible portion of fruit then compared to above and below 570 m asl (Sumantra *et al*., 2014; Sumantra and Martiningsih, 2016). Meanwhile, fruit weight and fruit quality of var. gondok and var. nenas have not been reported. Therefore, one way of handling salak quality is by undertaking severe studies for factors such as land and climate and adjusting agricultural patterns according to local climate conditions (Nassar *et al*., 2018). The success of each species to occupy the environment of an area is influenced by its ability to adapt optimally to all physical environmental factors (temperature, light, soil structure, humidity), biotic factors (interaction between species, competition, parasitism), and chemical factors including the availability of water, oxygen: pH, and nutrients (Nassar *et al*., 2018; Widyastuti *et al*., 2022). Moreover, a broad genetic variability would lead to wide phenotypic variability due to the effect of genetic-environment interaction (Ritonga *et al*., 2018). The research objective was to obtain the superior of some salak 'Gulapasir' both in production and fruit quality (sugar and acid ratio, vitamin C and tannin) in six different agricultural ecosystems in Bali.

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## 2. Materials and Methods

### *2.1 Experimental Site*

The study was carried out in six different locations, three sites in Karangasem Regency and three sites in the district of Tabanan. Locations in Karangasem (K) are lowlands (K < 560 m asl) which include several places, namely Telaga, Dukuh, and Karanganyar. Karangasem in the moderate plains (K 560 m to 650 m asl) has several areas, namely Kecing and Kutabali and highlands (K > 650 m asl), namely Tanah Apo and Kresek (Figure 1).

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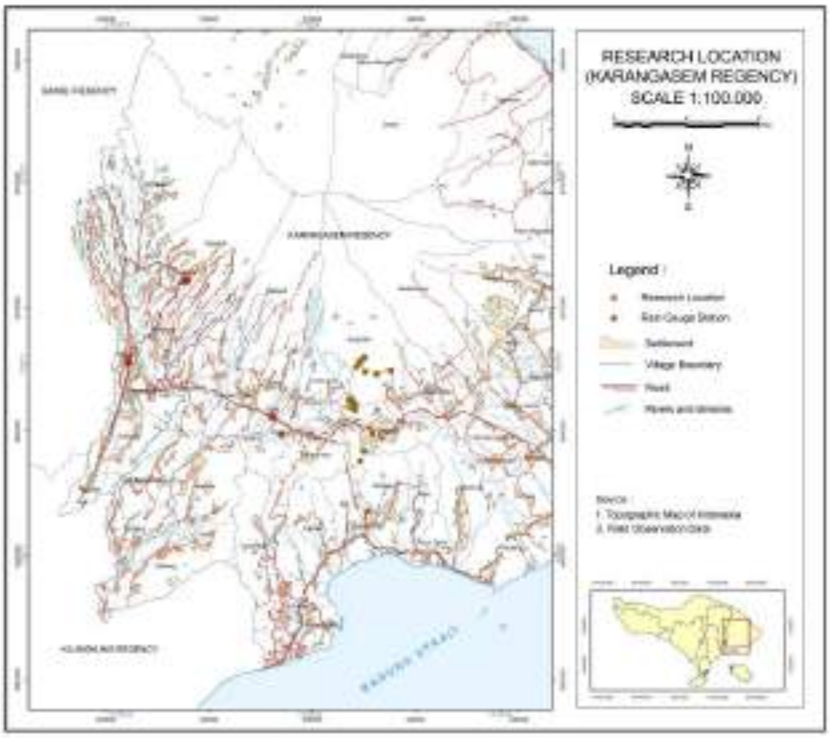


**Fig 1.** Research map and sampling point in Karangasem (K)

The research location is in Tabanan (T) in the lowlands (T < 560 m asl), including Wanagiri, Sari Buana, and Mundeh Kauh. Tabanan in the medium lands (T 560 m to 650 m asl) includes several places, namely Pajahan, Kebon Jero, and Angseri. Tabanan in the highlands (T > 650 m asl), namely Munduk Temu, Pempatan, and Batungsel (Figure 2).

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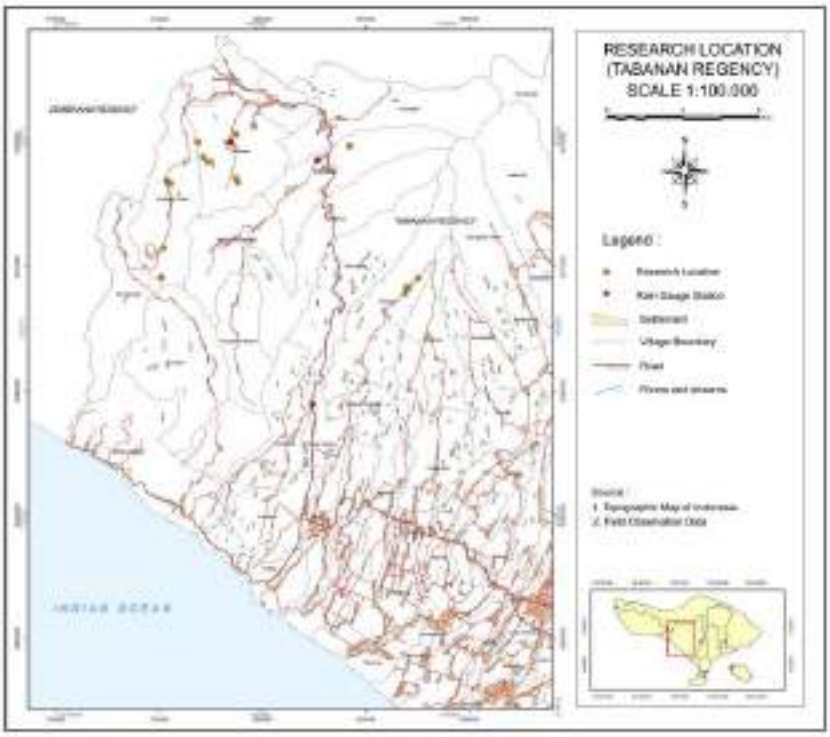


**Fig 2.** Research map and sampling point in Tabanan (T)

The non-independent variable was the three varieties of Salak 'Gulapasir' (SGP): SGP var.nangka (N), SGP var. nenas (NS), SGP.var.gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 m to 650 m asl, and K > 650 m asl) and Tabanan (T) : (T < 560 m asl, T 560 m to 650 m asl, T > 650 m) Repetition was carried out three times with the number of sample plants in each location, and cultivars were seven plants. The treatment tested is as shown in Table 1

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**Table 1**. Treatment of plant location and three varieties of Gulapasir salak

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| No | Treatment | Explanation |
|---|---|---|
| 1 | NT< 560 m asl | Salak GP.var. *Nangka* Tabanan < 560 m asl. |
| 2 | NT 560 m to 650 m asl | Salak GP.var. *Nangka* Tabanan 560 m to 650 m asl. |
| 3 | NT > 650 m asl. | Salak GP.var. *Nangka* Tabanan > 650 m asl. |
| 4 | NK < 560 m asl. | Salak GP.var. *Nangka* Karangasem < 560 m asl. |
| 5 | NK 560 m to 650 m asl | Salak GP.var. *Nangka* Karangasem 560 m to 650 m asl. |
| 6 | NK > 650 m asl. | Salak GP.var. *Nangka* Karangasem > 650 m asl. |
| 7 | GT< 560 m asl | Salak GP var. *Gondok* Tabanan < 560 m asl. |
| 8 | GT.560 to 650 m asl | Salak GP var. *Gondok* Tabanan 560 m to 650 m asl. |
| 9 | GT > 650 m asl | Salak GP var. *Gondok* Tabanan > 650 m asl. |
| 10 | GK.< 560 m asl | Salak GP var. *Gondok* Karangasem < 560 m asl. |
| 11 | GK 560 m to 650 m asl | Salak GP var. *Gondok* Karangasem 560 m to 650 m asl. |
| 12 | GK > 650 m asl | Salak GP var. *Gondok* Karangasem > 650 m asl. |
| 13 | NST < 560 m asl | Salak GP var. Nenas Tabanan < 560 m asl. |
| 14 | NST.560 m to 650 m asl | Salak GP var. *Nenas* Tabanan 560 m to 650 m asl. |
| 15 | NST > 650 m asl | Salak GP var. *Nenas* Tabanan > 650 m asl. |
| 16 | NSK .< 560 m asl | Salak GP var. *Nenas* Karangasem < 560 m asl. |
| 17 | NSK 560 m to 650 m asl | Salak GP var. *Nenas* Karangasem 560 m to 650 m asl.. |
| 18 | NSK > 650 m asl | Salak GP var. *Nenas* Karangasem > 650 m asl. |

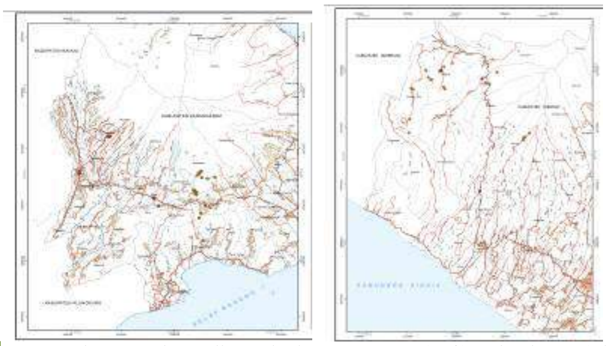

**Fig 1.** Research map and sampling point in Karangasem (Left) and Tabanan (Right)

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The study used a Composite Analysis of Variance (Andinurani, 2016, 2022) with the model determined using Equation (1) below:

$$Yjk = u + L\,i + \delta\,ik + Pj + (LP)\,ij + \varepsilon\,ijk \qquad (1)$$

Where:

Yijk = The observation value of the treatment (j) in the group (k), which is repeated at the location (i).

u = the actual average value

Li = additive effect from location i

δ ik = the error effect in group k at location i

Pj = additive effect of the next treatment

(LP) ij = the effect of treatment (j) at the location (i)

Ɛ ijk = the effect of error from the treatment (j) in the group (k) which was carried out at the location (i).

*2.2 Preparation of study materials*

The material used is the salak ‘Gulapasir’ plant with uniform growth, plants have been fruitful with uniform on morphological, age of plants and cultivation action. The intentional practice is that the plant only receives treatment in the midrib, tillers, and weed cleaning. In this study, the plants were not fertilized. The provision of water was only from rainfall following the habits applied by salak farmers. The sample plant maintains by trimming unproductive leaf midribs and removing young shoots. Plant material was taken from the salak development centre in six locations, namely at the centre of salak development in the Bebandem sub-districts, Karangasem district (K-lowland < 560 m asl, K-medium 560 m to 650 m asl and K-highland > 650 m asl), Bajre, West Slemadeg and Pupuan sub-districts, Tabanan district (T-lowland < 560 m asl, T-medium 560 to 650 m asl and T-highland > 650 m asl).

2.3 *Analysis of physicochemical properties of soil sample* and climate

Soil analysis was carried out to determine the physical and chemical properties of the soil. Soil sampling was carried out under sample plant trees, carried out in a composite manner at a depth of 0 cm to 40 cm. Chemical analysis was carried out on total N (Kjeldahl method), available P by Bray I method and $K_2O$ by the Bray I method, organic C, pH, Soil physical properties in the form of texture by pipette method (…..)

Rainfall data was taken for five years from 2015 to 2019. by collecting data from the six stations closest to the research site (Table 2). Daily temperature data obtained from the Denpasar Meteorology Climatology Agency.

**Table 2**. Research locations and place of climatology stations

| Research Locations | Climate observation station | Latitude and altitude |
|---|---|---|
| Tabanan Lowlands (< 560 m asl) | Ampadan, Tiyinggading No.St. 439 m | 8$^o$13'00"S/ 115$^o$1500"E; 400 m asl. |
| Tabanan Moderate (560 m to 650 m asl) | Coffee Breeding Center, Sai Pupuan No. St. 439 h | 08$^o$20'08.6"S/114$^o$ 59'17.4" E; 580 m asl. |

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**Commented [R43]:** Sy perbaiki
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| | | |
|---|---|---|
| Tabanan Highlands (> 650 m asl) | Agricultural Extension Center, Pupuan. No St.441 h | 08$^{o}$20'38.1" S/115$^{o}$01'35.2" E; 750 m asl. |
| Karangasem Lowlands (< 560 m asl) | Agricultural Extension Center, Selat. No. St. 444 d | 08$^{o}$26’25” S /115$^{o}$29’02” E; 450 m asl. |
| Karangasem Moderate (560 m to 650 m asl) | Horticulture Seed Center, Singerata No.St. 442 | 08$^{o}$24’57”S /115$^{o}$25’14”E; 580 m asl. |
| Karangasem Highlands (> 650 m asl) | Besakih Station. No.St.442 a | 08$^{o}$22’49”S /115$^{o}$26’47”E; 800 m asl. |

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*2.4 Observation of fruit and fruit quality*

Salak fruit can be harvested when it is ready for consumption. Consumable ripe fruit is a fruit that is ready to be consumed, characterized by a change in skin colour from dark brown to light brown, the thorns on the skin have reduced and are not sharp, and in general, at this stage, the fruit easily falls when shaken.

Observation and measurement of agronomic characters follow the method that has been done by Sumantra *et al*. (2014) including fruit weight, number of fruit bunches, the thickness of fruit flesh and fruit shape. The fruit characters from six-observed locations include the numbers of fruits per bunch, which is calculated manually on the formed fruits. The fruit weight per fruit and the fruit weight per tree is weighed after the fruits were removed from the bunch. The thickness of the mesocarpium is obtained by measuring the mesocarpium after it is cut vertically. The length of the flower sheath is measured on the stem of the sheath from the base to the tip of the sheath.

While fruit quality includes sugar content, tannins, titrated acid, sugar content and vitamin C. Titrated acid was analyzed by titration (Rengana, 1997). The fruit was weighed 10 g of sample was added to 100 mL of distilled water, then was homogenized using a slow spin blender, and filtered using an aseptic filter. The filtrate obtained was taken as much as 25 mL, then titrated with 0.1 N NaOH solution with phenolphthalein indicator until red in colour appeared. The results obtained are calculated as the percentage tartaric acid is determined using Equation (2) below :

$$A = \frac{\text{mL NaOH X N NaOH X P X BM}}{\text{Y X 1 000 X 2}} \times 100\ \% \qquad (2)$$

where:

A = percentage of total acid

P = amount of dilution

BM = molecular weight of tartaric acid

Y = sample weight (g).

Tannis content was analyzed as done by Thakur *et al*. (2021). Amount of 100 mg of the sample was homogenized by 2 mL of methanol. Centrifuged for 10 min at 10 000 rpm (1 rpm = 1/60 Hz) and collected the supernatant. Amount of 1 mL of supernatant mixed with 0.5 mL Folin's phenol reagent and 35 % $Na_2CO_3$ of 5 mL added and the mixture was kept at room temperature for 5 min. The blue colour of the reaction mixture was observed at 640 nm by UV/visible spectrophotometer (Shimadzu UV-1800, Japan). The content of tannin was calculated by calibration curve equation and determined using Equation (3) below:

$$Y = 0.0073x-0.0071 : R^2 = 0.9973 \qquad (3)$$

Vitamin C was determined by titration like the method used by Asamara (2016, Setyobudi *et al.* 2021, 2022). The material is weighed as much as 10 g and crushed in mortal. Then put into a 250 mL volumetric flask, set to the mark and filtered. Take 25

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**Commented [R49]:** SI

**Commented [R50R49]:** Sy perbaiki krn Bpk blm respon

**Commented [R51R49]:** X pakai multiplication sign

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**Commented [R53]:** SI

**Commented [R54R53]:** Sy perbaiki krn Bpk tdk respon

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**Commented [R56R55]:** Sy perbaiki krn Bpk blm respon

**Commented [R57]:** Sy perbaiki

**Commented [R58]:** Sya tambah

mL of the filtrate and titrate with 0.01 N Yod solution equivalent to 0.88 mg of ascorbic acid. The calculation of ascorbic acid content per 100 g of material is determined using Equation (4) below:

$$A = \frac{\text{mL Yod } 0.01 \text{ N} \times 0.88 \times P \times 100}{Y} \qquad (4)$$

where: A = mg of ascorbic acid per 100 g of material

P = amount of dilution

Y = gram sample weight

Sugar content as TSS is calculated using a hand refractometer (Bellingham and Stanley Ltd., London) at 20 $^{o}$C.

The ratio of sugar content (TSS) and total acid is calculated by the sugar content divided by the acid content multiplied by 100 %.

The materials used in this study were Folin-Ciocalteu reagent (Pro Analytic, Merck), NaOH (Pro Analytic, Merck), $Na_2CO_3$ (Pro Analytic, Merck), Phenolphereagent ascorbic acid (Pro Analytic, Merck), Phosphoric Acid (Pro Analytic, Merck), Sodium Phosphate (Pro Analytic, Merck) and Ammonium Molybdate (Pro Analytic, Merck).

The tools used in this study were analytical balances (Shimadzu ATY224, Japan), centrifuge tubes, Erlenmeyer flasks (pyrex), dropper pipettes (pyrex), volume pipettes (pyrex), vortex (Maxi Mix II Type 367000), measuring flask (pyrex), water bath (Memmert), blender (Miyako), and centrifuge (Damon /IEC Division). Whatman filter paper No 1 (Sigma – Aldrich, USA), measuring cup (Pyrex, USA), micropipette (Dragon Lab, Indonesia), spectrophotometer (Biochromsn 133467, UK), test tube (Pyrex¸ USA), vortex (Barnsteadl Thermolyne Type 37600 Mixer, USA), aluminum foil (Klin Pak, Indonesia).

Commented [R59]: perbaiki spt saran saya di (2)

Commented [R60R59]: X apakah kali ? Mhn diperbaiki ya Pak

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Commented [R63]: Saya perbaiki

*2.5 Study design*

This study used a randomized block design with the data analyzed using a Composite Analysis of Variance. If the variance test is significantly different, then it is continued with a different test with LSD at the 5 % level. Data analysis was performed using SPSS-IBM 18 (Adinurani, 2016, 2022) Each experimental treatment was repeated three times.

## 3. Results and Discussion

*3.1 Agroclimate characteristic*

The low production level and quality of salak fruit are caused by environmental factors that do not support growth or because the physiological processes of the plant are not optimal due to insufficient nutrients and water. The suitability of climatic and soil conditions at six locations of the centres for the development of the 'Gulapasir' salak was evaluated. The evaluation results show that the air temperature decreases as the altitude increases. The average air temperature at the 'Gulapasir' salak plantation in Tabanan is 22.90 $^{o}$C, while the air temperature at the Karangasem salak plantation is around 23.24 $^{o}$C. (Tabel 2)

Likewise, monthly rainfall and the average rainfall over the five years is presented in Table 2 and 3.

**Table 2.** Soil and climate characteristics of the research site in Tabanan and Karangasem in three subzones

| **Parameter** | **Tabanan (T)** | | | **Karangasem (K)** | | |
|---|---|---|---|---|---|---|
| | Lowlands (<560 m asl) | Moderate 560 m to 650 m asl) | Highlands (> 650 m asl) | Lowlands (< 560m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) |
| Temp. ($^{o}$C) | 23.82 | 22.75 | 22.12 | 24.29 | 23.35 | 22.09 |
| Rainfall (mm/month) | 188.24 | 199.91 | 231.008 | 237.242 | 254.183 | 289.216 |
| Soil Texture | loamy clay | loamy clay | loamy clay | clay | Clay | sandy loam |
| pH ($H_2O$) | 5.64(sa) | 5.75 (sa) | 5.84 (sa) | 6.08 (sa) | 6.05 (sa) | 6.03(sa) |
| C- organic (%) | 3.07(h) | 4.40 (h) | 5.90(h) | 3.93 (m) | 3.63 (h) | 4.79 (h) |

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Apakah C organik ini (3.07 to 5.90 terkatagori spt ini ?

**Commented [R66]:** Pendapat saya ini adalah low

**Commented [R67]:** Ini h ? Mhn lihat 3.93(m)

**Commented [R68R67]:** Di bawah tabel ini saya copas ambang C organik.. Pendapat saya tabel C organik ini 'salah'. Mhn rechek

**Commented [R69]:** Pendapat saya ini adalah m

**Commented [R70]:** Ini m ? lihat di sebelahnya 3.63(h)

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| | | | | | | |
|---|---|---|---|---|---|---|
| Nutrients available | | | | | | |
| N total (%) | 0.18 (l) | 0.16 (l) | 0.18 (l) | 0.24(m) | 0.23 (m) | 0.29 (m) |
| $P_2O_5$ (mg/g) | 9.38 (vl) | 9.12 (vl) | 13.50 (l) | 22.55 (m) | 24.18 (m) | 23.04 (m) |
| $K_2O$ (mg/g)) | 18.47 (vl) | 22.05 (vl) | 17.23 (vl) | 24.17 (vl) | 19.93 ( vl ) | 18.37 ( vl ) |

Notes: sa: slightly acidic; h: high; m: medium; l: low; vh: very high; h: high; asl: above sea level (The assessment criteria refer to Soil Research Center, Bogor 1983).

**Pusat Penelitian Tanah dari Departemen Pertanian (1983)** telah mengajukan kriteria penilaian sifat kimia tanah berdasarkan sifat umum tanah yang didapat secara empiris. Kriteria penilaian sifat kimia tanah tersebut disajikan pada gambar tabel berikut.

| Sifat Tanah | Sangat Rendah | Rendah | Sedang | Tinggi | Sangat Tinggi |
|---|---|---|---|---|---|
| C-organik (%) | < 1,0 | 2,0 | 3,3 | 5,0 | > 5,0 |

Annual rainfall in Tabanan (T < 560, T 560-650 and T > 650) is lower with an average of 2515.05 mm while in Karangasem (K < 560, K 560-650 and K > 650) it is 3122.05 mm. However, the six locations show a trend of increasing rainfall as altitude increases. The salak plantation area in Karangasem is in the southern part of Mount Agung. Meanwhile in Tabanan, the dominant salak plantation area is behind Mount Batukaru with a lower elevation than Mount Agung. Mount Agung with an altitude of 3 142 m asl (Andaru and Rau, 2019), while the Batukaru mountains area with an elevation 2 250 m asl (Asmiwyati *et al*., 2015). Mount Batukaru as a barrier, causing this area to be a rain shadow. Enyew & Steenveld (2014) state that rainfall in an area is influenced by topographical factors and mountain ranges. Decreasing the height of the mountains, provides a reduction in the maximum level of rainfall over the mountains and foothills by 50% (Flesch & Reuter, 2012). Topographical factors and regional weather systems have an important role in the amount and spatial pattern of rainfall in an area (Enyew & Steenveld, 2014).

**Commented [R74]:** Pakai eksponen negatif

**Commented [R75]:** idem

**Commented [R76]:** Saya sudah koreksi bahan organil. Saya khawatir, kita beda persepsi pula di ambang unsur hara yang lain. Mhn recheck dan bila perlu kita saling telpun u diskusi

**Commented [R77]:** Mhn lengkapi satuan . Mhn semua diperbaiki

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**Commented [R83]:** Mhn diperbaiki

**Commented [R84]:** Bpk ?

**Commented [R85]:** Bpk ?

**Commented [R86]:** Bpk ?

**Table 3.** The annual rainfall in the six study sites (2015 to 2019)

| Year | Tabanan : T (mm yr $^{-1}$) | | | Karangasem : K (mm yr $^{-1}$) | | |
|---|---|---|---|---|---|---|
| | T < 560 | T 560-650 | T > 650 | K < 560 | K 560-650 | K > 650 |
| 2015 | 2001.0 | 2462.7 | 2633.0 | 2470.5 | 2714.0 | 3291.0 |
| 2016 | 2095.0 | 2453.5 | 3049.5 | 2659.0 | 2885.0 | 3800.0 |
| 2017 | 1958.0 | 2152.5 | 2135.0 | 2903.0 | 3173.0 | 3500.0 |
| 2018 | 2335.5 | 2463.9 | 2955.0 | 3002.0 | 3057.0 | 3200.0 |
| 2019 | 2905.0 | 2462.0 | 3088.0 | 3200.0 | 3422. | 3562.0 |
| Average | 2258.9 | 2398.92 | 2772.1 | 2846.9 | 3050.2 | 3470.6 |

Based on the growing requirements of salak plants, rainfall and air temperature in the six locations evaluated were in the very suitable range to support plant growth and development. A good air temperature for the growth of salak plants is between 20 to 30 °C and an average rainfall of 200 to 400 mm/month (Nuary *et al*., 2019).

Soil C-organic content in six planting sites was in the moderate to high range. Availability of N and P nutrients in salak plantations in Tabanan in the lowlands, medium and highlands in low to very low conditions. Salak planting land in Karangasem, both in the lowlands, medium and highlands, these two nutrients are available in moderate conditions (Table 2). The nutrient content of potassium available in the six planting locations that have been evaluated shows a very low value. The results of this study indicate that the cultivation techniques carried out by farmers are very low, farmers do not apply fertilizers that only rely on litter from the pruning of salak midrib as reported by Rai *et al.* (2014), Warnita *et al.* (2019) and Ilmiah *et al*. (2021).

*3.2 Kharacteristics of Salak Gulapasir Varieties*

The salak 'Gulapasir' his monoecius plant, namely male and female flowers arranged on the same bunches, the shape of the bunches is compound, and the position of the flower is on the back of the midrib. The salak 'Gulapasir' is classified as special because of its sweet fruit taste and the price per unit weight is four times more expensive than the

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**Commented [R99]:** Pendapat saya ini adalah Cultivar. Bukan Varietas karena ada SK. Memang masyarakat salah kaprah dan bias antara kultivar dan varietas salak 'Bali' (Sumantra *et al*., 2012; Rai *et al*., 2014). The expansion of the cultivation of the salak 'Gulapasir' from its area of origin, Sibetan, Karangasem, has resulted in phenotypic diversity with a phenotypic similarity level of 58.62 % to 93.10 % (Sumantra and Martiningsih, 2016). In the same garden, you can find at least two to three different varieties of 'Gulapasir' salak, depending on fruit shape, aroma, color of fruit flesh and fruit weight (Sumantra and Martiningsih, 2016) The results of this study mean that the emergence of plant diversity due to plant propagation is done by seed, so new variants of salak 'Gulapasir' appear with local names such as salak 'Gulapasir' nenas, salak 'Gulapasir' gondok and salak 'Gulapasir' nangka. The striking difference between these three varieties lies in the shape and flesh of the fruit. The number of fruit branches of salak 'Gulapasir' nangka, 1 to 2 fruit, salak 'Gulapasir' nenas cultivar amount of 2 to 4 fruit and salak 'Gulapasir' gondok not branched. Salak 'Gulapasir', which is ready to harvest, has fruit flesh attached to the seed, and the fruit flesh is 0.63 cm thick. Meanwhile, the flesh of the salak 'Gulapasir' nenas is the thinnest and the seeds are attached to the flesh (Figure 3). Meanwhile, when the salak 'Gulapasir' gondok is ready to harvest, the seeds make a sound when shaken (Figure 4).

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**Fig.3** The shape and the thickness of the fruit flesh of SGP.var.*Nenas*

**Fig.4** The shape and the thickness of the fruit flesh of SGP.var.*Gondok*

**Fig.5** The shape  and the thickness of the fruit flesh of SGP.var.*Nangka*


**Fig.1** The form of the fruit from three cultivar

**Fig. 2** The  shape  and the thickness of the flesh of *Gondok Nenas*,   and  *Nangka* varieties


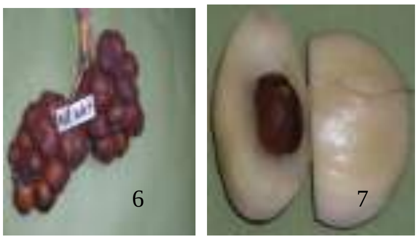


**Figure. 4 & 5** The shape of the bunches and the thickness of the fruit flesh gondok cv;

**Figure.6&7** The shape of the bunch and the thick flesh of the nenas cv.

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*3.3* Agronomic characteristics of 'Gulapasir' Salak

Analysis of variance showed that the interaction between planting locations and varieties of 'Gulapasir' salak had significant effect on the number of fruits per bunch, fruit weight per tree, fruit weight per fruit, number of fruits per bunch, the ratio of sugar and acid and vitamin C content. Meanwhile, the thick fruit flesh and tannin content was not significant (Table 4)

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**Table 4.** Recapitulation of the effects of varieties and growing locations on agronomic and fruits quality of Gulapasir salak

| No. | Character agronomic and fruits quality | Planting location | Varieties | Varieties x Location |
|---|---|---|---|---|
| 1 | Length of the flower sheath | ** | ** | * |
| 2 | Number of fruit bunches $^{-1}$ | ** | ** | * |
| 3 | Fruit tree weight $^{-1}$ | ** | ** | * |
| 4 | Fruit weight $^{-1}$ | ** | ** | * |
| 5 | TSS ratio and total acid | ** | ** | ** |
| 6 | Thick fruit flesh | ** | ** | Ns |
| 7 | Vitamin C | Ns | Ns | * |
| 8 | Tanin | Ns | Ns | Ns |
| 9 | Edible portion | ** | ** | Ns |

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Notes: *) significant P < 0.05, **) very significant P < 0.01 and Ns) not significantly different P > 0.05

The interaction of varieties and planting location had a significant effect on the length of the flower sheath and the number of fruit bunches $^{-1}$. Nenas variety grown in Tabanan (T < 560, T 560 to 650, and T > 650 ) and Karangasem (K < 560, K560 to 650, and K > 650) showed higher sheath length and a number of fruit bunches $^{-1}$ than with nangka. Nangka and gondok varieties (Table 5). Tabanan (T 560-650) and Karangasem (K<560 m asl) are ideal conditions for flower sheath development and fruit development of nenas.

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**Table 5.** Flower sheath length (cm) and a number of fruit bunches $^{-1}$ (fruit) of nangka, gondok and nenas *Nenas* varieties at six locations.

| Treatment | Sheath length (cm) | Amount fruit bunches $^{-1}$ |
|---|---|---|
| NT< 560 | 27.50 ± 0.34 bcd | 19.55 ± 0.82 hij |
| NT 560-650 | 28.83 ± 1.31 b | 20.39 ± 1.00 g |
| NT > 650 | 27.17 ± 0.96 cde | 19.02 ± 0.82 j |
| NK < 560 | 26.00 ± 0.82 e | 21.13 ± 0.82 ef |
| NK 560-650 | 27.17 ± 0.14 cde | 22.28± 2.45 c |
| NK > 650 | 26.67 ± 1.36 cde | 21.13 ± 0.74 ef |

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|---|---|---|
| GT<560 | 26.67 + 2.18 cde | 20.22 + 0.31 gh |
| GT.560-650 | 27.50 + 1.22 bcd | 20.55 + 0.62 fg |
| GT>650 | 27.70 + 1.98 bc | 19.22 + 0.74 ij |
| GK<560 | 25.83 + 1.41 e | 21.89 + 0.82 cd |
| GK 560 - 650 | 26.83 + 0.75 cde | 20.5 + 1.63 fg |
| GK >650 | 27.5 + 0.82 bcd | 21.28 + 0.78 def |
| NST <560 | 27.5 + 0.82 bcd | 21.41 + 0.91 de |
| NST560 - 650 | 27.67 + 0.82 bc | 22.00 + 1.56 cd |
| NST >650 | 26.17 + 2.16 de | 19.91 + 1.36 ghi |
| NSK <560 | 32.00 + 1.63 a | 25.27+ 1.41 a |
| NSK 560 - 650 | 30.90 + 2.10 a | 24.00 + 0.82 b |
| NSK >650 | 27.00 + 1.47 cde | 21.86 + 0.82 cde |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

| Location (Original m) | *Nangka* var | | *Gondok* var | | *Nenas* cv | | Average Location | |
|---|---|---|---|---|---|---|---|---|
| | Sheath length (cm) | Amount fruit bunches $^{-1}$ | Sheath length (cm) | Amount fruit bunches $^{-1}$ | Sheath length (cm) | Amount fruit bunches $^{-1}$ | sheath length (cm) | Amount fruit bunches $^{-1}$ |
| T<560 | 27.50ab A | 19.55 d b | 26.67ab A | 20.22cd B | 27.50bc A | 21.41c A | 27.22 | 20.39 |
| T.560-650 | 28.83a A | 20.39 c b | 27.50a A | 20.55bc B | 27.67b A | 22.00c A | 28.00 | 20.98 |
| T>650 | 27.17bc Ab | 19.02 d b | 27.70a A | 19.22d A | 26.17c B | 19.91d A | 27.01 | 19.38 |
| K.<560 | 26.00c B | 21.13 b b | 25.83b B | 21.89a B | 32.00a A | 25.27a A | 27.94 | 22.76 |
| K 560-650 | 27.17bc B | 22.28 a b | 26.83ab B | 10.50a B | 30.90a A | 24.00b A | 28.30 | 22.93 |
| K>650 | 26.67bc A | 21.13 b a | 27.50a A | 21.28ab A | 27.00bc A | 21.86c A | 27.06 | 21.42 |
| Average cultivar | 27.22 | 20.58 | 27.01 | 20.94 | 28.54 | 22.41 | - | - |

Remarks : Numbers followed by the same letter in the same row, column and parameter indicate a non-significant difference in BNT 5%.

From Table 5 above it can be explained that the three varieties planted in six locations produced a number of fruits between 19.02 to 25.27 fruits per bunch. Nenas variety planted in Karangasem at an altitude of < 560 m asl (treatment NSK < 560) produced the highest number of fruits of 25.27 per bunch, followed by NSK 560 - 650 and NST 560 - 650 with 24.00 and 22.00 fruits per bunch. In order for the salak plants to bear

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much fruit, the nangka variety is ideal in Karangasem 560 to 650 m asl (NK 560 - 650), while the gondok variety is very good when planted below 560 m asl (GK < 560) although the number of fruits is not significantly different from the same altitude  for NT 560 - 650 and GT < 560. The results of this study are in line with the findings of Sumantra and Martiningsih (2016) that the 'Gulapasir' salak var. nenas produces the highest number of fruits both in the on season (*gadu* season) and -off-season (*sela* season).

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The interaction of varieties and planting location had a significant effect on the fruit weigh (fruit tree$^{-1}$ and fruit$^{-1}$). Nangka variety grown in Tabanan (T<560, T560-650, and T>650) and Karangasem (K<560, K560-650, and K>650) showed higher of weight of fruit tree$^{-1}$ and fruit-$^{1}$ than with nenas and gondok varities (Table 6).

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**Table 6**. Fruit weight of Nangka, gondok, and nenas varieties in six locations

| **Treatment** | **Fruit$^{-1}$ (g)** | **Fruit tree-$^{1}$ (kg)** |
|---|---|---|
| NT < 560 | 45.32 ± 1.08 cd | 1.19 ± 0.08 def |
| NT 560-650 | 48.56 ± 0.71 c | 1.29 ± 0.07 cd |
| NT > 650 | 38.22 ± 0.46 ef | 1.03 ± 0.06 ghi |
| NK < 560 | 55.84 ± 1.37 a | 1.48 ± 0.02 b |
| NK 560-650 | 59.43 ± 0.71 a | 1.62 ± 0.07 a |
| NK > 650 | 49.4 ±1.65 b | 1.34 ± 0.05 c |
| GT <560 | 40.14 ± 0.11 e | 1.11± 0.09 fg |
| GT.560-650 | 38.67 ± 0.55 ef | 1.09 ± 0.07 fg |
| GT >650 | 32.95 ± 0.73 gh | 0.93 ± 0.10 i |
| GK <560 | 44.22 ± 0.18 d | 1.27 ± 0.06 cde |
| GK 560 – 650 | 38.20 ± 0.78 ef | 1.16 ± 0.05 defg |
| GK >650 | 36.20 ± 0.75 fg | 1.07 ± 0.11 fgh |
| NST <560 | 39.00 ± 1.07 ef | 1.14 ± 0.11 efg |
| NST560 – 650 | 37.79 ± 0.65 f | 1.13 ± 0.06 g |
| NST >650 | 32.12 ± 0.11 h | 0.94 ± 0.10 hi |
| NSK <560 | 41.80 ± 0.65 de | 1.36 ± 0.08 bc |
| NSK 560 - 650 | 36.57 ± 0.80 fg | 1.18 ± 0.09 def |
| NSK >650 | 37.10 ± 0.23 f | 1.11 ± 0.07 fg |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

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From Table 6 it can be explained that the three varieties grown in six locations produced fruit weight per tree between 0.93 kg and 1.62 kg. The salak nangka variety planted in Karangasem at an altitude of 560-650 m asl (NK 560-650) produced the heaviest fruit weight of 1.62 kg per tree, followed by NK < 560 and NT 560-650 with fruit weights of 1.48 and 1.29 kg. While the nenas variety produces the best fruit at altitudes <560 m asl (NSK <560 and NT <560). Salak 'Gulapasir' var. gondok is ideal when planted at altitudes < 560 m asl (GK < 560 and GT < 560), although the two growing locations showed a different yields.

Nenas and gondok varieties showed a trend of decreasing fruit weight in line with increasing altitude, both planted in Karangasem and Tabanan. The reverse occurred in the salak nangka cultivar, an increase in altitude from 550 m asl to 550-650 m asl caused an increase in fruit weight and after that the fruit weight decreased when planted at altitudes > 650 m asl. This finding is in line with the results of research that has been reported by Sumantra *et al*. (2014). However, for the gondok and nenas varieties, this is a new finding.

**Table 4**. Fruit weight of nangka, gondok, and nenas cultivars (cv) in six locations

| Location (m asl) | CV. Nangka | | CV. Gondok | | CV. Nenas | | Average location | |
|---|---|---|---|---|---|---|---|---|
| | Fruit$^{-1}$ (g) | Tree$^{-1}$ (kg) | Fruit-$^{1}$ (g) | Tree$^{-1}$ (kg) | Fruit$^{-1}$ (g) | Tree$^{-1}$ (kg) | Frui$^{-1}$ (g) | Tree$^{-1}$ (kg) |
| T< 550 | 45.32 c A | 1.19 d A | 40.14 b B | 1.11 b a | 39.0 ab B | 1.14 b A | 41.49 | 1.14 |
| T 550-650 | 48.56 bc A | 1.29 cd A | 38.67 b B | 1.09 b b | 37.79 b B | 1.13 b B | 41.67 | 1.17 |
| T>650 | 38.22 d A | 1.03 e A | 32.95 c B | 0.93 c a | 32.12 c B | 0.94 c A | 34.43 | 0.97 |
| K<550 | 55.84 a A | 1.48 b A | 44.22 a B | 1.27 a b | 41.80 a B | 1.36 a Ab | 47.29 | 1.37 |
| K 550- 650 | 59.43 a A | 1.62 a A | 38.20 b B | 1.16 ab b | 36.57 b B | 1.18 b B | 44.73 | 1.32 |
| K >650m | 49.40 b A | 1.34 c A | 36.20 bc B | 1.07 b b | 37.10 b B | 1.11 b B | 40.90 | 1.17 |
| Average Cultivar | 49.46 | 1.33 | 38.40 | 1.11 | 37.40 | 1.14 | - | - |

Notes: The number followed by the same letter in the row, column, and the same parameter shows a non-significant difference in LSD 5%.

Apart from being influenced by environmental factors, the production of salak 'Gulapasir' fruit is also influenced by internal plant factors (Lestari *et al*. 2011). The effect of altitude on plant growth and production is related to plant adaptation to plant

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tolerance to temperature (Fenech et al., 2019), and rainfall (Ritonga *et al*., 2018). Altitude increases, the average daily air temperature decreases and monthly rainfall increases (Table 2,3). Nuary *et al.* (2019) stated that the distribution and adaptation of salak plants is strongly influenced by temperature and rainfall. It was further stated, the contribution of daily temperature accounts for nearly 38.6% while rainfall is 27.8%. Kanzaria *et al.* (2015) reported that mango plants planted at an altitude of 229 m flowered slower than those at an altitude of 148 m and 81 m asl. The temperature regime at higher altitudes is colder than at lower altitudes. Lower temperatures accumulate less GDD and may result in late flowering. Table 6 shows that the 'Gulapasir' salak planted in Karangasem produced a higher fruit weight in the three salak varieties tested. This is related to the level of soil fertility and soil type. The results of soil analysis showed that the nutrient content of Potassium was very low, the pH of the soil was slightly acidic, the N and P content was very low to moderate (Table 2). Therefore, improving soil fertility through fertilization and calcium is highly recommended.

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*3.4 Quality characteristics of salak varieties*

The interaction between varieties and altitude significantly affected sugar/total acid and vitamin C content. The three varieties grown in Tabanan (T < 560, T 560 to 650 and T > 650) showed a lower TSS/acid ratio. The fruit flavour planted in three locations in Tabanan is sourer than the three locations in Karangasem. Sugar content is greatly affected by the geographical. The geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity, and rainfall (Ritonga *et al*., 2018). Table 7 also shows that the increase in altitude from 550 m to 700 m asl in Tabanan and the addition in altitude from 550 to 650 m asl in Karangasem causes the sugar/acid ratio decrease in all three varieties, and the lowest sugar/acid value occurs in *Nenas* variety in all locations. Each salak variety has an adaptation to an elevation closely related to plant tolerance to temperature (Sumantra and Martiningsih, 2016; 2018). Many factors influence fruit quality, but the most dominant are climate factors, especially temperature and rainfall. High rainfall and low air temperature during the fruit ripening phase can cause the dissolved solids in the fruit to become watery so that the TSS value is low (Singh *et al*., 2011).

Salak fruits from three different varieties grown in low lands in Karangasem (K < 560 m asl) showed the highest vitamin C content and were significantly different from the three cultivars when planted in other locations. In both areas land increased by > 650 m asl effects to vitamin C decrease, Nangka and gondok varieties showed higher levels of vitamin C between < 550 m to < 650 m asl. (Table 7).

**Table 7.** TSS/acid ratio and levels of vitamin C of Nangka, gondok, and nenas varieties in six locations.

| **Treatment** | **TSS/T.Acid** | **Vit. C (mg /100g)** |
|---|---|---|
| NT< 560 | 56.20 ± 0.16 abc | 27.50 ± 0.41 bde |
| NT 560-650 | 59.18 ± 0.82 a | 25.45 ± 0.37 defgh |
| NT > 650 | 37.89 ± 0.91 f | 22.52 ± 0.39 j |
| NK < 560 | 51.41 ± 0.33 cde | 27.74 ± 0.47 bd |
| NK 560-650 | 53.52± 0.82 abcd | 29.61 ± 0.50 ab |
| NK > 650 | 47.76 ± 0.11 de | 24.25 ± 0.20 fghij |
| GT<560 | 34.88± 0.72 fg | 25.50 ± 0.41 defgh |
| GT.560-650 | 34.80 ± 0.65 fg | 25.75 ± 0.20 defgh |
| GT>650 | 30.24 ± 0.20 gh | 23.34 ± 0.28 hij |
| GK<560 | 51.28 ± 0.23 cde | 30.31 ± 0.25 a |
| GK 560 - 650 | 58.44 ± 0.36 ab | 27.63 ± 0.30 bd |
| GK >650 | 53.04 ± 0.82 bcde | 25.07 ± 0.33 efghi |
| NST <560 | 31.50 ±0.41 gh | 26.71± 0.21 cdef |
| NST560 - 650 | 30.44 ± 0.36 gh | 25.88 ± 0.41 defg |
| NST >650 | 26.13 ± 0.11 h | 23.65 ± 0.29 ghij |
| NSK <560 | 53.73 ± 0.60 abc | 24.42 ± 0.34 fghij |
| NSK 560 - 650 | 52.63 ± 0.51 bcde | 22.82 ± 0.15 ij |
| NSK >650 | 47.60 ± 0.49 e | 25.16 ± 0.13 efghi |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

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**Table 5.** TSS / acid ratio and levels of vitamin C of Nangka, Gondok, and Nenas cultivars in six locations.

| Location (m asl) | Nangka cv | | Gondok cv | | Nenas cv | | Average location | |
|---|---|---|---|---|---|---|---|---|
| | TSS / T. acid | Vit. C (mg /100g) | TSS / T.acid | Vit. C (mg / 100g) | TSS/ T.acid | Vit. C (mg / 100g) | TSS / T.acid | Vit. C (mg / 100g) |
| T< 550 | 56.20ab a | 27.50 ab a | 34.88c a | 25.50 bc a | 31.50b b | 26.71 a A | 40.86 | 26.57 |
| T 550-650 | 59.18a a | 25.45 bc a | 34.80c b | 25.75 bc a | 30.44b B | 25.88 ab A | 41.48 | 25.69 |
| T>650 | 37.89d a | 22.52 d a | 30.24c a | 23.34 c a | 26.13b B | 23.65 bc A | 31.42 | 23.17 |
| K<550 | 51.41bc a | 27.74 ab b | 51.28b a | 30.31 a a | 53.73a A | 24.42 abc C | 52.14 | 27.49 |
| K 550- 650 | 53.52abc a | 29.61 a a | 58.44a a | 27.63 b a | 52.63a a | 22.82 c B | 54.86 | 26.68 |
| K >650m | 47.76c a | 24.25 cd a | 53.04a a | 25.07 c a | 47.60a a | 25.16 abc A | 49.46 | 24.83 |
| Average cultivar | 50.99 | 26.18 | 43.78 | 26.27 | 40.34 | 24.77 | - | - |

Note: The number followed by the same letter in the row, column, and the same parameter shows a non-significant difference in LSD 5%.

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The results showed that the varieties of the 'Gulapasir' salak needs different environmental requirements to optimize yields. Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019). Therefore, variety differences may depend on growing requirements and cultivation techniques. Vitamin C in the 'Gulapasir' salak is strongly influenced by the altitude of the land. To produce high levels of vitamin C, the Nangka and gondok varieties are ideal for planting at an altitude of 560 m to 650 m asl, while the nenas variety is ideal at a land altitude of < 560 m asl. However, changes in ascorbate levels during fruit ripening are species-dependent and environmental factors especially temperature and light (Fenech *et al*., 2019).

There was no interaction between varieties and altitude to the flesh thickness, edible fruit portion, and fruit sugar content. The nangka salak variety showed fruit quality, including TSS, edible parts of the fruit, and higher flesh thickness (Table 8).

**Table 8.** The effect of a single factor of varieties on TSS, the portion of edible flesh, and the thickness of salak fruits

| Varieties | TSS (°Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| Nangka | 16.59a | 72.50a | 0.63a |
| Gondok | 16.42a | 70.66ab | 0.59b |
| Nenas | 15.64b | 69.22b | 0.52c |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Salak grown in Karangasem both from the lowlands and the middle lands produces fruit thickness, and the edible portion of fruits is higher than plants in the highlands. This study indicates that the ideal growing place for salak plants is between 450 m to 650 m asl. This study is in line with several previous studies which explained that altitude affects the flowering process and fruit enlargement (Sophie *at al*., 2017; Spinardi *et al*., 2019; Widyastut *et al*., 2022).

**Table 9.** The effect of a single factor of planting location on TSS, the portion of edible flesh, and the thickness of salak fruits

| Planting locations (m asl) | TSS ( °Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| T< 550 | 16.28a | 73.13a | 0.54c |
| T550-650 | 16.27a | 69.89a | 0.58bc |
| T >650 | 16.14a | 63.87b | 0.49d |
| K550 | 16.81a | 73.15a | 0.61b |
| K550-650 | 16.11a | 72.29a | 0.66a |
| K>650 | 15.69 | 72.44a | 0.61b |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

**4. Conclusion and Recommendation**

Different cultivars caused different fruit weights, fruit bunches, and the sugar/acid ratio at various locations. The three varieties showed lower fruit weight and fruit quality in Tabanan (low, medium, and highlands) than the salak originating from Karangasem. The

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**Title:**

Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Different Agro-Ecosystems

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Agronomic Characters and Quality of Fruit of Salak Planted in Different Agro-Ecosystems

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# Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Different Agro-Ecosystems

## ABSTRACT

Salak [Salacca zalacca (Gaertn.) Voss] var. amboinensis cv. Gulapasir has been officially released by the Minister of Agriculture of the Republic of Indonesia since 1994. Salak 'Gulapasir' is one of five types of fruit that have been designated as the superior fruit of the Bali Province. Salak 'Gulapasir' preferred by consumers due to its specific fruit flesh taste. Salak 'Gulapasir' was propagated using seeds so that a new types of salak emerged. However, the characters of this new type of salak 'Gulapasir' is not yet known. The research objective was to obtain the superior of some Salak 'Gulapasir' both in production and fruit quality. The research used a Randomized Block Design with three replications. The non-independent variable was the three of Salak 'Gulapasir' (SGP): SGP var. nangka (N), SGP var. nenas (N), SGP var. gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 to 650 m asl, and K > 650 m asl) and Tabanan (T) : (T < 560 m asl, T 560 to 650 m asl, T > 650 m asl). Observations were made on the agronomic characters and fruit quality. Data were analyzed using variance analysis, and if the planting location and cultivars show a difference, then it is followed by the LSD test at the 5 % level. The results showed that different cultivars caused different fruit weights, fruit bunches, TSS, and total acid ratio. In Tabanan (in the low, medium, and highlands), the three varieties showed lower fruit weight and fruit quality than the salak originating from Karangasem. The SGP var. nangka in Karangasem showed higher fruit weight, vitamin C content, and TSS/total acid ratio, while the SGP var. nenas showed the highest number of fruit bunches$^{-1}$ in six locations.

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**Ke ywords :** Agro-ecosystem, Altitude, *Salacca zalacca* (Gaertn.) Voss, Snake fruit, Tropical fruit

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## 1. Introduction

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir is one of the important fruits in Indonesia and the plant can be found in most regions of Indonesia (Rai *et al*. 2016; Ritonga *et al*., 2018). The salak fruit belong to the family Palmae or Arecaceae, and are native to the Indonesian-Malaysian region (Hakim *et al.,* 2019; Zumaidar *et al*., 2014). One of the extraordinary strengths of this fruit commodity for Indonesia is the possession of high genetic diversity (Budiyanti *et al*., 2019). Also, the nutrition of salak fruit is rich in antioxidants, phenolics, vitamins, and minerals (Cepkova *et al.*, 2021; Mazumdar *et al*., 2019), and a good source of income and provides livelihood opportunities on seasonal days (Khan and Idrees, 2021). The fruit flesh and peel have shown some tremendous anti-inflammatory, anticancer and antidiabetic (Saleh *et al*., 2018), and anti-ageing agents (Girsang *et al*., 2019). Antioxidants are chemical compounds that play an essential role in protecting cells due to attacks against free radicals-induced damage to biomolecules (Puspitasari and Ningsih, 2016; Setyobudi *et al*., 2019, 2022). Despite its incredible food and medicinal benefits, salak fruit is still underutilized and unknown globally. So that this underutilized fruit remains an issue for future sustainable utilization and commercial value enhancement market (Mazumdar *et al*., 2019). Fruit quality is an important issue, especially for products that are consumed raw and fresh. One of the problems is the lack of fruit quality because of inadequate information about superior salak (Budiyanti *et al*., 2019; Herawati *et al*., 2018). Therefore, it is necessary to select superior salak to meet market demand and fulfil community nutrition.

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Salak 'Bali' is quite a lot, based on the shape, aroma, taste, and skin colour of the location where the plants are cultivated (Sumantra *et al*., 2012, 2014; Sumantra and Martiningsih, 2016, 2018). Under the Decree of the Minister of Agriculture of the Republic of Indonesia in 1994,

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Balinese zalacca was grouped into two superior zalacca: Salak 'Bali' (Decree No.584) and Salak 'Gulapasir' (Decree No.585). The second type, the salak Gulapasir (SGP) is the most superior salak because of its sweet fruit taste; even though the age of the fruit is still young, thick fruit flesh and seeds are not attached to the fruit flesh (Rai *et al*., 2014; Sumantra *et al*., 2016). The nature of this fruit is ideal for meeting market demands for both the domestic and export markets (Martiningsih *et al*., 2018). Salak 'Bali' is monoecious, so crossing does not need human help (Herawati *et al*., 2018), and can quickly develop using seeds (Sumantra and Martiningsih, 2016). Another advantage of zalacca plants in Indonesia compared to other fruits is harvest fruit 2 to 3 times a year if management is good (Rai *et al*., 2016; Warnita *et al.*, 2019). The expansion of salak 'Gulapasir' planting causes variations in phenotypic diversity. People can find 2 to 3 types of salak plants with a marker, fruit shape, aroma, flesh colour, and fruit weight (Martiningsih *et al*., 2018). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seeds so that new varieties of salak 'Gulapasir' appear, as reported by Sumantra and Martiningsih (2016). Based on the marker that can be used as a differentiator, salak farmers give it the name of SGP var. nenas, SGP var. gondok, and SGP var. nangka. The three varieties varieties have not yet identified their advantages in meeting market needs in line with the results of research (Sumantra and Martiningsih, 2016). The performance and produce are influenced by the characteristics of the agricultural ecosystem, particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status (Adelina *et al.,* 2021; Kumar *et al*., 2020) and growth hormone (Prihastanti and Haryanti. 2022; Rai *et al.,* 2016).

The salak 'Gulapasir' plantation in the District of Bebandem is the main producer of salak 'Gulapasir' in Bali is located in the southern part of Mount Agung with an altitude of 450 m to 700 m above sea level (m asl). The effect of altitude on plant growth and production is related to plant adaptation to temperature (Sumantra, *et al*., 2014), full sunlight (Sukawijaya *et al*., 2009), water status and soil quality (Raharjo *et al*., 2022; Rai *et al*., 2014; Ritonga *et al.*, 2018). Salak plants are not resistant to full sun but 50 % to 70 % enough, therefore it is necessary to have shade plants (Sukawijaya *et al*., 2009; Sumantra *et al*., 2012). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019). Water status and soil quality really determine the fruit set on the salak 'Gulapasir'. Low rainfall reduces the Relative Water Content in leaves (RWC), leaf chlorophyll content, and plant nutrient uptake (Rai *et al*., 2014). soil quality included the suitability of the physical, chemical and biological properties (Raharjo *et al*., 2022). Nuary *et al.* (2019) stated that the distribution of the salak 'Pondoh' plantation area in Sleman (Yogyakarta, Special Region) was greatly influenced by temperature and rainfall. The contribution of temperature in the modelling reached 38.6 % while the rainfall was 27.8 %. Furthermore, taking into account the probability of the temperature variable, the average temperature ranges from 17.41 °C to 25.65 °C, and the ideal month's rainfall ranges from 385.24 mm to 505.01 mm.

Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019). Therefore, varieties differences may depend on growing requirements and cultivation techniques. Likewise, Puspitasari *et al.* (2017) stated that tannin content, fruit size and flesh colour of salak fruit are strongly influenced by where it grows. Other studies also explain that salak 'Gulapasir' var. nangka which is grown 570 m asl, would result in a higher quality of fruit that includes thickness of the mesocarpium, edible portion of fruit then compared to above and below 570 m asl (Sumantra *et al*., 2014; Sumantra and Martiningsih, 2016). Meanwhile, fruit weight and fruit quality of var. gondok and var. nenas have not been reported. Therefore, one way of handling salak quality is by undertaking severe studies for factors such as land and climate and adjusting agricultural patterns according to local climate conditions (Nassar *et al*., 2018). The success of each species to occupy the environment of an area is influenced by its ability to adapt optimally to all physical environmental factors (temperature,

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light, soil structure, humidity), biotic factors (interaction between species, competition, parasitism), and chemical factors including the availability of water, oxyge, pH, and nutrients (Nassar *et al*., 2018; Widyastuti *et al*., 2022). Moreover, a broad genetic variability would lead to wide phenotypic variability due to the effect of genetic-environment interaction (Ritonga *et al*., 2018). The research objective was to obtain the superior of some salak 'Gulapasir' both in production and fruit quality (sugar and acid ratio, vitamin C and tannin) in six different agricultural ecosystems in Bali.

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**Commented [R17]:** Sy perbaiki

## 2. Materials and Methods

### *2.1 Experimental Site*

The research was conducted in Tabanan and Karangasem Regencies. Tabanan and Karangasem were selected as research locations because the domination of salak 'Gulapasir' in these two regencies was the highest. In 2021, the salak 'Gulapasir' population in Tabanan is 84 % of all salak species, while in Karangasem Regency the dominance of the salak 'Gulapasir' is more than 63% (Sumantra *et al*., 2022).

The study was carried out in six different locations, three sites in Karangasem Regency and three sites in the district of Tabanan. Locations in Karangasem (K) are lowlands (K < 560 m asl) which include several places, namely Telaga, Dukuh, and Karanganyar. Karangasem in the moderate plains (K 560 m to 650 m asl) has several areas, namely Kecing and Kutabali and highlands (K > 650 m asl), namely Tanah Apo and Kresek (Figure 1).

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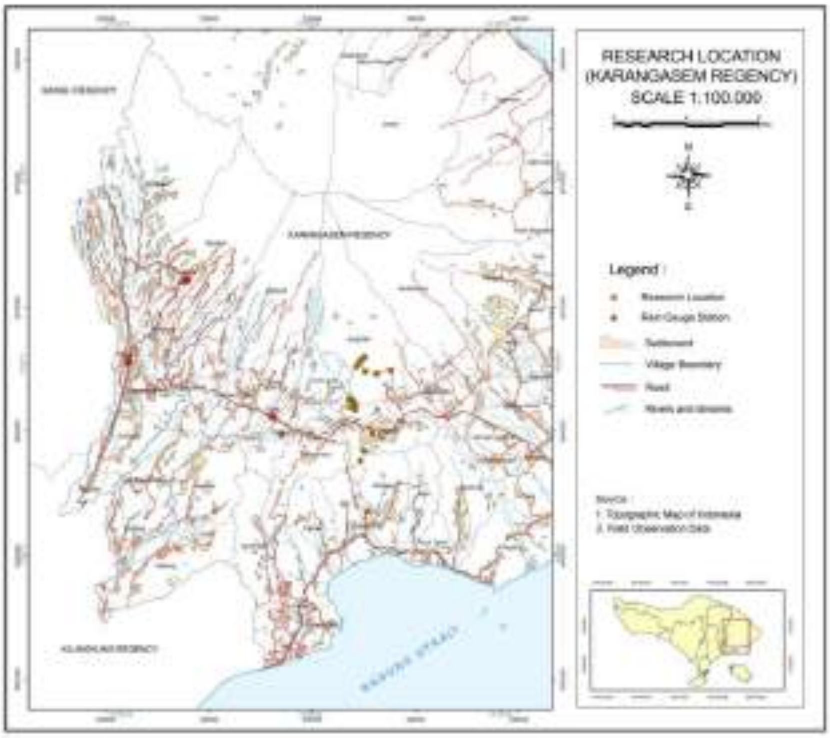


**Fig 1.** Research map and sampling point in Karangasem (K)

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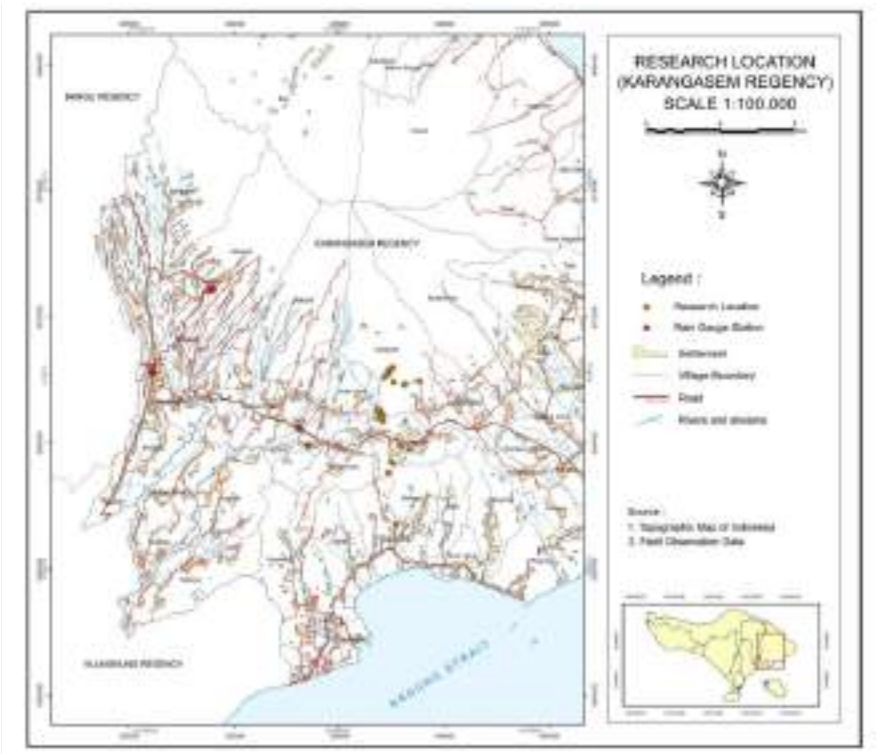


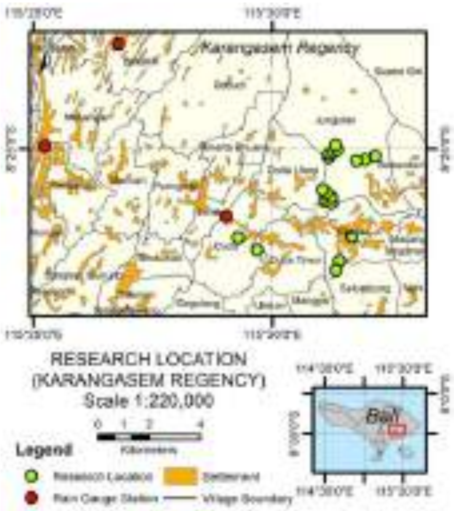
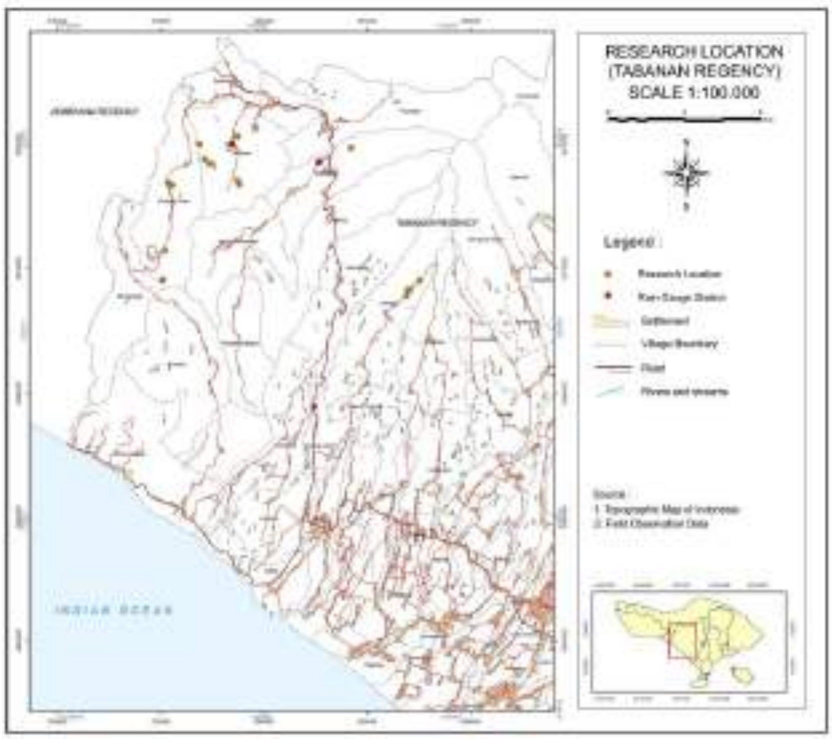




**Fig 1.** Research map and sampling point in Karangasem (K)

The research location is in Tabanan (T) in the lowlands (T < 560 m asl), including Wanagiri, Sari Buana, and Mundeh Kauh. Tabanan in the medium lands (T 560 m to 650 m asl) includes several places, namely Pajahan, Kebon Jero, and Angseri. Tabanan in the highlands (T > 650 m asl), namely Munduk Temu, Pempatan, and Batungsel (Figure 2).

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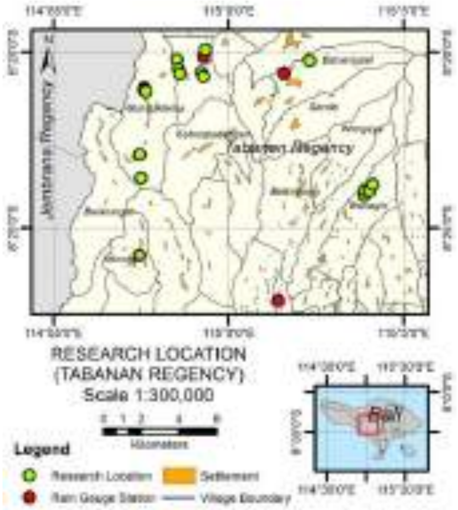


**Fig 2.** Research map and sampling point in Tabanan (T)

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**Fig 2.** Research map and sampling point in Tabanan (T)

The non-independent variable was the three varieties of Salak ‘Gulapasir’ (SGP): SGP var.nangka (N), SGP var. nenas (NS), SGP.var.gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 m to 650 m asl, and K > 650 m asl) and Tabanan (T) : (T < 560 m asl, T 560 m to 650 m asl, T > 650 m) Repetition was carried out three times with the number of sample plants in each location, and cultivars were seven plants. The treatment tested is as shown in Table 1

**Commented [R31]:** Sy perbaiki

**Commented [R32]:** Sy perbaiki

**Table 1**. Treatment of plant location and three varieties of Gulapasir salak

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| No | Treatment | Explanation |
|---|---|---|
| 1 | NT< 560 m asl | Salak GP.var. *Nangka* Tabanan < 560 m asl. |
| 2 | NT 560 m to 650 m asl | Salak GP.var. *Nangka* Tabanan 560 m to 650 m asl. |
| 3 | NT > 650 m asl. | Salak GP.var. *Nangka* Tabanan > 650 m asl. |
| 4 | NK < 560 m asl. | Salak GP.var. *Nangka* Karangasem < 560 m asl. |
| 5 | NK 560 m to 650 m asl | Salak GP.var. *Nangka* Karangasem 560 m to 650 m asl. |
| 6 | NK > 650 m asl. | Salak GP.var. *Nangka* Karangasem > 650 m asl. |
| 7 | GT< 560 m asl | Salak GP var. *Gondok* Tabanan < 560 m asl. |
| 8 | GT.560 to 650 m asl | Salak GP var. *Gondok* Tabanan 560 m to 650 m asl. |
| 9 | GT > 650 m asl | Salak GP var. *Gondok* Tabanan > 650 m asl. |
| 10 | GK.< 560 m asl | Salak GP var. *Gondok* Karangasem < 560 m asl. |
| 11 | GK 560 m to 650 m asl | Salak GP var. *Gondok* Karangasem 560 m to 650 m asl. |
| 12 | GK > 650 m asl | Salak GP var. *Gondok* Karangasem > 650 m asl. |
| 13 | NST < 560 m asl | Salak GP var. Nenas Tabanan < 560 m asl. |
| 14 | NST.560 m to 650 m asl | Salak GP var. *Nenas* Tabanan 560 m to 650 m asl. |

| | | |
|---|---|---|
| 15 | NST > 650 m asl | Salak GP var. *Nenas* Tabanan > 650 m asl. |
| 16 | NSK .< 560 m asl | Salak GP var. *Nenas* Karangasem < 560 m asl. |
| 17 | NSK 560 m to 650 m asl | Salak GP var. *Nenas* Karangasem 560 m to 650 m asl.. |
| 18 | NSK > 650 m asl | Salak GP var. *Nenas* Karangasem > 650 m asl. |

**Fig 1.** Research map and sampling point in Karangasem (Left) and Tabanan (Right)

The study used a Composite Analysis of Variance (Andinurani, 2016, 2022) with the model determined using Equation (1) below:

$$Yjk = u + L\,i + \delta\,ik + Pj + (LP)\,ij + \mathcal{E}\,ijk \qquad (1)$$

Where:

Yijk = The observation value of the treatment (j) in the group (k), which is repeated at the location (i).

u = the actual average value

Li = additive effect from location i

δ ik = the error effect in group k at location i

Pj = additive effect of the next treatment

(LP) ij = the effect of treatment (j) at the location (i)

Ɛ ijk = the effect of error from the treatment (j) in the group (k) which was carried out at the location (i).

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**Commented [KS35R34]:** Gambar sudah diperbaik saya siapkan file terpisah

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Ini Gambar 1 sudah diganti dengan Gambar 2 dan terakhir perbaikan gambar ke 3

*2.2 Preparation of study materials*

The material used is the salak 'Gulapasir' plant with uniform growth, plants have been fruitful with uniform on morphological, age of plants and cultivation action. The intentional practice is that the plant only receives treatment in the midrib, tillers, and weed cleaning. In this study, the plants were not fertilized. The provision of water was only from rainfall following the habits applied by salak farmers. The sample plant maintains by trimming unproductive leaf midribs and removing young shoots. Plant material was taken from the salak development centre in six locations, namely at the centre of salak development in the Bebandem sub-districts, Karangasem district (K-lowland < 560 m asl, K-medium 560 m to 650 m asl and K-highland > 650 m asl), Bajre, West Slemadeg and Pupuan sub-districts, Tabanan district (T-lowland < 560 m asl, T-medium 560 to 650 m asl and T-highland > 650 m asl).

2.3 *Analysis of physicochemical properties of soil sample* and climate

Soil analysis was carried out to determine the physical and chemical properties of the soil. Soil sampling was carried out under sample plant trees, carried out in a composite manner at a depth of 0 cm to 40 cm. Chemical analysis was carried out on total N (Kjeldahl method), available P by Bray I method and $K_2O$ by the Bray I method, organic C, pH, Soil physical properties in the form of texture by pipette method (Rzasa and Owczarzak, 2013; Hailu *et al*., 2015).)

Rainfall data was taken for five years from 2015 to 2019. Rainfall data has been collected from six nearby stations to the research site (Table 2). Daily temperature data obtained from the Denpasar Meteorology Climatology Agency.

**Table 2**. Research locations and place of climatology stations

| Research Locations | Climate observation station | Latitude and altitude |
|---|---|---|

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**Commented [R41R40]:** sy perbaiki
**Commented [R42]:** Sy perbaiki
**Commented [R43]:** Sy perbaiki
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**Commented [R48]:** tambahkan reference
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**Commented [MOU50R48]:** Saya sudah tambahkan kalau Bpk mau tambah lagi
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| | | |
|---|---|---|
| Tabanan Lowlands (< 560 m asl) | Ampadan, Tiyinggading No.St. 439 m | 8°27'5.0688"S/ 115°1'25.086 "E; 400 m asl. |
| Tabanan Moderate (560 m to 650 m asl) | Coffee Breeding Center, Sai Pupuan No. St. 439 h | 08°20'08.6"S/ 114° 59'17.4" E; 580 m asl. |
| Tabanan Highlands (> 650 m asl) | Agricultural Extension Center, Pupuan. No St.441 h | 08°20'38.1" S/ 115°01'35.2" E; 750 m asl. |
| Karangasem Lowlands (< 560 m asl) | Agricultural Extension Center, Selat. No. St. 444 d | 08°26'25" S / 115°29'02" E; 450 m asl. |
| Karangasem Moderate (560 m to 650 m asl) | Horticulture Seed Center, Singerata No.St. 442 | 08°24'57"S / 115°25'14"E; 580 m asl. |
| Karangasem Highlands (> 650 m asl) | Besakih Station. No.St.442 a | 08°22'49"S / 115°26'47"E; 800 m asl. |

*2.4 Observation of fruit and fruit quality*

Salak fruit can be harvested when it is ready for consumption. Consumable ripe fruit is a fruit that is ready to be consumed, characterized by a change in skin colour from dark brown to light brown, the thorns on the skin have reduced and are not sharp, and in general, at this stage, the fruit easily falls when shaken.

Observation and measurement of agronomic characters follow the method that has been done by Sumantra *et al*. (2014) including fruit weight, number of fruit bunches, the thickness of fruit flesh and fruit shape. The fruit characters from six-observed locations include the numbers of fruits per bunch, which is calculated manually on the formed fruits. The fruit weight per fruit and the fruit weight per tree is weighed after the fruits were

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removed from the bunch. The thickness of the mesocarpium is obtained by measuring the mesocarpium after it is cut vertically. The length of the flower sheath is measured on the stem of the sheath from the base to the tip of the sheath.

While fruit quality includes sugar content, tannins, titrated acid, sugar content and vitamin C. Titrated acid was analyzed by titration (Sripakdee *et al*., 2015). ). The fruit was weighed 10 g of sample was added to 100 mL of distilled water, then was homogenized using a slow spin blender, and filtered using an aseptic filter. The filtrate obtained was taken as much as 25 mL, then titrated with 0.1 N NaOH solution with phenolphthalein indicator until red in colour appeared. The results obtained are calculated as the percentage tartaric acid is determined using Equation (2) below :

$$A = \frac{\text{mL NaOH X N NaOH X P X BM}}{\text{Y X 1 000 X 2}} \times 100\ \% \qquad (2)$$

where:

A = percentage of total acid

P = amount of dilution

BM = molecular weight of tartaric acid

Y = sample weight (g).

Tannis content was analyzed as done by Thakur *et al*. (2021). Amount of 100 mg of the sample was homogenized by 2 mL of methanol. Centrifuged for 10 min at 10 000 rpm (1 rpm = 1/60 Hz) and collected the supernatant. Amount of 1 mL of supernatant mixed with 0.5 mL Folin's phenol reagent and 35 % $Na_2CO_3$ of 5 mL added and the mixture was kept at room temperature for 5 min. The blue colour of the reaction mixture was observed at 640 nm by UV/visible spectrophotometer (Shimadzu UV-1800, Japan). The content of tannin was calculated by calibration curve equation and determined using Equation (3) below:

$$Y = 0.0073x - 0.0071 : R^2 = 0.9973 \qquad (3)$$

**Commented [R58]:** Renggana tua sekali. Mhn diganti atau tambahkan sitasi lagi agar memenuhi syarat JJBS

**Commented [MOU59R58]:** Diganti Srpakdee et al

**Commented [R60]:** SI

**Commented [R61R60]:** Sy perbaiki krn Bpk blm respon

**Commented [R62R60]:** X pakai multiplication sign

**Commented [R63]:** Sy perbaiki

**Commented [R64]:** SI

**Commented [R65R64]:** Sy perbaiki krn Bpk tdk respon

**Commented [R66]:** Ini bukan SI, beri padanan

**Commented [R67R66]:** Sy perbaiki krn Bpk blm respon

**Commented [R68]:** Sy perbaiki

**Commented [R69]:** Sya tambah

Vitamin C was determined by titration like the method used by Asamara (2016, Setyobudi *et al.* 2021, 2022). The material is weighed as much as 10 g and crushed in mortal. Then put into a 250 mL volumetric flask, set to the mark and filtered. Take 25 mL of the filtrate and titrate with 0.01 N Yod solution equivalent to 0.88 mg of ascorbic acid. The calculation of ascorbic acid content per 100 g of material is determined using Equation (4) below:

$$A = \frac{\text{mL Yod } 0.01 \text{ N} \times 0.88 \times P \times 100}{Y} \qquad (4)$$

where: A = mg of ascorbic acid per 100 g of material

P = amount of dilution

Y = gram sample weight

Sugar content as TSS is calculated using a hand refractometer (Bellingham and Stanley Ltd., London) at 20 $^{o}$C.

The ratio of sugar content (TSS) and total acid is calculated by the sugar content divided by the acid content multiplied by 100 %.

The materials used in this study were Folin-Ciocalteu reagent (Pro Analytic, Merck), NaOH (Pro Analytic, Merck), $Na_2CO_3$ (Pro Analytic, Merck), Phenol reagent ascorbic acid (Pro Analytic, Merck), Phosphoric Acid (Pro Analytic, Merck), Sodium Phosphate (Pro Analytic, Merck) and Ammonium Molybdate (Pro Analytic, Merck).

The tools used in this study were analytical balances (Shimadzu ATY224, Japan), centrifuge tubes, Erlenmeyer flasks (pyrex), dropper pipettes (pyrex), volume pipettes (pyrex), vortex (Maxi Mix II Type 367000), measuring flask (pyrex), water bath (Memmert), blender (Miyako), and centrifuge (Damon /IEC Division). Whatman filter paper No 1 (Sigma – Aldrich, USA), measuring cup (Pyrex, USA), micropipette (Dragon Lab, Indonesia), spectrophotometer (Biochromsn 133467, UK), test tube (Pyrex¸ USA),

**Commented [R70]:** perbaiki spt saran saya di (2)

**Commented [R71R70]:** X apakah kali ? Mhn diperbaiki ya Pak

**Commented [MOU72R70]:** X kali sdh diperbaiki

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vortex (Barnsteadl Thermolyne Type 37600 Mixer, USA), aluminum foil (Klin Pak, Indonesia).

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*2.5 Study design*

This study used a randomized block design with the data analyzed using a Composite Analysis of Variance. If the variance test is significantly different, then it is continued with a different test with LSD at the 5 % level. Data analysis was performed using SPSS-IBM 18 (Adinurani, 2016, 2022) Each experimental treatment was repeated three times.

**3. Results and Discussion**

*3.1 Agroclimate characteristic*

The low production level and quality of salak fruit are caused by environmental factors that do not support growth or because the physiological processes of the plant are not optimal due to insufficient nutrients and water. The suitability of climatic and soil conditions at six locations of the centres for the development of the 'Gulapasir' salak was evaluated. The evaluation results show that the air temperature decreases as the altitude increases. The average air temperature at the 'Gulapasir' salak plantation in Tabanan is 22.90 $^{o}$C, while the air temperature at the Karangasem salak plantation is around 23.24 $^{o}$C. (Tabel 2)

Likewise, monthly rainfall and the average rainfall over the five years is presented in Table 2 and 3.

**Table 2.** Soil and climate characteristics of the research site in Tabanan and Karangasem in three subzones

| **Parameter** | **Tabanan (T)** | | | **Karangasem (K)** | | |
|---|---|---|---|---|---|---|
| | Lowlands (< 560 m asl) | Moderate 560 m to 650 m asl) | Highlands (> 650 m asl) | Lowlands (< 560m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) |
| Temp. ($^{o}$C) | 23.82 | 22.75 | 22.12 | 24.29 | 23.35 | 22.09 |
| Rainfall (mm month$^{-1}$) | 188.24 | 199.91 | 231.008 | 237.242 | 254.183 | 289.216 |

Commented [R76]: Pakai exponen negatif

| | | | | | | |
|---|---|---|---|---|---|---|
| Soil Texture | loamy clay | loamy clay | loamy clay | clay | Clay | sandy loam |
| pH ($H_2O$) | 5.64(sa) | 5.75 (sa) | 5.84 (sa) | 6.08 (sa) | 6.05 (sa) | 6.03(sa) |
| C- organic (%) | 2.94(m) | 3.40 (h) | 3.25 (h) | 2.77 (m) | 3.63 (h) | 3.32 (h) |
| Nutrients available | | | | | | |
| N total (%) | 0.18 (l) | 0.16 (l) | 0.18 (l) | 0.24(m) | 0.23 (m) | 0.29 (m) |
| $P_2O_5$ (mg $g^{-1}$) | 9.38 (vl) | 9.12 (vl) | 13.50 (l) | 22.55 (m) | 24.18 (m) | 23.04 (m) |
| $K_2O$ (mg $g^{-1}$)) | 18.47 (vl) | 22.05 (vl) | 17.23 (vl) | 24.17 (vl) | 19.93 ( vl ) | 18.37 ( vl ) |

Notes: sa: slightly acidic; h: high; m: medium; l: low; vh: very high; h: high; asl: above sea level (The assessment criteria refer to Soil Research Center, Bogor 1983).

**Pusat Penelitian Tanah dari Departemen Pertanian (1983)** telah mengajukan kriteria penilaian sifat kimia tanah berdasarkan sifat umum tanah yang didapat secara empiris. Kriteria penilaian sifat kimia tanah tersebut disajikan pada gambar tabel berikut.

| Sifat Tanah | Sangat Rendah | Rendah | Sedang | Tinggi | Sangat Tinggi |
|---|---|---|---|---|---|
| C-organik (%) | < 1,0 | 2,0 | 3,3 | 5,0 | > 5,0 |

Annual rainfall in Tabanan (T < 560, T 560-650 and T > 650) is lower with an average of 2515.05 mm while in Karangasem (K < 560, K 560 to 650 and K > 650) it is 3122.05 mm. However, the six locations show a trend of increasing rainfall as altitude increases. The salak plantation area in Karangasem is in the southern part of Mount Agung. Meanwhile in Tabanan, the dominant salak plantation area is behind Mount Batukaru with a lower elevation than Mount Agung. Mount Agung with an altitude of 3 142 m asl (Andaru and Rau, 2019), while the Batukaru mountains area with an elevation 2 250 m asl (Asmiwyati *et al*., 2015). Mount Batukaru as a barrier, causing this area to be a rain shadow. Enyew and Steenveld (2014) state that rainfall in an area is influenced by topographical factors and mountain ranges. Decreasing the height of the mountains, provides a reduction in the maximum level of rainfall over the mountains and foothills by 50 % (Flesch and Reuter, 2012). Topographical factors and regional weather systems have an important role in the amount and spatial pattern of rainfall in an area (Enyew and Steenveld, 2014).

**Table 3.** The annual rainfall in the six study sites (2015 to 2019)

**Commented [R77]:** Mhn check ulang
Apakah C organik ini (3.07 to 5.90 terkatagori spt ini ?

**Commented [R78]:** Pendapat saya ini adalah low

**Commented [R79]:** Ini h ? Mhn lihat 3.93(m)

**Commented [R80R79]:** Di bawah tabel ini saya copas ambang C organik.. Pendapat saya tabel C organik ini 'salah'. Mhn rechek

**Commented [R81]:** Pendapat saya ini adalah m

**Commented [R82]:** Ini m ? lihat di sebelahnya 3.63(h)

**Commented [R83R82]:**

**Commented [R84]:** Pendapat saya ini adalah m BUKAN h

**Commented [MOU85R84]:** Tinggi (3,01-5,00). Saya salah merata-ratakan dan sudah diperbaiki

**Commented [R86]:** Pendapat saya ini adalah m

**Commented [MOU87R86]:** Tinggi (3,01-5,00)
➢5 sangat tinggi

**Commented [R88]:** Pakai eksponen negatif

**Commented [R89]:** idem

**Commented [R90]:** Saya sudah koreksi bahan organil. Saya khawatir, kita beda persepsi pula di ambang unsur hara yang lain. Mhn recheck dan bila perlu kita saling telpun u diskusi

**Commented [MOU91R90]:** Sudah saya cek sayasalah kutip

**Commented [R92]:** Mhn lengkapi satuan . Mhn semua diperbaiki

**Commented [R93]:** to

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**Commented [R101]:** Bpk ?

**Commented [MOU102R101]:** Maaf saya tulis & sudah diperbaiki and

**Commented [R103]:** Semua data pakai digit spacing

| Year | Tabanan : T (mm yr $^{-1}$) | | | Karangasem : K (mm yr $^{-1}$) | | |
|---|---|---|---|---|---|---|
| | T < 560 | T 560 to 650 | T > 650 | K < 560 | K 560 to 650 | K > 650 |
| 2015 | 2001.0 | 2462.7 | 2633.0 | 2470.5 | 2714.0 | 3291.0 |
| 2016 | 2095.0 | 2453.5 | 3049.5 | 2659.0 | 2885.0 | 3800.0 |
| 2017 | 1958.0 | 2152.5 | 2135.0 | 2903.0 | 3173.0 | 3500.0 |
| 2018 | 2335.5 | 2463.9 | 2955.0 | 3002.0 | 3057.0 | 3200.0 |
| 2019 | 2905.0 | 2462.0 | 3088.0 | 3200.0 | 3422. | 3562.0 |
| Average | 2258.9 | 2398.92 | 2772.1 | 2846.9 | 3050.2 | 3470.6 |

Based on the growing requirements of salak plants, rainfall and air temperature in the six locations evaluated were in the very suitable range to support plant growth and development. A good air temperature for the growth of salak plants is between 20 to 30 °C and an average rainfall of 200 to 400 mm.month$^{-1}$ (Nuary *et al*., 2019).

Soil C-organic content in six planting sites was in the medium to high range. Availability of N and P nutrients in salak plantations in Tabanan in the lowlands, medium and highlands in low to very low conditions. Salak planting land in Karangasem, both in the lowlands, medium and highlands, these two nutrients are available in moderate conditions (Table 2). The nutrient content of potassium available in the six planting locations that have been evaluated shows a very low value. The results of this study indicate that the cultivation techniques carried out by farmers are very low, farmers do not apply an organic fertilizers that only rely on litter from the pruning of salak midrib as reported by Ilmiah *et al*. (2021), Rai *et al.* (2014), and Warnita *et al.* (2019).

### 3.2 *Characteristics of Salak Gulapasir*

The salak 'Gulapasir' his monoecius plant, namely male and female flowers arranged on the same bunches, the shape of the bunches is compound, and the position of the flower is on the back of the midrib. The salak 'Gulapasir' is classified as special because of its sweet fruit taste and the price per unit weight is four times more expensive than the salak

**Commented [R104]:** Bpk ?

**Commented [R105]:** Bpk ?

**Commented [R106]:** SI

**Commented [R107R106]:** Belum diperbaiki

**Commented [R108]:** SI dan eksponen negatif

**Commented [R109]:** Mohon check ulang. Saya ragu pencantuman data ini

**Commented [R110R109]:** Saya sudah koreksi bahan organik. Saya khawatir, kita beda persepsi pula di ambang unsur hara yang lain. Mhn recheck dan bila perlu kita saling telpun u diskusi

**Commented [R111]:** Mhn recheck. Saya khawatir kita beda persepsi

**Commented [R112]:** Idem mhn recheck

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**Commented [R114]:** Maksud Bapak adalah pupuk kimia ? Apa juga tidak pupuk organik ?

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‘Bali’ (Rai *et al*., 2014; Sumantra *et al*., 2012). The expansion of the cultivation of the salak ‘Gulapasir’ from its area of origin, Sibetan, Karangasem, has resulted in phenotypic diversity with a phenotypic similarity level of 58.62 % to 93.10 % (Sumantra and Martiningsih, 2016). In the same garden, more than one type of Gulapasir salak appears, , depending on fruit shape, aroma, color of fruit flesh and fruit weight (Sumantra and Martiningsih, 2016). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seed, so new variants of salak ‘Gulapasir’ appear with local names such as salak ‘Gulapasir’ nenas, salak ‘Gulapasir’ gondok and salak ‘Gulapasir’ nangka. The striking difference between these three varieties lies in the shape and flesh of the fruit. The number of fruit branches of salak ‘Gulapasir’ nangka, 1 to 2 branches, salak ‘Gulapasir’ nenas amount of 2 to 4 branches and salak ‘Gulapasir’ gondok the fruit bunches that do not form fruit branches. Salak ‘Gulapasir’, which is ready to harvest, has fruit flesh attached to the seed, and the fruit flesh is 0.63 cm thick. Meanwhile, the flesh of the salak ‘Gulapasir’ nenas is the thinnest and the seeds are attached to the flesh. Meanwhile, when the salak ‘Gulapasir’ gondok is ready to harvest, the seeds make a sound when shaken (Figure 3).

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**Fig.3** The shape and the thickness of the fruit flesh of SGP.var.*Nenas, Gondok and Nangka*

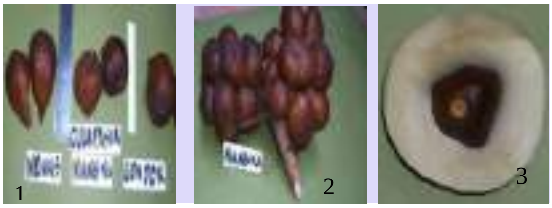


**Fig.1** The form of the fruit from three varieties

**Fig. 2** The shape and the thickness of the flesh of *Gondok Nenas*, and *Nangka* varieties

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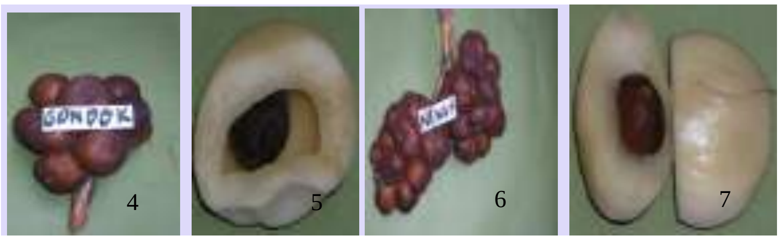


**Figure. 4 and 5** The shape of the bunches and the thickness of the fruit flesh gondok

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**Figure.6 and 7** The shape of the bunch and the thick flesh of the nenas

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*3.3* Agronomic characteristics of 'Gulapasir' Salak

Analysis of variance showed that the interaction between planting locations and varieties of 'Gulapasir' salak had significant effect on the number of fruits per bunch, fruit weight per tree, fruit weight per fruit, number of fruits per bunch, the ratio of sugar and acid and vitamin C content. Meanwhile, the thick fruit flesh and tannins content was not significant (Table 4)

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**Table 4.** Recapitulation of the effects of varieties and growing locations on agronomic and fruits quality of Gulapasir salak

| No. | Character agronomic and fruits quality | Planting location | Varieties | Varieties x Location |
|---|---|---|---|---|
| 1 | Length of the flower sheath | ** | ** | * |
| 2 | Number of fruit bunches $^{-1}$ | ** | ** | * |
| 3 | Fruit tree weight $^{-1}$ | ** | ** | * |
| 4 | Fruit weight $^{-1}$ | ** | ** | * |
| 5 | TSS ratio and total acid | ** | ** | ** |
| 6 | Thick fruit flesh | ** | ** | Ns |
| 7 | Vitamin C | Ns | Ns | * |
| 8 | Tannins | Ns | Ns | Ns |
| 9 | Edible portion | ** | ** | Ns |

Notes: *) significant P < 0.05, **) very significant P < 0.01 and Ns) not significantly different P > 0.05

The interaction of varieties and planting location had a significant effect on the length of the flower sheath and the number of fruit bunches $^{-1}$. Nenas variety grown in Tabanan (T < 560, T 560 to 650, and T > 650 ) and Karangasem (K < 560, K560 to 650, and K > 650) showed higher sheath length and a number of fruit bunches$^{-1}$ than with nangka. Nangka and Gondok varieties (Table 5). Tabanan (T 560 to 650) and Karangasem (K<560 m asl) are ideal conditions for flower sheath development and fruit development of nenas.

**Table 5.** Flower sheath length (cm) and a number of fruit bunches $^{-1}$ (fruit) of nangka, gondok and nenas *Nenas* varieties at six locations.

| **Treatment** | **Sheath length (cm)** | **Amount fruit bunches $^{-1}$** |
|---|---|---|
| NT < 560 | 27.50 ± 0.34 bcd | 19.55 ± 0.82 hij |
| NT 560 to 650 | 28.83 ± 1.31 b | 20.39 ± 1.00 g |
| NT > 650 | 27.17 ± 0.96 cde | 19.02 ± 0.82 j |
| NK < 560 | 26.00 ± 0.82 e | 21.13 ± 0.82 ef |
| NK 560 to 50 | 27.17 ± 0.14 cde | 22.28± 2.45 c |
| NK > 650 | 26.67 ± 1.36 cde | 21.13 ± 0.74 ef |
| GT < 560 | 26.67 ± 2.18 cde | 20.22 ± 0.31 gh |
| GT 560 to 650 | 27.50 ± 1.22 bcd | 20.55 ± 0.62 fg |
| GT > 650 | 27.70 ± 1.98 bc | 19.22 ± 0.74 ij |
| GK< 560 | 25.83 ± 1.41 e | 21.89 ± 0.82 cd |
| GK 560 to 650 | 26.83 ± 0.75 cde | 20.5 ± 1.63 fg |
| GK > 650 | 27.5 ± 0.82 bcd | 21.28 ± 0.78 def |
| NST < 560 | 27.5 ± 0.82 bcd | 21.41 ± 0.91 de |
| NST 560 to 650 | 27.67 ± 0.82 bc | 22.00 ± 1.56 cd |
| NST > 650 | 26.17 ± 2.16 de | 19.91 ± 1.36 ghi |
| NSK < 560 | 32.00 ± 1.63 a | 25.27± 1.41 a |
| NSK 560 to 650 | 30.90 ± 2.10 a | 24.00 ± 0.82 b |
| NSK > 650 | 27.00 ± 1.47 cde | 21.86 ± 0.82 cde |

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Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

| Location (Original m) | *Nangka* var | | *Gondok* var | | *Nenas* cv | | Average Location | |
|---|---|---|---|---|---|---|---|---|
| | Sheath length (cm) | Amount fruit bunches $^{-1}$ | Sheath length (cm) | Amount fruit bunches $^{-1}$ | Sheath length (cm) | Amount fruit bunches $^{-1}$ | sheath length (cm) | Amount fruit bunches $^{-1}$ |
| T<560 | 27.50ab A | 19.55 d B | 26.67ab A | 20.22cd B | 27.50bc A | 21.41c A | 27.22 | 20.39 |
| T.560-650 | 28.83a A | 20.39 c B | 27.50a A | 20.55bc B | 27.67b A | 22.00c A | 28.00 | 20.98 |
| T>650 | 27.17bc Ab | 19.02 d B | 27.70a A | 19.22d A | 26.17c B | 19.91d A | 27.01 | 19.38 |
| K.<560 | 26.00c B | 21.13 b B | 25.83b B | 21.89a B | 32.00a A | 25.27a A | 27.94 | 22.76 |
| K 560-650 | 27.17bc B | 22.28 a B | 26.83ab B | 10.50a B | 30.90a A | 24.00b A | 28.30 | 22.93 |
| K>650 | 26.67bc A | 21.13 b A | 27.50a A | 21.28ab A | 27.00bc A | 21.86c A | 27.06 | 21.42 |
| Average cultivar | 27.22 | 20.58 | 27.01 | 20.94 | 28.54 | 22.41 | - | - |

Remarks : Numbers followed by the same letter in the same row, column and parameter indicate a non-significant difference in LSD 5%.

From Table 5 above it can be explained that the three varieties planted in six locations produced a number of fruits between 19.02 to 25.27 fruits per bunch. Nenas variety planted in Karangasem at an altitude of < 560 m asl (treatment NSK < 560) produced the highest number of fruits of 25.27 per bunch, followed by NSK 560 to 650 and NST 560 to 650 with 24.00 and 22.00 fruits per bunch. In order for the salak plants to bear much fruit, the nangka variety is ideal in Karangasem 560 to 650 m asl (NK 560 to 650), while the gondok variety is very good when planted below 560 m asl (GK < 560) although the number of fruits is not significantly different from the same altitude for NT 560 to 650 and GT < 560. The results of this study are in line with the findings of Sumantra and Martiningsih (2016) that the 'Gulapasir' salak var. nenas produces the highest number of fruits both in the on season (*gadu* season) and -off-season (*sela* season). Sumantra *et al*. (2014) reported that the emergence of new sheaths occurred on the third or fourth leaf midrib from the growing point depending on the altitude and plant conditions. The time for new sheaths to appear

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ranges from 129.00 days - 145.10 days with the required heat units between 1233.62 - 1047.90 d $^{o}$C. The higher altitude, the longer the sheath appears, as well as the harvest time.

The interaction of varieties and planting location had a significant effect on the fruit weigh (fruit tree$^{-1}$ and fruit$^{-1}$). Nangka variety grown in Tabanan (T < 560, T 560 to 650, and T > 650) and Karangasem (K < 560, K 560 to 650, and K > 650) showed higher of weight of fruit tree$^{-1}$ and fruit-$^{1}$ than with nenas and gondok (Table 6).

**Table 6**. Fruit weight of Nangka, gondok, and nenas varieties in six locations

| **Treatment** | **Fruit$^{-1}$ (g)** | **Fruit tree-$^{1}$ (kg)** |
|---|---|---|
| NT < 560 | 45.32 ± 1.08 cd | 1.19 ± 0.08 def |
| NT 560 to 650 | 48.56 ± 0.71 c | 1.29 ± 0.07 cd |
| NT > 650 | 38.22 ± 0.46 ef | 1.03 ± 0.06 ghi |
| NK < 560 | 55.84 ± 1.37 a | 1.48 ± 0.02 b |
| NK 560 to 650 | 59.43 ± 0.71 a | 1.62 ± 0.07 a |
| NK > 650 | 49.4 ±1.65 b | 1.34 ± 0.05 c |
| GT < 560 | 40.14 ± 0.11 e | 1.11± 0.09 fg |
| GT 560 to 650 | 38.67 ± 0.55 ef | 1.09 ± 0.07 fg |
| GT > 650 | 32.95 ± 0.73 gh | 0.93 ± 0.10 i |
| GK < 560 | 44.22 ± 0.18 d | 1.27 ± 0.06 cde |
| GK 560 to 650 | 38.20 ± 0.78 ef | 1.16 ± 0.05 defg |
| GK > 650 | 36.20 ± 0.75 fg | 1.07 ± 0.11 fgh |
| NST < 560 | 39.00 ± 1.07 ef | 1.14 ± 0.11 efg |
| NST 560 to 650 | 37.79 ± 0.65 f | 1.13 ± 0.06 g |
| NST > 650 | 32.12 ± 0.11 h | 0.94 ± 0.10 hi |
| NSK < 560 | 41.80 ± 0.65 de | 1.36 ± 0.08 bc |
| NSK 560 to 650 | 36.57 ± 0.80 fg | 1.18 ± 0.09 def |
| NSK > 650 | 37.10 ± 0.23 f | 1.11 ± 0.07 fg |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

From Table 6 it can be explained that the three varieties grown in six locations produced fruit weight per tree between 0.93 kg and 1.62 kg. The salak nangka variety planted in Karangasem at an altitude of 560 to 650 m asl (NK 560 to 650) produced the heaviest fruit weight of 1.62 kg tree$^{-1}$, followed by NK < 560 and NT 560 to 650 with fruit weights of 1.48 and 1.29 kg. While the nenas variety produces the best fruit at altitudes < 560 m asl (NSK < 560 and NT < 560). Salak 'Gulapasir' var. gondok is ideal when planted

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at altitudes < 560 m asl (GK < 560 and GT < 560), although the two growing locations showed a different yields.

Nenas and gondok varieties showed a trend of decreasing fruit weight in line with increasing altitude, both planted in Karangasem and Tabanan. The reverse occurred in the salak nangka variety, an increase in altitude from 550 m asl to 550 to 650 m asl caused an increase in fruit weight and after that the fruit weight decreased when planted at altitudes > 650 m asl. This finding is in line with the results of research that has been reported by Sumantra *et al*. (2014). However, for the gondok and nenas varieties, this is a new finding.

**Table 4**. Fruit weight of nangka, gondok, and nenas cultivars (cv) in six locations

| Location (m asl) | CV. Nangka | | CV. Gondok | | CV. Nenas | | Average location | |
|---|---|---|---|---|---|---|---|---|
| | Fruit$^{-1}$ (g) | Tree$^{-1}$ (kg) | Fruit-$^{1}$ (g) | Tree$^{-1}$ (kg) | Fruit$^{-1}$ (g) | Tree$^{-1}$ (kg) | Frui$^{-1}$ (g) | Tree$^{-1}$ (kg) |
| T< 550 | 45.32 c A | 1.19 d A | 40.14 b B | 1.11 b a | 39.0 ab B | 1.14 b A | 41.49 | 1.14 |
| T 550-650 | 48.56 bc A | 1.29 cd A | 38.67 b B | 1.09 b b | 37.79 b B | 1.13 b B | 41.67 | 1.17 |
| T>650 | 38.22 d A | 1.03 e A | 32.95 c B | 0.93 c a | 32.12 c B | 0.94 c A | 34.43 | 0.97 |
| K<550 | 55.84 a A | 1.48 b A | 44.22 a B | 1.27 a b | 41.80 a B | 1.36 a Ab | 47.29 | 1.37 |
| K 550- 650 | 59.43 a A | 1.62 a A | 38.20 b B | 1.16 ab b | 36.57 b B | 1.18 b B | 44.73 | 1.32 |
| K >650m | 49.40 b A | 1.34 c A | 36.20 bc B | 1.07 b b | 37.10 b B | 1.11 b B | 40.90 | 1.17 |
| Average Cultivar | 49.46 | 1.33 | 38.40 | 1.11 | 37.40 | 1.14 | - | - |

Notes: The number followed by the same letter in the row, column, and the same parameter shows a non-significant difference in LSD 5%.

Apart from being influenced by environmental factors, the production of salak 'Gulapasir' fruit is also influenced by internal plant factors (Lestari *et al*. 2011). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019), and rainfall (Ritonga *et al*., 2018). Altitude increases, the average daily air temperature decreases and monthly rainfall increases (Table 2 and Tabel 3). Nuary *et al.* (2019) stated that the distribution and adaptation of salak plants is strongly influenced by temperature and rainfall. It was further stated, the contribution of

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**Commented [R166]:** mhn check typo ini daily temperature accounts for nearly 38.6 % while rainfall is 27.8 %. Kanzaria *et al.* (2015) reported that mango plants planted at an altitude of 229 m flowered slower than those at an altitude of 148 m and 81 m asl. The temperature regime at higher altitudes is colder than at lower altitudes. Lower temperatures accumulate less GDD and may result in late flowering. Table 6 shows that the 'Gulapasir' salak planted in Karangasem produced a higher fruit weight in the three salak varieties tested. This is related to the level of soil fertility. The soil nitrogen and phosphate nutrient content at three locations in Karangasem was higher than at three locations in Tabanan. Meanwhile, the potassium content in the six research locations was low (Table 2). Therefore it is necessary to make improvements by providing fertilizers containing elements of N, P and K to meet ideal conditions for growth, although more data is needed to fully support this conclusion (Hailu *et al.*, 2015). ).

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*3.4 Quality characteristics of salak varieties*

The interaction between varieties and altitude significantly affected sugar/total acid and vitamin C content. The three varieties grown in Tabanan (T < 560, T 560 to 650 and T > 650) showed a lower TSS/acid ratio. The fruit flavour planted in three locations in Tabanan is sourer than the three locations in Karangasem. Sugar content is greatly affected by the geographical. The geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity, and rainfall (Ritonga *et al*., 2018). Table 7 also shows that the increase in altitude from 550 m to 700 m asl in Tabanan and the addition in altitude from 550 to 650 m asl in Karangasem causes the sugar/acid ratio decrease in all three varieties, and the lowest sugar/acid value occurs in *Nenas* variety in all locations. Each salak variety has an adaptation to an elevation closely related to plant tolerance to temperature (Sumantra and Martiningsih, 2016; 2018). Many factors influence fruit quality, but the most dominant are climate factors, especially temperature and rainfall.

High rainfall and low air temperature during the fruit ripening phase can cause the dissolved solids in the fruit to become watery so that the TSS value is low (Singh *et al*., 2011).

Salak fruits from three different varieties grown in low lands in Karangasem (K < 560 m asl) showed the highest vitamin C content and were significantly different from the three cultivars when planted in other locations. In both areas land increased by > 650 m asl effects to vitamin C decrease, nangka and gondok varieties showed higher levels of vitamin C between < 550 m to < 650 m asl. (Table 7).

**Table 7.** TSS/acid ratio and levels of vitamin C of Nangka, gondok, and nenas varieties in six locations.

| Treatment | TSS/T.Acid | Vit. C (mg /100g) |
|---|---|---|
| NT < 560 | 56.20 ± 0.16 abc | 27.50 ± 0.41 bde |
| NT 560 to 650 | 59.18 ± 0.82 a | 25.45 ± 0.37 defgl |
| NT > 650 | 37.89 ± 0.91 f | 22.52 ± 0.39 j |
| NK < 560 | 51.41 ± 0.33 cde | 27.74 ± 0.47 bd |
| NK 560 to 650 | 53.52± 0.82 abcd | 29.61 ± 0.50 ab |
| NK > 650 | 47.76 ± 0.11 de | 24.25 ± 0.20 fghij |
| GT < 560 | 34.88± 0.72 fg | 25.50 ± 0.41 defgl |
| GT 560 to 650 | 34.80 ± 0.65 fg | 25.75 ± 0.20 defgl |
| GT > 650 | 30.24 ± 0.20 gh | 23.34 ± 0.28 hij |
| GK < 560 | 51.28 ± 0.23 cde | 30.31 ± 0.25 a |
| GK 560 to 650 | 58.44 ± 0.36 ab | 27.63 ± 0.30 bd |
| GK > 650 | 53.04 ± 0.82 bcde | 25.07 ± 0.33 efgh |
| NST < 560 | 31.50 ± 0.41 gh | 26.71± 0.21 cdef |
| NST 560 to 650 | 30.44 ± 0.36 gh | 25.88 ± 0.41 defg |
| NST > 650 | 26.13 ± 0.11 h | 23.65 ± 0.29 ghij |
| NSK < 560 | 53.73 ± 0.60 abc | 24.42 ± 0.34 fghij |
| NSK 560 to 650 | 52.63 ± 0.51 bcde | 22.82 ± 0.15 ij |
| NSK > 650 | 47.60 ± 0.49 e | 25.16 ± 0.13 efgh |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

**Table 5.** TSS / acid ratio and levels of vitamin C of Nangka, Gondok, and Nenas cultivars in six locations.

| Location | Nangka cv | Gondok cv | Nenas cv | Average location |
|---|---|---|---|---|

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| (m asl) | TSS / T. acid | Vit. C (mg /100g) | TSS / T.acid | Vit. C (mg / 100g) | TSS/ T.acid | Vit. C (mg / 100g) | TSS / T.acid | Vit. C (mg / 100g) |
|---|---|---|---|---|---|---|---|---|
| T< 550 | 56.20ab a | 27.50 ab A | 34.88c a | 25.50 bc a | 31.50b b | 26.71 a A | 40.86 | 26.57 |
| T 550-650 | 59.18a a | 25.45 bc A | 34.80c b | 25.75 bc a | 30.44b B | 25.88 ab A | 41.48 | 25.69 |
| T>650 | 37.89d a | 22.52 d A | 30.24c a | 23.34 c a | 26.13b B | 23.65 bc A | 31.42 | 23.17 |
| K<550 | 51.41bc a | 27.74 ab B | 51.28b a | 30.31 a a | 53.73a A | 24.42 abc C | 52.14 | 27.49 |
| K 550- 650 | 53.52abc a | 29.61 a A | 58.44a a | 27.63 b a | 52.63a a | 22.82 c B | 54.86 | 26.68 |
| K >650m | 47.76c a | 24.25 cd A | 53.04a a | 25.07 c a | 47.60a a | 25.16 abc A | 49.46 | 24.83 |
| Average cultivar | 50.99 | 26.18 | 43.78 | 26.27 | 40.34 | 24.77 | - | - |

Note: The number followed by the same letter in the row, column, and the same parameter shows a non-significant difference in LSD 5%.

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The results showed that the varieties of the ‘Gulapasir’ salak needs different environmental requirements to optimize yields. Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019). Therefore, variety differences may depend on growing requirements and cultivation techniques. Vitamin C in the ‘Gulapasir’ salak is strongly influenced by the altitude of the land. To produce high levels of vitamin C, the nangka and gondok varieties are ideal for planting at an altitude of 560 m to 650 m asl, while the nenas variety is ideal at a land altitude of < 560 m asl. However, changes in ascorbate levels during fruit ripening are species-dependent and environmental factors especially temperature and light (Fenech *et al*., 2019).

There was no interaction between varieties and altitude to the flesh thickness, edible fruit portion, and fruit sugar content. The nangka salak variety showed fruit quality, including TSS, edible parts of the fruit, and higher flesh thickness (Table 8).

**Table 8.** The effect of a single factor of varieties on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment | TSS (ºBrix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Nangka | 16.59a | 72.50a | 0.63a |
| Gondok | 16.42a | 70.66ab | 0.59b |
| Nenas | 15.64b | 69.22b | 0.52c |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Salak grown in Karangasem both from the lowlands and the middle lands produces fruit thickness, and the edible portion of fruits is higher than plants in the highlands. This study indicates that the ideal growing place for salak plants is between 450 m to 650 m asl. This study is in line with several previous studies which explained that altitude affects the flowering process and fruit enlargement (Sophie *at al*., 2017; Spinardi *et al*., 2019; Widyastut *et al*., 2022).

**Table 9.** The effect of a single factor of planting location on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment (m asl) | TSS ( ºBrix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| T < 550 | 16.28a | 73.13a | 0.54c |
| T 550 to 650 | 16.27a | 69.89a | 0.58bc |
| T > 650 | 16.14a | 63.87b | 0.49d |
| K 550 | 16.81a | 73.15a | 0.61b |
| K 550 to 650 | 16.11a | 72.29a | 0.66a |
| K > 650 | 15.69a | 72.44a | 0.61b |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

## 4. Conclusion and Recommendation

Different cultivars caused different fruit weights, fruit bunches, and the sugar/acid ratio at various locations. The three varieties showed lower fruit weight and fruit quality in Tabanan (low, medium, and highlands) than the salak originating from Karangasem. The nangka variety in Karangasem showed higher fruit weight, vitamin C content, and sugar/ acid ratio, while the nenas salak showed the highest number of fruit bunches$^{-1}$ in six locations. Nangka salak are very suitable to be planted at an altitude of 550 m to 650 m asl. In contrast, the

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*nenas* and gondok varieties are developed naturally at low altitudes < 550 m asl. In order for all cultivars to be able to produce optimally, efforts to improve the cultivation system are needed through fertilization and the provision of calcium is highly recommended.

**Commented [R178]:** Mhn konsisten Nanas atau Nenas

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**Title:**

Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Different Agro-Ecosystems

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**Running Title:**

Assessment Salak Planted in Different Agro-Ecosystems

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# Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Different Agro-Ecosystems

**ABSTRACT**

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir has been officially released by the Minister of Agriculture of the Republic of Indonesia since 1994. Salak 'Gulapasir' is one of five types of fruit that have been designated as the superior fruit of the Bali Province. Salak 'Gulapasir' preferred by consumers due to its specific fruit flesh taste. Salak 'Gulapasir' was propagated using seeds so that a new types of salak emerged. However, the characters of this new type of salak 'Gulapasir' is not yet known. The research objective was to obtain the superior of some Salak 'Gulapasir' both in production and fruit quality. The research used a Randomized Block Design with three replications. The non-independent variable was the three of Salak 'Gulapasir' (SGP): SGP var. nangka (N), SGP var. nenas (N), SGP var. gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 to 650 m asl, and K > 650 m asl) and Tabanan (T): (T < 560 m asl, T 560 to 650 m asl, T > 650 m asl). Observations were made on the agronomic characters and fruit quality. Data were analyzed using variance analysis, and if the planting location and varieties show a difference, then it is followed by the LSD test at the 5 % level. The results showed that different varieties caused different fruit weights, fruit bunches, TSS, and total acid ratio. In Tabanan (in the low, medium, and highlands), the three varieties showed lower fruit weight and fruit quality than the salak originating from Karangasem. The SGP var. nangka in Karangasem showed higher fruit weight, vitamin C content, and TSS/total acid ratio, while the SGP var. nenas showed the highest number of fruit bunches$^{-1}$ in six locations.

**Keywords :** Altitude, *Salacca zalacca* (Gaertn.) Voss, Salak 'Gulapasir' var. gondok, Salak 'Gulapasir' var. nangka, Salak 'Gulapasir' var. nenas, Salak sustainable agriculture, Snake fruit, Tropical fruit

## 1. Introduction

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir is one of the important fruits in Indonesia and the plant can be found in most regions of Indonesia (Rai *et al*. 2016; Ritonga *et al*., 2018). The salak fruit belong to the family Palmae or Arecaceae, and are native to the Indonesian-Malaysian region (Hakim *et al.,* 2019; Zumaidar *et al*., 2014). One of the extraordinary strengths of this fruit commodity for Indonesia is the possession of high genetic diversity (Budiyanti *et al*., 2019). Also, the nutrition of salak fruit is rich in antioxidants, phenolics, vitamins, and minerals (Cepkova *et al.,* 2021; Mazumdar *et al*., 2019), and a good source of income and provides livelihood opportunities on seasonal days (Khan and Idrees, 2021). The fruit flesh and peel have shown some tremendous anti-inflammatory, anticancer and antidiabetic (Saleh *et al*., 2018), and anti-ageing agents (Girsang *et al*., 2019). Antioxidants are chemical compounds that play an essential role in protecting cells due to attacks against free radicals-induced damage to biomolecules (Damat *et al*., 2019, 2020; Puspitasari and Ningsih, 2016; Setyobudi *et al*., 2019). Despite its incredible food and medicinal benefits, salak fruit is still underutilized and unknown globally. So that this underutilized fruit remains an issue for future sustainable utilization and commercial value enhancement market (Mazumdar *et al*., 2019). Fruit quality is an important issue, especially for products that are consumed raw and fresh. One of the problems is the lack of fruit quality because of inadequate information about superior salak (Budiyanti *et al*., 2019; Herawati *et al*., 2018). Therefore, it is necessary to select superior salak to meet market demand and fulfil community nutrition.

Salak 'Bali' is quite a lot, based on the shape, aroma, taste, and skin colour of the location where the plants are cultivated (Sumantra *et al*., 2012, 2014; Sumantra and Martiningsih, 2016,

2018). Under the Decree of the Minister of Agriculture of the Republic of Indonesia in 1994, Balinese zalacca was grouped into two superior zalacca: Salak 'Bali' (SK Mentan, 19941b) and Salak 'Gulapasir' (SK mentan, 1994a). The second type, the salak 'Gulapasir' (SGP) is the most superior salak because of its sweet fruit taste; even though the age of the fruit is still young, thick fruit flesh and seeds are not attached to the fruit flesh (Rai *et al*., 2014; Sumantra *et al*., 2016). The nature of this fruit is ideal for meeting market demands for both the domestic and export markets (Martiningsih *et al*., 2018). Salak 'Bali' is monoecious, so crossing does not need human help (Herawati *et al*., 2018), and can quickly develop using seeds (Sumantra and Martiningsih, 2016). Another advantage of salak plants in Indonesia compared to other fruits is harvest fruit 2 to 3 times a year if management is good (Rai *et al*., 2016; Warnita *et al.*, 2019). The expansion of salak 'Gulapasir' planting causes variations in phenotypic diversity. People can find two to three types of salak plants with a marker, fruit shape, aroma, flesh colour, and fruit weight (Martiningsih *et al*., 2018). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seeds so that new varieties of salak 'Gulapasir' (SGP) appear, as reported by Sumantra and Martiningsih (2016). Based on the marker that can be used as a differentiator, salak farmers give it the name of SGP var. nenas, SGP var. gondok, and SGP var. nangka. The three varieties varieties have not yet identified their advantages in meeting market needs in line with the results of research (Sumantra and Martiningsih, 2016). The performance and produce are influenced by the characteristics of the agricultural ecosystem, particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status (Adelina *et al.,* 2021; Kumar *et al*., 2020) and growth hormone (Prihastanti and Haryanti. 2022; Rai *et al.,* 2016).

The salak 'Gulapasir' plantation in the District of Bebandem is the main producer of salak 'Gulapasir' in Bali is located in the southern part of Mount Agung with an altitude of 450 m to 700 m above sea level (m asl). The effect of altitude on plant growth and production is related to plant adaptation to temperature (Sumantra, *et al*., 2014), full sunlight (Sukawijaya *et al*., 2009), water status and soil quality (Raharjo *et al*., 2022; Rai *et al*., 2014; Ritonga *et al.,* 2018). Salak plants are not resistant to full sun but 50 % to 70 % enough, therefore it is necessary to have shade plants (Sukawijaya *et al*., 2009; Sumantra *et al*., 2012). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019). Water status and soil quality really determine the fruit set on the salak 'Gulapasir'. Low rainfall reduces the Relative Water Content in leaves (RWC), leaf chlorophyll content, and plant nutrient uptake (Rai *et al*., 2014). soil quality included the suitability of the physical, chemical and biological properties (Raharjo *et al*., 2022). Nuary *et al*. (2019) stated that the distribution of the salak 'Pondoh' plantation area in Sleman (Yogyakarta, Special Region) was greatly influenced by temperature and rainfall. The contribution of temperature in the modelling reached 38.6 % while the rainfall was 27.8 %. Furthermore, taking into account the probability of the temperature variable, the average temperature ranges from 17.41 °C to 25.65 °C, and the ideal month's rainfall ranges from 385.24 mm to 505.01 mm.

Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al*., 2021, 2022). Therefore, varieties differences may depend on growing requirements and cultivation techniques. Likewise, Puspitasari *et al*. (2017) stated that tannin content, fruit size and flesh colour of salak fruit are strongly influenced by where it grows. Other studies also explain that salak 'Gulapasir' var. nangka which is grown 570 m asl, would result in a higher quality of fruit that includes thickness of the mesocarpium, edible portion of fruit then compared to above and below 570 m asl (Sumantra *et al*., 2014; Sumantra and Martiningsih, 2016). Meanwhile, fruit weight and fruit quality of var. gondok and var. nenas have not been reported. Therefore, one way of handling salak quality is by undertaking severe studies for factors such as land and climate and adjusting agricultural patterns according to local climate conditions (Nassar *et al*., 2018). The success of each species to occupy the environment of an area is influenced by its ability to adapt optimally to all physical environmental factors (temperature, light, soil structure, humidity), biotic factors (interaction between species, competition, parasitism), and chemical factors including the availability of water, oxyge, pH, and nutrients (Nassar *et al*., 2018; Widyastuti *et al*., 2022). Moreover, a broad genetic variability would lead to wide phenotypic variability due to the effect of genetic-environment interaction (Ritonga *et al*., 2018). The research objective was to obtain the superior of some salak 'Gulapasir' both in production and fruit quality (sugar and acid ratio, vitamin C and tannin) in six different agricultural ecosystems in Bali.

## 2. Materials and Methods

### *2.1 Experimental site*

The research was conducted in Tabanan and Karangasem Regencies. Tabanan and Karangasem were selected as research locations because the domination of salak 'Gulapasir' in these two regencies was the highest. In 2021, the salak 'Gulapasir' population in Tabanan is 84 % of all salak species, while in Karangasem Regency the dominance of the salak 'Gulapasir' is more than 63 % (Sumantra *et al*., 2022).

The study was carried out in six different locations, three sites in Karangasem Regency and three sites in the district of Tabanan. Locations in Karangasem (K) are lowlands (K < 560 m asl) which include several places, namely Telaga, Dukuh, and Karanganyar. Karangasem in the moderate plains (K 560 m to 650 m asl) has several areas, namely Kecing and Kutabali and highlands (K > 650 m asl), namely Tanah Apo and Kresek (Figure 1).

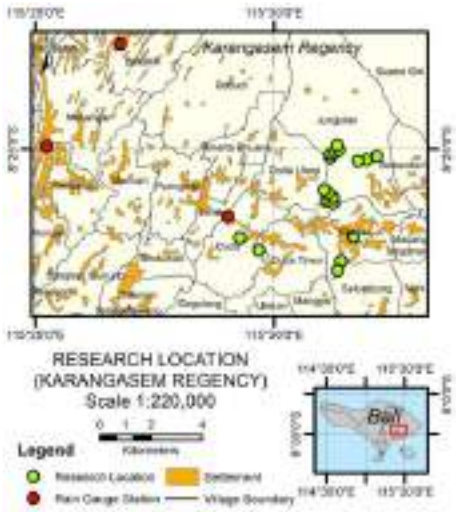


**Fig 1.** Research map and sampling point in Karangasem (K)

The research location is in Tabanan (T) in the lowlands (T < 560 m asl), including Wanagiri, Sari Buana, and Mundeh Kauh. Tabanan in the medium lands (T 560 m to 650 m asl) includes several places, namely Pajahan, Kebon Jero, and Angseri. Tabanan in the highlands (T > 650 m asl), namely Munduk Temu, Pempatan, and Batungsel (Figure 2).

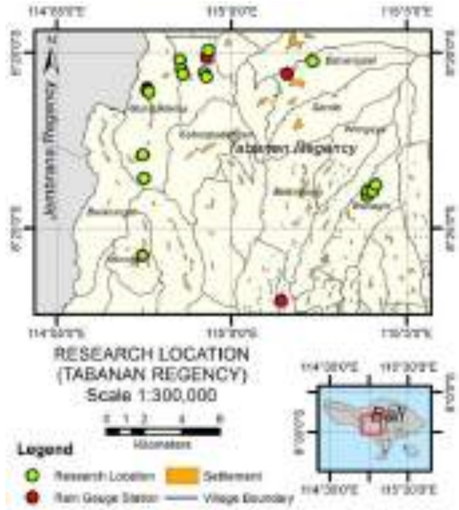

**Fig 2.** Research map and sampling point in Tabanan (T)

The non-independent variable was the three varieties of Salak 'Gulapasir' (SGP): SGP var.nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 m to 650 m asl, and K > 650 m asl) and Tabanan (T) : (T < 560 m asl, T 560 m to 650 m asl, T > 650 m) Repetition was carried out three times with the number of sample plants in each location, and cultivars were seven plants. The treatment tested is as shown in Table 1

**Table 1**. Treatment of plant location and three varieties of 'Gulapasir' salak

| No | Treatment | Explanation |
|---|---|---|
| 1 | NT< 560 m asl | Salak GP.var. nangka Tabanan < 560 m asl. |
| 2 | NT 560 m to 650 m asl | Salak GP.var. nangka Tabanan 560 m to 650 m asl. |
| 3 | NT > 650 m asl. | Salak GP.var. nangka Tabanan > 650 m asl. |
| 4 | NK < 560 m asl. | Salak GP.var. nangka Karangasem < 560 m asl. |
| 5 | NK 560 m to 650 m asl | Salak GP.var. nangka Karangasem 560 m to 650 m asl. |
| 6 | NK > 650 m asl. | Salak GP.var. nangka Karangasem > 650 m asl. |
| 7 | GT< 560 m asl | Salak GP var. gondok Tabanan < 560 m asl. |
| 8 | GT.560 to 650 m asl | Salak GP var. gondok Tabanan 560 m to 650 m asl. |
| 9 | GT > 650 m asl | Salak GP var. gondok Tabanan > 650 m asl. |
| 10 | GK.< 560 m asl | Salak GP var. gondok Karangasem < 560 m asl. |
| 11 | GK 560 m to 650 m asl | Salak GP var. gondok Karangasem 560 m to 650 m asl. |
| 12 | GK > 650 m asl | Salak GP var. gondok Karangasem > 650 m asl. |
| 13 | NST < 560 m asl | Salak GP var. nenas Tabanan < 560 m asl. |
| 14 | NST.560 m to 650 m asl | Salak GP var. nenas Tabanan 560 m to 650 m asl. |

| | | |
|---|---|---|
| 15 | NST > 650 m asl | Salak GP var. nenas Tabanan > 650 m asl. |
| 16 | NSK .< 560 m asl | Salak GP var. nenas Karangasem < 560 m asl. |
| 17 | NSK 560 m to 650 m asl | Salak GP var. nenas Karangasem 560 m to 650 m asl.. |
| 18 | NSK > 650 m asl | Salak GP var. nenas Karangasem > 650 m asl. |

The study used a Composite Analysis of Variance (Andinurani, 2016, 2022) with the model determined using Equation (1) below:

$$Yjk = u + L\ i + \delta\ ik + Pj + (LP)\ ij + \mathcal{E}\ ijk \quad (1)$$

Where:

Yijk = The observation value of the treatment (j) in the group (k), which is repeated at the location (i).

u = the actual average value

Li = additive effect from location i

δ ik = the error effect in group k at location i

Pj = additive effect of the next treatment

(LP) ij = the effect of treatment (j) at the location (i)

Ɛ ijk = the effect of error from the treatment (j) in the group (k) which was carried out at the location (i).

*2.2 Preparation of study materials*

The material used is the salak 'Gulapasir' plant with uniform growth, plants have been fruitful with uniform on morphological, age of plants and cultivation action. The intentional practice is that the plant only receives treatment in the midrib, tillers, and weed cleaning. In this study, the plants were not fertilized. The provision of water was only from rainfall following the habits applied by salak farmers. The sample plant maintains by trimming unproductive leaf midribs and removing young shoots. Plant material was taken

from the Salak Development Centre in six locations, namely at the Centre of Salak Development in the Bebandem sub-districts, Karangasem district (K-lowland < 560 m asl, K-medium 560 m to 650 m asl and K-highland > 650 m asl), Bajre, West Slemadeg and Pupuan sub-districts, Tabanan district (T-lowland < 560 m asl, T-medium 560 to 650 m asl and T-highland > 650 m asl).

2.*3 Analysis of physicochemical properties of soil sample* and climate

Soil analysis was carried out to determine the physical and chemical properties of the soil. Soil sampling was carried out under sample plant trees, carried out in a composite manner at a depth of 0 cm to 40 cm. Chemical analysis was carried out on total N (Kjeldahl method), available P by Bray I method and $K_2O$ by the Bray I method, organic C, pH, soil physical properties in the form of texture by pipette method (Hailu *et al*., 2015; Prasetyo *et al*., 2022; Rzasa and Owczarzak, 2013).

Rainfall data was taken for five years from 2015 to 2019. Rainfall data has been collected from six nearby stations to the research site (Table 2). Daily temperature data obtained from the Denpasar Meteorology Climatology Agency.

**Table 2**. Research locations and place of climatology stations

**Commented [R2]:** Mhn check krn di bawah ada Table 2 juga

| Research Locations | Climate observation station | Latitude and altitude |
|---|---|---|
| Tabanan Lowlands (< 560 m asl) | Ampadan, Tiyinggading No.St. 439 m | 8$^o$27'5.0688"S/ 115$^o$1'25.086 "E; 400 m asl. |
| Tabanan Moderate (560 m to 650 m asl) | Coffee Breeding Center, Sai Pupuan No. St. 439 h | 08$^o$20'08.6"S/ 114$^o$ 59'17.4" E; 580 m asl. |
| Tabanan Highlands (> 650 m asl) | Agricultural Extension Center, Pupuan. No St.441 h | 08$^o$20'38.1" S/ 115$^o$01'35.2" E; 750 m asl. |

| | | |
|---|---|---|
| Karangasem Lowlands (< 560 m asl) | Agricultural Extension Center, Selat. No. St. 444 d | 08°26’25” S / 115°29’02” E; 450 m asl. |
| Karangasem Moderate (560 m to 650 m asl) | Horticulture Seed Center, Singerata No.St. 442 | 08°24’57”S / 115°25’14”E; 580 m asl. |
| Karangasem Highlands (> 650 m asl) | Besakih Station. No.St.442 a | 08°22’49”S / 115°26’47”E; 800 m asl. |

*2.4 Observation of fruit and fruit quality*

Salak fruit can be harvested when it is ready for consumption. Consumable ripe fruit is a fruit that is ready to be consumed, characterized by a change in skin colour from dark brown to light brown, the thorns on the skin have reduced and are not sharp, and in general, at this stage, the fruit easily falls when shaken.

Observation and measurement of agronomic characters follow the method that has been done by Sumantra *et al*. (2014) including fruit weight, number of fruit bunches, the thickness of fruit flesh and fruit shape. The fruit characters from six-observed locations include the numbers of fruits per bunch, which is calculated manually on the formed fruits. The fruit weight per fruit and the fruit weight per tree is weighed after the fruits were removed from the bunch. The thickness of the mesocarpium is obtained by measuring the mesocarpium after it is cut vertically. The length of the flower sheath is measured on the stem of the sheath from the base to the tip of the sheath.

While fruit quality includes sugar content, tannins, titrated acid, sugar content and vitamin C. Titrated acid was analyzed by titration (Sripakdee *et al*., 2015). The fruit was weighed 10 g of sample was added to 100 mL of distilled water, then was homogenized using a slow spin blender, and filtered using an aseptic filter. The filtrate obtained was taken as much as 25 mL, then titrated with 0.1 N NaOH solution with phenolphthalein

indicator until red in colour appeared. The results obtained are calculated as the percentage tartaric acid is determined using Equation (2) below :

$$A = \frac{mL\ NaOH \times N\ NaOH \times P \times BM}{Y \times 1\,000 \times 2} \times 100\ \% \qquad (2)$$

Commented [R3]: Saya perbaiki krn Bpk blm respon

where:

A = percentage of total acid

P = amount of dilution

BM = molecular weight of tartaric acid

Y = sample weight (g).

Tannis content was analyzed as done by Thakur *et al*. (2021), Setyobudi *et al*. (2022). Amount of 100 mg of the sample was homogenized by 2 mL of methanol. Centrifuged for 10 min at 10 000 rpm (1 rpm = 1/60 Hz) and collected the supernatant. Amount of 1 mL of supernatant mixed with 0.5 mL Folin's phenol reagent and 35 % $Na_2CO_3$ of 5 mL added and the mixture was kept at room temperature for 5 min. The blue colour of the reaction mixture was observed at 640 nm by UV/visible spectrophotometer (Shimadzu UV-1800, Japan). The content of tannin was calculated by calibration curve equation and determined using Equation (3) below:

$$Y = 0.0073x - 0.0071 : R^2 = 0.9973 \qquad (3)$$

Vitamin C was determined by titration like the method used by Asamara (2016), Setyobudi *et al.* (2021, 2022). The material is weighed as much as 10 g and crushed in mortal. Then put into a 250 mL volumetric flask, set to the mark and filtered. Take 25 mL of the filtrate and titrate with 0.01 N Yod solution equivalent to 0.88 mg of ascorbic acid. The calculation of ascorbic acid content per 100 g of material is determined using Equation (4) below:

$$A = \frac{\text{mL Yod } 0.01\text{ N} \times 0.88 \times P \times 100}{Y} \quad (4)$$

Commented [R4]: Saya perbaiki krn Bpk tdk respon

where: A = mg of ascorbic acid per 100 g of material

P = amount of dilution

Y = gram sample weight

Sugar content as TSS is calculated using a hand refractometer (Bellingham and Stanley Ltd., London) at 20 $^{o}$C.

The ratio of sugar content (TSS) and total acid is calculated by the sugar content divided by the acid content multiplied by 100 %.

The materials used in this study were Folin-Ciocalteu reagent (Pro Analytic, Merck), NaOH (Pro Analytic, Merck), $Na_2CO_3$ (Pro Analytic, Merck), Phenolphereagent ascorbic acid (Pro Analytic, Merck), Phosphoric Acid (Pro Analytic, Merck), Sodium Phosphate (Pro Analytic, Merck) and Ammonium Molybdate (Pro Analytic, Merck).

The tools used in this study were analytical balances (Shimadzu ATY224, Japan), centrifuge tubes, Erlenmeyer flasks (pyrex), dropper pipettes (pyrex), volume pipettes (pyrex), vortex (Maxi Mix II Type 367000), measuring flask (pyrex), water bath (Memmert), blender (Miyako), and centrifuge (Damon /IEC Division). Whatman filter paper No 1 (Sigma – Aldrich, USA), measuring cup (Pyrex, USA), micropipette (Dragon Lab, Indonesia), spectrophotometer (Biochromsn 133467, UK), test tube (Pyrex¸ USA), vortex (Barnsteadl Thermolyne Type 37600 Mixer, USA), aluminum foil (Klin Pak, Indonesia).

*2.5 Study design*

This study used a randomized block design with the data analyzed using a Composite Analysis of Variance. If the variance test is significantly different, then it is continued with a different test with LSD at the 5 % level. Data analysis was performed using SPSS-IBM 18 (Adinurani, 2016, 2022). Each experimental treatment was repeated three times.

## 3. Results and Discussion

*3.1 Agroclimate characteristic*

The low production level and quality of salak fruit are caused by environmental factors that do not support growth or because the physiological processes of the plant are not optimal due to insufficient nutrients and water. The suitability of climatic and soil conditions at six locations of the centres for the development of the ‘Gulapasir’ salak was evaluated. The evaluation results show that the air temperature decreases as the altitude increases. The average air temperature at the ‘Gulapasir’ salak plantation in Tabanan is 22.90 $^{o}$C, while the air temperature at the Karangasem salak plantation is around 23.24 $^{o}$C. (Tabel 2)

**Commented [R5]:** Ini SALAH ?

Likewise, monthly rainfall and the average rainfall over the 5 yr is presented in Table 2 and Table 3.

**Commented [R6]:** Mhn diperbaiki urutan tabel

**Table 2.** Soil and climate characteristics of the research site in Tabanan and Karangasem in three subzones

**Commented [R7]:** Ini mhn diperbaiki krn di atas ada tabel 2 juga

| **Parameter** | **Tabanan (T)** | | | **Karangasem (K)** | | |
|---|---|---|---|---|---|---|
| | Lowlands (< 560 m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) | Lowlands (< 560m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) |
| Temp. ($^{o}$C) | 23.82 | 22.75 | 22.12 | 24.29 | 23.35 | 22.09 |
| Rainfall (mm mo$^{-1}$) | 188.24 | 199.91 | 231.008 | 237.242 | 254.183 | 289.216 |
| Soil texture | loamy clay | loamy clay | loamy clay | clay | clay | sandy loam |
| pH ($H_2O$) | 5.64(sa) | 5.75 (sa) | 5.84 (sa) | 6.08 (sa) | 6.05 (sa) | 6.03(sa) |
| C- organic (%) | 2.94(m) | 3.40 (h) | 3.25 (h) | 2.77 (m) | 3.63 (h) | 3.32 (h) |
| Nutrients available | | | | | | |
| N total (%) | 0.18 (l) | 0.16 (l) | 0.18 (l) | 0.24(m) | 0.23 (m) | 0.29 (m) |
| $P_2O_5$ (mg g$^{-1}$) | 9.38 (vl) | 9.12 (vl) | 13.50 (l) | 22.55 (m) | 24.18 (m) | 23.04 (m) |
| $K_2O$ (mg g$^{-1}$)) | 18.47 (vl) | 22.05 (vl) | 17.23 (vl) | 24.17 (vl) | 19.93 ( vl ) | 18.37 ( vl ) |

Notes: sa: slightly acidic; h: high; m: medium; l: low; vh: very high; h: high; asl: above sea level (The assessment criteria refer to PPT, 1983).

Annual rainfall in Tabanan (T < 560, T 560 to 650 and T > 650) is lower with an average of 2515.05 mm while in Karangasem (K < 560, K 560 to 650 and K > 650) it is 3 122.05 mm. However, the six locations show a trend of increasing rainfall as altitude increases. The salak plantation area in Karangasem is in the southern part of Mount Agung. Meanwhile in Tabanan, the dominant salak plantation area is behind Mount Batukaru with a lower elevation than Mount Agung. Mount Agung with an altitude of 3 142 m asl (Andaru and Rau, 2019), while the Batukaru mountains area with an elevation 2 250 m asl (Asmiwyati *et al*., 2015). Mount Batukaru as a barrier, causing this area to be a rain shadow. Enyew and Steenveld (2014) state that rainfall in an area is influenced by topographical factors and mountain ranges. Decreasing the height of the mountains, provides a reduction in the maximum level of rainfall over the mountains and foothills by 50 % (Flesch and Reuter, 2012). Topographical factors and regional weather systems have an important role in the amount and spatial pattern of rainfall in an area (Enyew and Steenveld, 2014).

**Table 3.** The annual rainfall in the six study sites (2015 to 2019)

Commented [R8]: Mhn diperbaiki

| Year | Tabanan: T (mm $yr^{-1}$) | | | Karangasem: K (mm $yr^{-1}$) | | |
|---|---|---|---|---|---|---|
| | T < 560 | T 560 to 650 | T > 650 | K < 560 | K 560 to 650 | K > 650 |
| 2015 | 2 001.0 | 2 462.7 | 2 633.0 | 2 470.5 | 2 714.0 | 3 291.0 |
| 2016 | 2 095.0 | 2 453.5 | 3 049.5 | 2 659.0 | 2 885.0 | 3 800.0 |
| 2017 | 1 958.0 | 2 152.5 | 2 135.0 | 2 903.0 | 3 173.0 | 3 500.0 |
| 2018 | 2 335.5 | 2 463.9 | 2 955.0 | 3 002.0 | 3 057.0 | 3 200.0 |
| 2019 | 2 905.0 | 2 462.0 | 3 088.0 | 3 200.0 | 3 422.0 | 3 562.0 |
| Average | 2 258.9 | 2 398.92 | 2 772.1 | 2846.9 | 3 050.2 | 3 470.6 |

Based on the growing requirements of salak plants, rainfall and air temperature in the six locations evaluated were in the very suitable range to support plant growth and development. A good air temperature for the growth of salak plants is between 20 °C to 30 °C and an average rainfall of (200 to 400) mm $mo^{-1}$ (Nuary *et al*., 2019).

Soil C-organic content in six planting sites was in the medium to high range. Availability of N and P nutrients in salak plantations in Tabanan in the lowlands, medium and highlands in low to very low conditions. Salak planting land in Karangasem, both in the lowlands, medium and highlands, these two nutrients are available in moderate conditions (Table 2). The nutrient content of potassium available in the six planting locations that have been evaluated shows a very low value. The results of this study indicate that the cultivation techniques carried out by farmers are very low. Farmers do not apply an fertilizers that only rely on litter from the pruning of salak midrib as reported by Ilmiah *et al*. (2021), Rai *et al.* (2014), and Warnita *et al.* (2019). To cultivate sustainable agriculture, especially in agroecosystems salak in Bali. The authors will discuss this issue more in the future research paragraph.

*3.2 Characteristics of Salak 'Gulapasir'*

The salak 'Gulapasir' his monoecius plant, namely male and female flowers arranged on the same bunches, the shape of the bunches is compound, and the position of the flower is on the back of the midrib. The salak 'Gulapasir' is classified as special because of its sweet fruit taste and the price per unit weight is four times more expensive than the salak 'Bali' (Rai *et al*., 2014; Sumantra *et al*., 2012). The expansion of the cultivation of the salak 'Gulapasir' from its area of origin, Sibetan, Karangasem, has resulted in phenotypic diversity with a phenotypic similarity level of 58.62 % to 93.10 % (Sumantra and Martiningsih, 2016). In the same garden, more than one type of 'Gulapasir' salak appears, depending on fruit shape, aroma, color of fruit flesh and fruit weight (Sumantra and Martiningsih, 2016). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seed, so new variants of salak 'Gulapasir' appear with local names such as salak 'Gulapasir' nenas, salak 'Gulapasir' gondok and salak 'Gulapasir' nangka. The striking difference between these three varieties lies in the shape and flesh of the fruit. The number of fruit branches of salak 'Gulapasir' nangka, 1 to 2 branches, salak 'Gulapasir' nenas amount of 2 to 4 branches and salak 'Gulapasir' gondok the fruit bunches that do not form fruit branches. Salak 'Gulapasir', which is ready to harvest, has fruit flesh attached to the seed, and the fruit flesh is 0.63 cm thick. Meanwhile, the flesh of the salak 'Gulapasir' nenas is the thinnest and the seeds are attached to the flesh. Meanwhile, when the salak 'Gulapasir' gondok is ready to harvest, the seeds make a sound when shaken (Figure 3).


**Fig. 3** The shape and the thickness of the fruit flesh of SGP.var.nenas, gondok and nangka

**Fig.1** The form of the fruit from three varieties

Commented [R9]: Mhn fig. di tata lagi ya Pak

**Fig. 2** The shape and the thickness of the flesh of *Gondok Nenas,* and *Nangka* varieties

1 2 3

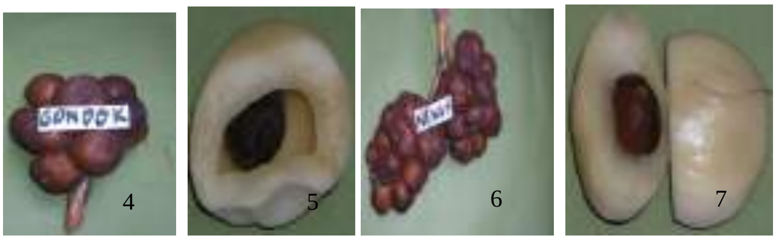

**Fig. 4 and Fig 5** The shape of the bunches and the thickness of the fruit flesh gondok

**Fig.6 and Fig. 7** The shape of the bunch and the thick flesh of the nenas

*3.3* Agronomic characteristics of ‘Gulapasir’ Salak

Analysis of variance showed that the interaction between planting locations and varieties of ‘Gulapasir’ salak had significant effect on the number of fruits per bunch, fruit weight per tree, fruit weight per fruit, number of fruits per bunch, the ratio of sugar and acid and vitamin C content. Meanwhile, the thick fruit flesh and tannins content was not significant (Table 4)

**Commented [R10]:** Perbaiki

**Table 4.** Recapitulation of the effects of varieties and growing locations on agronomic and fruits quality of ‘Gulapasir’ salak

**Commented [R11]:** Perbaiki

| No. | Character agronomic and fruits quality | Planting location | Varieties | Varieties x Location |
|---|---|---|---|---|
| 1 | Length of the flower sheath | ** | ** | * |
| 2 | Number of fruit bunches $^{-1}$ | ** | ** | * |
| 3 | Fruit tree weight $^{-1}$ | ** | ** | * |
| 4 | Fruit weight $^{-1}$ | ** | ** | * |
| 5 | TSS ratio and total acid | ** | ** | ** |
| 6 | Thick fruit flesh | ** | ** | Ns |
| 7 | Vitamin C | Ns | Ns | * |
| 8 | Tannins | Ns | Ns | Ns |
| 9 | Edible portion | ** | ** | Ns |

Notes: *) significant $P < 0.05$, **) very significant $P < 0.01$ and Ns) not significantly different $P > 0.05$

The interaction of varieties and planting location had a significant effect on the length of the flower sheath and the number of fruit bunches $^{-1}$. Nenas variety grown in Tabanan (T < 560, T 560 to 650, and T > 650 ) and Karangasem (K < 560, K560 to 650, and K >

650) showed higher sheath length and a number of fruit bunches$^{-1}$ than with nangka. Nangka and Gondok varieties (Table 5). Tabanan (T 560 to 650) and Karangasem (K<560 m asl) are ideal conditions for flower sheath development and fruit development of nenas.

Commented [R12]: ????

**Table 5.** Flower sheath length (cm) and a number of fruit bunches $^{-1}$ (fruit) of nangka, gondok and nenas *Nenas* varieties at six locations.

Commented [R13]: ??????

| Treatment | Sheath length (cm) | Amount fruit bunches $^{-1}$ |
|---|---|---|
| NT < 560 | 27.50 ± 0.34 bcd | 19.55 ± 0.82 hij |
| NT 560 to 650 | 28.83 ± 1.31 b | 20.39 ± 1.00 g |
| NT > 650 | 27.17 ± 0.96 cde | 19.02 ± 0.82 j |
| NK < 560 | 26.00 ± 0.82 e | 21.13 ± 0.82 ef |
| NK 560 to 50 | 27.17 ± 0.14 cde | 22.28± 2.45 c |
| NK > 650 | 26.67 ± 1.36 cde | 21.13 ± 0.74 ef |
| GT < 560 | 26.67 ± 2.18 cde | 20.22 ± 0.31 gh |
| GT 560 to 650 | 27.50 ± 1.22 bcd | 20.55 ± 0.62 fg |
| GT > 650 | 27.70 ± 1.98 bc | 19.22 ± 0.74 ij |
| GK< 560 | 25.83 ± 1.41 e | 21.89 ± 0.82 cd |
| GK 560 to 650 | 26.83 ± 0.75 cde | 20.5 ± 1.63 fg |
| GK > 650 | 27.5 ± 0.82 bcd | 21.28 ± 0.78 def |
| NST < 560 | 27.5 ± 0.82 bcd | 21.41 ± 0.91 de |
| NST 560 to 650 | 27.67 ± 0.82 bc | 22.00 ± 1.56 cd |
| NST > 650 | 26.17 ± 2.16 de | 19.91 ± 1.36 ghi |
| NSK < 560 | 32.00 ± 1.63 a | 25.27± 1.41 a |
| NSK 560 to 650 | 30.90 ± 2.10 a | 24.00 ± 0.82 b |
| NSK > 650 | 27.00 ± 1.47 cde | 21.86 ± 0.82 cde |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

From Table 5 above it can be explained that the three varieties planted in six locations produced a number of fruits between 19.02 to 25.27 fruits per bunch. Nenas variety planted in Karangasem at an altitude of < 560 m asl (treatment NSK < 560) produced the highest number of fruits of 25.27 per bunch, followed by NSK 560 to 650 and NST 560 to 650 with 24.00 and 22.00 fruits per bunch. In order for the salak plants to bear much fruit, the nangka variety is ideal in Karangasem 560 to 650 m asl (NK 560 to 650), while the gondok variety is very good when planted below 560 m asl (GK < 560) although the number of fruits is not significantly different from the same altitude for NT 560 to 650 and GT < 560. The results of this study are in line with the findings of Sumantra and Martiningsih (2016) that the 'Gulapasir' salak var. nenas produces the highest number of fruits both in the on season (*gadu* season) and -off-season (*sela* season). Sumantra *et al*. (2014) reported that the emergence of new sheaths occurred on the third or fourth leaf midrib from the growing point depending on the altitude and plant conditions. The time for new sheaths to appear ranges from 129.00 d to145.10 d with the required heat units between 1233.62 - 1047.90 d °C. The higher altitude, the longer the sheath appears, as well as the harvest time.

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Mhn saya dijelaskan angka ini, agar saya dapat membantu ttg SI

The interaction of varieties and planting location had a significant effect on the fruit weigh (fruit tree$^{-1}$ and fruit$^{-1}$). Nangka variety grown in Tabanan (T < 560, T 560 to 650, and T > 650) and Karangasem (K < 560, K 560 to 650, and K > 650) showed higher of weight of fruit tree$^{-1}$ and fruit-$^{1}$ than with nenas and gondok (Table 6).

Commented [R15]: ??????

**Table 6**. Fruit weight of nangka, gondok, and nenas varieties in six locations

Commented [R16]: ?????

| **Treatment** | **Fruit$^{-1}$ (g)** | **Fruit tree-$^{1}$ (kg)** |
|---|---|---|
| NT < 560 | 45.32 ± 1.08 cd | 1.19 ± 0.08 def |
| NT 560 to 650 | 48.56 ± 0.71 c | 1.29 ± 0.07 cd |
| NT > 650 | 38.22 ± 0.46 ef | 1.03 ± 0.06 ghi |
| NK < 560 | 55.84 ± 1.37 a | 1.48 ± 0.02 b |
| NK 560 to 650 | 59.43 ± 0.71 a | 1.62 ± 0.07 a |
| NK > 650 | 49.4 ±1.65 b | 1.34 ± 0.05 c |
| GT < 560 | 40.14 ± 0.11 e | 1.11± 0.09 fg |
| GT 560 to 650 | 38.67 ± 0.55 ef | 1.09 ± 0.07 fg |
| GT > 650 | 32.95 ± 0.73 gh | 0.93 ± 0.10 i |
| GK < 560 | 44.22 ± 0.18 d | 1.27 ± 0.06 cde |
| GK 560 to 650 | 38.20 ± 0.78 ef | 1.16 ± 0.05 defg |
| GK > 650 | 36.20 ± 0.75 fg | 1.07 ± 0.11 fgh |
| NST < 560 | 39.00 ± 1.07 ef | 1.14 ± 0.11 efg |
| NST 560 to 650 | 37.79 ± 0.65 f | 1.13 ± 0.06 g |
| NST > 650 | 32.12 ± 0.11 h | 0.94 ± 0.10 hi |
| NSK < 560 | 41.80 ± 0.65 de | 1.36 ± 0.08 bc |
| NSK 560 to 650 | 36.57 ± 0.80 fg | 1.18 ± 0.09 def |
| NSK > 650 | 37.10 ± 0.23 f | 1.11 ± 0.07 fg |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

From Table 6 it can be explained that the three varieties grown in six locations produced fruit weight per tree between 0.93 kg and 1.62 kg. The salak nangka variety planted in Karangasem at an altitude of 560 to 650 m asl (NK 560 to 650) produced the heaviest fruit weight of 1.62 kg tree$^{-1}$, followed by NK < 560 and NT 560 to 650 with fruit weights of 1.48 and 1.29 kg. While the nenas variety produces the best fruit at altitudes < 560 m asl (NSK < 560 and NT < 560). Salak 'Gulapasir' var. gondok is ideal when planted at altitudes < 560 m asl (GK < 560 and GT < 560), although the two growing locations showed a different yields.

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Nenas and gondok varieties showed a trend of decreasing fruit weight in line with increasing altitude, both planted in Karangasem and Tabanan. The reverse occurred in the salak nangka variety, an increase in altitude from 550 m asl to 550 to 650 m asl caused an increase in fruit weight and after that the fruit weight decreased when planted at altitudes > 650 m asl. This finding is in line with the results of research that has been reported by Sumantra *et al*. (2014). However, for the gondok and nenas varieties, this is a new finding.

**Table 4**. Fruit weight of nangka, gondok, and nenas varieties in six locations

**Commented [R18]:** Ini kok Tabel 4 ?

**Commented [R19]:** Ini BUKAN cultivar, Bapak. Anda di kalimat atasnya sudah menulis varietas

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| Location (m asl) | Nangka | | Gondok | | Nenas | | Average location | |
|---|---|---|---|---|---|---|---|---|
| | Fruit$^{-1}$ (g) | Tree$^{-1}$ (kg) | Fruit-$^{1}$ (g) | Tree$^{-1}$ (kg) | Fruit$^{-1}$ (g) | Tree$^{-1}$ (kg) | Frui$^{-1}$ (g) | Tree$^{-1}$ (kg) |
| T< 550 | 45.32 c A | 1.19 d A | 40.14 b B | 1.11 b a | 39.0 ab B | 1.14 b A | 41.49 | 1.14 |
| T 550-650 | 48.56 bc A | 1.29 cd A | 38.67 b B | 1.09 b b | 37.79 b B | 1.13 b B | 41.67 | 1.17 |
| T>650 | 38.22 d A | 1.03 e A | 32.95 c B | 0.93 c a | 32.12 c B | 0.94 c A | 34.43 | 0.97 |
| K<550 | 55.84 a A | 1.48 b A | 44.22 a B | 1.27 a b | 41.80 a B | 1.36 a Ab | 47.29 | 1.37 |
| K 550- 650 | 59.43 a A | 1.62 a A | 38.20 b B | 1.16 ab b | 36.57 b B | 1.18 b B | 44.73 | 1.32 |
| K >650m | 49.40 b A | 1.34 c A | 36.20 bc B | 1.07 b b | 37.10 b B | 1.11 b B | 40.90 | 1.17 |
| Average Cultivar | 49.46 | 1.33 | 38.40 | 1.11 | 37.40 | 1.14 | - | - |

Notes: The number followed by the same letter in the row, column, and the same parameter shows a non-significant difference in LSD 5 %.

Apart from being influenced by environmental factors, the production of salak 'Gulapasir' fruit is also influenced by internal plant factors (Lestari *et al*. 2011). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019), and rainfall (Ritonga *et al*., 2018). Altitude increases, the average daily air temperature decreases and monthly rainfall increases (Table 2 and Tabel 3). Nuary *et al.* (2019) stated that the distribution and adaptation of salak plants is strongly influenced by temperature and rainfall. It was further stated, the contribution of daily temperature accounts for nearly 38.6 % while rainfall is 27.8 %. Kanzaria *et al.* (2015) reported that mango plants planted at an altitude of 229 m flowered slower than those at an altitude of 148 m and 81 m asl. The temperature regime at higher altitudes is colder than at lower altitudes. Lower temperatures accumulate less GDD and may result in late flowering. Table 6 shows that the 'Gulapasir' salak planted in Karangasem produced a higher fruit weight in the three salak varieties tested. This is related to the level of soil fertility. The soil nitrogen and phosphate nutrient content at three locations in Karangasem was higher than at three locations in Tabanan. Meanwhile, the potassium content in the six research locations was low (Table 2). Therefore it is necessary to make improvements by providing fertilizers containing elements of N, P and K to meet ideal conditions for growth, although more data is needed to fully support this conclusion (Hailu *et al.*, 2015).

**Commented [R21]:** Akronim apa ? Bila mucul akronim pertama kali mhn dijabarkan

**Commented [R22R21]:** growing degree days

*3.4 Quality characteristics of salak varieties*

The interaction between varieties and altitude significantly affected sugar/total acid and vitamin C content. The three varieties grown in Tabanan (T < 560, T 560 to 650 and T > 650) showed a lower TSS/acid ratio. The fruit flavour planted in three locations in Tabanan is sourer than the three locations in Karangasem. Sugar content is greatly affected by the geographical. The geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity, and rainfall (Ritonga *et al*., 2018). Table 7 also shows that the increase in altitude from 550 m to 700 m asl in Tabanan and the addition in altitude from 550 to 650 m asl in Karangasem causes the sugar/acid ratio decrease in all three varieties, and the lowest sugar/acid value occurs in nenas variety in all locations. Each salak variety has an adaptation to an elevation closely related to plant tolerance to temperature (Sumantra and Martiningsih, 2016; 2018). Many factors influence fruit quality, but the most dominant are climate factors, especially temperature and rainfall. High rainfall and low air temperature during the fruit ripening phase can cause the dissolved solids in the fruit to become watery so that the TSS value is low (Singh *et al*., 2011).

Salak fruits from three different varieties grown in low lands in Karangasem (K < 560 m asl) showed the highest vitamin C content and were significantly different from the three cultivars when planted in other locations. In both areas land increased by > 650 m asl effects to vitamin C decrease, nangka and gondok varieties showed higher levels of vitamin C between < 550 m to < 650 m asl. (Table 7).

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**Table 7.** TSS/acid ratio and levels of vitamin C of Nangka, gondok, and nenas varieties in six locations.

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| Treatment | TSS/T.Acid | Vit. C (mg /100g) |
|---|---|---|
| NT < 560 | 56.20 ± 0.16 abc | 27.50 ± 0.41 bde |
| NT 560 to 650 | 59.18 ± 0.82 a | 25.45 ± 0.37 defgl |
| NT > 650 | 37.89 ± 0.91 f | 22.52 ± 0.39 j |
| NK < 560 | 51.41 ± 0.33 cde | 27.74 ± 0.47 bd |
| NK 560 to 650 | 53.52± 0.82 abcd | 29.61 ± 0.50 ab |
| NK > 650 | 47.76 ± 0.11 de | 24.25 ± 0.20 fghij |
| GT < 560 | 34.88± 0.72 fg | 25.50 ± 0.41 defgl |
| GT 560 to 650 | 34.80 ± 0.65 fg | 25.75 ± 0.20 defgl |
| GT > 650 | 30.24 ± 0.20 gh | 23.34 ± 0.28 hij |
| GK < 560 | 51.28 ± 0.23 cde | 30.31 ± 0.25 a |
| GK 560 to 650 | 58.44 ± 0.36 ab | 27.63 ± 0.30 bd |

| | | |
|---|---|---|
| GK > 650 | 53.04 ± 0.82 bcde | 25.07 ± 0.33 efgh |
| NST < 560 | 31.50 ± 0.41 gh | 26.71± 0.21 cdef |
| NST 560 to 650 | 30.44 ± 0.36 gh | 25.88 ± 0.41 defg |
| NST > 650 | 26.13 ± 0.11 h | 23.65 ± 0.29 ghij |
| NSK < 560 | 53.73 ± 0.60 abc | 24.42 ± 0.34 fghij |
| NSK 560 to 650 | 52.63 ± 0.51 bcde | 22.82 ± 0.15 ij |
| NSK > 650 | 47.60 ± 0.49 e | 25.16 ± 0.13 efgh |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

The results showed that the varieties of the 'Gulapasir' salak needs different environmental requirements to optimize yields. Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al*., 2021, 2022). Therefore, variety differences may depend on growing requirements and cultivation techniques. Vitamin C in the 'Gulapasir' salak is strongly influenced by the altitude of the land. To produce high levels of vitamin C, the nangka and gondok varieties are ideal for planting at an altitude of 560 m to 650 m asl, while the nenas variety is ideal at a land altitude of < 560 m asl. However, changes in ascorbate levels during fruit ripening are species-dependent and environmental factors especially temperature and light (Fenech *et al*., 2019).

There was no interaction between varieties and altitude to the flesh thickness, edible fruit portion, and fruit sugar content. The nangka salak variety showed fruit quality, including TSS, edible parts of the fruit, and higher flesh thickness (Table 8).

**Table 8.** The effect of a single factor of varieties on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment | TSS (ºBrix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| Nangka | 16.59a | 72.50a | 0.63a |
| Gondok | 16.42a | 70.66ab | 0.59b |
| Nenas | 15.64b | 69.22b | 0.52c |

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**Commented [R26]:** ??????

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Salak grown in Karangasem both from the lowlands and the middle lands produces fruit thickness, and the edible portion of fruits is higher than plants in the highlands. This study indicates that the ideal growing place for salak plants is between 450 m to 650 m asl. This study is in line with several previous studies which explained that altitude affects the flowering process and fruit enlargement (Sophie *at al*., 2017; Spinardi *et al*., 2019; Widyastuti *et al*., 2022).

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**Table 9.** The effect of a single factor of planting location on TSS, the portion of edible flesh, and the thickness of salak fruits

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| Treatment (m asl) | TSS ($^o$Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| T < 550 | 16.28a | 73.13a | 0.54c |
| T 550 to 650 | 16.27a | 69.89a | 0.58bc |
| T > 650 | 16.14a | 63.87b | 0.49d |
| K 550 | 16.81a | 73.15a | 0.61b |
| K 550 to 650 | 16.11a | 72.29a | 0.66a |
| K > 650 | 15.69a | 72.44a | 0.61b |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Further research can be applied using sustainable salak agriculture. Table 2 shows that salak cultivation in the research location still needs to implement sustainable farming. There are indications some of decrease in soil fertility, especially potassium available in the six planting locations that have been evaluated shows a very low value. Potassium levels in Table 2 are lower than the observations of Ashari (2013) and Woran *et al.* (2018) in salak cultivation areas in Swaru – Malang (very high), Sleman – Yogya (moderate), Bangkalan – Madura (very high), and Pangu – Minahasa (moderate).

Potassium helps produce good fruit quality, such as bigger, heavier, and sweeter fruit. Another benefit of the nutrient potassium in plants is to increase the growth of meristem tissue and regulate the movement of stomata. Potassium also helps the development of plant roots so that plant stems can stand upright and do not collapse easily (Adinurani *et al.,* 2018; Budiono *et al*., 2019). Therefore, Nasution (2022) recommends more $K_20$ fertilizer than $P_20_5$ fertilizer and N fertilizer. In addition, salak needs 70 kg of $K_2O$ because this nutrient is found in the leaves at an amount (12.2 to 14.7) mg $g^{-1}$ (Ashari, 2013).

Authors realize that using chemical fertilizers (e.g., KCl) is too expensive for Salak farmers. Therefore, the application of sustainable farming should apply local wisdom including the use of the pruning of salak midrib. Consider this policy because C organic is essential to soil fertility (Budiono *et al*. 2021; Goenadi *et al*. 2021). The success of this midrib decomposition is demonstrated by the C organic in Table 2, which is classified as medium to high. But, in the next stage, some of the salak midribs should be burned into ashes which can be used as a source of potassium nutrients (Ekawati and Purwanto, 2012; Vincevica-Gaile *et al*., 2021a, 2021b).

Another measure to increase and maintain land fertility is in salak cultivation, namely the application of Plant Growth Promoting Rhizobacteria (PGPR) or biological fertilizer (Basu *et al*., 2021; Ekawati, *et al.,* 2019). Several researchers (Adinurani *et al*., 2021; Kumalawati *et al*., 2021; Muhammad *et al*. 2021) have reported using mycorrhiza, which positively impacts various plants, including salak cultivation (Amnah and Friska, 2018; Dewi *et al*., 2020; Rai *et al*., 2021). Multiplication of mycorrhiza is relatively simple (Sportes *et al*., 2021; Sukmawati *et al*., 2021) and can be done by farmer groups with initial guidance from universities.

## 4. Conclusion and Recommendation

Different cultivars caused different fruit weights, fruit bunches, and the sugar/acid ratio at various locations. The three varieties showed lower fruit weight and fruit quality in Tabanan (low, medium, and highlands) than the salak originating from Karangasem. The nangka variety in Karangasem showed higher fruit weight, vitamin C content, and sugar/ acid ratio, while the nenas salak showed the highest number of fruit bunches$^{-1}$ in six locations. Nangka salak are very suitable to be planted at an altitude of 550 m to 650 m asl. In contrast, the nenas and gondok varieties are developed naturally at low altitudes < 550 m asl. In order for all cultivars to be able to produce optimally, efforts to improve the cultivation system are needed through fertilization and the provision of calcium is highly recommended. Further research can be applied using sustainable salak agriculture, especially to maintenance the soil fertility.

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**Running Title:**

Assessment Salak Planted in Different Agro-Ecosystems

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# Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Different Agro-Ecosystems

**ABSTRACT**

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir has been officially released by the Minister of Agriculture of the Republic of Indonesia since 1994. Salak 'Gulapasir' is one of five types of fruit that have been designated as the superior fruit of the Bali Province. Salak 'Gulapasir' preferred by consumers due to its specific fruit flesh taste. Salak 'Gulapasir' was propagated using seeds so that a new types of salak emerged. However, the characters of this new type of salak 'Gulapasir' is not yet known. The research objective was to obtain the superior of some Salak 'Gulapasir' both in production and fruit quality. The research used a Randomized Block Design with three replications. The non-independent variable was the three of Salak 'Gulapasir' (SGP): SGP var. nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 to 650 m asl, and K > 650 m asl) and Tabanan (T): (T < 560 m asl, T 560 to 650 m asl, T > 650 m asl). Observations were made on the agronomic characters and fruit quality. Data were analyzed using variance analysis, and if the planting location and varieties show a difference, then it is followed by the LSD test at the 5 % level. The results showed that different varieties caused different fruit weights, fruit bunches, TSS, and total acid ratio. In Tabanan (in the low, medium, and highlands), the three varieties showed lower fruit weight and fruit quality than the salak originating from Karangasem. The SGP var. nangka in Karangasem showed higher fruit weight, vitamin C content, and TSS/total acid ratio, while the SGP var. nenas showed the highest number of fruit bunches$^{-1}$ in six locations.

**Keywords :** Altitude, *Salacca zalacca* (Gaertn.) Voss, Salak 'Gulapasir' var. gondok, Salak 'Gulapasir' var. nangka, Salak 'Gulapasir' var. nenas, Salak sustainable agriculture, Snake fruit, Tropical fruit

## 1. Introduction

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir is one of the important fruits in Indonesia and the plant can be found in most regions of Indonesia (Rai *et al*. 2016; Ritonga *et al*., 2018). The salak fruit belong to the family Palmae or Arecaceae, and are native to the Indonesian-Malaysian region (Hakim *et al.,* 2019; Zumaidar *et al*., 2014). One of the extraordinary strengths of this fruit commodity for Indonesia is the possession of high genetic diversity (Budiyanti *et al*., 2019). Also, the nutrition of salak fruit is rich in antioxidants, phenolics, vitamins, and minerals (Cepkova *et al.,* 2021; Mazumdar *et al*., 2019), and a good source of income and provides livelihood opportunities on seasonal days (Khan and Idrees, 2021). The fruit flesh and peel have shown some tremendous anti-inflammatory, anticancer and antidiabetic (Saleh *et al*., 2018), and anti-ageing agents (Girsang *et al*., 2019). Antioxidants are chemical compounds that play an essential role in protecting cells due to attacks against free radicals-induced damage to biomolecules (Damat *et al*., 2019, 2020; Puspitasari and Ningsih, 2016; Setyobudi *et al*., 2019). Despite its incredible food and medicinal benefits, salak fruit is still underutilized and unknown globally. So that this underutilized fruit remains an issue for future sustainable utilization and commercial value enhancement market (Mazumdar *et al*., 2019). Fruit quality is an important issue, especially for products that are consumed raw and fresh. One of the problems is the lack of fruit quality because of inadequate information about superior salak (Budiyanti *et al*., 2019; Herawati *et al*., 2018). Therefore, it is necessary to select superior salak to meet market demand and fulfil community nutrition.

Salak 'Bali' is quite a lot, based on the shape, aroma, taste, and skin colour of the location where the plants are cultivated (Sumantra *et al*., 2012, 2014; Sumantra and Martiningsih, 2016,

2018). Under the Decree of the Minister of Agriculture of the Republic of Indonesia in 1994, Balinese zalacca was grouped into two superior zalacca: Salak ‘Bali’ (SK Mentan, 1994a) and Salak ‘Gulapasir’ (SK mentan, 1994b). The second type, the salak ‘Gulapasir’ (SGP) is the most superior salak because of its sweet fruit taste; even though the age of the fruit is still young, thick fruit flesh and seeds are not attached to the fruit flesh (Rai *et al*., 2014; Sumantra *et al*., 2016). The nature of this fruit is ideal for meeting market demands for both the domestic and export markets (Martiningsih *et al*., 2018). Salak ‘Bali’ is monoecious, so crossing does not need human help (Herawati *et al*., 2018), and can quickly develop using seeds (Sumantra and Martiningsih, 2016). Another advantage of salak plants in Indonesia compared to other fruits is harvest fruit 2 to 3 times a year if management is good (Rai *et al*., 2016; Warnita *et al.*, 2019). The expansion of salak ‘Gulapasir’ planting causes variations in phenotypic diversity. People can find two to three types of salak plants with a marker, fruit shape, aroma, flesh colour, and fruit weight (Martiningsih *et al*., 2018). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seeds so that new varieties of salak ‘Gulapasir’ (SGP) appear, as reported by Sumantra and Martiningsih (2016). Based on the marker that can be used as a differentiator, salak farmers give it the name of SGP var. nenas, SGP var. gondok, and SGP var. nangka. The three varieties have not yet identified their advantages in meeting market needs in line with the results of research (Sumantra and Martiningsih, 2016). The performance and produce are influenced by the characteristics of the agricultural ecosystem, particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status (Adelina *et al.*, 2021a; Kumar *et al*., 2020) and growth hormone (Prihastanti and Haryanti. 2022; Rai *et al.*, 2016).

The salak ‘Gulapasir’ plantation in the District of Bebandem is the main producer of salak ‘Gulapasir’ in Bali is located in the southern part of Mount Agung with an altitude of 450 m to 700 m above sea level (m asl). The effect of altitude on plant growth and production is related to plant adaptation to temperature (Sumantra, *et al*., 2014), full sunlight (Sukawijaya *et al*., 2009), water status and soil quality (Raharjo *et al*., 2022; Rai *et al*., 2014; Ritonga *et al.,* 2018). Salak plants are not resistant to full sun but 50 % to 70 % enough, therefore it is necessary to have shade plants (Sukawijaya *et al*., 2009; Sumantra *et al*., 2012). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019). Water status and soil quality really determine the fruit set on the salak 'Gulapasir'. Low rainfall reduces the Relative Water Content in leaves (RWC), leaf chlorophyll content, and plant nutrient uptake (Rai *et al*., 2014). soil quality included the suitability of the physical, chemical and biological properties (Raharjo *et al*., 2022). Nuary *et al*. (2019) stated that the distribution of the salak 'Pondoh' plantation area in Sleman (Yogyakarta, Special Region) was greatly influenced by temperature and rainfall. The contribution of temperature in the modelling reached 38.6 % while the rainfall was 27.8 %. Furthermore, taking into account the probability of the temperature variable, the average temperature ranges from 17.41 °C to 25.65 °C, and the ideal month's rainfall ranges from 385.24 mm to 505.01 mm.

Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al*., 2021, 2022). Therefore, varieties differences may depend on growing requirements and cultivation techniques. Likewise, Puspitasari *et al*. (2016) stated that tannin content, fruit size and flesh colour of salak fruit are strongly influenced by where it grows. Other studies also explain that salak 'Gulapasir' var. nangka which is grown 570 m asl, would result in a higher quality of fruit that includes thickness of the mesocarpium, edible portion of fruit then compared to above and below 570 m asl (Sumantra *et al*., 2014; Sumantra and Martiningsih, 2016). Meanwhile, fruit weight and fruit quality of var. gondok and var. nenas have not been reported. Therefore, one way of handling salak quality is by undertaking severe studies for factors such as land and climate and adjusting agricultural patterns according to local climate conditions (Nassar *et al*., 2018). The success of each species to occupy the environment of an area is influenced by its ability to adapt optimally to all physical environmental factors (temperature, light, soil structure, humidity), biotic factors (interaction between species, competition, parasitism), and chemical factors including the availability of water, oxyge, pH, and nutrients (Nassar *et al*., 2018; Widyastuti *et al*., 2022). Moreover, a broad genetic variability would lead to wide phenotypic variability due to the effect of genetic-environment interaction (Ritonga *et al*., 2018). The research objective was to obtain the superior of some salak ‘Gulapasir’ both in production and fruit quality (sugar and acid ratio, vitamin C and tannin) in six different agricultural ecosystems in Bali.

## 2. Materials and Methods

### *2.1 Experimental site*

The research was conducted in Tabanan and Karangasem Regencies. Tabanan and Karangasem were selected as research locations because the domination of salak 'Gulapasir' in these two regencies was the highest. In 2021, the salak 'Gulapasir' population in Tabanan is 84 % of all salak species, while in Karangasem Regency the dominance of the salak 'Gulapasir' is more than 63 % (Sumantra *et al*., 2022).

The study was carried out in six different locations, three sites in Karangasem Regency and three sites in the district of Tabanan. Locations in Karangasem (K) are lowlands (K < 560 m asl) which include several places, namely Telaga, Dukuh, and Karanganyar. Karangasem in the moderate plains (K 560 m to 650 m asl) has several areas, namely Kecing and Kutabali and highlands (K > 650 m asl), namely Tanah Apo and Kresek (Figure 1).

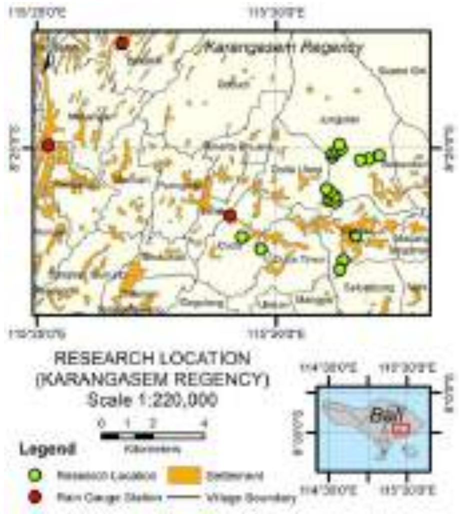


**Fig 1.** Research map and sampling point in Karangasem (K)

The research location is in Tabanan (T) in the lowlands (T < 560 m asl), including Wanagiri, Sari Buana, and Mundeh Kauh. Tabanan in the medium lands (T 560 m to 650 m asl) includes several places, namely Pajahan, Kebon Jero, and Angseri. Tabanan in the highlands (T > 650 m asl), namely Munduk Temu, Pempatan, and Batungsel (Figure 2).

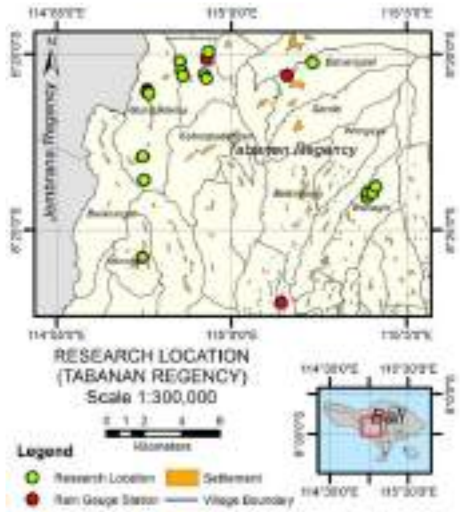

**Fig 2.** Research map and sampling point in Tabanan (T)

The non-independent variable was the three varieties of Salak ‘Gulapasir’ (SGP): SGP var.nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 m to 650 m asl, and K > 650 m asl) and Tabanan (T) : (T < 560 m asl, T 560 m to 650 m asl, T > 650 m) Repetition was carried out three times with the number of sample plants in each location, and cultivars were seven plants. The treatment tested is as shown in Table 1

**Table 1**. Treatment of plant location and three varieties of ‘Gulapasir’ salak

| No | Treatment | Explanation |
|---|---|---|
| 1 | NT< 560 m asl | Salak GP.var. nangka Tabanan < 560 m asl. |
| 2 | NT 560 m to 650 m asl | Salak GP.var. nangka Tabanan 560 m to 650 m asl. |
| 3 | NT > 650 m asl. | Salak GP.var. nangka Tabanan > 650 m asl. |
| 4 | NK < 560 m asl. | Salak GP.var. nangka Karangasem < 560 m asl. |
| 5 | NK 560 m to 650 m asl | Salak GP.var. nangka Karangasem 560 m to 650 m asl. |
| 6 | NK > 650 m asl. | Salak GP.var. nangka Karangasem > 650 m asl. |
| 7 | GT< 560 m asl | Salak GP var. gondok Tabanan < 560 m asl. |
| 8 | GT.560 to 650 m asl | Salak GP var. gondok Tabanan 560 m to 650 m asl. |
| 9 | GT > 650 m asl | Salak GP var. gondok Tabanan > 650 m asl. |
| 10 | GK.< 560 m asl | Salak GP var. gondok Karangasem < 560 m asl. |
| 11 | GK 560 m to 650 m asl | Salak GP var. gondok Karangasem 560 m to 650 m asl. |
| 12 | GK > 650 m asl | Salak GP var. gondok Karangasem > 650 m asl. |
| 13 | NST < 560 m asl | Salak GP var. nenas Tabanan < 560 m asl. |
| 14 | NST.560 m to 650 m asl | Salak GP var. nenas Tabanan 560 m to 650 m asl. |

| | | |
|---|---|---|
| 15 | NST > 650 m asl | Salak GP var. nenas Tabanan > 650 m asl. |
| 16 | NSK .< 560 m asl | Salak GP var. nenas Karangasem < 560 m asl. |
| 17 | NSK 560 m to 650 m asl | Salak GP var. nenas Karangasem 560 m to 650 m asl.. |
| 18 | NSK > 650 m asl | Salak GP var. nenas Karangasem > 650 m asl. |

The study used a Composite Analysis of Variance (Andinurani, 2016, 2022) with the model determined using Equation (1) below:

$$Yjk = u + L\,i + \delta\,ik + Pj + (LP)\,ij + \varepsilon\,ijk \qquad (1)$$

Where:

Yijk = The observation value of the treatment (j) in the group (k), which is repeated at the location (i).

u = the actual average value

Li = additive effect from location i

δ ik = the error effect in group k at location i

Pj = additive effect of the next treatment

(LP) ij = the effect of treatment (j) at the location (i)

Ɛ ijk = the effect of error from the treatment (j) in the group (k) which was carried out at the location (i).

*2.2 Preparation of study materials*

The material used is the salak 'Gulapasir' plant with uniform growth, plants have been fruitful with uniform on morphological, age of plants and cultivation action. The intentional practice is that the plant only receives treatment in the midrib, tillers, and weed cleaning. In this study, the plants were not fertilized. The provision of water was only from rainfall following the habits applied by salak farmers. The sample plant maintains by trimming unproductive leaf midribs and removing young shoots. Plant material was taken

from the Salak Development Centre in six locations, namely at the Centre of Salak Development in the Bebandem sub-districts, Karangasem district (K-lowland < 560 m asl, K-medium 560 m to 650 m asl and K-highland > 650 m asl), Bajre, West Slemadeg and Pupuan sub-districts, Tabanan district (T-lowland < 560 m asl, T-medium 560 to 650 m asl and T-highland > 650 m asl).

2.*3 Analysis of physicochemical properties of soil sample* and climate

Soil analysis was carried out to determine the physical and chemical properties of the soil. Soil sampling was carried out under sample plant trees, carried out in a composite manner at a depth of 0 cm to 40 cm. Chemical analysis was carried out on total N (Kjeldahl method), available P by Bray I method and $K_2O$ by the Bray I method, organic C, pH, soil physical properties in the form of texture by pipette method (Hailu *et al*., 2015; Prasetyo *et al*., 2022; Rzasa and Owczarzak, 2013).

Rainfall data was taken for five years from 2015 to 2019. Rainfall data has been collected from six nearby stations to the research site (Table 2). Daily temperature data obtained from the Denpasar Meteorology Climatology Agency.

**Table 2**. Research locations and place of climatology stations

| Research Locations | Climate observation station | Latitude and altitude |
|---|---|---|
| Tabanan Lowlands (< 560 m asl) | Ampadan, Tiyinggading No.St. 439 m | 8°27'5.0688"S/ 115°1'25.086 "E; 400 m asl. |
| Tabanan Moderate (560 m to 650 m asl) | Coffee Breeding Center, Sai Pupuan No. St. 439 h | 08°20'08.6"S/ 114° 59'17.4" E; 580 m asl. |
| Tabanan Highlands (> 650 m asl) | Agricultural Extension Center, Pupuan. No St.441 h | 08°20'38.1" S/ 115°01'35.2" E; 750 m asl. |

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**Commented [KS3R2]:** Sudah di cek dan diperbaiki

| | | |
|---|---|---|
| Karangasem Lowlands (< 560 m asl) | Agricultural Extension Center, Selat. No. St. 444 d | 08°26'25" S / 115°29'02" E; 450 m asl. |
| Karangasem Moderate (560 m to 650 m asl) | Horticulture Seed Center, Singerata No.St. 442 | 08°24'57"S / 115°25'14"E; 580 m asl. |
| Karangasem Highlands (> 650 m asl) | Besakih Station. No.St.442 a | 08°22'49"S / 115°26'47"E; 800 m asl. |

*2.4 Observation of fruit and fruit quality*

Salak fruit can be harvested when it is ready for consumption. Consumable ripe fruit is a fruit that is ready to be consumed, characterized by a change in skin colour from dark brown to light brown, the thorns on the skin have reduced and are not sharp, and in general, at this stage, the fruit easily falls when shaken.

Observation and measurement of agronomic characters follow the method that has been done by Sumantra *et al*. (2014) including fruit weight, number of fruit bunches, the thickness of fruit flesh and fruit shape. The fruit characters from six-observed locations include the numbers of fruits per bunch, which is calculated manually on the formed fruits. The fruit weight per fruit and the fruit weight per tree is weighed after the fruits were removed from the bunch. The thickness of the mesocarpium is obtained by measuring the mesocarpium after it is cut vertically. The length of the flower sheath is measured on the stem of the sheath from the base to the tip of the sheath.

While fruit quality includes sugar content, tannins, titrated acid, sugar content and vitamin C. Titrated acid was analyzed by titration (Sripakdee *et al*., 2015). The fruit was weighed 10 g of sample was added to 100 mL of distilled water, then was homogenized using a slow spin blender, and filtered using an aseptic filter. The filtrate obtained was taken as much as 25 mL, then titrated with 0.1 N NaOH solution with phenolphthalein

indicator until red in colour appeared. The results obtained are calculated as the percentage tartaric acid is determined using Equation (2) below :

$$A = \frac{mL\ NaOH \times N\ NaOH \times P \times BM}{Y \times 1\,000 \times 2} \times 100\ \% \qquad (2)$$

Commented [R4]: Saya perbaiki krn Bpk blm respon

Commented [KS5R4]: Tks pak, ini karena bingun lihat contoh beda-beda penyajian

where:

A = percentage of total acid

P = amount of dilution

BM = molecular weight of tartaric acid

Y = sample weight (g).

Tannis content was analyzed as done by Thakur *et al*. (2021), Setyobudi *et al*. (2022). Amount of 100 mg of the sample was homogenized by 2 mL of methanol. Centrifuged for 10 min at 10 000 rpm (1 rpm = 1/60 Hz) and collected the supernatant. Amount of 1 mL of supernatant mixed with 0.5 mL Folin's phenol reagent and 35 % $Na_2CO_3$ of 5 mL added and the mixture was kept at room temperature for 5 min. The blue colour of the reaction mixture was observed at 640 nm by UV/visible spectrophotometer (Shimadzu UV-1800, Japan). The content of tannin was calculated by calibration curve equation and determined using Equation (3) below:

$$Y = 0.0073x - 0.0071 : R^2 = 0.9973 \qquad (3)$$

Vitamin C was determined by titration like the method used by Asamara (2016), Setyobudi *et al.* (2021, 2022). The material is weighed as much as 10 g and crushed in mortal. Then put into a 250 mL volumetric flask, set to the mark and filtered. Take 25 mL of the filtrate and titrate with 0.01 N Yod solution equivalent to 0.88 mg of ascorbic acid. The calculation of ascorbic acid content per 100 g of material is determined using Equation (4) below:

$$A = \frac{\text{mL Yod } 0.01\text{ N} \times 0.88 \times P \times 100}{Y} \quad (4)$$

Commented [R6]: Saya perbaiki krn Bpk tdk respon

where: A = mg of ascorbic acid per 100 g of material

P = amount of dilution

Y = gram sample weight

Sugar content as TSS is calculated using a hand refractometer (Bellingham and Stanley Ltd., London) at 20 °C.

The ratio of sugar content (TSS) and total acid is calculated by the sugar content divided by the acid content multiplied by 100 %.

The materials used in this study were Folin-Ciocalteu reagent (Pro Analytic, Merck), NaOH (Pro Analytic, Merck), $Na_2CO_3$ (Pro Analytic, Merck), Phenolphereagent ascorbic acid (Pro Analytic, Merck), Phosphoric Acid (Pro Analytic, Merck), Sodium Phosphate (Pro Analytic, Merck) and Ammonium Molybdate (Pro Analytic, Merck).

The tools used in this study were analytical balances (Shimadzu ATY224, Japan), centrifuge tubes, Erlenmeyer flasks (pyrex), dropper pipettes (pyrex), volume pipettes (pyrex), vortex (Maxi Mix II Type 367000), measuring flask (pyrex), water bath (Memmert), blender (Miyako), and centrifuge (Damon /IEC Division). Whatman filter paper No 1 (Sigma – Aldrich, USA), measuring cup (Pyrex, USA), micropipette (Dragon Lab, Indonesia), spectrophotometer (Biochromsn 133467, UK), test tube (Pyrex¸ USA), vortex (Barnsteadl Thermolyne Type 37600 Mixer, USA), aluminum foil (Klin Pak, Indonesia).

*2.5 Study design*

This study used a randomized block design with the data analyzed using a Composite Analysis of Variance. If the variance test is significantly different, then it is continued with a different test with LSD at the 5 % level. Data analysis was performed using SPSS-IBM 18 (Adinurani, 2016, 2022). Each experimental treatment was repeated three times.

## 3. Results and Discussion

### *3.1 Agroclimate characteristic*

The low production level and quality of salak fruit are caused by environmental factors that do not support growth or because the physiological processes of the plant are not optimal due to insufficient nutrients and water. The suitability of climatic and soil conditions at six locations of the centres for the development of the 'Gulapasir' salak was evaluated. The evaluation results show that the air temperature decreases as the altitude increases. The average air temperature at the 'Gulapasir' salak plantation in Tabanan is 22.90 $^oC$, while the air temperature at the Karangasem salak plantation is around 23.24 $^oC$. (Tabel 3)

**Table 3.** Soil and climate characteristics of the research site in Tabanan and Karangasem in three subzones

| **Parameter** | **Tabanan (T)** | | | **Karangasem (K)** | | |
|---|---|---|---|---|---|---|
| | Lowlands (< 560 m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) | Lowlands (< 560m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) |
| Temp. ($^o$C) | 23.82 | 22.75 | 22.12 | 24.29 | 23.35 | 22.09 |
| Rainfall (mm mo$^{-1}$) | 188.24 | 199.91 | 231.008 | 237.242 | 254.183 | 289.216 |
| Soil texture | loamy clay | loamy clay | loamy clay | clay | clay | sandy loam |
| pH ($H_2O$) | 5.64(sa) | 5.75 (sa) | 5.84 (sa) | 6.08 (sa) | 6.05 (sa) | 6.03(sa) |
| C- organic (%) | 2.94(m) | 3.40 (h) | 3.25 (h) | 2.77 (m) | 3.63 (h) | 3.32 (h) |
| Nutrients available | | | | | | |
| N total (%) | 0.18 (l) | 0.16 (l) | 0.18 (l) | 0.24(m) | 0.23 (m) | 0.29 (m) |
| $P_2O_5$ (mg g$^{-1}$) | 9.38 (vl) | 9.12 (vl) | 13.50 (l) | 22.55 (m) | 24.18 (m) | 23.04 (m) |
| $K_2O$ (mg g$^{-1}$)) | 18.47 (vl) | 22.05 (vl) | 17.23 (vl) | 24.17 (vl) | 19.93 ( vl ) | 18.37 ( vl ) |

Notes: sa: slightly acidic; h: high; m: medium; l: low; vh: very high; h: high; asl: above sea level (The assessment criteria refer to PPT, 1983).

Likewise monthly rainfall, the average rainfall over the 5 yr is presented in Table Table 4. Annual rainfall in Tabanan (T < 560, T 560 to 650 and T > 650) is lower with an average of 2515.05 mm while in Karangasem (K < 560, K 560 to 650 and K > 650) it is 3 122.05 mm. However, the six locations show a trend of increasing rainfall as altitude

**Commented [R7]:** Ini SALAH ?

**Commented [KS8R7]:** Jadi Tabel 3

**Commented [R9]:** Ini mhn diperbaiki krn di atas ada tabel 2 juga

**Commented [R10]:** Mhn diperbaiki urutan tabel

**Commented [KS11R10]:** Urutan Tabel sdh dperbaiki. Total tabel 1-10 increases. The salak plantation area in Karangasem is in the southern part of Mount Agung. Meanwhile in Tabanan, the dominant salak plantation area is behind Mount Batukaru with a lower elevation than Mount Agung. Mount Agung with an altitude of 3 142 m asl (Andaru and Rau, 2019), while the Batukaru mountains area with an elevation 2 250 m asl (Asmiwyati *et al.*, 2015). Mount Batukaru as a barrier, causing this area to be a rain shadow. Enyew and Steenveld (2014) state that rainfall in an area is influenced by topographical factors and mountain ranges. Decreasing the height of the mountains, provides a reduction in the maximum level of rainfall over the mountains and foothills by 50 % (Flesch and Reuter, 2012). Topographical factors and regional weather systems have an important role in the amount and spatial pattern of rainfall in an area (Enyew and Steenveld, 2014).

**Table 4.** The annual rainfall in the six study sites (2015 to 2019)

Commented [R12]: Mhn diperbaiki

Commented [KS13R12]: Sdh diurut bds nomor tabel

| Year | Tabanan: T (mm yr $^{-1}$) | | | Karangasem: K (mm yr $^{-1}$) | | |
|---|---|---|---|---|---|---|
| | T < 560 | T 560 to 650 | T > 650 | K < 560 | K 560 to 650 | K > 650 |
| 2015 | 2 001.0 | 2 462.7 | 2 633.0 | 2 470.5 | 2 714.0 | 3 291.0 |
| 2016 | 2 095.0 | 2 453.5 | 3 049.5 | 2 659.0 | 2 885.0 | 3 800.0 |
| 2017 | 1 958.0 | 2 152.5 | 2 135.0 | 2 903.0 | 3 173.0 | 3 500.0 |
| 2018 | 2 335.5 | 2 463.9 | 2 955.0 | 3 002.0 | 3 057.0 | 3 200.0 |
| 2019 | 2 905.0 | 2 462.0 | 3 088.0 | 3 200.0 | 3 422.0 | 3 562.0 |
| Average | 2 258.9 | 2 398.92 | 2 772.1 | 2846.9 | 3 050.2 | 3 470.6 |

Based on the growing requirements of salak plants, rainfall and air temperature in the six locations evaluated were in the very suitable range to support plant growth and development. A good air temperature for the growth of salak plants is between 20 °C to 30 °C and an average rainfall of (200 to 400) mm mo$^{-1}$ (Nuary *et al.*, 2019).

Soil C-organic content in six planting sites was in the medium to high range. Availability of N and P nutrients in salak plantations in Tabanan in the lowlands, medium and highlands in low to very low conditions. Salak planting land in Karangasem, both in the lowlands, medium and highlands, these two nutrients are available in moderate conditions (Table 3). The nutrient content of potassium available in the six planting locations that have been evaluated shows a very low value. The results of this study indicate that the cultivation techniques carried out by farmers are very low. Farmers do not apply an fertilizers that only rely on litter from the pruning of salak midrib as reported by Ilmiah *et al*. (2021), Rai *et al.* (2014), and Warnita *et al.* (2019). To cultivate sustainable agriculture, especially in agroecosystems salak in Bali. The authors will discuss this issue more in the future research paragraph.

*3.2 Characteristics of Salak 'Gulapasir'*

The salak 'Gulapasir' his monoecius plant, namely male and female flowers arranged on the same bunches, the shape of the bunches is compound, and the position of the flower is on the back of the midrib. The salak 'Gulapasir' is classified as special because of its sweet fruit taste and the price per unit weight is four times more expensive than the salak 'Bali' (Rai *et al*., 2014; Sumantra *et al*., 2012). The expansion of the cultivation of the salak 'Gulapasir' from its area of origin, Sibetan, Karangasem, has resulted in phenotypic diversity with a phenotypic similarity level of 58.62 % to 93.10 % (Sumantra and Martiningsih, 2016). In the same garden, more than one type of 'Gulapasir' salak appears, depending on fruit shape, aroma, color of fruit flesh and fruit weight (Sumantra and Martiningsih, 2016). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seed, so new variants of salak 'Gulapasir' appear with local names such as salak 'Gulapasir' nenas, salak 'Gulapasir' gondok and salak 'Gulapasir' nangka. The striking difference between these three varieties lies in the shape and flesh of the fruit. The number of fruit branches of salak 'Gulapasir' nangka, 1 to 2 branches, salak 'Gulapasir' nenas amount of 2 to 4 branches and salak 'Gulapasir' gondok the fruit bunches that do not form fruit branches. Salak 'Gulapasir', which is ready to harvest, has fruit flesh attached to the seed, and the fruit flesh is 0.63 cm thick. Meanwhile, the flesh of the salak 'Gulapasir' nenas is the thinnest and the seeds are attached to the flesh. Meanwhile, when the salak 'Gulapasir' gondok is ready to harvest, the seeds make a sound when shaken (Figure 3).


**Fig. 3** The shape  and the thickness of the fruit flesh of SGP.var.nenas, gondok and nangka


**Fig. 4** The shape of the bunch and the number of fuits  of SGP var. gondok,nenas, and nangka

*3.3* Agronomic characteristics of 'Gulapasir' Salak

Analysis of variance showed that the interaction between planting locations and varieties of 'Gulapasir' salak  had significant effect on the number of fruits per bunch, fruit weight per tree, fruit weight per fruit, number of fruits per bunch, the ratio of sugar and acid and vitamin C content. Meanwhile, the thick fruit flesh and tannins content was not significant (Table 5)

Commented [R14]: Perbaiki

Commented [KS15R14]: Awal Tabel 4 menjadi Tabel 5

**Table 5.** Recapitulation of the effects of varieties and growing locations on agronomic and fruits quality of 'Gulapasir' salak

Commented [R16]: Perbaiki

| No. | Character agronomic and fruits quality | Planting location | Varieties | Varieties x Location |
|---|---|---|---|---|
| 1 | Length of the flower sheath | ** | ** | * |
| 2 | Number of fruit bunches $^{-1}$ | ** | ** | * |
| 3 | Fruit tree weight $^{-1}$ | ** | ** | * |
| 4 | Fruit weight $^{-1}$ | ** | ** | * |
| 5 | TSS ratio and total acid | ** | ** | ** |
| 6 | Thick fruit flesh | ** | ** | Ns |
| 7 | Vitamin C | Ns | Ns | * |
| 8 | Tannins | Ns | Ns | Ns |
| 9 | Edible portion | ** | ** | Ns |

Notes: *) significant $P$ < 0.05, **) very significant $P$ < 0.01 and Ns) not significantly different $P$ > 0.05

The interaction of varieties and planting location had a significant effect on the length of the flower sheath and the number of fruit bunches $^{-1}$. Nenas variety grown in Tabanan (T < 560, T 560 to 650, and T > 650 ) and Karangasem (K < 560, K560 to 650, and K > 650) showed higher sheath length and a number of fruit bunches$^{-1}$ than with nangka and gondok varieties (Table 6). Tabanan (T 560 to 650) and Karangasem (K<560 m asl) are ideal conditions for flower sheath development and fruit development of nenas.

Commented [R17]: ????

Commented [KS18R17]: Tabel 5 Jadi Tabel 6

**Table 6.** Flower sheath length (cm) and a number of fruit bunches $^{-1}$ (fruit) of nangka, gondok and nenas varieties at six locations.

Commented [R19]: ??????

Commented [KS20R19]: Tabel 5 Jadi Tabel6

| Treatment | Sheath length (cm) | Amount fruit bunches $^{-1}$ |
|---|---|---|
| NT < 560 | 27.50 $\pm$ 0.34 bcd | 19.55 $\pm$ 0.82 hij |
| NT 560 to 650 | 28.83 $\pm$ 1.31 b | 20.39 $\pm$ 1.00 g |
| NT > 650 | 27.17 $\pm$ 0.96 cde | 19.02 $\pm$ 0.82 j |
| NK < 560 | 26.00 $\pm$ 0.82 e | 21.13 $\pm$ 0.82 ef |
| NK 560 to 50 | 27.17 $\pm$ 0.14 cde | 22.28$\pm$ 2.45 c |
| NK > 650 | 26.67 $\pm$ 1.36 cde | 21.13 $\pm$ 0.74 ef |
| GT < 560 | 26.67 $\pm$ 2.18 cde | 20.22 $\pm$ 0.31 gh |
| GT 560 to 650 | 27.50 $\pm$ 1.22 bcd | 20.55 $\pm$ 0.62 fg |
| GT > 650 | 27.70 $\pm$ 1.98 bc | 19.22 $\pm$ 0.74 ij |
| GK< 560 | 25.83 $\pm$ 1.41 e | 21.89 $\pm$ 0.82 cd |

| | | |
|---|---|---|
| GK 560 to 650 | 26.83 ± 0.75 cde | 20.5 ± 1.63 fg |
| GK > 650 | 27.5 ± 0.82 bcd | 21.28 ± 0.78 def |
| NST < 560 | 27.5 ± 0.82 bcd | 21.41 ± 0.91 de |
| NST 560 to 650 | 27.67 ± 0.82 bc | 22.00 ± 1.56 cd |
| NST > 650 | 26.17 ± 2.16 de | 19.91 ± 1.36 ghi |
| NSK < 560 | 32.00 ± 1.63 a | 25.27± 1.41 a |
| NSK 560 to 650 | 30.90 ± 2.10 a | 24.00 ± 0.82 b |
| NSK > 650 | 27.00 ± 1.47 cde | 21.86 ± 0.82 cde |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

From Table 6 above it can be explained that the three varieties planted in six locations produced a number of fruits between 19.02 to 25.27 fruits per bunch. The nenas variety planted in Karangasem at an altitude of < 560 m asl (treatment NSK < 560) produced the highest number of fruits of 25.27 per bunch, followed by NSK 560 to 650 and NST 560 to 650 with 24.00 and 22.00 fruits per bunch. In order for the salak plants to bear much fruit, the nangka variety is ideal in Karangasem 560 to 650 m asl (NK 560 to 650), while the gondok variety is very good when planted below 560 m asl (GK < 560) although the number of fruits is not significantly different from the same altitude for NT 560 to 650 and GT < 560. The results of this study are in line with the findings of Sumantra and Martiningsih (2016) that the ‘Gulapasir’ salak var. nenas produces the highest number of fruits both in the on season (*gadu* season) and -off-season (*sela* season). Sumantra *et al*. (2014) reported that the emergence of new sheaths occurred on the third or fourth leaf midrib from the growing point depending on the altitude and plant conditions. The time for new sheaths to appear ranges from 129.00 day to145.10 day with the required heat units between 1233.62 - 1047.90 Degree-Day (DD). The higher altitude, the longer the sheath appears, as well as the harvest time.

**Commented [R21]:** Saya mohon konfirmasi kok ada derajat Celcius.
Mhn saya dijelaskan angka ini, agar saya dapat membantu ttg SI

**Commented [KS22R21]:** d°C di perbaiki DD

The interaction of varieties and planting location had a significant effect on the fruit weigh (fruit tree$^{-1}$ and fruit$^{-1}$). Nangka variety grown in Tabanan (T < 560, T 560 to 650, and T > 650) and Karangasem (K < 560, K 560 to 650, and K > 650) showed higher of weight of fruit tree$^{-1}$ and fruit-$^{1}$ than with nenas and gondok (Table 7).

Commented [R23]: ??????

Commented [KS24R23]: Tabel 6 jadi Tabel 7

**Table 7.** Fruit weight of nangka, gondok, and nenas varieties in six locations

Commented [R25]: ?????

Commented [KS26R25]: idem

| **Treatment** | **Fruit$^{-1}$ (g)** | **Fruit tree-$^{1}$ (kg)** |
|---|---|---|
| NT < 560 | 45.32 ± 1.08 cd | 1.19 ± 0.08 def |
| NT 560 to 650 | 48.56 ± 0.71 c | 1.29 ± 0.07 cd |
| NT > 650 | 38.22 ± 0.46 ef | 1.03 ± 0.06 ghi |
| NK < 560 | 55.84 ± 1.37 a | 1.48 ± 0.02 b |
| NK 560 to 650 | 59.43 ± 0.71 a | 1.62 ± 0.07 a |
| NK > 650 | 49.4 ±1.65 b | 1.34 ± 0.05 c |
| GT < 560 | 40.14 ± 0.11 e | 1.11± 0.09 fg |
| GT 560 to 650 | 38.67 ± 0.55 ef | 1.09 ± 0.07 fg |
| GT > 650 | 32.95 ± 0.73 gh | 0.93 ± 0.10 i |
| GK < 560 | 44.22 ± 0.18 d | 1.27 ± 0.06 cde |
| GK 560 to 650 | 38.20 ± 0.78 ef | 1.16 ± 0.05 defg |
| GK > 650 | 36.20 ± 0.75 fg | 1.07 ± 0.11 fgh |
| NST < 560 | 39.00 ± 1.07 ef | 1.14 ± 0.11 efg |
| NST 560 to 650 | 37.79 ± 0.65 f | 1.13 ± 0.06 g |
| NST > 650 | 32.12 ± 0.11 h | 0.94 ± 0.10 hi |
| NSK < 560 | 41.80 ± 0.65 de | 1.36 ± 0.08 bc |
| NSK 560 to 650 | 36.57 ± 0.80 fg | 1.18 ± 0.09 def |
| NSK > 650 | 37.10 ± 0.23 f | 1.11 ± 0.07 fg |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

From Table 7 it can be explained that the three varieties grown in six locations produced fruit weight per tree between 0.93 kg and 1.62 kg. The salak nangka variety planted in Karangasem at an altitude of 560 to 650 m asl (NK 560 to 650) produced the heaviest fruit weight of 1.62 kg tree$^{-1}$, followed by NK < 560 and NT 560 to 650 with fruit weights of 1.48 and 1.29 kg. While the nenas variety produces the best fruit at altitudes < 560 m asl (NSK < 560 and NT < 560). Salak 'Gulapasir' var. gondok is ideal when planted at altitudes < 560 m asl (GK < 560 and GT < 560), although the two growing locations showed a different yields.

Commented [R27]: ??????

Commented [KS28R27]: Tabel 6 jadi Tabel 7

Nenas and gondok varieties showed a trend of decreasing fruit weight in line with increasing altitude, both planted in Karangasem and Tabanan. The reverse occurred in the salak nangka variety, an increase in altitude from 550 m asl to 550 to 650 m asl caused an increase in fruit weight and after that the fruit weight decreased when planted at altitudes > 650 m asl. This finding is in line with the results of research that has been reported by Sumantra *et al*. (2014). However, for the gondok and nenas varieties, this is a new finding.

Apart from being influenced by environmental factors, the production of salak 'Gulapasir' fruit is also influenced by internal plant factors (Adelina *et al*., 2021b: Lestari *et al*. 2011). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019), and rainfall (Ritonga *et al*., 2018). Altitude increases, the average daily air temperature decreases and monthly rainfall increases (Table 3). Nuary *et al.* (2019) stated that the distribution and adaptation of salak plants is strongly influenced by temperature and rainfall. It was further stated, the contribution of daily temperature accounts for nearly 38.6 % while rainfall is 27.8 %. Kanzaria *et al.* (2015) reported that mango plants planted at an altitude of 229 m flowered slower than those at an altitude of 148 m and 81 m asl. The temperature regime at higher altitudes is colder than at lower altitudes. Lower temperatures accumulate less growing degree day (GDD) and may result in late flowering. Table 7 shows that the 'Gulapasir' salak planted in Karangasem produced a higher fruit weight in the three salak varieties tested. This is related to the level of soil fertility. The soil nitrogen and phosphate nutrient content at three locations in Karangasem was higher than at three locations in Tabanan. Meanwhile, the potassium content in the six research locations was low (Table 3). Therefore it is necessary to make improvements by providing fertilizers containing elements of N, P and K to meet ideal conditions for growth, although more data is needed to fully support this conclusion (Hailu *et al.*, 2015).

**Commented [R29]:** Akronim apa ? Bila mucul akronim pertama kali mhn dijabarkan

**Commented [R30R29]:** growing degree days (GDD)

*3.4 Quality characteristics of salak varieties*

The interaction between varieties and altitude significantly affected sugar/total acid and vitamin C content. The three varieties grown in Tabanan (T < 560, T 560 to 650 and T > 650) showed a lower TSS/acid ratio. The fruit flavour planted in three locations in Tabanan is sourer than the three locations in Karangasem. Sugar content is greatly affected by the geographical. The geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity, and rainfall (Ritonga *et al*., 2018). Table 8 also shows that the increase in altitude from 550 m to 700 m asl in Tabanan and the addition in altitude from 550 to 650 m asl in Karangasem causes the sugar/acid ratio decrease in all three varieties, and the lowest sugar/acid value occurs in nenas variety in all locations. Each salak variety has an adaptation to an elevation closely related to plant tolerance to temperature (Sumantra and Martiningsih, 2016; 2018). Many factors influence fruit quality, but the most dominant are climate factors, especially temperature and rainfall. High rainfall and low air temperature during the fruit ripening phase can cause the dissolved solids in the fruit to become watery so that the TSS value is low (Singh *et al*., 2011).

Salak fruits from three different varieties grown in low lands in Karangasem (K < 560 m asl) showed the highest vitamin C content and were significantly different from the three cultivars when planted in other locations. In both areas land increased by > 650 m asl effects to vitamin C decrease, nangka and gondok varieties showed higher levels of vitamin C between < 550 m to < 650 m asl. (Table 8).

**Commented [R31]:** ??????

**Commented [KS32R31]:** Tabel 7 jadi Tabel 8

**Table 8.** TSS/acid ratio and levels of vitamin C of nangka, gondok, and nenas varieties in six locations.

**Commented [R33]:** ??????

**Commented [KS34R33]:** Tabel 7 jadi Tabel 8

| Treatment | TSS/T.Acid | Vit. C (mg /100g) |
|---|---|---|
| NT < 560 | 56.20 ± 0.16 abc | 27.50 ± 0.41 bde |
| NT 560 to 650 | 59.18 ± 0.82 a | 25.45 ± 0.37 defgl |

| | | |
|---|---|---|
| NT > 650 | 37.89 ± 0.91 f | 22.52 ± 0.39 j |
| NK < 560 | 51.41 ± 0.33 cde | 27.74 ± 0.47 bd |
| NK 560 to 650 | 53.52± 0.82 abcd | 29.61 ± 0.50 ab |
| NK > 650 | 47.76 ± 0.11 de | 24.25 ± 0.20 fghij |
| GT < 560 | 34.88± 0.72 fg | 25.50 ± 0.41 defgh |
| GT 560 to 650 | 34.80 ± 0.65 fg | 25.75 ± 0.20 defgh |
| GT > 650 | 30.24 ± 0.20 gh | 23.34 ± 0.28 hij |
| GK < 560 | 51.28 ± 0.23 cde | 30.31 ± 0.25 a |
| GK 560 to 650 | 58.44 ± 0.36 ab | 27.63 ± 0.30 bd |
| GK > 650 | 53.04 ± 0.82 bcde | 25.07 ± 0.33 efghi |
| NST < 560 | 31.50 ± 0.41 gh | 26.71± 0.21 cdef |
| NST 560 to 650 | 30.44 ± 0.36 gh | 25.88 ± 0.41 defg |
| NST > 650 | 26.13 ± 0.11 h | 23.65 ± 0.29 ghij |
| NSK < 560 | 53.73 ± 0.60 abc | 24.42 ± 0.34 fghij |
| NSK 560 to 650 | 52.63 ± 0.51 bcde | 22.82 ± 0.15 ij |
| NSK > 650 | 47.60 ± 0.49 e | 25.16 ± 0.13 efghi |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

The results showed that the varieties of the 'Gulapasir' salak needs different environmental requirements to optimize yields. Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al*., 2021, 2022). Therefore, variety differences may depend on growing requirements and cultivation techniques. Vitamin C in the 'Gulapasir' salak is strongly influenced by the altitude of the land. To produce high levels of vitamin C, the nangka and gondok varieties are ideal for planting at an altitude of 560 m to 650 m asl, while the nenas variety is ideal at a land altitude of < 560 m asl. However, changes in ascorbate levels during fruit ripening are species-dependent and environmental factors especially temperature and light (Fenech *et al*., 2019).

There was no interaction between varieties and altitude to the flesh thickness, edible fruit portion, and fruit sugar content. The nangka salak variety showed fruit quality, including TSS, edible parts of the fruit, and higher flesh thickness (Table 9).

**Table 9.** The effect of a single factor of varieties on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment | TSS (°Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| Nangka | 16.59a | 72.50a | 0.63a |
| Gondok | 16.42a | 70.66ab | 0.59b |
| Nenas | 15.64b | 69.22b | 0.52c |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Salak grown in Karangasem both from the lowlands and the middle lands produces fruit thickness, and the edible portion of fruits is higher than plants in the highlands. This study indicates that the ideal growing place for salak plants is between 450 m to 650 m asl. This study is in line with several previous studies which explained that altitude affects the flowering process and fruit enlargement (Sophie *at al*., 2017; Spinardi *et al*., 2019; Widyastuti *et al*., 2022).

**Table 10.** The effect of a single factor of planting location on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment (m asl) | TSS (°Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| T < 550 | 16.28a | 73.13a | 0.54c |
| T 550 to 650 | 16.27a | 69.89a | 0.58bc |
| T > 650 | 16.14a | 63.87b | 0.49d |
| K 550 | 16.81a | 73.15a | 0.61b |
| K 550 to 650 | 16.11a | 72.29a | 0.66a |
| K > 650 | 15.69a | 72.44a | 0.61b |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

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Further research can be applied using sustainable salak agriculture. Table 3 shows that salak cultivation in the research location still needs to implement sustainable farming. There are indications some of decrease in soil fertility, especially potassium available in the six planting locations that have been evaluated shows a very low value. Potassium levels in Table 3 are lower than the observations of Ashari (2013) and Woran *et al.* (2018) in salak cultivation areas in Swaru – Malang (very high), Sleman – Yogya (moderate), Bangkalan – Madura (very high), and Pangu – Minahasa (moderate).

Potassium helps produce good fruit quality, such as bigger, heavier, and sweeter fruit. Another benefit of the nutrient potassium in plants is to increase the growth of meristem tissue and regulate the movement of stomata. Potassium also helps the development of plant roots so that plant stems can stand upright and do not collapse easily (Adinurani *et al.*, 2018; Budiono *et al*., 2019). Therefore, Nasution (2022) recommends more $K_20$ fertilizer than $P_20_5$ fertilizer and N fertilizer. In addition, salak needs 70 kg of $K_2O$ because this nutrient is found in the leaves at an amount (12.2 to 14.7) mg $g^{-1}$ (Ashari, 2013).

Authors realize that using chemical fertilizers (e.g., KCl) is too expensive for Salak farmers. Therefore, the application of sustainable farming should apply local wisdom including the use of the pruning of salak midrib. Consider this policy because C organic is essential to soil fertility (Budiono *et al*. 2021; Goenadi *et al*. 2021). The success of this midrib decomposition is demonstrated by the C organic in Table 3, which is classified as medium to high. But, in the next stage, some of the salak midribs should be burned into ashes which can be used as a source of potassium nutrients (Ekawati and Purwanto, 2012; Vincevica-Gaile *et al*., 2021a, 2021b).

Another measure to increase and maintain land fertility is in salak cultivation, namely the application of Plant Growth Promoting Rhizobacteria (PGPR) or biological fertilizer (Basu *et al*., 2021; Ekawati, *et al.,* 2019). Several researchers (Adinurani *et al*., 2021;

Kumalawati *et al*., 2021; Muhammad *et al*. 2021) have reported using mycorrhiza, which positively impacts various plants, including salak cultivation (Amnah and Friska, 2018; Dewi *et al*., 2020; Rai *et al*., 2021). Multiplication of mycorrhiza is relatively simple (Sportes *et al*., 2021; Sukmawati *et al*., 2021) and can be done by farmer groups with initial guidance from universities.

## 4. Conclusion and Recommendation

Different cultivars caused different fruit weights, fruit bunches, and the sugar/acid ratio at various locations. The three varieties showed lower fruit weight and fruit quality in Tabanan (low, medium, and highlands) than the salak originating from Karangasem. The nangka variety in Karangasem showed higher fruit weight, vitamin C content, and sugar/ acid ratio, while the nenas salak showed the highest number of fruit bunches$^{-1}$ in six locations. Nangka salak are very suitable to be planted at an altitude of 550 m to 650 m asl. In contrast, the nenas and gondok varieties are developed naturally at low altitudes < 550 m asl. In order for all cultivars to be able to produce optimally, efforts to improve the cultivation system are needed through fertilization and the provision of calcium is highly recommended. Further research can be applied using sustainable salak agriculture, especially to maintenance the soil fertility.

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**Title:**

# Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Different Agro-Ecosystems

**Running Title:**

Assessment Salak Planted in Different Agro-Ecosystems

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# Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Different Agro-Ecosystems


## ABSTRACT

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir has been officially released by the Minister of Agriculture of the Republic of Indonesia since 1994. Salak 'Gulapasir' is one of five types of fruit that have been designated as the superior fruit of the Bali Province. Salak 'Gulapasir' preferred by consumers due to its specific fruit flesh taste. Salak 'Gulapasir' was propagated using seeds so that a new types of salak emerged. However, the characters of this new type of salak 'Gulapasir' is not yet known. The research objective was to obtain the superior of some Salak 'Gulapasir' both in production and fruit quality. The research used a Randomized Block Design with three replications. The non-independent variable was the three of Salak 'Gulapasir' (SGP): SGP var. nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 to 650 m asl, and K > 650 m asl) and Tabanan (T): (T < 560 m asl, T 560 to 650 m asl, T > 650 m asl). Observations were made on the agronomic characters and fruit quality. Data were analyzed using variance analysis, and if the planting location and varieties show a difference, then it is followed by the LSD test at the 5 % level. The results showed that different varieties caused different fruit weights, fruit bunches, TSS, and total acid ratio. In Tabanan (in the low, medium, and highlands), the three varieties showed lower fruit weight and fruit quality than the salak originating from Karangasem. The SGP var. nangka in Karangasem showed higher fruit weight, vitamin C content, and TSS/total acid ratio, while the SGP var. nenas showed the highest number of fruit bunches$^{-1}$ in six locations. Further research can be applied using sustainable salak organic agriculture to maintain soil fertility.

**Keywords :** Altitude, *Salacca zalacca* (Gaertn.) Voss, Salak 'Gulapasir' var. gondok, Salak 'Gulapasir' var. nangka, Salak 'Gulapasir' var. nenas, Salak sustainable agriculture, Snake fruit, Tropical fruit

## 1. Introduction

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir is one of the important fruits in Indonesia and the plant can be found in most regions of Indonesia (Rai *et al*. 2016; Ritonga *et al*., 2018). The salak fruit belong to the family Palmae or Arecaceae, and are native to the Indonesian-Malaysian region (Hakim *et al.,* 2019; Zumaidar *et al*., 2014). One of the extraordinary strengths of this fruit commodity for Indonesia is the possession of high genetic diversity (Budiyanti *et al*., 2019). Also, the nutrition of salak fruit is rich in antioxidants, phenolics, vitamins, and minerals (Cepkova *et al.,* 2021; Mazumdar *et al*., 2019), and a good source of income and provides livelihood opportunities on seasonal days (Khan and Idrees, 2021). The fruit flesh and peel have shown some tremendous anti-inflammatory, anticancer and antidiabetic (Saleh *et al*., 2018), and anti-ageing agents (Girsang *et al*., 2019). Antioxidants are chemical compounds that play an essential role in protecting cells due to attacks against free radicals-induced damage to biomolecules (Damat *et al*., 2019, 2020; Puspitasari and Ningsih, 2016; Setyobudi *et al*., 2019). Despite its incredible food and medicinal benefits, salak fruit is still underutilized and unknown globally. So that this underutilized fruit remains an issue for future sustainable utilization and commercial value enhancement market (Mazumdar *et al*., 2019). Fruit quality is an important issue, especially for products that are consumed raw and fresh. One of the problems is the lack of fruit quality because of inadequate information about superior salak (Budiyanti *et al*., 2019; Herawati *et al*., 2018). Therefore, it is necessary to select superior salak to meet market demand and fulfil community nutrition.

Salak ‘Bali’ is quite a lot, based on the shape, aroma, taste, and skin colour of the location where the plants are cultivated (Sumantra *et al*., 2012, 2014; Sumantra and Martiningsih, 2016, 2018). Under the Decree of the Minister of Agriculture of the Republic of Indonesia in 1994, Balinese zalacca was grouped into two superior zalacca: Salak ‘Bali’ (SK Mentan, 1994a) and Salak ‘Gulapasir’ (SK Mentan, 1994b). The second type, the salak ‘Gulapasir’ (SGP) is the most superior salak because of its sweet fruit taste; even though the age of the fruit is still young, thick fruit flesh and seeds are not attached to the fruit flesh (Rai *et al*., 2014; Sumantra *et al*., 2016). The nature of this fruit is ideal for meeting market demands for both the domestic and export markets (Martiningsih *et al*., 2018). Salak ‘Bali’ is monoecious, so crossing does not need human help (Herawati *et al*., 2018), and can quickly develop using seeds (Sumantra and Martiningsih, 2016). Another advantage of salak plants in Indonesia compared to other fruits is harvest fruit 2 to 3 times a year if management is good (Rai *et al*., 2016; Warnita *et al*., 2019). The expansion of salak ‘Gulapasir’ planting causes variations in phenotypic diversity. People can find two to three types of salak plants with a marker, fruit shape, aroma, flesh colour, and fruit weight (Martiningsih *et al*., 2018). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seeds so that new varieties of salak ‘Gulapasir’ (SGP) appear, as reported by Sumantra and Martiningsih (2016). Based on the marker that can be used as a differentiator, salak farmers give it the name of SGP var. nenas, SGP var. gondok, and SGP var. nangka. The three varieties have not yet identified their advantages in meeting market needs in line with the results of research (Sumantra and Martiningsih, 2016). The performance and produce are influenced by the characteristics of the agricultural ecosystem, particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status (Adelina *et al.,* 2021a; Kumar *et al*., 2020) and growth hormone (Prihastanti and Haryanti. 2022; Rai *et al.,* 2016).

The salak ‘Gulapasir’ plantation in the District of Bebandem is the main producer of salak ‘Gulapasir’ in Bali is located in the southern part of Mount Agung with an altitude of 450 m to 700 m above sea level (m asl). The effect of altitude on plant growth and production is related to plant adaptation to temperature (Sumantra, *et al*., 2014), full sunlight (Sukawijaya *et al*., 2009), water status and soil quality (Raharjo *et al*., 2022; Rai *et al*., 2014; Ritonga *et al.*, 2018). Salak plants are not resistant to full sun but 50 % to 70 % enough, therefore it is necessary to have shade plants (Sukawijaya *et al*., 2009; Sumantra *et al*., 2012). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019). Water status and soil quality really determine the fruit set on the salak ‘Gulapasir’. Low rainfall reduces the Relative Water Content in leaves (RWC), leaf chlorophyll content, and plant nutrient uptake (Rai *et al*., 2014). soil quality included the suitability of the physical, chemical and biological properties (Raharjo *et al*., 2022). Nuary *et al*. (2019) stated that the distribution of the salak ‘Pondoh’ plantation area in Sleman (Yogyakarta, Special Region) was greatly influenced by temperature and rainfall. The contribution of temperature in the modelling reached 38.6 % while the rainfall was 27.8 %. Furthermore, taking into account the probability of the temperature variable, the average temperature ranges from 17.41 °C to 25.65 °C, and the ideal month's rainfall ranges from 385.24 mm to 505.01 mm.

Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al*., 2021, 2022). Therefore, varieties differences may depend on growing requirements and cultivation techniques. Likewise, Puspitasari *et al*. (2016) stated that tannin content, fruit size and flesh colour of salak fruit are strongly influenced by where it grows. Other studies also explain that salak ‘Gulapasir’ var. nangka which is grown 570 m asl, would result in a higher quality of fruit that includes thickness of the mesocarpium, edible portion of fruit then compared to above and below 570 m asl (Sumantra *et al*., 2014; Sumantra and Martiningsih, 2016). Meanwhile, fruit weight and fruit quality of var. gondok and var.

nenas have not been reported. Therefore, one way of handling salak quality is by undertaking severe studies for factors such as land and climate and adjusting agricultural patterns according to local climate conditions (Nassar *et al*., 2018). The success of each species to occupy the environment of an area is influenced by its ability to adapt optimally to all physical environmental factors (temperature, light, soil structure, humidity), biotic factors (interaction between species, competition, parasitism), and chemical factors including the availability of water, oxyge, pH, and nutrients (Nassar *et al*., 2018; Widyastuti *et al*., 2022). Moreover, a broad genetic variability would lead to wide phenotypic variability due to the effect of genetic-environment interaction (Ritonga *et al*., 2018). The research objective was to obtain the superior of some salak 'Gulapasir' both in production and fruit quality (sugar and acid ratio, vitamin C and tannin) in six different agricultural ecosystems in Bali.

## 2. Materials and Methods

### *2.1 Experimental site*

The research was conducted in Tabanan and Karangasem Regencies. Tabanan and Karangasem were selected as research locations because the domination of salak 'Gulapasir' in these two regencies was the highest. In 2021, the salak 'Gulapasir' population in Tabanan is 84 % of all salak species, while in Karangasem Regency the dominance of the salak 'Gulapasir' is more than 63 % (Sumantra *et al*., 2022).

The study was carried out in six different locations, three sites in Karangasem Regency and three sites in the district of Tabanan. Locations in Karangasem (K) are lowlands (K < 560 m asl) which include several places, namely Telaga, Dukuh, and Karanganyar. Karangasem in the moderate plains (K 560 m to 650 m asl) has several areas, namely Kecing and Kutabali and highlands (K > 650 m asl), namely Tanah Apo and Kresek (Figure 1).

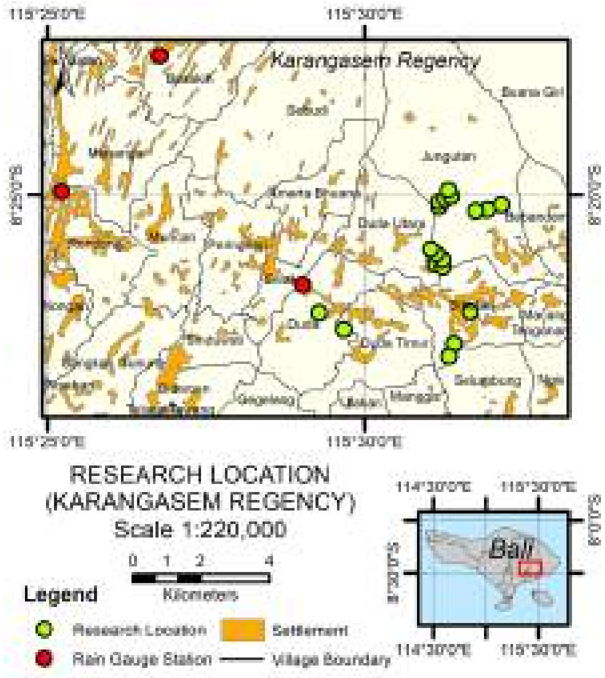


**Fig 1.** Research map and sampling point in Karangasem (K)

The research location is in Tabanan (T) in the lowlands (T < 560 m asl), including Wanagiri, Sari Buana, and Mundeh Kauh. Tabanan in the medium lands (T 560 m to 650 m asl) includes several places, namely Pajahan, Kebon Jero, and Angseri. Tabanan in the highlands (T > 650 m asl), namely Munduk Temu, Pempatan, and Batungsel (Figure 2).

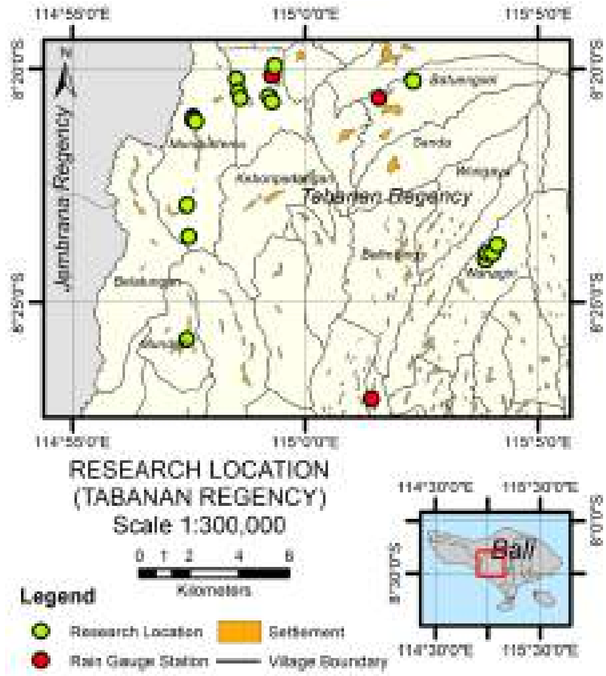

**Fig 2.** Research map and sampling point in Tabanan (T)

The non-independent variable was the three varieties of Salak 'Gulapasir' (SGP): SGP var.nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 m to 650 m asl, and K > 650 m asl) and Tabanan (T) : (T < 560 m asl, T 560 m to 650 m asl, T > 650 m) Repetition was carried out three times with the number of sample plants in each location, and cultivars were seven plants. The treatment tested is as shown in Table 1

**Table 1**. Treatment of plant location and three varieties of 'Gulapasir' salak

| No | Treatment | Explanation |
|---|---|---|
| 1 | NT< 560 m asl | Salak GP.var. nangka Tabanan < 560 m asl. |
| 2 | NT 560 m to 650 m asl | Salak GP.var. nangka Tabanan 560 m to 650 m asl. |
| 3 | NT > 650 m asl. | Salak GP.var. nangka Tabanan > 650 m asl. |
| 4 | NK < 560 m asl. | Salak GP.var. nangka Karangasem < 560 m asl. |
| 5 | NK 560 m to 650 m asl | Salak GP.var. nangka Karangasem 560 m to 650 m asl. |
| 6 | NK > 650 m asl. | Salak GP.var. nangka Karangasem > 650 m asl. |
| 7 | GT< 560 m asl | Salak GP var. gondok Tabanan < 560 m asl. |
| 8 | GT.560 to 650 m asl | Salak GP var. gondok Tabanan 560 m to 650 m asl. |
| 9 | GT > 650 m asl | Salak GP var. gondok Tabanan > 650 m asl. |
| 10 | GK.< 560 m asl | Salak GP var. gondok Karangasem < 560 m asl. |
| 11 | GK 560 m to 650 m asl | Salak GP var. gondok Karangasem 560 m to 650 m asl. |
| 12 | GK > 650 m asl | Salak GP var. gondok Karangasem > 650 m asl. |
| 13 | NST < 560 m asl | Salak GP var. nenas Tabanan < 560 m asl. |
| 14 | NST.560 m to 650 m asl | Salak GP var. nenas Tabanan 560 m to 650 m asl. |

| | | |
|---|---|---|
| 15 | NST > 650 m asl | Salak GP var. nenas Tabanan > 650 m asl. |
| 16 | NSK .< 560 m asl | Salak GP var. nenas Karangasem < 560 m asl. |
| 17 | NSK 560 m to 650 m asl | Salak GP var. nenas Karangasem 560 m to 650 m asl.. |
| 18 | NSK > 650 m asl | Salak GP var. nenas Karangasem > 650 m asl. |

The study used a Composite Analysis of Variance (Andinurani, 2016, 2022) with the model determined using Equation (1) below:

$$Yjk = u + L\ i + \delta\ ik + Pj + (LP)\ ij + \varepsilon\ ijk \quad (1)$$

Where:

Yijk = The observation value of the treatment (j) in the group (k), which is repeated at the location (i).

u = the actual average value

Li = additive effect from location i

δ ik = the error effect in group k at location i

Pj = additive effect of the next treatment

(LP) ij = the effect of treatment (j) at the location (i)

Ɛ ijk = the effect of error from the treatment (j) in the group (k) which was carried out at the location (i).

*2.2 Preparation of study materials*

The material used is the salak 'Gulapasir' plant with uniform growth, plants have been fruitful with uniform on morphological, age of plants and cultivation action. The intentional practice is that the plant only receives treatment in the midrib, tillers, and weed cleaning. In this study, the plants were not fertilized. The provision of water was only from rainfall following the habits applied by salak farmers. The sample plant maintains by trimming unproductive leaf midribs and removing young shoots. Plant material was taken

from the Salak Development Centre in six locations, namely at the Centre of Salak Development in the Bebandem sub-districts, Karangasem district (K-lowland < 560 m asl, K-medium 560 m to 650 m asl and K-highland > 650 m asl), Bajre, West Slemadeg and Pupuan sub-districts, Tabanan district (T-lowland < 560 m asl, T-medium 560 to 650 m asl and T-highland > 650 m asl).

2.*3 Analysis of physicochemical properties of soil sample and climate*

Soil analysis was carried out to determine the physical and chemical properties of the soil. Soil sampling was carried out under sample plant trees, carried out in a composite manner at a depth of 0 cm to 40 cm. Chemical analysis was carried out on total N (Kjeldahl method), available P by Bray I method and $K_2O$ by the Bray I method, organic C, pH, soil physical properties in the form of texture by pipette method (Eviati and Sulaeman. 2009; Hailu *et al*., 2015; Prasetyo *et al*., 2022a; Rzasa and Owczarzak, 2013).

Rainfall data was taken for five years from 2015 to 2019. Rainfall data has been collected from six nearby stations to the research site (Table 2). Daily temperature data obtained from the Denpasar Meteorology Climatology Agency.

**Table 2**. Research locations and place of climatology stations

| Research Locations | Climate observation station | Latitude and altitude |
|---|---|---|
| Tabanan Lowlands (< 560 m asl) | Ampadan, Tiyinggading No.St. 439 m | 8°27'5.0688"S/ 115°1'25.086 "E; 400 m asl. |
| Tabanan Moderate (560 m to 650 m asl) | Coffee Breeding Center, Sai Pupuan No. St. 439 h | 08°20'08.6"S/ 114° 59'17.4" E; 580 m asl. |
| Tabanan Highlands (> 650 m asl) | Agricultural Extension Center, Pupuan. No St.441 h | 08°20'38.1" S/ 115°01'35.2" E; 750 m asl. |

| | | |
|---|---|---|
| Karangasem Lowlands (< 560 m asl) | Agricultural Extension Center, Selat. No. St. 444 d | 08º26’25” S / 115º29’02” E; 450 m asl. |
| Karangasem Moderate (560 m to 650 m asl) | Horticulture Seed Center, Singerata No.St. 442 | 08º24’57”S / 115º25’14”E; 580 m asl. |
| Karangasem Highlands (> 650 m asl) | Besakih Station. No.St.442 a | 08º22’49”S / 115º26’47”E; 800 m asl. |

*2.4 Observation of fruit and fruit quality*

Salak fruit can be harvested when it is ready for consumption. Consumable ripe fruit is a fruit that is ready to be consumed, characterized by a change in skin colour from dark brown to light brown, the thorns on the skin have reduced and are not sharp, and in general, at this stage, the fruit easily falls when shaken.

Observation and measurement of agronomic characters follow the method that has been done by Sumantra *et al*. (2014) including fruit weight, number of fruit bunches, the thickness of fruit flesh and fruit shape. The fruit characters from six-observed locations include the numbers of fruits per bunch, which is calculated manually on the formed fruits. The fruit weight per fruit and the fruit weight per tree is weighed after the fruits were removed from the bunch. The thickness of the mesocarpium is obtained by measuring the mesocarpium after it is cut vertically. The length of the flower sheath is measured on the stem of the sheath from the base to the tip of the sheath.

While fruit quality includes sugar content, tannins, titrated acid, sugar content and vitamin C. Titrated acid was analyzed by titration (Sripakdee *et al*., 2015). The fruit was weighed 10 g of sample was added to 100 mL of distilled water, then was homogenized using a slow spin blender, and filtered using an aseptic filter. The filtrate obtained was taken as much as 25 mL, then titrated with 0.1 N NaOH solution with phenolphthalein

indicator until red in colour appeared. The results obtained are calculated as the percentage tartaric acid is determined using Equation (2) below :

$$A = \frac{\text{mL NaOH} \times \text{N NaOH} \times P \times BM}{Y \times 1\,000 \times 2} \times 100\ \% \qquad (2)$$

where:

A = percentage of total acid

P = amount of dilution

BM = molecular weight of tartaric acid

Y = sample weight (g).

Tannis content was analyzed as done by Thakur *et al*. (2021), Setyobudi *et al*. (2022). Amount of 100 mg of the sample was homogenized by 2 mL of methanol. Centrifuged for 10 min at 10 000 rpm (1 rpm = 1/60 Hz) and collected the supernatant. Amount of 1 mL of supernatant mixed with 0.5 mL Folin's phenol reagent and 35 % $Na_2CO_3$ of 5 mL added and the mixture was kept at room temperature for 5 min. The blue colour of the reaction mixture was observed at 640 nm by UV/visible spectrophotometer (Shimadzu UV-1800, Japan). The content of tannin was calculated by calibration curve equation and determined using Equation (3) below:

$$Y = 0.0073x - 0.0071 : R^2 = 0.9973 \qquad (3)$$

Vitamin C was determined by titration like the method used by Asamara (2016), Setyobudi *et al.* (2021a, 2022). The material is weighed as much as 10 g and crushed in mortal. Then put into a 250 mL volumetric flask, set to the mark and filtered. Take 25 mL of the filtrate and titrate with 0.01 N Yod solution equivalent to 0.88 mg of ascorbic acid. The calculation of ascorbic acid content per 100 g of material is determined using Equation (4) below:

$$A = \frac{\text{mL Yod } 0.01\ N \times 0.88 \times P \times 100}{Y} \quad (4)$$

where: A = mg of ascorbic acid per 100 g of material

P = amount of dilution

Y = gram sample weight

Sugar content as TSS is calculated using a hand refractometer (Bellingham and Stanley Ltd., London) at 20 $^{o}$C.

The ratio of sugar content (TSS) and total acid is calculated by the sugar content divided by the acid content multiplied by 100 %.

The materials used in this study were Folin-Ciocalteu reagent (Pro Analytic, Merck), NaOH (Pro Analytic, Merck), $Na_2CO_3$ (Pro Analytic, Merck), Phenolphereagent ascorbic acid (Pro Analytic, Merck), Phosphoric Acid (Pro Analytic, Merck), Sodium Phosphate (Pro Analytic, Merck) and Ammonium Molybdate (Pro Analytic, Merck).

The tools used in this study were analytical balances (Shimadzu ATY224, Japan), centrifuge tubes, Erlenmeyer flasks (pyrex), dropper pipettes (pyrex), volume pipettes (pyrex), vortex (Maxi Mix II Type 367000), measuring flask (pyrex), water bath (Memmert), blender (Miyako), and centrifuge (Damon /IEC Division). Whatman filter paper No 1 (Sigma – Aldrich, USA), measuring cup (Pyrex, USA), micropipette (Dragon Lab, Indonesia), spectrophotometer (Biochromsn 133467, UK), test tube (Pyrex¸ USA), vortex (Barnsteadl Thermolyne Type 37600 Mixer, USA), aluminum foil (Klin Pak, Indonesia).

*2.5 Study design*

This study used a randomized block design with the data analyzed using a Composite Analysis of Variance. If the variance test is significantly different, then it is continued with a different test with LSD at the 5 % level. Data analysis was performed using SPSS-IBM 18 (Adinurani, 2016, 2022). Each experimental treatment was repeated three times.

## 3. Results and Discussion

### *3.1 Agroclimate characteristic*

The low production level and quality of salak fruit are caused by environmental factors that do not support growth or because the physiological processes of the plant are not optimal due to insufficient nutrients and water. The suitability of climatic and soil conditions at six locations of the centres for the development of the ‘Gulapasir’ salak was evaluated. The evaluation results show that the air temperature decreases as the altitude increases. The average air temperature at the ‘Gulapasir’ salak plantation in Tabanan is 22.90 $^oC$, while the air temperature at the Karangasem salak plantation is around 23.24 $^oC$. (Tabel 3)

**Table 3.** Soil and climate characteristics of the research site in Tabanan and Karangasem in three subzones

| **Parameter** | **Tabanan (T)** | | | **Karangasem (K)** | | |
|---|---|---|---|---|---|---|
| | Lowlands (< 560 m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) | Lowlands (< 560m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) |
| Temp. ($^o$ C) | 23.82 | 22.75 | 22.12 | 24.29 | 23.35 | 22.09 |
| Rainfall (mm $mo^{-1}$) | 188.24 | 199.91 | 231.008 | 237.242 | 254.183 | 289.216 |
| Soil texture | loamy clay | loamy clay | loamy clay | clay | clay | sandy loam |
| pH ($H_2O$) | 5.64(sa) | 5.75 (sa) | 5.84 (sa) | 6.08 (sa) | 6.05 (sa) | 6.03(sa) |
| C- organic (%) | 2.94(m) | 3.40 (h) | 3.25 (h) | 2.77 (m) | 3.63 (h) | 3.32 (h) |
| Nutrients available | | | | | | |
| N total (%) | 0.18 (l) | 0.16 (l) | 0.18 (l) | 0.24(m) | 0.23 (m) | 0.29 (m) |
| $P_2O_5$ (mg $g^{-1}$) | 9.38 (vl) | 9.12 (vl) | 13.50 (l) | 22.55 (m) | 24.18 (m) | 23.04 (m) |
| $K_2O$ (mg $g^{-1}$)) | 18.47 (vl) | 22.05 (vl) | 17.23 (vl) | 24.17 (vl) | 19.93 ( vl ) | 18.37 ( vl ) |

Notes: sa: slightly acidic; h: high; m: medium; l: low; vh: very high; h: high; asl: above sea level (The assessment criteria refer to Eviati and Sulaeman. 2009; PPT, 1983).

Likewise monthly rainfall, the average rainfall over the 5 yr is presented in Table Table 4. Annual rainfall in Tabanan (T < 560, T 560 to 650 and T > 650) is lower with an average of 2515.05 mm while in Karangasem (K < 560, K 560 to 650 and K > 650) it is 3 122.05 mm. However, the six locations show a trend of increasing rainfall as altitude increases. The salak plantation area in Karangasem is in the southern part of Mount Agung. Meanwhile in Tabanan, the dominant salak plantation area is behind Mount Batukaru with a lower elevation than Mount Agung. Mount Agung with an altitude of 3 142 m asl (Andaru and Rau, 2019), while the Batukaru mountains area with an elevation 2 250 m asl (Asmiwyati *et al*., 2015). Mount Batukaru as a barrier, causing this area to be a rain shadow. Enyew and Steenveld (2014) state that rainfall in an area is influenced by topographical factors and mountain ranges. Decreasing the height of the mountains, provides a reduction in the maximum level of rainfall over the mountains and foothills by 50 % (Flesch and Reuter, 2012). Topographical factors and regional weather systems have an important role in the amount and spatial pattern of rainfall in an area (Enyew and Steenveld, 2014).

**Table 4.** The annual rainfall in the six study sites (2015 to 2019)

| Year | Tabanan: T (mm yr $^{-1}$) | | | Karangasem: K (mm yr $^{-1}$) | | |
|---|---|---|---|---|---|---|
| | T < 560 | T 560 to 650 | T > 650 | K < 560 | K 560 to 650 | K > 650 |
| 2015 | 2 001.0 | 2 462.7 | 2 633.0 | 2 470.5 | 2 714.0 | 3 291.0 |
| 2016 | 2 095.0 | 2 453.5 | 3 049.5 | 2 659.0 | 2 885.0 | 3 800.0 |
| 2017 | 1 958.0 | 2 152.5 | 2 135.0 | 2 903.0 | 3 173.0 | 3 500.0 |
| 2018 | 2 335.5 | 2 463.9 | 2 955.0 | 3 002.0 | 3 057.0 | 3 200.0 |
| 2019 | 2 905.0 | 2 462.0 | 3 088.0 | 3 200.0 | 3 422.0 | 3 562.0 |
| Average | 2 258.9 | 2 398.92 | 2 772.1 | 2846.9 | 3 050.2 | 3 470.6 |

Based on the growing requirements of salak plants, rainfall and air temperature in the six locations evaluated were in the very suitable range to support plant growth and development. A good air temperature for the growth of salak plants is between 20 °C to 30 °C and an average rainfall of (200 to 400) mm mo$^{-1}$ (Nuary *et al*., 2019).

Soil C-organic content in six planting sites was in the medium to high range. Availability of N and P nutrients in salak plantations in Tabanan in the lowlands, medium and highlands in low to very low conditions. Salak planting land in Karangasem, both in the lowlands, medium and highlands, these two nutrients are available in moderate conditions (Table 3). The nutrient content of potassium available in the six planting locations that have been evaluated shows a very low value. The results of this study indicate that the cultivation techniques carried out by farmers are very low. Farmers do not apply an fertilizers that only rely on litter from the pruning of salak midrib as reported by Ilmiah *et al*. (2021), Rai *et al.* (2014), and Warnita *et al.* (2019). To cultivate sustainable agriculture, especially in agroecosystems salak in Bali. The authors will discuss this issue more in the future research paragraph.

*3.2 Characteristics of Salak 'Gulapasir'*

The salak 'Gulapasir' his monoecius plant, namely male and female flowers arranged on the same bunches, the shape of the bunches is compound, and the position of the flower is on the back of the midrib. The salak 'Gulapasir' is classified as special because of its sweet fruit taste and the price per unit weight is four times more expensive than the salak 'Bali' (Rai *et al*., 2014; Sumantra *et al*., 2012). The expansion of the cultivation of the salak 'Gulapasir' from its area of origin, Sibetan, Karangasem, has resulted in phenotypic diversity with a phenotypic similarity level of 58.62 % to 93.10 % (Sumantra and Martiningsih, 2016). In the same garden, more than one type of 'Gulapasir' salak appears, depending on fruit shape, aroma, color of fruit flesh and fruit weight (Sumantra and Martiningsih, 2016). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seed, so new variants of salak 'Gulapasir' appear with local names such as salak 'Gulapasir' nenas, salak 'Gulapasir' gondok and salak 'Gulapasir' nangka. The striking difference between these three varieties lies in the shape and flesh of the fruit. The number of fruit branches of salak 'Gulapasir' nangka, 1 to 2 branches, salak 'Gulapasir' nenas amount of 2 to 4 branches and salak 'Gulapasir' gondok the fruit bunches that do not form fruit branches. Salak 'Gulapasir', which is ready to harvest, has fruit flesh attached to the seed, and the fruit flesh is 0.63 cm thick. Meanwhile, the flesh of the salak 'Gulapasir' nenas is the thinnest and the seeds are attached to the flesh. Meanwhile, when the salak 'Gulapasir' gondok is ready to harvest, the seeds make a sound when shaken (Figure 3).


**Fig. 3.** The shape  and the thickness of the fruit flesh of SGP.var.nenas, gondok and nangka


**Fig. 4.** The shape of the bunch and the number of fuits  of SGP var. gondok,nenas, and nangka

*3.3* Agronomic characteristics of 'Gulapasir' Salak

Analysis of variance showed that the interaction between planting locations and varieties of 'Gulapasir' salak  had significant effect on the number of fruits per bunch, fruit weight per tree, fruit weight per fruit, number of fruits per bunch, the ratio of sugar and acid and vitamin C content. Meanwhile, the thick fruit flesh and tannins content was not significant (Table 5)

**Table 5.** Recapitulation of the effects of varieties and growing locations on agronomic and fruits quality of ‘Gulapasir’ salak

| No. | Character agronomic and fruits quality | Planting location | Varieties | Varieties x Location |
|---|---|---|---|---|
| 1 | Length of the flower sheath | ** | ** | * |
| 2 | Number of fruit bunches $^{-1}$ | ** | ** | * |
| 3 | Fruit tree weight $^{-1}$ | ** | ** | * |
| 4 | Fruit weight $^{-1}$ | ** | ** | * |
| 5 | TSS ratio and total acid | ** | ** | ** |
| 6 | Thick fruit flesh | ** | ** | Ns |
| 7 | Vitamin C | Ns | Ns | * |
| 8 | Tannins | Ns | Ns | Ns |
| 9 | Edible portion | ** | ** | Ns |

Notes: *) significant $P < 0.05$, **) very significant $P < 0.01$ and Ns) not significantly different $P > 0.05$

The interaction of varieties and planting location had a significant effect on the length of the flower sheath and the number of fruit bunches $^{-1}$. Nenas variety grown in Tabanan (T < 560, T 560 to 650, and T > 650 ) and Karangasem (K < 560, K560 to 650, and K > 650) showed higher sheath length and a number of fruit bunches$^{-1}$ than with nangka and gondok varieties (Table 6). Tabanan (T 560 to 650) and Karangasem (K<560 m asl) are ideal conditions for flower sheath development and fruit development of nenas.

**Table 6.** Flower sheath length (cm) and a number of fruit bunches $^{-1}$ (fruit) of nangka, gondok and nenas varieties at six locations.

| **Treatment** | **Sheath length (cm)** | **Amount fruit bunches $^{-1}$** |
|---|---|---|
| NT < 560 | 27.50 ± 0.34 bcd | 19.55 ± 0.82 hij |
| NT 560 to 650 | 28.83 ± 1.31 b | 20.39 ± 1.00 g |
| NT > 650 | 27.17 ± 0.96 cde | 19.02 ± 0.82 j |
| NK < 560 | 26.00 ± 0.82 e | 21.13 ± 0.82 ef |
| NK 560 to 50 | 27.17 ± 0.14 cde | 22.28± 2.45 c |
| NK > 650 | 26.67 ± 1.36 cde | 21.13 ± 0.74 ef |
| GT < 560 | 26.67 ± 2.18 cde | 20.22 ± 0.31 gh |
| GT 560 to 650 | 27.50 ± 1.22 bcd | 20.55 ± 0.62 fg |
| GT > 650 | 27.70 ± 1.98 bc | 19.22 ± 0.74 ij |
| GK< 560 | 25.83 ± 1.41 e | 21.89 ± 0.82 cd |

| | | |
|---|---|---|
| GK 560 to 650 | 26.83 ± 0.75 cde | 20.5 ± 1.63 fg |
| GK > 650 | 27.5 ± 0.82 bcd | 21.28 ± 0.78 def |
| NST < 560 | 27.5 ± 0.82 bcd | 21.41 ± 0.91 de |
| NST 560 to 650 | 27.67 ± 0.82 bc | 22.00 ± 1.56 cd |
| NST > 650 | 26.17 ± 2.16 de | 19.91 ± 1.36 ghi |
| NSK < 560 | 32.00 ± 1.63 a | 25.27± 1.41 a |
| NSK 560 to 650 | 30.90 ± 2.10 a | 24.00 ± 0.82 b |
| NSK > 650 | 27.00 ± 1.47 cde | 21.86 ± 0.82 cde |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

From Table 6 above it can be explained that the three varieties planted in six locations produced a number of fruits between 19.02 to 25.27 fruits per bunch. The nenas variety planted in Karangasem at an altitude of < 560 m asl (treatment NSK < 560) produced the highest number of fruits of 25.27 per bunch, followed by NSK 560 to 650 and NST 560 to 650 with 24.00 and 22.00 fruits per bunch. In order for the salak plants to bear much fruit, the nangka variety is ideal in Karangasem 560 to 650 m asl (NK 560 to 650), while the gondok variety is very good when planted below 560 m asl (GK < 560) although the number of fruits is not significantly different from the same altitude for NT 560 to 650 and GT < 560. The results of this study are in line with the findings of Sumantra and Martiningsih (2016) that the ‘Gulapasir’ salak var. nenas produces the highest number of fruits both in the on season (*gadu* season) and -off-season (*sela* season). Sumantra *et al*. (2014) reported that the emergence of new sheaths occurred on the third or fourth leaf midrib from the growing point depending on the altitude and plant conditions. The time for new sheaths to appear ranges from 129.00 d to145.10 d with the required heat units between (1 233.62 to 1 047.90) Degree-Day (DD). The higher altitude, the longer the sheath appears, as well as the harvest time.

The interaction of varieties and planting location had a significant effect on the fruit weigh (fruit tree$^{-1}$ and fruit$^{-1}$). Nangka variety grown in Tabanan (T < 560, T 560 to 650, and T > 650) and Karangasem (K < 560, K 560 to 650, and K > 650) showed higher of weight of fruit tree$^{-1}$ and fruit-$^{1}$ than with nenas and gondok (Table 7).

**Table 7**. Fruit weight of nangka, gondok, and nenas varieties in six locations

| **Treatment** | **Fruit$^{-1}$ (g)** | **Fruit tree-$^{1}$ (kg)** |
|---|---|---|
| NT < 560 | 45.32 ± 1.08 cd | 1.19 ± 0.08 def |
| NT 560 to 650 | 48.56 ± 0.71 c | 1.29 ± 0.07 cd |
| NT > 650 | 38.22 ± 0.46 ef | 1.03 ± 0.06 ghi |
| NK < 560 | 55.84 ± 1.37 a | 1.48 ± 0.02 b |
| NK 560 to 650 | 59.43 ± 0.71 a | 1.62 ± 0.07 a |
| NK > 650 | 49.4 ±1.65 b | 1.34 ± 0.05 c |
| GT < 560 | 40.14 ± 0.11 e | 1.11± 0.09 fg |
| GT 560 to 650 | 38.67 ± 0.55 ef | 1.09 ± 0.07 fg |
| GT > 650 | 32.95 ± 0.73 gh | 0.93 ± 0.10 i |
| GK < 560 | 44.22 ± 0.18 d | 1.27 ± 0.06 cde |
| GK 560 to 650 | 38.20 ± 0.78 ef | 1.16 ± 0.05 defg |
| GK > 650 | 36.20 ± 0.75 fg | 1.07 ± 0.11 fgh |
| NST < 560 | 39.00 ± 1.07 ef | 1.14 ± 0.11 efg |
| NST 560 to 650 | 37.79 ± 0.65 f | 1.13 ± 0.06 g |
| NST > 650 | 32.12 ± 0.11 h | 0.94 ± 0.10 hi |
| NSK < 560 | 41.80 ± 0.65 de | 1.36 ± 0.08 bc |
| NSK 560 to 650 | 36.57 ± 0.80 fg | 1.18 ± 0.09 def |
| NSK > 650 | 37.10 ± 0.23 f | 1.11 ± 0.07 fg |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

From Table 7 it can be explained that the three varieties grown in six locations produced fruit weight per tree between 0.93 kg and 1.62 kg. The salak nangka variety planted in Karangasem at an altitude of 560 to 650 m asl (NK 560 to 650) produced the heaviest fruit weight of 1.62 kg tree$^{-1}$, followed by NK < 560 and NT 560 to 650 with fruit weights of 1.48 and 1.29 kg. While the nenas variety produces the best fruit at altitudes < 560 m asl (NSK < 560 and NT < 560). Salak 'Gulapasir' var. gondok is ideal when planted at altitudes < 560 m asl (GK < 560 and GT < 560), although the two growing locations showed a different yields.

Nenas and gondok varieties showed a trend of decreasing fruit weight in line with increasing altitude, both planted in Karangasem and Tabanan. The reverse occurred in the salak nangka variety, an increase in altitude from 550 m asl to 550 to 650 m asl caused an increase in fruit weight and after that the fruit weight decreased when planted at altitudes > 650 m asl. This finding is in line with the results of research that has been reported by Sumantra *et al*. (2014). However, for the gondok and nenas varieties, this is a new finding.

Apart from being influenced by environmental factors, the production of salak 'Gulapasir' fruit is also influenced by internal plant factors (Adelina *et al*., 2021b: Lestari *et al*. 2011). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019), and rainfall (Ritonga *et al*., 2018). Altitude increases, the average daily air temperature decreases and monthly rainfall increases (Table 3). Nuary *et al.* (2019) stated that the distribution and adaptation of salak plants is strongly influenced by temperature and rainfall. It was further stated, the contribution of daily temperature accounts for nearly 38.6 % while rainfall is 27.8 %. Kanzaria *et al.* (2015) reported that mango plants planted at an altitude of 229 m flowered slower than those at an altitude of 148 m and 81 m asl. The temperature regime at higher altitudes is colder than at lower altitudes. Lower temperatures accumulate less growing degree day (GDD) and may result in late flowering. Table 7 shows that the 'Gulapasir' salak planted in Karangasem produced a higher fruit weight in the three salak varieties tested. This is related to the level of soil fertility. The soil nitrogen and phosphate nutrient content at three locations in Karangasem was higher than at three locations in Tabanan. Meanwhile, the potassium content in the six research locations was low (Table 3). Therefore it is necessary to make improvements by providing fertilizers containing elements of N, P and K to meet ideal conditions for growth, although more data is needed to fully support this conclusion (Hailu *et al.*, 2015).

*3.4 Quality characteristics of salak varieties*

The interaction between varieties and altitude significantly affected sugar/total acid and vitamin C content. The three varieties grown in Tabanan (T < 560, T 560 to 650 and T > 650) showed a lower TSS/acid ratio. The fruit flavour planted in three locations in Tabanan is sourer than the three locations in Karangasem. Sugar content is greatly affected by the geographical. The geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity, and rainfall (Ritonga *et al*., 2018). Table 8 also shows that the increase in altitude from 550 m to 700 m asl in Tabanan and the addition in altitude from 550 to 650 m asl in Karangasem causes the sugar/acid ratio decrease in all three varieties, and the lowest sugar/acid value occurs in nenas variety in all locations. Each salak variety has an adaptation to an elevation closely related to plant tolerance to temperature (Sumantra and Martiningsih, 2016; 2018). Many factors influence fruit quality, but the most dominant are climate factors, especially temperature and rainfall. High rainfall and low air temperature during the fruit ripening phase can cause the dissolved solids in the fruit to become watery so that the TSS value is low (Singh *et al*., 2011).

Salak fruits from three different varieties grown in low lands in Karangasem (K < 560 m asl) showed the highest vitamin C content and were significantly different from the three cultivars when planted in other locations. In both areas land increased by > 650 m asl effects to vitamin C decrease, nangka and gondok varieties showed higher levels of vitamin C between < 550 m to < 650 m asl. (Table 8).

**Table 8.** TSS/acid ratio and levels of vitamin C of nangka, gondok, and nenas varieties in six locations.

| Treatment | TSS/T.Acid | Vit. C (mg /100g) |
|---|---|---|
| NT < 560 | 56.20 ± 0.16 abc | 27.50 ± 0.41 bde |
| NT 560 to 650 | 59.18 ± 0.82 a | 25.45 ± 0.37 defgl |
| NT > 650 | 37.89 ± 0.91 f | 22.52 ± 0.39 j |
| NK < 560 | 51.41 ± 0.33 cde | 27.74 ± 0.47 bd |
| NK 560 to 650 | 53.52± 0.82 abcd | 29.61 ± 0.50 ab |
| NK > 650 | 47.76 ± 0.11 de | 24.25 ± 0.20 fghij |
| GT < 560 | 34.88± 0.72 fg | 25.50 ± 0.41 defgl |
| GT 560 to 650 | 34.80 ± 0.65 fg | 25.75 ± 0.20 defgl |
| GT > 650 | 30.24 ± 0.20 gh | 23.34 ± 0.28 hij |
| GK < 560 | 51.28 ± 0.23 cde | 30.31 ± 0.25 a |
| GK 560 to 650 | 58.44 ± 0.36 ab | 27.63 ± 0.30 bd |
| GK > 650 | 53.04 ± 0.82 bcde | 25.07 ± 0.33 efgh |
| NST < 560 | 31.50 ± 0.41 gh | 26.71± 0.21 cdef |
| NST 560 to 650 | 30.44 ± 0.36 gh | 25.88 ± 0.41 defg |
| NST > 650 | 26.13 ± 0.11 h | 23.65 ± 0.29 ghij |
| NSK < 560 | 53.73 ± 0.60 abc | 24.42 ± 0.34 fghij |
| NSK 560 to 650 | 52.63 ± 0.51 bcde | 22.82 ± 0.15 ij |
| NSK > 650 | 47.60 ± 0.49 e | 25.16 ± 0.13 efgh |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

The results showed that the varieties of the ‘Gulapasir’ salak needs different environmental requirements to optimize yields. Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al*., 2021, 2022). Therefore, variety differences may depend on growing requirements and cultivation techniques. Vitamin C in the ‘Gulapasir’ salak is strongly influenced by the altitude of the land. To produce high levels of vitamin C, the nangka and gondok varieties are ideal for planting at an altitude of 560 m to 650 m asl, while the nenas variety is ideal at a land altitude

of < 560 m asl. However, changes in ascorbate levels during fruit ripening are species-dependent and environmental factors especially temperature and light (Fenech *et al*., 2019).

There was no interaction between varieties and altitude to the flesh thickness, edible fruit portion, and fruit sugar content. The nangka salak variety showed fruit quality, including TSS, edible parts of the fruit, and higher flesh thickness (Table 9).

**Table 9.** The effect of a single factor of varieties on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment | TSS (°Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| Nangka | 16.59a | 72.50a | 0.63a |
| Gondok | 16.42a | 70.66ab | 0.59b |
| Nenas | 15.64b | 69.22b | 0.52c |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Salak grown in Karangasem both from the lowlands and the middle lands produces fruit thickness, and the edible portion of fruits is higher than plants in the highlands. This study indicates that the ideal growing place for salak plants is between 450 m to 650 m asl. This study is in line with several previous studies which explained that altitude affects the flowering process and fruit enlargement (Sophie *at al*., 2017; Spinardi *et al*., 2019; Widyastuti *et al*., 2022).

**Table 10.** The effect of a single factor of planting location on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment (m asl) | TSS (°Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| T < 550 | 16.28a | 73.13a | 0.54c |
| T 550 to 650 | 16.27a | 69.89a | 0.58bc |
| T > 650 | 16.14a | 63.87b | 0.49d |
| K 550 | 16.81a | 73.15a | 0.61b |
| K 550 to 650 | 16.11a | 72.29a | 0.66a |
| K > 650 | 15.69a | 72.44a | 0.61b |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Further research can be applied using sustainable salak organic agriculture (Budiasa, 2014; Handayani, 2022; Nurhidayat *et al*., 2022; Rahmah *et al*., 2022; Wimatsari *et al*., 2019). Table 3 shows that salak cultivation in the research location still needs to implement sustainable farming (Prasetyo *et al*., 2022b; 2022a). There are indications some of decrease in soil fertility, especially potassium available in the six planting locations that shows a very low value. Potassium levels in Table 3 are lower than the observations of Ashari (2013) and Woran *et al.* (2018) in salak cultivation areas in Swaru – Malang (very high), Sleman – Yogya (moderate), Bangkalan – Madura (very high), and Pangu – Minahasa (moderate).

Potassium helps produce good fruit quality, such as bigger, heavier, and sweeter fruit. Another benefit of the nutrient potassium in plants is to increase the growth of meristem tissue and regulate the movement of stomata. Potassium also helps the development of plant roots so that plant stems can stand upright and do not collapse easily (Adinurani *et al*., 2018; Budiono *et al*., 2019). Therefore, Nasution (2022) recommends more $K_20$ fertilizer than $P_20_5$ fertilizer and N fertilizer. In addition, salak needs 70 kg of $K_2O$ because this nutrient is found in the leaves at an amount (12.2 to 14.7) mg $g^{-1}$ (Ashari, 2013).

The chemical fertilizers (e.g., KCl) are too expensive for Salak farmers and do not support the salak organic. Therefore, the application of sustainable farming should apply local wisdom including the use of the pruning of salak midrib. Consider this policy because C organic is essential to soil fertility (Budiono *et al*. 2021; Goenadi *et al*. 2021). The success of this midrib decomposition is demonstrated by the C organic in Table 3, which is classified as medium to high. This finding support Faizah and Fauzan (2021), Saputra *et al.* (2018) in salak plantation of Purwosari District - Pasuruan Regency, and Wonosalam District – Jombang Regency.

But, in the next stage, some of the salak midribs should be burned into ashes which can be used as a source of potassium nutrients (Ekawati and Purwanto, 2012; Vincevica-Gaile *et al*., 2021a, 2021b). Another organic source of potassium is the pulp/husk of coffee cherries. Karangasem and Tabanan districts are coffee cultivation areas in Bali, so they should take advantage of this coffee processing waste. Several researchers stated that coffee pulp/husk contains higher potassium than nitrogen or phosphorus nutrients (Bahri *et al*., Falahuddin *et al*., 2016; Novita *et al*., 2018; Setyobudi *et al*., 2018).

Several researchers (Analianasari *et al*. 2022; Ningsih, 2020; Wachisbu, 2020) recommend soaking the pulp/husk coffee cherries and uses as liquid organic fertilizer with benefits for various plants. To develop this idea, salak farmers in Karangasem and Tabanan Regency should create biogas as household or communal scale digesters (Prespa *et al*., 2020; Setyobudi *et al.* 2021b; Susanto *et al*., 2020a) or use digesters from used drums (Adinurani *et al*., 2017; Hendroko *et al*., 2013). All household organic waste is processed in the digester, including kitchen waste, leftover food, and human excrement from pit latrines and septic tank (Anukam and Nyamukamba, 2022; Somorin, 2020; Susanto *et al*., 2020b; Zhou *et al*., 2022). This action has various advantages, namely reducing global warming, obtaining clean - renewable energy, and two kinds of organic fertilizer, i.e., liquid and solid (Abdullah *et al*., 2020; Burlakovs *et al*., 2022; Hendroko *et al*., 2014; Prespa *et al*., 2020; Setyobudi, *et al*., 2018). In addition, many researchers have reported (among other things Benyahya *et al*., 2022; Baştabak and Koça, 2020; Li *et al*., 2021) the benefits of organic fertilizers from biogas digesters.

Another measure to increase and maintain land fertility is in salak cultivation, namely the application of Plant Growth Promoting Rhizobacteria (PGPR) or biological fertilizer (Basu *et al*., 2021; Ekawati, *et al.*, 2019). Several researchers (Adinurani *et al*., 2021; Kumalawati *et al*., 2021; Muhammad *et al*. 2021) have reported using mycorrhiza, which positively impacts various plants, including salak cultivation (Amnah and Friska, 2018; Dewi *et al*., 2020; Rai *et al*., 2021). Multiplication of mycorrhiza is relatively simple (Sportes *et al*., 2021; Sukmawati *et al*., 2021) and can be done by farmer groups with initial guidance from universities.

**4. Conclusion and Recommendation**

Different cultivars caused different fruit weights, fruit bunches, and the sugar/acid ratio at various locations. The three varieties showed lower fruit weight and fruit quality in Tabanan (low, medium, and highlands) than the salak originating from Karangasem. The nangka variety in Karangasem showed higher fruit weight, vitamin C content, and sugar/ acid ratio, while the nenas salak showed the highest number of fruit bunches$^{-1}$ in six locations. Nangka salak are very suitable to be planted at an altitude of 550 m to 650 m asl. In contrast, the nenas and gondok varieties are developed naturally at low altitudes < 550 m asl. In order for all cultivars to be able to produce optimally, efforts to improve the cultivation system are needed through fertilization and the provision of calcium is highly recommended. Further research can be applied using sustainable salak organic agriculture to maintain soil fertility.

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Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir  Planted in Different Agro-Ecosystems

**Running Title:**

Assessment Salak Planted in Different Agro-Ecosystems


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# Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Different Agro-Ecosystems

## ABSTRACT

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir has been officially released by the Minister of Agriculture of the Republic of Indonesia since 1994. Salak 'Gulapasir' is one of five types of fruit that have been designated as the superior fruit of the Bali Province. Salak 'Gulapasir' preferred by consumers due to its specific fruit flesh taste. Salak 'Gulapasir' was propagated using seeds so that a new types of salak emerged. However, the characters of this new type of salak 'Gulapasir' is not yet known. The research objective was to obtain the superior of some Salak 'Gulapasir' both in production and fruit quality. The research used a Randomized Block Design with three replications. The non-independent variable was the three of Salak 'Gulapasir' (SGP): SGP var. nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 to 650 m asl, and K > 650 m asl) and Tabanan (T): (T < 560 m asl, T 560 to 650 m asl, T > 650 m asl). Observations were made on the agronomic characters and fruit quality. Data were analyzed using variance analysis, and if the planting location and varieties show a difference, then it is followed by the LSD test at the 5 % level. The results showed that different varieties caused different fruit weights, fruit bunches, TSS, and total acid ratio. In Tabanan (in the low, medium, and highlands), the three varieties showed lower fruit weight and fruit quality than the salak originating from Karangasem. The SGP var. nangka in Karangasem showed higher fruit weight, vitamin C content, and TSS/total acid ratio, while the SGP var. nenas showed the highest number of fruit bunches$^{-1}$ in six locations. Further research can be applied using sustainable salak organic agriculture to maintain soil fertility.

**Keywords :** Altitude, *Salacca zalacca* (Gaertn.) Voss, Salak 'Gulapasir' var. gondok, Salak 'Gulapasir' var. nangka, Salak 'Gulapasir' var. nenas, Salak sustainable agriculture, Snake fruit, Tropical fruit

## 1. Introduction

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir is one of the important fruits in Indonesia and the plant can be found in most regions of Indonesia (Rai *et al*. 2016; Ritonga *et al*., 2018). The salak fruit belong to the family Palmae or Arecaceae, and are native to the Indonesian-Malaysian region (Hakim *et al.*, 2019; Zumaidar *et al*., 2014). One of the extraordinary strengths of this fruit commodity for Indonesia is the possession of high genetic diversity (Budiyanti *et al*., 2019). Also, the nutrition of salak fruit is rich in antioxidants, phenolics, vitamins, and minerals (Cepkova *et al.*, 2021; Mazumdar *et al*., 2019), and a good source of income and provides livelihood opportunities on seasonal days (Khan and Idrees, 2021). The fruit flesh and peel have shown some tremendous anti-inflammatory, anticancer and antidiabetic (Saleh *et al*., 2018), and anti-ageing agents (Girsang *et al*., 2019). Antioxidants are chemical compounds that play an essential role in protecting cells due to attacks against free radicals-induced damage to biomolecules (Damat *et al*., 2019, 2020; Puspitasari and Ningsih, 2016; Setyobudi *et al*., 2019). Despite its incredible food and medicinal benefits, salak fruit is still underutilized and unknown globally. So that this underutilized fruit remains an issue for future sustainable utilization and commercial value enhancement market (Mazumdar *et al*., 2019). Fruit quality is an important issue, especially for products that are consumed raw and fresh. One of the problems is the lack of fruit quality because of inadequate information about superior salak (Budiyanti *et al*., 2019; Herawati *et al*., 2018). Therefore, it is necessary to select superior salak to meet market demand and fulfil community nutrition.

Salak 'Bali' is quite a lot, based on the shape, aroma, taste, and skin colour of the location where the plants are cultivated (Sumantra *et al*., 2012, 2014; Sumantra and Martiningsih, 2016,

2018). Under the Decree of the Minister of Agriculture of the Republic of Indonesia in 1994, Balinese zalacca was grouped into two superior zalacca: Salak 'Bali' (SK Mentan, 1994a) and Salak 'Gulapasir' (SK Mentan, 1994b). The second type, the salak 'Gulapasir' (SGP) is the most superior salak because of its sweet fruit taste; even though the age of the fruit is still young, thick fruit flesh and seeds are not attached to the fruit flesh (Rai *et al*., 2014; Sumantra *et al*., 2016). The nature of this fruit is ideal for meeting market demands for both the domestic and export markets (Martiningsih *et al*., 2018). Salak 'Bali' is monoecious, so crossing does not need human help (Herawati *et al*., 2018), and can quickly develop using seeds (Sumantra and Martiningsih, 2016). Another advantage of salak plants in Indonesia compared to other fruits is harvest fruit 2 to 3 times a year if management is good (Rai *et al*., 2016; Warnita *et al*., 2019). The expansion of salak 'Gulapasir' planting causes variations in phenotypic diversity. People can find two to three types of salak plants with a marker, fruit shape, aroma, flesh colour, and fruit weight (Martiningsih *et al*., 2018). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seeds so that new varieties of salak 'Gulapasir' (SGP) appear, as reported by Sumantra and Martiningsih (2016). Based on the marker that can be used as a differentiator, salak farmers give it the name of SGP var. nenas, SGP var. gondok, and SGP var. nangka. The three varieties have not yet identified their advantages in meeting market needs in line with the results of research (Sumantra and Martiningsih, 2016). The performance and produce are influenced by the characteristics of the agricultural ecosystem, particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status (Adelina *et al.*, 2021a; Kumar *et al*., 2020) and growth hormone (Prihastanti and Haryanti. 2022; Rai *et al.*, 2016).

The salak 'Gulapasir' plantation in the District of Bebandem is the main producer of salak 'Gulapasir' in Bali is located in the southern part of Mount Agung with an altitude of 450 m to 700 m above sea level (m asl). The effect of altitude on plant growth and production is related to plant adaptation to temperature (Sumantra, *et al*., 2014), full sunlight (Sukawijaya *et al*., 2009), water status and soil quality (Raharjo *et al*., 2022; Rai *et al*., 2014; Ritonga *et al.*, 2018). Salak plants are not resistant to full sun but 50 % to 70 % enough, therefore it is necessary to have shade plants (Sukawijaya *et al*., 2009; Sumantra *et al*., 2012). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019). Water status and soil quality really determine the fruit set on the salak ‘Gulapasir’. Low rainfall reduces the Relative Water Content in leaves (RWC), leaf chlorophyll content, and plant nutrient uptake (Rai *et al*., 2014). soil quality included the suitability of the physical, chemical and biological properties (Raharjo *et al*., 2022). Nuary *et al*. (2019) stated that the distribution of the salak ‘Pondoh’ plantation area in Sleman (Yogyakarta, Special Region) was greatly influenced by temperature and rainfall. The contribution of temperature in the modelling reached 38.6 % while the rainfall was 27.8 %. Furthermore, taking into account the probability of the temperature variable, the average temperature ranges from 17.41 °C to 25.65 °C, and the ideal month's rainfall ranges from 385.24 mm to 505.01 mm.

Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al.*, 2021, 2022). Therefore, varieties differences may depend on growing requirements and cultivation techniques. Likewise, Puspitasari *et al*. (2016) stated that tannin content, fruit size and flesh colour of salak fruit are strongly influenced by where it grows. Other studies also explain that salak ‘Gulapasir’ var. nangka which is grown 570 m asl, would result in a higher quality of fruit that includes thickness of the mesocarpium, edible portion of fruit then compared to above and below 570 m asl (Sumantra *et al*., 2014; Sumantra and Martiningsih, 2016). Meanwhile, fruit weight and fruit quality of var. gondok and var. nenas have not been reported. Therefore, one way of handling salak quality is by undertaking severe studies for factors such as land and climate and adjusting agricultural patterns according to local climate conditions (Nassar *et al*., 2018). The success of each species to occupy the environment of an area is influenced by its ability to adapt optimally to all physical environmental factors (temperature, light, soil structure, humidity), biotic factors (interaction between species, competition, parasitism), and chemical factors including the availability of water, oxyge, pH, and nutrients (Nassar *et al*., 2018; Widyastuti *et al*., 2022). Moreover, a broad genetic variability would lead to wide phenotypic variability due to the effect of genetic-environment interaction (Ritonga *et al*., 2018). The research objective was to obtain the superior of some salak 'Gulapasir' both in production and fruit quality (sugar and acid ratio, vitamin C and tannin) in six different agricultural ecosystems in Bali.

## 2. Materials and Methods

### *2.1 Experimental site*

The research was conducted in Tabanan and Karangasem Regencies. Tabanan and Karangasem were selected as research locations because the domination of salak 'Gulapasir' in these two regencies was the highest. In 2021, the salak 'Gulapasir' population in Tabanan is 84 % of all salak species, while in Karangasem Regency the dominance of the salak 'Gulapasir' is more than 63 % (Sumantra *et al*., 2022).

The study was carried out in six different locations, three sites in Karangasem Regency and three sites in the district of Tabanan. Locations in Karangasem (K) are lowlands (K < 560 m asl) which include several places, namely Telaga, Dukuh, and Karanganyar. Karangasem in the moderate plains (K 560 m to 650 m asl) has several areas, namely Kecing and Kutabali and highlands (K > 650 m asl), namely Tanah Apo and Kresek (Figure 1).

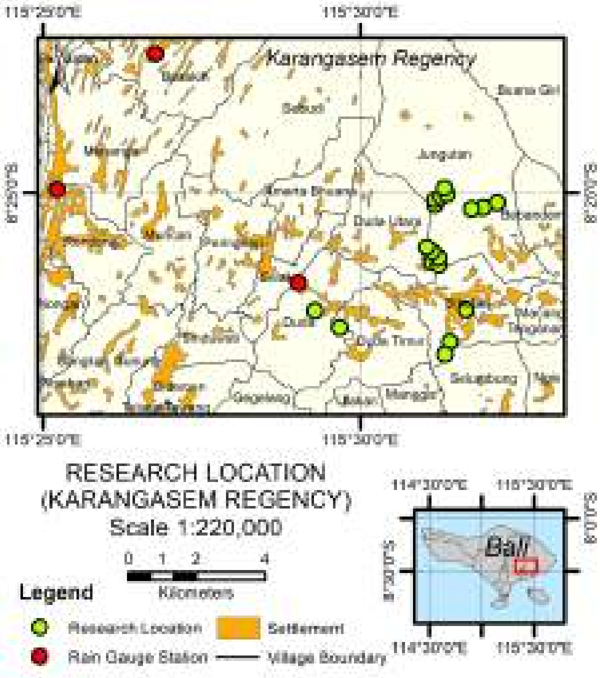


**Fig 1.** Research map and sampling point in Karangasem (K)

The research location is in Tabanan (T) in the lowlands (T < 560 m asl), including Wanagiri, Sari Buana, and Mundeh Kauh. Tabanan in the medium lands (T 560 m to 650 m asl) includes several places, namely Pajahan, Kebon Jero, and Angseri. Tabanan in the highlands (T > 650 m asl), namely Munduk Temu, Pempatan, and Batungsel (Figure 2).

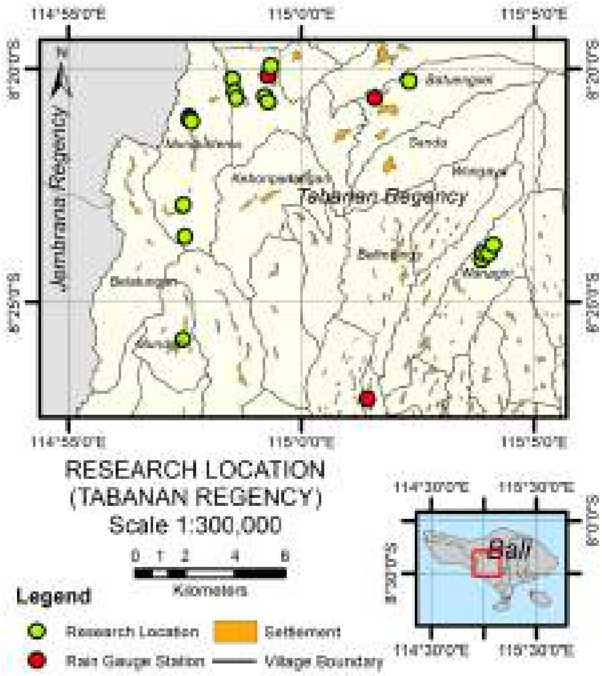

**Fig 2.** Research map and sampling point in Tabanan (T)

The non-independent variable was the three varieties of Salak 'Gulapasir' (SGP): SGP var.nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 m to 650 m asl, and K > 650 m asl) and Tabanan (T) : (T < 560 m asl, T 560 m to 650 m asl, T > 650 m) Repetition was carried out three times with the number of sample plants in each location, and cultivars were seven plants. The treatment tested is as shown in Table 1

**Table 1**. Treatment of plant location and three varieties of 'Gulapasir' salak

| No | Treatment | Explanation |
|---|---|---|
| 1 | NT< 560 m asl | Salak GP.var. nangka Tabanan < 560 m asl. |
| 2 | NT 560 m to 650 m asl | Salak GP.var. nangka Tabanan 560 m to 650 m asl. |
| 3 | NT > 650 m asl. | Salak GP.var. nangka Tabanan > 650 m asl. |
| 4 | NK < 560 m asl. | Salak GP.var. nangka Karangasem < 560 m asl. |
| 5 | NK 560 m to 650 m asl | Salak GP.var. nangka Karangasem 560 m to 650 m asl. |
| 6 | NK > 650 m asl. | Salak GP.var. nangka Karangasem > 650 m asl. |
| 7 | GT< 560 m asl | Salak GP var. gondok Tabanan < 560 m asl. |
| 8 | GT.560 to 650 m asl | Salak GP var. gondok Tabanan 560 m to 650 m asl. |
| 9 | GT > 650 m asl | Salak GP var. gondok Tabanan > 650 m asl. |
| 10 | GK.< 560 m asl | Salak GP var. gondok Karangasem < 560 m asl. |
| 11 | GK 560 m to 650 m asl | Salak GP var. gondok Karangasem 560 m to 650 m asl. |
| 12 | GK > 650 m asl | Salak GP var. gondok Karangasem > 650 m asl. |
| 13 | NST < 560 m asl | Salak GP var. nenas Tabanan < 560 m asl. |
| 14 | NST.560 m to 650 m asl | Salak GP var. nenas Tabanan 560 m to 650 m asl. |

| | | |
|---|---|---|
| 15 | NST > 650 m asl | Salak GP var. nenas Tabanan > 650 m asl. |
| 16 | NSK .< 560 m asl | Salak GP var. nenas Karangasem < 560 m asl. |
| 17 | NSK 560 m to 650 m asl | Salak GP var. nenas Karangasem 560 m to 650 m asl.. |
| 18 | NSK > 650 m asl | Salak GP var. nenas Karangasem > 650 m asl. |

The study used a Composite Analysis of Variance (Andinurani, 2016, 2022) with the model determined using Equation (1) below:

$$Yjk = u + L\,i + \delta\,ik + Pj + (LP)\,ij + \mathcal{E}\,ijk \quad (1)$$

Where:

Yijk = The observation value of the treatment (j) in the group (k), which is repeated at the location (i).

u = the actual average value

Li = additive effect from location i

δ ik = the error effect in group k at location i

Pj = additive effect of the next treatment

(LP) ij = the effect of treatment (j) at the location (i)

Ɛ ijk = the effect of error from the treatment (j) in the group (k) which was carried out at the location (i).

*2.2 Preparation of study materials*

The material used is the salak ‘Gulapasir’ plant with uniform growth, plants have been fruitful with uniform on morphological, age of plants and cultivation action. The intentional practice is that the plant only receives treatment in the midrib, tillers, and weed cleaning. In this study, the plants were not fertilized. The provision of water was only from rainfall following the habits applied by salak farmers. The sample plant maintains by trimming unproductive leaf midribs and removing young shoots. Plant material was taken from the

Salak Development Centre in six locations, namely at the Centre of Salak Development in the Bebandem sub-districts, Karangasem district (K-lowland < 560 m asl, K-medium 560 m to 650 m asl and K-highland > 650 m asl), Bajre, West Slemadeg and Pupuan sub-districts, Tabanan district (T-lowland < 560 m asl, T-medium 560 to 650 m asl and T-highland > 650 m asl).

2.*3 Analysis of physicochemical properties of soil sample and climate*

Soil analysis was carried out to determine the physical and chemical properties of the soil. Soil sampling was carried out under sample plant trees, carried out in a composite manner at a depth of 0 cm to 40 cm. Chemical analysis was carried out on total N (Kjeldahl method), available P by Bray I method and $K_2O$ by the Bray I method, organic C, pH, soil physical properties in the form of texture by pipette method (Eviati and Sulaeman. 2009; Hailu *et al*., 2015; Prasetyo *et al*., 2022a; Rzasa and Owczarzak, 2013).

Rainfall data was taken for five years from 2015 to 2019. Rainfall data has been collected from six nearby stations to the research site (Table 2). Daily temperature data obtained from the Denpasar Meteorology Climatology Agency.

**Table 2**. Research locations and place of climatology stations

| Research Locations | Climate observation station | Latitude and altitude |
|---|---|---|
| Tabanan Lowlands (< 560 m asl) | Ampadan, Tiyinggading No.St. 439 m | 8°27'5.0688"S/ 115°1’25.086 "E; 400 m asl. |
| Tabanan Moderate (560 m to 650 m asl) | Coffee Breeding Center, Sai Pupuan No. St. 439 h | 08°20'08.6"S/ 114° 59'17.4" E; 580 m asl. |
| Tabanan Highlands (> 650 m asl) | Agricultural Extension Center, Pupuan. No St.441 h | 08°20'38.1" S/ 115°01'35.2" E; 750 m asl. |

| | | |
|---|---|---|
| Karangasem Lowlands (< 560 m asl) | Agricultural Extension Center, Selat. No. St. 444 d | 08°26'25" S / 115°29'02" E; 450 m asl. |
| Karangasem Moderate (560 m to 650 m asl) | Horticulture Seed Center, Singerata No.St. 442 | 08°24'57"S / 115°25'14"E; 580 m asl. |
| Karangasem Highlands (> 650 m asl) | Besakih Station. No.St.442 a | 08°22'49"S / 115°26'47"E; 800 m asl. |

*2.4 Observation of fruit and fruit quality*

Salak fruit can be harvested when it is ready for consumption. Consumable ripe fruit is a fruit that is ready to be consumed, characterized by a change in skin colour from dark brown to light brown, the thorns on the skin have reduced and are not sharp, and in general, at this stage, the fruit easily falls when shaken.

Observation and measurement of agronomic characters follow the method that has been done by Sumantra *et al*. (2014) including fruit weight, number of fruit bunches, the thickness of fruit flesh and fruit shape. The fruit characters from six-observed locations include the numbers of fruits per bunch, which is calculated manually on the formed fruits. The fruit weight per fruit and the fruit weight per tree is weighed after the fruits were removed from the bunch. The thickness of the mesocarpium is obtained by measuring the mesocarpium after it is cut vertically. The length of the flower sheath is measured on the stem of the sheath from the base to the tip of the sheath.

While fruit quality includes sugar content, tannins, titrated acid, sugar content and vitamin C. Titrated acid was analyzed by titration (Sripakdee *et al*., 2015). The fruit was weighed 10 g of sample was added to 100 mL of distilled water, then was homogenized using a slow spin blender, and filtered using an aseptic filter. The filtrate obtained was taken as much as 25 mL, then titrated with 0.1 N NaOH solution with phenolphthalein indicator until red in colour appeared. The results obtained are calculated as the percentage tartaric acid is determined using Equation (2) below :

$$A = \frac{\text{mL NaOH} \times \text{N NaOH} \times P \times BM}{Y \times 1\,000 \times 2} \times 100\ \% \qquad (2)$$

where:

A = percentage of total acid

P = amount of dilution

BM = molecular weight of tartaric acid

Y = sample weight (g).

Tannis content was analyzed as done by Thakur *et al*. (2021), Setyobudi *et al*. (2022). Amount of 100 mg of the sample was homogenized by 2 mL of methanol. Centrifuged for 10 min at 10 000 rpm (1 rpm = 1/60 Hz) and collected the supernatant. Amount of 1 mL of supernatant mixed with 0.5 mL Folin's phenol reagent and 35 % $Na_2CO_3$ of 5 mL added and the mixture was kept at room temperature for 5 min. The blue colour of the reaction mixture was observed at 640 nm by UV/visible spectrophotometer (Shimadzu UV-1800, Japan). The content of tannin was calculated by calibration curve equation and determined using Equation (3) below:

$$Y = 0.0073x - 0.0071 : R^2 = 0.9973 \qquad (3)$$

Vitamin C was determined by titration like the method used by Asamara (2016), Setyobudi *et al*. (2021a, 2022). The material is weighed as much as 10 g and crushed in mortal. Then put into a 250 mL volumetric flask, set to the mark and filtered. Take 25 mL of the filtrate and titrate with 0.01 N Yod solution equivalent to 0.88 mg of ascorbic acid. The calculation of ascorbic acid content per 100 g of material is determined using Equation (4) below:

$$A = \frac{\text{mL Yod } 0.01\ N \times 0.88 \times P \times 100}{Y} \qquad (4)$$

where: A = mg of ascorbic acid per 100 g of material

P = amount of dilution

Y = gram sample weight

Sugar content as TSS is calculated using a hand refractometer (Bellingham and Stanley Ltd., London) at 20 $^{o}$C.

The ratio of sugar content (TSS) and total acid is calculated by the sugar content divided by the acid content multiplied by 100 %.

The materials used in this study were Folin-Ciocalteu reagent (Pro Analytic, Merck), NaOH (Pro Analytic, Merck), $Na_2CO_3$ (Pro Analytic, Merck), Phenolphereagent ascorbic acid (Pro Analytic, Merck), Phosphoric Acid (Pro Analytic, Merck), Sodium Phosphate (Pro Analytic, Merck) and Ammonium Molybdate (Pro Analytic, Merck).

The tools used in this study were analytical balances (Shimadzu ATY224, Japan), centrifuge tubes, Erlenmeyer flasks (pyrex), dropper pipettes (pyrex), volume pipettes (pyrex), vortex (Maxi Mix II Type 367000), measuring flask (pyrex), water bath (Memmert), blender (Miyako), and centrifuge (Damon /IEC Division). Whatman filter paper No 1 (Sigma – Aldrich, USA), measuring cup (Pyrex, USA), micropipette (Dragon Lab, Indonesia), spectrophotometer (Biochromsn 133467, UK), test tube (Pyrex¸ USA), vortex (Barnsteadl Thermolyne Type 37600 Mixer, USA), aluminum foil (Klin Pak, Indonesia).

*2.5 Study design*

This study used a randomized block design with the data analyzed using a Composite Analysis of Variance. If the variance test is significantly different, then it is continued with a different test with LSD at the 5 % level. Data analysis was performed using SPSS-IBM 18 (Adinurani, 2016, 2022). Each experimental treatment was repeated three times.

## 3. Results and Discussion

*3.1 Agroclimate characteristic*

The low production level and quality of salak fruit are caused by environmental factors that do not support growth or because the physiological processes of the plant are not optimal due to insufficient nutrients and water. The suitability of climatic and soil conditions at six locations of the centres for the development of the ‘Gulapasir’ salak was evaluated. The evaluation results show that the air temperature decreases as the altitude increases. The average air temperature at the ‘Gulapasir’ salak plantation in Tabanan is 22.90 $^{o}$C, while the air temperature at the Karangasem salak plantation is around 23.24 $^{o}$C. (Tabel 3)

**Table 3.** Soil and climate characteristics of the research site in Tabanan and Karangasem in three subzones

| **Parameter** | **Tabanan (T)** | | | **Karangasem (K)** | | |
|---|---|---|---|---|---|---|
| | Lowlands (< 560 m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) | Lowlands (< 560m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) |
| Temp. ($^{o}$C) | 23.82 | 22.75 | 22.12 | 24.29 | 23.35 | 22.09 |
| Rainfall (mm mo$^{-1}$) | 188.24 | 199.91 | 231.008 | 237.242 | 254.183 | 289.216 |
| Soil texture | loamy clay | loamy clay | loamy clay | clay | clay | sandy loam |
| pH ($H_2O$) | 5.64(sa) | 5.75 (sa) | 5.84 (sa) | 6.08 (sa) | 6.05 (sa) | 6.03(sa) |
| C- organic (%) | 2.94(m) | 3.40 (h) | 3.25 (h) | 2.77 (m) | 3.63 (h) | 3.32 (h) |
| Nutrients available | | | | | | |
| N total (%) | 0.18 (l) | 0.16 (l) | 0.18 (l) | 0.24(m) | 0.23 (m) | 0.29 (m) |
| $P_2O_5$ (mg g$^{-1}$) | 9.38 (vl) | 9.12 (vl) | 13.50 (l) | 22.55 (m) | 24.18 (m) | 23.04 (m) |
| $K_2O$ (mg g$^{-1}$)) | 18.47 (vl) | 22.05 (vl) | 17.23 (vl) | 24.17 (vl) | 19.93 ( vl ) | 18.37 ( vl ) |

Notes: sa: slightly acidic; h: high; m: medium; l: low; vh: very high; h: high; asl: above sea level (The assessment criteria refer to Eviati and Sulaeman. 2009; PPT, 1983).

Likewise monthly rainfall, the average rainfall over the 5 yr is presented in Table Table 4. Annual rainfall in Tabanan (T < 560, T 560 to 650 and T > 650) is lower with an average of 2515.05 mm while in Karangasem (K < 560, K 560 to 650 and K > 650) it is 3 122.05 mm. However, the six locations show a trend of increasing rainfall as altitude increases. The salak plantation area in Karangasem is in the southern part of Mount Agung. Meanwhile in Tabanan, the dominant salak plantation area is behind Mount Batukaru with a lower elevation than Mount Agung. Mount Agung with an altitude of 3 142 m asl (Andaru and Rau, 2019), while the Batukaru mountains area with an elevation 2 250 m asl (Asmiwyati *et al*., 2015). Mount Batukaru as a barrier, causing this area to be a rain shadow. Enyew and Steenveld (2014) state that rainfall in an area is influenced by topographical factors and mountain ranges. Decreasing the height of the mountains, provides a reduction in the maximum level of rainfall over the mountains and foothills by 50 % (Flesch and Reuter, 2012). Topographical factors and regional weather systems have an important role in the amount and spatial pattern of rainfall in an area (Enyew and Steenveld, 2014).

**Table 4.** The annual rainfall in the six study sites (2015 to 2019)

| Year | Tabanan: T (mm yr $^{-1}$) | | | Karangasem: K (mm yr $^{-1}$) | | |
|---|---|---|---|---|---|---|
| | T < 560 | T 560 to 650 | T > 650 | K < 560 | K 560 to 650 | K > 650 |
| 2015 | 2 001.0 | 2 462.7 | 2 633.0 | 2 470.5 | 2 714.0 | 3 291.0 |
| 2016 | 2 095.0 | 2 453.5 | 3 049.5 | 2 659.0 | 2 885.0 | 3 800.0 |
| 2017 | 1 958.0 | 2 152.5 | 2 135.0 | 2 903.0 | 3 173.0 | 3 500.0 |
| 2018 | 2 335.5 | 2 463.9 | 2 955.0 | 3 002.0 | 3 057.0 | 3 200.0 |
| 2019 | 2 905.0 | 2 462.0 | 3 088.0 | 3 200.0 | 3 422.0 | 3 562.0 |
| Average | 2 258.9 | 2 398.92 | 2 772.1 | 2846.9 | 3 050.2 | 3 470.6 |

Based on the growing requirements of salak plants, rainfall and air temperature in the six locations evaluated were in the very suitable range to support plant growth and development. A good air temperature for the growth of salak plants is between 20 °C to 30 °C and an average rainfall of (200 to 400) mm mo$^{-1}$ (Nuary *et al*., 2019).

Soil C-organic content in six planting sites was in the medium to high range. Availability of N and P nutrients in salak plantations in Tabanan in the lowlands, medium and highlands in low to very low conditions. Salak planting land in Karangasem, both in the lowlands, medium and highlands, these two nutrients are available in moderate conditions (Table 3). The nutrient content of potassium available in the six planting locations that have been evaluated shows a very low value. The results of this study indicate that the cultivation techniques carried out by farmers are very low. Farmers do not apply an fertilizers that only rely on litter from the pruning of salak midrib as reported by Ilmiah *et al*. (2021), Rai *et al.* (2014), and Warnita *et al.* (2019). To cultivate sustainable agriculture, especially in agroecosystems salak in Bali. The authors will discuss this issue more in the future research paragraph.

*3.2 Characteristics of Salak 'Gulapasir'*

The salak 'Gulapasir' his monoecius plant, namely male and female flowers arranged on the same bunches, the shape of the bunches is compound, and the position of the flower is on the back of the midrib. The salak 'Gulapasir' is classified as special because of its sweet fruit taste and the price per unit weight is four times more expensive than the salak 'Bali' (Rai *et al*., 2014; Sumantra *et al*., 2012). The expansion of the cultivation of the salak 'Gulapasir' from its area of origin, Sibetan, Karangasem, has resulted in phenotypic diversity with a phenotypic similarity level of 58.62 % to 93.10 % (Sumantra and Martiningsih, 2016). In the same garden, more than one type of 'Gulapasir' salak appears, depending on fruit shape, aroma, color of fruit flesh and fruit weight (Sumantra and Martiningsih, 2016). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seed, so new variants of salak 'Gulapasir' appear with local names such as salak 'Gulapasir' nenas, salak 'Gulapasir' gondok and salak 'Gulapasir' nangka. The striking difference between these three varieties lies in the shape and flesh of the fruit. The number of fruit branches of salak 'Gulapasir' nangka, 1 to 2 branches, salak 'Gulapasir' nenas amount of 2 to 4 branches and salak 'Gulapasir' gondok the fruit bunches that do not form fruit branches. Salak 'Gulapasir', which is ready to harvest, has fruit flesh attached to the seed, and the fruit flesh is 0.63 cm thick. Meanwhile, the flesh of the salak 'Gulapasir' nenas is the thinnest and the seeds are attached to the flesh. Meanwhile, when the salak ‘Gulapasir’ gondok is ready to harvest, the seeds make a sound when shaken (Figure 3).


**Fig. 3.** The shape  and the thickness of the fruit flesh of SGP.var.nenas, gondok and nangka


**Fig. 4.** The shape of the bunch and the number of fuits  of SGP var. gondok,nenas, and nangka

*3.3* Agronomic characteristics of ‘Gulapasir’ Salak

Analysis of variance showed that the interaction between planting locations and  varieties of ‘Gulapasir’ salak  had significant effect on the number of fruits per bunch, fruit weight per tree, fruit weight per fruit, number of fruits per bunch, the ratio of sugar and acid and vitamin C content. Meanwhile, the thick fruit flesh and tannins content was not significant (Table 5)

**Table 5.** Recapitulation of the effects of varieties and growing locations on agronomic and fruits quality of 'Gulapasir' salak

| No. | Character agronomic and fruits quality | Planting location | Varieties | Varieties x Location |
|---|---|---|---|---|
| 1 | Length of the flower sheath | ** | ** | * |
| 2 | Number of fruit bunches $^{-1}$ | ** | ** | * |
| 3 | Fruit tree weight $^{-1}$ | ** | ** | * |
| 4 | Fruit weight $^{-1}$ | ** | ** | * |
| 5 | TSS ratio and total acid | ** | ** | ** |
| 6 | Thick fruit flesh | ** | ** | Ns |
| 7 | Vitamin C | Ns | Ns | * |
| 8 | Tannins | Ns | Ns | Ns |
| 9 | Edible portion | ** | ** | Ns |

Notes: *) significant $P < 0.05$, **) very significant $P < 0.01$ and Ns) not significantly different $P > 0.05$

The interaction of varieties and planting location had a significant effect on the length of the flower sheath and the number of fruit bunches $^{-1}$. Nenas variety grown in Tabanan (T < 560, T 560 to 650, and T > 650 ) and Karangasem (K < 560, K560 to 650, and K > 650) showed higher sheath length and a number of fruit bunches$^{-1}$ than with nangka and gondok varieties (Table 6). Tabanan (T 560 to 650) and Karangasem (K<560 m asl) are ideal conditions for flower sheath development and fruit development of nenas.

**Table 6.** Flower sheath length (cm) and a number of fruit bunches $^{-1}$ (fruit) of nangka, gondok and nenas varieties at six locations.

| **Treatment** | **Sheath length (cm)** | **Amount fruit bunches $^{-1}$** |
|---|---|---|
| NT < 560 | 27.50 $\pm$ 0.34 bcd | 19.55 $\pm$ 0.82 hij |
| NT 560 to 650 | 28.83 $\pm$ 1.31 b | 20.39 $\pm$ 1.00 g |
| NT > 650 | 27.17 $\pm$ 0.96 cde | 19.02 $\pm$ 0.82 j |
| NK < 560 | 26.00 $\pm$ 0.82 e | 21.13 $\pm$ 0.82 ef |
| NK 560 to 50 | 27.17 $\pm$ 0.14 cde | 22.28$\pm$ 2.45 c |
| NK > 650 | 26.67 $\pm$ 1.36 cde | 21.13 $\pm$ 0.74 ef |
| GT < 560 | 26.67 $\pm$ 2.18 cde | 20.22 $\pm$ 0.31 gh |
| GT 560 to 650 | 27.50 $\pm$ 1.22 bcd | 20.55 $\pm$ 0.62 fg |
| GT > 650 | 27.70 $\pm$ 1.98 bc | 19.22 $\pm$ 0.74 ij |
| GK< 560 | 25.83 $\pm$ 1.41 e | 21.89 $\pm$ 0.82 cd |
| GK 560 to 650 | 26.83 $\pm$ 0.75 cde | 20.5 $\pm$ 1.63 fg |
| GK > 650 | 27.5 $\pm$ 0.82 bcd | 21.28 $\pm$ 0.78 def |

| | | |
|---|---|---|
| NST < 560 | 27.5 ± 0.82 bcd | 21.41 ± 0.91 de |
| NST 560 to 650 | 27.67 ± 0.82 bc | 22.00 ± 1.56 cd |
| NST > 650 | 26.17 ± 2.16 de | 19.91 ± 1.36 ghi |
| NSK < 560 | 32.00 ± 1.63 a | 25.27± 1.41 a |
| NSK 560 to 650 | 30.90 ± 2.10 a | 24.00 ± 0.82 b |
| NSK > 650 | 27.00 ± 1.47 cde | 21.86 ± 0.82 cde |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

From Table 6 above it can be explained that the three varieties planted in six locations produced a number of fruits between 19.02 to 25.27 fruits per bunch. The nenas variety planted in Karangasem at an altitude of < 560 m asl (treatment NSK < 560) produced the highest number of fruits of 25.27 per bunch, followed by NSK 560 to 650 and NST 560 to 650 with 24.00 and 22.00 fruits per bunch. In order for the salak plants to bear much fruit, the nangka variety is ideal in Karangasem 560 to 650 m asl (NK 560 to 650), while the gondok variety is very good when planted below 560 m asl (GK < 560) although the number of fruits is not significantly different from the same altitude for NT 560 to 650 and GT < 560. The results of this study are in line with the findings of Sumantra and Martiningsih (2016) that the 'Gulapasir' salak var. nenas produces the highest number of fruits both in the on season (*gadu* season) and -off-season (*sela* season). Sumantra *et al*. (2014) reported that the emergence of new sheaths occurred on the third or fourth leaf midrib from the growing point depending on the altitude and plant conditions. The time for new sheaths to appear ranges from 129.00 d to145.10 d with the required heat units between (1 233.62 to 1 047.90) Degree-Day (DD). The higher altitude, the longer the sheath appears, as well as the harvest time.

The interaction of varieties and planting location had a significant effect on the fruit weigh (fruit tree$^{-1}$ and fruit$^{-1}$). Nangka variety grown in Tabanan (T < 560, T 560 to 650, and T > 650) and Karangasem (K < 560, K 560 to 650, and K > 650) showed higher of weight of fruit tree$^{-1}$ and fruit-$^{1}$ than with nenas and gondok (Table 7).

**Table 7**. Fruit weight of nangka, gondok, and nenas varieties in six locations

| Treatment | Fruit$^{-1}$ (g) | Fruit tree-$^{1}$ (kg) |
|---|---|---|
| NT < 560 | 45.32 ± 1.08 cd | 1.19 ± 0.08 def |
| NT 560 to 650 | 48.56 ± 0.71 c | 1.29 ± 0.07 cd |
| NT > 650 | 38.22 ± 0.46 ef | 1.03 ± 0.06 ghi |
| NK < 560 | 55.84 ± 1.37 a | 1.48 ± 0.02 b |
| NK 560 to 650 | 59.43 ± 0.71 a | 1.62 ± 0.07 a |
| NK > 650 | 49.4 ±1.65 b | 1.34 ± 0.05 c |
| GT < 560 | 40.14 ± 0.11 e | 1.11± 0.09 fg |
| GT 560 to 650 | 38.67 ± 0.55 ef | 1.09 ± 0.07 fg |
| GT > 650 | 32.95 ± 0.73 gh | 0.93 ± 0.10 i |
| GK < 560 | 44.22 ± 0.18 d | 1.27 ± 0.06 cde |
| GK 560 to 650 | 38.20 ± 0.78 ef | 1.16 ± 0.05 defg |
| GK > 650 | 36.20 ± 0.75 fg | 1.07 ± 0.11 fgh |
| NST < 560 | 39.00 ± 1.07 ef | 1.14 ± 0.11 efg |
| NST 560 to 650 | 37.79 ± 0.65 f | 1.13 ± 0.06 g |
| NST > 650 | 32.12 ± 0.11 h | 0.94 ± 0.10 hi |
| NSK < 560 | 41.80 ± 0.65 de | 1.36 ± 0.08 bc |
| NSK 560 to 650 | 36.57 ± 0.80 fg | 1.18 ± 0.09 def |
| NSK > 650 | 37.10 ± 0.23 f | 1.11 ± 0.07 fg |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

From Table 7 it can be explained that the three varieties grown in six locations produced fruit weight per tree between 0.93 kg and 1.62 kg. The salak nangka variety planted in Karangasem at an altitude of 560 to 650 m asl (NK 560 to 650) produced the heaviest fruit weight of 1.62 kg tree$^{-1}$, followed by NK < 560 and NT 560 to 650 with fruit weights of 1.48 and 1.29 kg. While the nenas variety produces the best fruit at altitudes < 560 m asl (NSK < 560 and NT < 560). Salak 'Gulapasir' var. gondok is ideal when planted at altitudes < 560 m asl (GK < 560 and GT < 560), although the two growing locations showed a different yields.

Nenas and gondok varieties showed a trend of decreasing fruit weight in line with increasing altitude, both planted in Karangasem and Tabanan. The reverse occurred in the salak nangka variety, an increase in altitude from 550 m asl to 550 to 650 m asl caused an increase in fruit weight and after that the fruit weight decreased when planted at altitudes >

650 m asl. This finding is in line with the results of research that has been reported by Sumantra *et al*. (2014). However, for the gondok and nenas varieties, this is a new finding.

Apart from being influenced by environmental factors, the production of salak 'Gulapasir' fruit is also influenced by internal plant factors (Adelina *et al*., 2021b: Lestari *et al*. 2011). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019), and rainfall (Ritonga *et al*., 2018). Altitude increases, the average daily air temperature decreases and monthly rainfall increases (Table 3). Nuary *et al.* (2019) stated that the distribution and adaptation of salak plants is strongly influenced by temperature and rainfall. It was further stated, the contribution of daily temperature accounts for nearly 38.6 % while rainfall is 27.8 %. Kanzaria *et al.* (2015) reported that mango plants planted at an altitude of 229 m flowered slower than those at an altitude of 148 m and 81 m asl. The temperature regime at higher altitudes is colder than at lower altitudes. Lower temperatures accumulate less growing degree day (GDD) and may result in late flowering. Table 7 shows that the 'Gulapasir' salak planted in Karangasem produced a higher fruit weight in the three salak varieties tested. This is related to the level of soil fertility. The soil nitrogen and phosphate nutrient content at three locations in Karangasem was higher than at three locations in Tabanan. Meanwhile, the potassium content in the six research locations was low (Table 3). Therefore it is necessary to make improvements by providing fertilizers containing elements of N, P and K to meet ideal conditions for growth, although more data is needed to fully support this conclusion (Hailu *et al.*, 2015).

*3.4 Quality characteristics of salak varieties*

The interaction between varieties and altitude significantly affected sugar/total acid and vitamin C content. The three varieties grown in Tabanan (T < 560, T 560 to 650 and T > 650) showed a lower TSS/acid ratio. The fruit flavour planted in three locations in Tabanan is sourer than the three locations in Karangasem. Sugar content is greatly affected by the geographical. The geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity, and rainfall (Ritonga *et al*., 2018). Table 8 also shows that the increase in altitude from 550 m to 700 m asl in Tabanan and the addition in altitude from 550 to 650 m asl in Karangasem causes the sugar/acid ratio decrease in all three varieties, and the lowest sugar/acid value occurs in nenas variety in all locations. Each salak variety has an adaptation to an elevation closely related to plant tolerance to temperature (Sumantra and Martiningsih, 2016; 2018). Many factors influence fruit quality, but the most dominant are climate factors, especially temperature and rainfall. High rainfall and low air temperature during the fruit ripening phase can cause the dissolved solids in the fruit to become watery so that the TSS value is low (Singh *et al*., 2011).

Salak fruits from three different varieties grown in low lands in Karangasem (K < 560 m asl) showed the highest vitamin C content and were significantly different from the three cultivars when planted in other locations. In both areas land increased by > 650 m asl effects to vitamin C decrease, nangka and gondok varieties showed higher levels of vitamin C between < 550 m to < 650 m asl. (Table 8).

**Table 8.** TSS/acid ratio and levels of vitamin C of nangka, gondok, and nenas varieties in six locations.

| Treatment | TSS/T.Acid | Vit. C (mg /100g) |
|---|---|---|
| NT < 560 | 56.20 ± 0.16 abc | 27.50 ± 0.41 bde |
| NT 560 to 650 | 59.18 ± 0.82 a | 25.45 ± 0.37 defgh |
| NT > 650 | 37.89 ± 0.91 f | 22.52 ± 0.39 j |
| NK < 560 | 51.41 ± 0.33 cde | 27.74 ± 0.47 bd |
| NK 560 to 650 | 53.52± 0.82 abcd | 29.61 ± 0.50 ab |
| NK > 650 | 47.76 ± 0.11 de | 24.25 ± 0.20 fghij |
| GT < 560 | 34.88± 0.72 fg | 25.50 ± 0.41 defgh |
| GT 560 to 650 | 34.80 ± 0.65 fg | 25.75 ± 0.20 defgh |
| GT > 650 | 30.24 ± 0.20 gh | 23.34 ± 0.28 hij |
| GK < 560 | 51.28 ± 0.23 cde | 30.31 ± 0.25 a |
| GK 560 to 650 | 58.44 ± 0.36 ab | 27.63 ± 0.30 bd |

| | | |
|---|---|---|
| GK > 650 | 53.04 ± 0.82 bcde | 25.07 ± 0.33 efgh |
| NST < 560 | 31.50 ± 0.41 gh | 26.71± 0.21 cdef |
| NST 560 to 650 | 30.44 ± 0.36 gh | 25.88 ± 0.41 defg |
| NST > 650 | 26.13 ± 0.11 h | 23.65 ± 0.29 ghij |
| NSK < 560 | 53.73 ± 0.60 abc | 24.42 ± 0.34 fghij |
| NSK 560 to 650 | 52.63 ± 0.51 bcde | 22.82 ± 0.15 ij |
| NSK > 650 | 47.60 ± 0.49 e | 25.16 ± 0.13 efgh |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

The results showed that the varieties of the 'Gulapasir' salak needs different environmental requirements to optimize yields. Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al*., 2021, 2022). Therefore, variety differences may depend on growing requirements and cultivation techniques. Vitamin C in the 'Gulapasir' salak is strongly influenced by the altitude of the land. To produce high levels of vitamin C, the nangka and gondok varieties are ideal for planting at an altitude of 560 m to 650 m asl, while the nenas variety is ideal at a land altitude of < 560 m asl. However, changes in ascorbate levels during fruit ripening are species-dependent and environmental factors especially temperature and light (Fenech *et al*., 2019).

There was no interaction between varieties and altitude to the flesh thickness, edible fruit portion, and fruit sugar content. The nangka salak variety showed fruit quality, including TSS, edible parts of the fruit, and higher flesh thickness (Table 9).

**Table 9.** The effect of a single factor of varieties on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment | TSS ($^o$Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| Nangka | 16.59a | 72.50a | 0.63a |
| Gondok | 16.42a | 70.66ab | 0.59b |
| Nenas | 15.64b | 69.22b | 0.52c |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Salak grown in Karangasem both from the lowlands and the middle lands produces fruit thickness, and the edible portion of fruits is higher than plants in the highlands. This study indicates that the ideal growing place for salak plants is between 450 m to 650 m asl. This study is in line with several previous studies which explained that altitude affects the flowering process and fruit enlargement (Sophie *at al*., 2017; Spinardi *et al*., 2019; Widyastuti *et al*., 2022).

**Table 10.** The effect of a single factor of planting location on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment (m asl) | TSS ($^{o}$Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| T < 550 | 16.28a | 73.13a | 0.54c |
| T 550 to 650 | 16.27a | 69.89a | 0.58bc |
| T > 650 | 16.14a | 63.87b | 0.49d |
| K 550 | 16.81a | 73.15a | 0.61b |
| K 550 to 650 | 16.11a | 72.29a | 0.66a |
| K > 650 | 15.69a | 72.44a | 0.61b |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Further research can be applied using sustainable salak organic agriculture (Budiasa, 2014; Handayani, 2022; Nurhidayat *et al*., 2022; Rahmah *et al*., 2022; Wimatsari *et al*., 2019). Table 3 shows that salak cultivation in the research location still needs to implement sustainable farming (Prasetyo *et al*., 2022b; 2022a). There are indications some of decrease in soil fertility, especially potassium available in the six planting locations that shows a very low value. Potassium levels in Table 3 are lower than the observations of Ashari (2013) and Woran *et al.* (2018) in salak cultivation areas in Swaru – Malang (very high), Sleman – Yogya (moderate), Bangkalan – Madura (very high), and Pangu – Minahasa (moderate).

Potassium helps produce good fruit quality, such as bigger, heavier, and sweeter fruit. Another benefit of the nutrient potassium in plants is to increase the growth of meristem tissue and regulate the movement of stomata. Potassium also helps the development of plant roots so that plant stems can stand upright and do not collapse easily (Adinurani *et al.*, 2018; Budiono *et al*., 2019). Therefore, Nasution (2022) recommends more $K_20$ fertilizer than $P_20_5$ fertilizer and N fertilizer. In addition, salak needs 70 kg of $K_2O$ because this nutrient is found in the leaves at an amount (12.2 to 14.7) mg $g^{-1}$ (Ashari, 2013).

The chemical fertilizers (e.g., KCl) are too expensive for Salak farmers and do not support the salak organic. Therefore, the application of sustainable farming should apply local wisdom including the use of the pruning of salak midrib. Consider this policy because C organic is essential to soil fertility (Budiono *et al*. 2021; Goenadi *et al*. 2021). The success of this midrib decomposition is demonstrated by the C organic in Table 3, which is classified as medium to high. This finding support Faizah and Fauzan (2021), Saputra *et al.* (2018) in salak plantation of Purwosari District - Pasuruan Regency, and Wonosalam District – Jombang Regency.

But, in the next stage, some of the salak midribs should be burned into ashes which can be used as a source of potassium nutrients (Ekawati and Purwanto, 2012; Vincevica-Gaile *et al*., 2021a, 2021b). Another organic source of potassium is the pulp/husk of coffee cherries. Karangasem and Tabanan districts are coffee cultivation areas in Bali, so they should take advantage of this coffee processing waste. Several researchers stated that coffee pulp/husk contains higher potassium than nitrogen or phosphorus nutrients (Bahri *et al*., Falahuddin *et al*., 2016; Novita *et al.*, 2018; Setyobudi *et al*., 2018).

Several researchers (Analianasari *et al*. 2022; Ningsih, 2020; Wachisbu, 2020) recommend soaking the pulp/husk coffee cherries and uses as liquid organic fertilizer with benefits for various plants. To develop this idea, salak farmers in Karangasem and Tabanan Regency should create biogas as household or communal scale digesters (Prespa *et al*., 2020; Setyobudi *et al.* 2021b; Susanto *et al*., 2020a) or use digesters from used drums (Adinurani *et al*., 2017; Hendroko *et al*., 2013). All household organic waste is processed in the digester, including kitchen waste, leftover food, and human excrement from pit latrines and septic tank

(Anukam and Nyamukamba, 2022; Somorin, 2020; Susanto *et al*., 2020b; Zhou *et al*., 2022). This action has various advantages, namely reducing global warming, obtaining clean - renewable energy, and two kinds of organic fertilizer, i.e., liquid and solid (Abdullah *et al*., 2020; Burlakovs *et al*., 2022; Hendroko *et al*., 2014; Prespa *et al*., 2020; Setyobudi, *et al*., 2018). In addition, many researchers have reported (among other things Benyahya *et al*., 2022; Baştabak and Koça, 2020; Li *et al*., 2021) the benefits of organic fertilizers from biogas digesters.

Another measure to increase and maintain land fertility is in salak cultivation, namely the application of Plant Growth Promoting Rhizobacteria (PGPR) or biological fertilizer (Basu *et al*., 2021; Ekawati, *et al*., 2019). Several researchers (Adinurani *et al*., 2021; Kumalawati *et al*., 2021; Muhammad *et al*. 2021) have reported using mycorrhiza, which positively impacts various plants, including salak cultivation (Amnah and Friska, 2018; Dewi *et al*., 2020; Rai *et al*., 2021). Multiplication of mycorrhiza is relatively simple (Sportes *et al*., 2021; Sukmawati *et al*., 2021) and can be done by farmer groups with initial guidance from universities.

## 4. Conclusion and Recommendation

Different cultivars caused different fruit weights, fruit bunches, and the sugar/acid ratio at various locations. The three varieties showed lower fruit weight and fruit quality in Tabanan (low, medium, and highlands) than the salak originating from Karangasem. The nangka variety in Karangasem showed higher fruit weight, vitamin C content, and sugar/ acid ratio, while the nenas salak showed the highest number of fruit bunches$^{-1}$ in six locations. Nangka salak are very suitable to be planted at an altitude of 550 m to 650 m asl. In contrast, the nenas and gondok varieties are developed naturally at low altitudes < 550 m asl. In order for all cultivars to be able to produce optimally, efforts to improve the cultivation system are needed through fertilization and the provision of calcium is highly recommended. Further research can be applied using sustainable salak organic agriculture to maintain soil fertility.

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# POTENTIAL RIVIEWERS

**Riviewer and author :**

**Title article : Agronomic Characters and Quality of Fruit of Some Cultivars Salak Gulapasir Planted in Different Agro-Ecosystems**

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|---|---|---|---|
| | | fruiting physiology, and off-season fruit production | |

# Tahap 6 : Proses Proses Riview dan Revisi tanggal Feb 2023 – Maret 2023

ROBUTTAL DARI REF-1 DAN REF-2 DISAJIKAN PADA BAGIAN HALAMAN AKHIR

Jordan Journal of Biological Sciences (JJBS)
ISSN 1995- 6673 (Print), 2307- 7166 (Online)
http://jjbs.hu.edu.jo
Scientific Research and Innovation Support Fund
Jordan Journal of Biological Sciences
Hashemite University
Deanship of Scientific Research

**Manuscript Evaluation Report- Referee2**

**Manuscript ID: JJBS 131/22** **Due date: March 22, 2023**

**MS Title: Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Different Agro-Ecosystems**

**Type of Article**: ☐ Review Article ☐ **Research Paper** ☐ Case Report

**PART A:**

**On a scale of 1 – 5 (1 being lowest and 5 being highest), rate the manuscript based on the following criteria;**

| NO. | Criteria | Score |
|---|---|---|
| 1 | **Is the topic of the manuscript within the scope of the journal?** | 4 |
| 2 | **Does the title clearly and sufficiently reflect its content?** | 4 (but requires slight revision) |
| 3 | **Are the keywords and abstracts sufficient and informative?** | 4 (but requires slight revision) |
| 4 | **What is the scholarly quality of the manuscript?** | 4 (requires minor revision) |
| 5 | **Is this a new and/ or original contribution?** | 5 |
| 6 | **Is the research methodology utilized appropriate and properly administered?** | 5 |
| 7 | **Are the methods of data analysis acceptable?** | 5 |
| 8 | **Are the results and conclusions clear, adequately presented, and organized in relation to rest of manuscript?** | 4 (requires minor revision) |
| 9 | **Are the illustrations and tables necessary and in an acceptable format?** | 4 (requires minor revision) |
| 10 | **Are the interpretations/ conclusions sound and justified by the data?** | 4 (requires minor revision) |
| 11 | **Are the References in a proper format according to JJBS author Instructions?** | 5 |
| 12 | **Is the MS written in correct and satisfactory English?** | 3 (requires correction and thorough checking). Please check the manuscript corrections in track |

| | | |
|---|---|---|
| | | changes, as an example. |

**Please rate the priority for publication of this article (10 is the highest priority, 1 is the lowest priority)**

| |
|---|
| **8** |

**PART B: Comments per Section of Manuscript**:

| | |
|---|---|
| **Abstract** | Sufficient but requires an enrichment with quantitative data on the results part.<br><br>The keywords require to be added with other keyword reflecting fruit quality and remove similar category (many on salak cultivar names) as the journal allows up to 8 keywords. |
| **Introduction** | Requires an enrichment on more clearly with the problem to address |
| **Methodology** | Sufficient |
| **Results** | Sufficient but requires a variation in showing the data by changing several tables into graphs or charts to make them more interesting and not to monotonous. Please add a table, if possible, (otherwise in a discussion) the correlation between the quality of fruits and the growth conditions (soil, climate, agroecosystem in general). |
| **Discussion and Conclusion** | requires a change of the wording as the sentences should NOT be the same as presenting the results but should relate with the reason why they are the best. In addition, it should also refer to the problem addressed in the Introduction as it should solve or partly solve the problem and refer the research objectives or the aims as well as include future work and provide a recommendation. |
| **References** | Sufficient |

**PART C: Recommendation ( Kindly Mark With An ✓ )**

| | |
|---|---|
| **Acceptable in its Present Form** | |

| | |
|---|---|
| **Acceptable with Minor Revision** | v |
| **Reconsidered after Major Revision** | |
| **Reject on Ground of ( Please be Specific)** | |

**<u>PART D: Additional Comments:</u>**

Please add any other additional comments or specific suggestions on the enclosed comments sheet:

| |
|---|
| The topic of the manuscript is important and it requires research. If the information in the Introduction is valid, no publication yet on Salak gula pasir of the cultivars or varieties studied and the locations of the studied areas were different and the inclusion of fruit quality is adding the value, the publication of this manuscript is necessary. The results of the research conducted also interesting but requires more discussion on the correlation of the fruit quality with soil or climate or agroecosystem condition. With minor corrections, the manuscript could be approved for publication if corrections are made based on the comments or review.<br>Other corrections were directly on the manuscripts using track changes mode. Please refer to the corrected/reviewed manuscript. |

# Jordan Journal of Biological Sciences (JJBS)
**ISSN 1995- 6673 (Print), 2307- 7166 (Online)**

**http://jjbs.hu.edu.jo**

**Scientific Research and Innovation Support Fund** | **Hashemite University**
**Jordan Journal of Biological Sciences** | **Deanship of Scientific Research**


**Manuscript Evaluation Report- Referee 1**

**Manuscript ID: JJBS 131/R2/22** **Due date: Feb 6, 2023**

**MS Title**: **Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Different Agro-Ecosystems**

**Type of Article**: ☐ Review Article ☐ **Research Paper** ☐ Case Report

**PART A:**

**On a scale of 1 – 5 (1 being lowest and 5 being highest), rate the manuscript based on the following criteria**;

| NO. | Criteria | Score |
|---|---|---|
| 1 | **Is the topic of the manuscript within the scope of the journal?** | 7 |
| 2 | **Does the title clearly and sufficiently reflect its content?** | 8 |
| 3 | **Are the keywords and abstracts sufficient and informative?** | 8 |
| 4 | **What is the scholarly quality of the manuscript?** | 7 |
| 5 | **Is this a new and/ or original contribution?** | 8 |
| 6 | **Is the research methodology utilized appropriate and properly administered?** | 7 |
| 7 | **Are the methods of data analysis acceptable?** | 7 |
| 8 | **Are the results and conclusions clear, adequately presented, and organized in relation to rest of manuscript?** | 8 |
| 9 | **Are the illustrations and tables necessary and in an acceptable format?** | 7 |
| 10 | **Are the interpretations/ conclusions sound and justified by the data?** | 7 |
| 11 | **Are the References in a proper format according to JJBS author Instructions?** | 8 |
| 12 | **Is the MS written in correct and satisfactory English?** | 7 |

**Please rate the priority for publication of this article (10 is the highest priority, 1 is the lowest priority)**

| |
|---|
| 7 |

**PART B: Comments per Section of Manuscript**:

| | |
|---|---|
| **Abstract** | The abstract describes the whole manuscript clearly, but still needs to clarify or avoid some confusing abbreviations/symbols such as "T" and "K". The abstract need to shorten the methodology part, so it can highlight the best results and some unique findings only. |
| **Introduction** | This part described the salak in a very well story and understandable. It delivered the general story of salak, then the "gulapasir" var, and finally some references to salak characteristics which will support the discussion part. |
| **Methodology** | Some equations can be removed to shorten this part, particularly which already cite some references |
| **Results** | • Data visualization needs to be improved to increase the attractiveness of the manuscript; too many tables in the presentation. It will be better if it changes into a graph or complex figure.<br>• There is no explanation and story related to Table 10, so it has to be removed, or provide more explanation about that Table.<br>• The paragraph after Table 10 should have a new subtitle since it describes a different topic from the previous paragraph of Table 10. That part discusses further research particularly related to organic farms, sustainable farms, and farm waste processing. Some parts can be moved as recommendations or suggestion part in the conclusion. |
| **Discussion and Conclusion** | The calcium addition was mentioned in the last part of the "conclusion and recommendation", but there is no discussion about that in the previous part. Potassium treatment is more appropriate to write in this conclusion than calcium since there are some discussions about it in the previous part. |
| **References** | It has sufficient references |

**PART C: Recommendation ( Kindly Mark With An ✓ )**

| | |
|---|---|
| **Acceptable in its Present Form** | |
| **Acceptable with Minor Revision** | ✓ |
| **Reconsidered after Major Revision** | |
| | |

| | |
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| **Reject on Ground of ( Please be Specific)** | |

**PART D: Additional Comments:**

Please add any other additional comments or specific suggestions on the enclosed comments sheet:

| |
|---|
| In general, the topic is very interesting and has good scholarly. The data of this manuscript is very rich and can answer the objective of the research. However, the visualization and presentation of data need to increase much to elevate the attractiveness of the paper. |

# RIVIEW FROM REFEREE



**Title:**

Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Different Agro-Ecosystems

**Commented [ES1]:** If the quality only specifically concerning the fruits, it is suggested to change the title to : Agronomic Characters and Fruit Quality of Salak cv Gulapasir Planted in VArious Agroecosystems

**Running Title:**

Assessment Salak Planted in Different Agro-Ecosystems

**Commented [ES2]:** Assessment of Salak cv. Gulapasir Fruit Quality and Agronomic Characters Planted in Different Agroecosystems


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# Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Different Agro-Ecosystems

Commented [ES3]: Please refer to the comment about the title


## ABSTRACT

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir has been officially released by the Minister of Agriculture of the Republic of Indonesia since 1994. Salak 'Gulapasir' is one of five types of fruit that have been designated as the superior fruit of the Bali Province. Salak 'Gulapasir' preferred by consumers due to its specific fruit flesh taste. Salak 'Gulapasir' was propagated using seeds so that a new types of salak emerged. However, the characters of this new type of salak 'Gulapasir' is not yet known. The research objective was to obtain the superior of some Salak 'Gulapasir' both in production and fruit quality. The research used a Randomized Block Design with three replications. The non-independent variable was the three of Salak 'Gulapasir' (SGP): SGP var. nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 to 650 m asl, and K > 650 m asl) and Tabanan (T): (T < 560 m asl, T 560 to 650 m asl, T > 650 m asl). Observations were made on the agronomic characters and fruit quality. Data were analyzed using variance analysis, and if the planting location and varieties show a difference, then it is followed by the LSD test at the 5 % level. The results showed that different varieties caused different fruit weights, fruit bunches, TSS, and total acid ratio. In Tabanan (in the low, medium, and highlands), the three varieties showed lower fruit weight and fruit quality than the salak originating from Karangasem. The SGP var. nangka in Karangasem showed higher fruit weight, vitamin C content, and TSS/total acid ratio, while the SGP var. nenas showed the highest number of fruit bunches$^{-1}$ in six locations. Further research can be applied using sustainable salak organic agriculture to maintain soil fertility.


Commented [ES4]: Should include quantitative values in the abstract, not just higher or highest

**Keywords :** Altitude, *Salacca zalacca* (Gaertn.) Voss, Salak 'Gulapasir' var. gondok, Salak 'Gulapasir' -var. nenas, Salak 'Gulapasir' var. nangka, Salak sustainable agriculture, Snake fruit, Tropical fruit, Fruit quality

**Commented [ES5]:** Keywords normally only 6-6 but here already dominated by salak of different cultivars. Would be better to include : fruit quality

## 1. Introduction

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir is one of the important fruits in Indonesia and the plant can be found in most regions of Indonesia (Rai *et al*. 2016; Ritonga *et al*., 2018). The salak fruit belong to the family Palmae or Arecaceae, and are native to the Indonesian-Malaysian region (Hakim *et al.,* 2019; Zumaidar *et al*., 2014). One of the extraordinary strengths of this fruit commodity for Indonesia is the possession of high genetic diversity (Budiyanti *et al*., 2019). Also, the nutrition of salak fruit is rich in antioxidants, phenolics, vitamins, and minerals (Cepkova *et al.,* 2021; Mazumdar *et al*., 2019), and a good source of income and provides livelihood opportunities on seasonal days (Khan and Idrees, 2021). The fruit flesh and peel have shown some tremendous anti-inflammatory, anticancer and antidiabetic (Saleh *et al*., 2018), and anti-ageing agents (Girsang *et al*., 2019). Antioxidants are chemical compounds that play an essential role in protecting cells due to attacks against free radicals-induced damage to biomolecules (Damat *et al*., 2019, 2020; Puspitasari and Ningsih, 2016; Setyobudi *et al*., 2019). Despite its incredible food and medicinal benefits, salak fruit is still underutilized and unknown globally. So that this underutilized fruit remains an issue for future sustainable utilization and commercial value enhancement market (Mazumdar *et al*., 2019). Fruit quality is an important issue, especially for products that are consumed raw and fresh. One of the problems is the lack of fruit quality because of inadequate information about superior salak (Budiyanti *et al*., 2019; Herawati *et al*., 2018). Therefore, it is necessary to select superior salak to meet market demand and fulfil community nutrition.

Salak ‘Bali’ is quite a lot, based on the shape, aroma, taste, and skin colour of the location where the plants are cultivated (Sumantra *et al*., 2012, 2014; Sumantra and Martiningsih, 2016, 2018). Under the Decree of the Minister of Agriculture of the Republic of Indonesia in 1994, Balinese zalacca was grouped into two superior zalacca: Salak ‘Bali’ (SK Mentan, 1994a) and Salak ‘Gulapasir’ (SK Mentan, 1994b). The second type, the salak ‘Gulapasir’ (SGP) is the most superior salak because of its sweet fruit taste; even though the age of the fruit is still young, thick fruit flesh and seeds are not attached to the fruit flesh (Rai *et al*., 2014; Sumantra *et al*., 2016). The nature of this fruit is ideal for meeting market demands for both the domestic and export markets (Martiningsih *et al*., 2018). Salak ‘Bali’ is monoecious, so crossing does not need human help (Herawati *et al*., 2018), and can quickly develop using seeds (Sumantra and Martiningsih, 2016). Another advantage of salak plants in Indonesia compared to other fruits is harvest fruit 2 to 3 times a year if management is good (Rai *et al*., 2016; Warnita *et al.*, 2019). The expansion of salak ‘Gulapasir’ planting causes variations in phenotypic diversity. People can find two to three types of salak plants with a marker, fruit shape, aroma, flesh colour, and fruit weight (Martiningsih *et al*., 2018). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seeds so that new varieties of salak ‘Gulapasir’ (SGP) appear, as reported by Sumantra and Martiningsih (2016). Based on the marker that can be used as a differentiator, salak farmers give it the name of SGP var. nenas, SGP var. gondok, and SGP var. nangka. The three varieties have not yet identified their advantages in meeting market needs in line with the results of research (Sumantra and Martiningsih, 2016). The performance and produce are influenced by the characteristics of the agricultural ecosystem, particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status (Adelina *et al.,* 2021a; Kumar *et al*., 2020) and growth hormone (Prihastanti and Haryanti. 2022; Rai *et al.,* 2016).

The salak ‘Gulapasir’ plantation in the District of Bebandem is the main producer of salak ‘Gulapasir’ in Bali is located in the southern part of Mount Agung with an altitude of 450 m to 700 m above sea level (m asl). The effect of altitude on plant growth and production is related to plant adaptation to temperature (Sumantra, *et al*., 2014), full sunlight (Sukawijaya *et al*., 2009), water status and soil quality (Raharjo *et al*., 2022; Rai *et al*., 2014; Ritonga *et al.*, 2018). Salak plants are not resistant to full sun but 50 % to 70 % enough, therefore it is necessary to have shade plants (Sukawijaya *et al*., 2009; Sumantra *et al*., 2012). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019). Water status and soil quality really determine the fruit set on the salak ‘Gulapasir’. Low rainfall reduces the Relative Water Content in leaves (RWC), leaf chlorophyll content, and plant nutrient uptake (Rai *et al*., 2014). soil quality included the suitability of the physical, chemical and biological properties (Raharjo *et al*., 2022). Nuary *et al*. (2019) stated that the distribution of the salak ‘Pondoh’ plantation area in Sleman (Yogyakarta, Special Region) was greatly influenced by temperature and rainfall. The contribution of temperature in the modelling reached 38.6 % while the rainfall was 27.8 %. Furthermore, taking into account the probability of the temperature variable, the average temperature ranges from 17.41 °C to 25.65 °C, and the ideal month's rainfall ranges from 385.24 mm to 505.01 mm.

Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al*., 2021, 2022). Therefore, varieties differences may depend on growing requirements and cultivation techniques. Likewise, Puspitasari *et al*. (2016) stated that tannin content, fruit size and flesh colour of salak fruit are strongly influenced by where it grows. Other studies also explain that salak ‘Gulapasir’ var. nangka which is grown 570 m asl, would result in a higher quality of fruit that includes thickness of the mesocarpium, edible portion of fruit then compared to above and below 570 m asl (Sumantra *et al*., 2014; Sumantra and Martiningsih, 2016). Meanwhile, fruit weight and fruit quality of var. gondok and var.

nenas have not been reported. Therefore, one way of handling salak quality is by undertaking severe studies for factors such as land and climate and adjusting agricultural patterns according to local climate conditions (Nassar *et al*., 2018). The success of each species to occupy the environment of an area is influenced by its ability to adapt optimally to all physical environmental factors (temperature, light, soil structure, humidity), biotic factors (interaction between species, competition, parasitism), and chemical factors including the availability of water, oxyge, pH, and nutrients (Nassar *et al*., 2018; Widyastuti *et al*., 2022). Moreover, a broad genetic variability would lead to wide phenotypic variability due to the effect of genetic-environment interaction (Ritonga *et al*., 2018). The research objective was to obtain several ~~the~~ superior ~~of some~~ salak 'Gulapasir' both in production and fruit quality (sugar and acid ratio, vitamin C and tannin) in six different agricultural ecosystems in Bali.

## 2. Materials and Methods

### *2.1 Experimental site*

The research was conducted in Tabanan and Karangasem Regencies. Tabanan and Karangasem were selected as research locations because the domination of salak 'Gulapasir' in these two regencies was the highest. In 2021, the salak 'Gulapasir' population in Tabanan is 84 % of all salak species, while in Karangasem Regency the dominance of the salak 'Gulapasir' is more than 63 % (Sumantra *et al*., 2022).

The study was carried out in six different locations, three sites in Karangasem Regency and three sites in the district of Tabanan. Locations in Karangasem (K) are lowlands (K < 560 m asl) which include several places, namely Telaga, Dukuh, and Karanganyar. Karangasem in the moderate plains (K 560 m to 650 m asl) has several areas, namely Kecing and Kutabali and highlands (K > 650 m asl), namely Tanah Apo and Kresek (Figure 1).

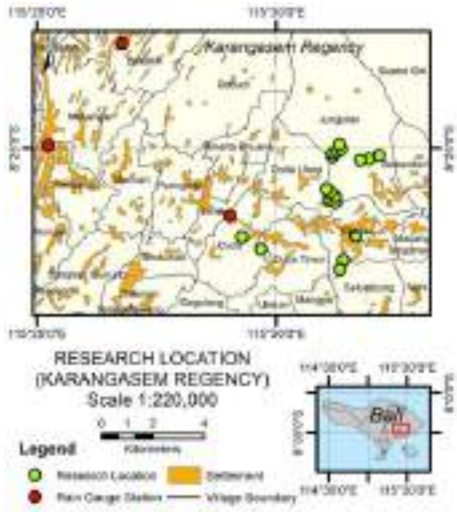


**Fig 1.** Research map and sampling point in Karangasem (K)

The research location is in Tabanan (T) in the lowlands (T < 560 m asl), including Wanagiri, Sari Buana, and Mundeh Kauh. Tabanan in the medium lands (T 560 m to 650 m asl) includes several places, namely Pajahan, Kebon Jero, and Angseri. Tabanan in the highlands (T > 650 m asl), namely Munduk Temu, Pempatan, and Batungsel (Figure 2).

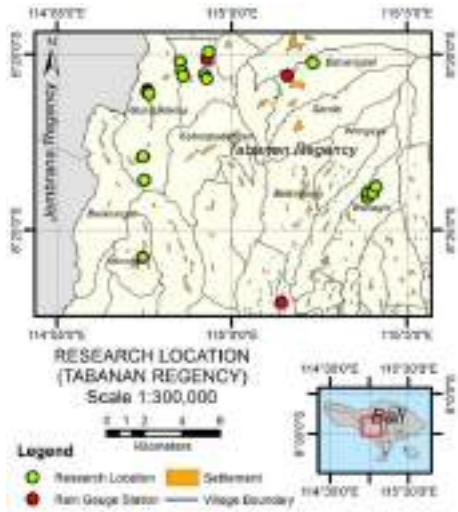

**Fig 2.** Research map and sampling point in Tabanan (T)

The non-independent variable was the three varieties of Salak 'Gulapasir' (SGP): SGP var.nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 m to 650 m asl, and K > 650 m asl) and Tabanan (T) : (T < 560 m asl, T 560 m to 650 m asl, T > 650 m) Repetition was carried out three times with the number of sample plants in each location, and cultivars were seven plants. The treatment tested is as shown in Table 1

**Table 1**. Treatment of plant location and three varieties of 'Gulapasir' salak

| No | Treatment | Explanation |
|---|---|---|
| 1 | NT< 560 m asl | Salak GP.var. nangka Tabanan < 560 m asl. |
| 2 | NT 560 m to 650 m asl | Salak GP.var. nangka Tabanan 560 m to 650 m asl. |
| 3 | NT > 650 m asl. | Salak GP.var. nangka Tabanan > 650 m asl. |
| 4 | NK < 560 m asl. | Salak GP.var. nangka Karangasem < 560 m asl. |
| 5 | NK 560 m to 650 m asl | Salak GP.var. nangka Karangasem 560 m to 650 m asl. |
| 6 | NK > 650 m asl. | Salak GP.var. nangka Karangasem > 650 m asl. |
| 7 | GT< 560 m asl | Salak GP var. gondok Tabanan < 560 m asl. |
| 8 | GT.560 to 650 m asl | Salak GP var. gondok Tabanan 560 m to 650 m asl. |
| 9 | GT > 650 m asl | Salak GP var. gondok Tabanan > 650 m asl. |
| 10 | GK.< 560 m asl | Salak GP var. gondok Karangasem < 560 m asl. |
| 11 | GK 560 m to 650 m asl | Salak GP var. gondok Karangasem 560 m to 650 m asl. |
| 12 | GK > 650 m asl | Salak GP var. gondok Karangasem > 650 m asl. |
| 13 | NST < 560 m asl | Salak GP var. nenas Tabanan < 560 m asl. |
| 14 | NST.560 m to 650 m asl | Salak GP var. nenas Tabanan 560 m to 650 m asl. |

| | | |
|---|---|---|
| 15 | NST > 650 m asl | Salak GP var. nenas Tabanan > 650 m asl. |
| 16 | NSK .< 560 m asl | Salak GP var. nenas Karangasem < 560 m asl. |
| 17 | NSK 560 m to 650 m asl | Salak GP var. nenas Karangasem 560 m to 650 m asl.. |
| 18 | NSK > 650 m asl | Salak GP var. nenas Karangasem > 650 m asl. |

The study used a Composite Analysis of Variance (Andinurani, 2016, 2022) with the model determined using Equation (1) below:

$$Yjk = u + L\,i + \delta\,ik + Pj + (LP)\,ij + \mathcal{E}\,ijk \qquad (1)$$

Where:

Yijk = The observation value of the treatment (j) in the group (k), which is repeated at the location (i).

u = the actual average value

Li = additive effect from location i

δ ik = the error effect in group k at location i

Pj = additive effect of the next treatment

(LP) ij = the effect of treatment (j) at the location (i)

Ɛ ijk = the effect of error from the treatment (j) in the group (k) which was carried out at the location (i).

*2.2 Preparation of study materials*

The material used is the salak 'Gulapasir' plant with uniform growth, plants have been fruitful with uniform on morphological, age of plants and cultivation action. The intentional practice is that the plant only receives treatment in the midrib, tillers, and weed cleaning. In this study, the plants were not fertilized. The provision of water was only from rainfall following the habits applied by salak farmers. The sample plant maintains by trimming unproductive leaf midribs and removing young shoots. Plant material was taken

from the Salak Development Centre in six locations, namely at the Centre of Salak Development in the Bebandem sub-districts, Karangasem district (K-lowland < 560 m asl, K-medium 560 m to 650 m asl and K-highland > 650 m asl), Bajre, West Slemadeg and Pupuan sub-districts, Tabanan district (T-lowland < 560 m asl, T-medium 560 to 650 m asl and T-highland > 650 m asl).

2.*3 Analysis of physicochemical properties of soil sample and climate*

Soil analysis was carried out to determine the physical and chemical properties of the soil. Soil sampling was carried out under sample plant trees, carried out in a composite manner at a depth of 0 cm to 40 cm. Chemical analysis was carried out on total N (Kjeldahl method), available P by Bray I method and $K_2O$ by the Bray I method, organic C, pH, soil physical properties in the form of texture by pipette method (Eviati and Sulaeman. 2009; Hailu *et al*., 2015; Prasetyo *et al*., 2022a; Rzasa and Owczarzak, 2013).

Rainfall data was taken for five years from 2015 to 2019. Rainfall data has been collected from six nearby stations to the research site (Table 2). Daily temperature data obtained from the Denpasar Meteorology Climatology Agency.

**Table 2**. Research locations and place of climatology stations

| Research Locations | Climate observation station | Latitude and altitude |
|---|---|---|
| Tabanan Lowlands (< 560 m asl) | Ampadan, Tiyinggading No.St. 439 m | 8°27'5.0688"S/ 115°1'25.086 "E; 400 m asl. |
| Tabanan Moderate (560 m to 650 m asl) | Coffee Breeding Center, Sai Pupuan No. St. 439 h | 08°20'08.6"S/ 114° 59'17.4" E; 580 m asl. |
| Tabanan Highlands (> 650 m asl) | Agricultural Extension Center, Pupuan. No St.441 h | 08°20'38.1" S/ 115°01'35.2" E; 750 m asl. |

| | | |
|---|---|---|
| Karangasem Lowlands (< 560 m asl) | Agricultural Extension Center, Selat. No. St. 444 d | 08°26'25" S / 115°29'02" E; 450 m asl. |
| Karangasem Moderate (560 m to 650 m asl) | Horticulture Seed Center, Singerata No.St. 442 | 08°24'57"S / 115°25'14"E; 580 m asl. |
| Karangasem Highlands (> 650 m asl) | Besakih Station. No.St.442 a | 08°22'49"S / 115°26'47"E; 800 m asl. |

*2.4 Observation of fruit and fruit quality*

Salak fruit can be harvested when it is ready for consumption. Consumable ripe fruit is a fruit that is ready to be consumed, characterized by a change in skin colour from dark brown to light brown, the thorns on the skin have reduced and are not sharp, and in general, at this stage, the fruit easily falls when shaken.

Observation and measurement of agronomic characters follow the method that has been done by Sumantra *et al*. (2014) including fruit weight, number of fruit bunches, the thickness of fruit flesh and fruit shape. The fruit characters from six-observed locations include the numbers of fruits per bunch, which is calculated manually on the formed fruits. The fruit weight per fruit and the fruit weight per tree is weighed after the fruits were removed from the bunch. The thickness of the mesocarpium is obtained by measuring the mesocarpium after it is cut vertically. The length of the flower sheath is measured on the stem of the sheath from the base to the tip of the sheath.

While fruit quality includes sugar content, tannins, titrated acid, sugar content and vitamin C. Titrated acid was analyzed by titration (Sripakdee *et al*., 2015). The fruit which was weighed 10 g of sample was added to 100 mL of distilled water, then was homogenized using a slow spin blender, and filtered using an aseptic filter. The filtrate obtained was taken as much as 25 mL, then titrated with 0.1 N NaOH solution with phenolphthalein indicator until red in colour appeared. The results obtained are calculated as the percentage tartaric acid is determined using Equation (2) below :

$$A = \frac{mL\ NaOH \times N\ NaOH \times P \times BM}{Y \times 1\ 000 \times 2} \times 100\ \% \qquad (2)$$

where:

A = percentage of total acid

P = amount of dilution

BM = molecular weight of tartaric acid

Y = sample weight (g).

Tannis content was analyzed as done by Thakur *et al*. (2021), Setyobudi *et al*. (2022). Amount of 100 mg of the sample was homogenized by 2 mL of methanol. Centrifuged for 10 min at 10 000 rpm (1 rpm = 1/60 Hz) and collected the supernatant. Amount of 1 mL of supernatant mixed with 0.5 mL Folin's phenol reagent and 35 % $Na_2CO_3$ of 5 mL added and the mixture was kept at room temperature for 5 min. The blue colour of the reaction mixture was observed at 640 nm by UV/visible spectrophotometer (Shimadzu UV-1800, Japan). The content of tannin was calculated by calibration curve equation and determined using Equation (3) below:

$$Y = 0.0073x-0.0071 : R^2 = 0.9973 \qquad (3)$$

Vitamin C was determined by titration like the method used by Asamara (2016), Setyobudi *et al.* (2021a, 2022). The material is weighed as much as 10 g and crushed in mortal. Then put into a 250 mL volumetric flask, set to the mark and filtered. Take 25 mL of the filtrate and titrate with 0.01 N Yod solution equivalent to 0.88 mg of ascorbic acid. The calculation of ascorbic acid content per 100 g of material is determined using Equation (4) below:

$$A = \frac{\text{mL Yod } 0.01 \text{ N} \times 0.88 \times P \times 100}{Y} \quad (4)$$

where: A = mg of ascorbic acid per 100 g of material

P = amount of dilution

Y = gram sample weight

Sugar content as TSS is calculated using a hand refractometer (Bellingham and Stanley Ltd., London) at 20 $^{o}$C.

The ratio of sugar content (TSS) and total acid is calculated by the sugar content divided by the acid content multiplied by 100 %.

The materials used in this study were Folin-Ciocalteu reagent (Pro Analytic, Merck), NaOH (Pro Analytic, Merck), $Na_2CO_3$ (Pro Analytic, Merck), Phenolphereagent ascorbic acid (Pro Analytic, Merck), Phosphoric Acid (Pro Analytic, Merck), Sodium Phosphate (Pro Analytic, Merck) and Ammonium Molybdate (Pro Analytic, Merck).

The tools used in this study were analytical balances (Shimadzu ATY224, Japan), centrifuge tubes, Erlenmeyer flasks (pyrex), dropper pipettes (pyrex), volume pipettes (pyrex), vortex (Maxi Mix II Type 367000), measuring flask (pyrex), water bath (Memmert), blender (Miyako), and centrifuge (Damon /IEC Division). Whatman filter paper No 1 (Sigma – Aldrich, USA), measuring cup (Pyrex, USA), micropipette (Dragon Lab, Indonesia), spectrophotometer (Biochromsn 133467, UK), test tube (Pyrex¸ USA), vortex (Barnsteadl Thermolyne Type 37600 Mixer, USA), aluminum foil (Klin Pak, Indonesia).

*2.5 Study design*

This study used a randomized block design with the data analyzed using a Composite Analysis of Variance. If the variance test is significantly different, then it is continued with a different test with LSD at the 5 % level. Data analysis was performed using SPSS-IBM 18 (Adinurani, 2016, 2022). Each experimental treatment was repeated three times.

## 3. Results and Discussion

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### *3.1 Agroclimate characteristic*

The low production level and quality of salak fruit are caused by environmental factors that do not support growth or because the physiological processes of the plant are not optimal due to insufficient nutrients and water. The suitability of climatic and soil conditions at six locations of the centres for the development of the 'Gulapasir' salak was evaluated. The evaluation results show that the air temperature decreases as the altitude increases. The average air temperature at the 'Gulapasir' salak plantation in Tabanan is 22.90 $^{o}$C, while the air temperature at the Karangasem salak plantation is around 23.24 $^{o}$C. (Tabel 3)

**Table 3.** Soil and climate characteristics of the research site in Tabanan and Karangasem in three subzones

| Parameter | Tabanan (T) | | | Karangasem (K) | | |
|---|---|---|---|---|---|---|
| | Lowlands (< 560 m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) | Lowlands (< 560m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) |
| Temp. ($^{o}$C) | 23.82 | 22.75 | 22.12 | 24.29 | 23.35 | 22.09 |
| Rainfall (mm mo$^{-1}$) | 188.24 | 199.91 | 231.008 | 237.242 | 254.183 | 289.216 |
| Soil texture | loamy clay | loamy clay | loamy clay | clay | clay | sandy loam |
| pH ($H_2O$) | 5.64(sa) | 5.75 (sa) | 5.84 (sa) | 6.08 (sa) | 6.05 (sa) | 6.03(sa) |
| C- organic (%) | 2.94(m) | 3.40 (h) | 3.25 (h) | 2.77 (m) | 3.63 (h) | 3.32 (h) |
| Nutrients available | | | | | | |
| N total (%) | 0.18 (l) | 0.16 (l) | 0.18 (l) | 0.24(m) | 0.23 (m) | 0.29 (m) |
| $P_2O_5$ (mg g$^{-1}$) | 9.38 (vl) | 9.12 (vl) | 13.50 (l) | 22.55 (m) | 24.18 (m) | 23.04 (m) |
| $K_2O$ (mg g$^{-1}$)) | 18.47 (vl) | 22.05 (vl) | 17.23 (vl) | 24.17 (vl) | 19.93 ( vl ) | 18.37 ( vl ) |

Notes: sa: slightly acidic; h: high; m: medium; l: low; vh: very high; h: high; asl: above sea level (The assessment criteria refer to Eviati and Sulaeman. 2009; PPT, 1983).

In addition to~~Likewise~~ monthly rainfall, the average rainfall over ~~the~~ 5 years is presented in Table Table 4. Annual rainfall in Tabanan (T < 560, T 560 to 650 and T > 650) is lower with an average of 2515.05 mm while in Karangasem (K < 560, K 560 to 650 and K > 650) it is 3 122.05 mm. However, the six locations show a trend of

Commented [ES7]: Should not be shortened increasing rainfall as altitude increases. The salak plantation area in Karangasem is in the southern part of Mount Agung. Meanwhile in Tabanan, the dominant salak plantation area is behind Mount Batukaru with a lower elevation than Mount Agung. Mount Agung with an altitude of 3 142 m asl (Andaru and Rau, 2019), while the Batukaru mountains area with an elevation 2 250 m asl (Asmiwyati *et al*., 2015). Mount Batukaru as a barrier, causing this area to be a rain shadow. Enyew and Steenveld (2014) state that rainfall in an area is influenced by topographical factors and mountain ranges. Decreasing the height of the mountains, provides a reduction in the maximum level of rainfall over the mountains and foothills by 50 % (Flesch and Reuter, 2012). Topographical factors and regional weather systems have an important role in the amount and spatial pattern of rainfall in an area (Enyew and Steenveld, 2014).

**Table 4.** The annual rainfall in the six study sites (2015 to 2019)

| Year | Tabanan: T (mm yr $^{-1}$) | | | Karangasem: K (mm yr $^{-1}$) | | |
|---|---|---|---|---|---|---|
| | T < 560 | T 560 to 650 | T > 650 | K < 560 | K 560 to 650 | K > 650 |
| 2015 | 2 001.0 | 2 462.7 | 2 633.0 | 2 470.5 | 2 714.0 | 3 291.0 |
| 2016 | 2 095.0 | 2 453.5 | 3 049.5 | 2 659.0 | 2 885.0 | 3 800.0 |
| 2017 | 1 958.0 | 2 152.5 | 2 135.0 | 2 903.0 | 3 173.0 | 3 500.0 |
| 2018 | 2 335.5 | 2 463.9 | 2 955.0 | 3 002.0 | 3 057.0 | 3 200.0 |
| 2019 | 2 905.0 | 2 462.0 | 3 088.0 | 3 200.0 | 3 422.0 | 3 562.0 |
| Average | 2 258.9 | 2 398.92 | 2 772.1 | 2846.9 | 3 050.2 | 3 470.6 |

Based on the growing requirements of salak plants, rainfall and air temperature in the six locations evaluated were in the very suitable range to support plant growth and development. A good air temperature for the growth of salak plants is between 20 °C to 30 °C and an average rainfall of (200 to 400) mm mo$^{-1}$ (Nuary *et al*., 2019).

Soil C-organic content in six planting sites was in the medium to high range. Availability of N and P nutrients in salak plantations in Tabanan in the lowlands, medium and highlands in low to very low conditions. Salak planting land in Karangasem, both in the lowlands, medium and highlands, these two nutrients are available in moderate conditions (Table 3). The nutrient content of potassium available in the six planting locations that have been evaluated shows a very low value. The results of this study indicate that the cultivation techniques carried out by farmers are very low. Farmers do not apply an fertilizers that only rely on litter from the pruning of salak midrib as reported by Ilmiah *et al*. (2021), Rai *et al.* (2014), and Warnita *et al.* (2019). To cultivate sustainable agriculture, especially in agroecosystems salak in Bali. The authors will discuss this issue more in the future research paragraph.

*3.2 Characteristics of Salak 'Gulapasir'*

**Commented [ES8]:** Need to be specified : what type of characters as the umbrella of the subtitle

The salak 'Gulapasir' his monoecius plant, namely male and female flowers arranged on the same bunches, the shape of the bunches is compound, and the position of the flower is on the back of the midrib. The salak 'Gulapasir' is classified as special because of its sweet fruit taste and the price per unit weight is four times more expensive than the salak 'Bali' (Rai *et al*., 2014; Sumantra *et al*., 2012). The expansion of the cultivation of the salak 'Gulapasir' from its area of origin, Sibetan, Karangasem, has resulted in phenotypic diversity with a phenotypic similarity level of 58.62 % to 93.10 % (Sumantra and Martiningsih, 2016). In the same garden, more than one type of 'Gulapasir' salak appears, depending on fruit shape, aroma, color of fruit flesh and fruit weight (Sumantra and Martiningsih, 2016). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seed, so new variants of salak 'Gulapasir' appear with local names such as salak 'Gulapasir' nenas, salak 'Gulapasir' gondok and salak 'Gulapasir' nangka. The striking difference between these three varieties lies in the shape and flesh of the fruit. The number of fruit branches of salak 'Gulapasir' nangka, 1 to 2 branches, salak 'Gulapasir' nenas amount of 2 to 4 branches and salak 'Gulapasir' gondok the fruit bunches that do not form fruit branches. Salak ‘Gulapasir’, which is ready to harvest, has fruit flesh attached to the seed, and the fruit flesh is 0.63 cm thick. Meanwhile, the flesh of the salak ‘Gulapasir’ nenas is the thinnest and the seeds are attached to the flesh. Meanwhile, when the salak ‘Gulapasir’ gondok is ready to harvest, the seeds make a sound when shaken (Figure 3).


**Fig. 3.** The shape and the thickness of the fruit flesh of SGP.var.nenas, gondok and nangka


**Fig. 4.** The shape of the bunch and the number of fuits of SGP var. gondok,nenas, and nangka

*3.3* Agronomic characteristics of ‘Gulapasir’ Salak

Analysis of variance showed that the interaction between planting locations and varieties of ‘Gulapasir’ salak had significant effect on the number of fruits per bunch, fruit weight per tree, fruit weight per fruit, number of fruits per bunch, the ratio of sugar and acid and vitamin C content. Meanwhile, the thick fruit flesh and tannins content was not significant (Table 5)

**Table 5.** Recapitulation of the effects of varieties and growing locations on agronomic and fruits quality of 'Gulapasir' salak

| No. | Character agronomic and fruits quality | Planting location | Varieties | Varieties x Location |
|---|---|---|---|---|
| 1 | Length of the flower sheath | ** | ** | * |
| 2 | Number of fruit bunches $^{-1}$ | ** | ** | * |
| 3 | Fruit tree weight $^{-1}$ | ** | ** | * |
| 4 | Fruit weight $^{-1}$ | ** | ** | * |
| 5 | TSS ratio and total acid | ** | ** | ** |
| 6 | Thick fruit flesh | ** | ** | Ns |
| 7 | Vitamin C | Ns | Ns | * |
| 8 | Tannins | Ns | Ns | Ns |
| 9 | Edible portion | ** | ** | Ns |

Notes: *) significant $P < 0.05$, **) very significant $P < 0.01$ and Ns) not significantly different $P > 0.05$

The interaction of varieties and planting location had a significant effect on the length of the flower sheath and the number of fruit bunches $^{-1}$. Nenas variety grown in Tabanan (T < 560, T 560 to 650, and T > 650 ) and Karangasem (K < 560, K560 to 650, and K > 650) showed higher sheath length and a number of fruit bunches$^{-1}$ than with nangka and gondok varieties (Table 6). Tabanan (T 560 to 650) and Karangasem (K<560 m asl) are ideal conditions for flower sheath development and fruit development of nenas.

**Table 6.** Flower sheath length (cm) and a number of fruit bunches $^{-1}$ (fruit) of nangka, gondok and nenas varieties at six locations.

| **Treatment** | **Sheath length (cm)** | **Amount fruit bunches $^{-1}$** |
|---|---|---|
| NT < 560 | 27.50 ± 0.34 bcd | 19.55 ± 0.82 hij |
| NT 560 to 650 | 28.83 ± 1.31 b | 20.39 ± 1.00 g |
| NT > 650 | 27.17 ± 0.96 cde | 19.02 ± 0.82 j |
| NK < 560 | 26.00 ± 0.82 e | 21.13 ± 0.82 ef |
| NK 560 to 50 | 27.17 ± 0.14 cde | 22.28± 2.45 c |
| NK > 650 | 26.67 ± 1.36 cde | 21.13 ± 0.74 ef |
| GT < 560 | 26.67 ± 2.18 cde | 20.22 ± 0.31 gh |
| GT 560 to 650 | 27.50 ± 1.22 bcd | 20.55 ± 0.62 fg |

| | | |
|---|---|---|
| GT > 650 | 27.70 + 1.98 bc | 19.22 + 0.74 ij |
| GK< 560 | 25.83 + 1.41 e | 21.89 + 0.82 cd |
| GK 560 to 650 | 26.83 + 0.75 cde | 20.5 + 1.63 fg |
| GK > 650 | 27.5 + 0.82 bcd | 21.28 + 0.78 def |
| NST < 560 | 27.5 + 0.82 bcd | 21.41 + 0.91 de |
| NST 560 to 650 | 27.67 + 0.82 bc | 22.00 + 1.56 cd |
| NST > 650 | 26.17 + 2.16 de | 19.91 + 1.36 ghi |
| NSK < 560 | 32.00 + 1.63 a | 25.27+ 1.41 a |
| NSK 560 to 650 | 30.90 + 2.10 a | 24.00 + 0.82 b |
| NSK > 650 | 27.00 + 1.47 cde | 21.86 + 0.82 cde |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

From Table 6 above it can be explained that the three varieties planted in six locations produced a number of fruits between 19.02 to 25.27 fruits per bunch. The nenas variety planted in Karangasem at an altitude of < 560 m asl (treatment NSK < 560) produced the highest number of fruits of 25.27 per bunch, followed by NSK 560 to 650 and NST 560 to 650 with 24.00 and 22.00 fruits per bunch. In order for the salak plants to bear much fruit, the nangka variety is ideal in Karangasem 560 to 650 m asl (NK 560 to 650), while the gondok variety is very good when planted below 560 m asl (GK < 560) although the number of fruits is not significantly different from the same altitude for NT 560 to 650 and GT < 560. The results of this study are in line with the findings of Sumantra and Martiningsih (2016) that the 'Gulapasir' salak var. nenas produces the highest number of fruits both in the on season (*gadu* season) and -off-season (*sela* season). Sumantra *et al*. (2014) reported that the emergence of new sheaths occurred on the third or fourth leaf midrib from the growing point depending on the altitude and plant conditions. The time for new sheaths to appear ranges from 129.00 d to145.10 d with the required heat units between (1 233.62 to 1 047.90) Degree-Day (DD). The higher altitude, the longer the sheath appears, as well as the harvest time.

The interaction of varieties and planting location had a significant effect on the fruit weigh (fruit tree$^{-1}$ and fruit$^{-1}$). Nangka variety grown in Tabanan (T < 560, T 560 to 650, and T > 650) and Karangasem (K < 560, K 560 to 650, and K > 650) showed higher of weight of fruit tree$^{-1}$ and fruit-$^{1}$ than with nenas and gondok (Table 7).

**Table 7**. Fruit weight of nangka, gondok, and nenas varieties in six locations

| **Treatment** | **Fruit$^{-1}$ (g)** | **Fruit tree-$^{1}$ (kg)** |
|---|---|---|
| NT < 560 | 45.32 ± 1.08 cd | 1.19 ± 0.08 def |
| NT 560 to 650 | 48.56 ± 0.71 c | 1.29 ± 0.07 cd |
| NT > 650 | 38.22 ± 0.46 ef | 1.03 ± 0.06 ghi |
| NK < 560 | 55.84 ± 1.37 a | 1.48 ± 0.02 b |
| NK 560 to 650 | 59.43 ± 0.71 a | 1.62 ± 0.07 a |
| NK > 650 | 49.4 ±1.65 b | 1.34 ± 0.05 c |
| GT < 560 | 40.14 ± 0.11 e | 1.11± 0.09 fg |
| GT 560 to 650 | 38.67 ± 0.55 ef | 1.09 ± 0.07 fg |
| GT > 650 | 32.95 ± 0.73 gh | 0.93 ± 0.10 i |
| GK < 560 | 44.22 ± 0.18 d | 1.27 ± 0.06 cde |
| GK 560 to 650 | 38.20 ± 0.78 ef | 1.16 ± 0.05 defg |
| GK > 650 | 36.20 ± 0.75 fg | 1.07 ± 0.11 fgh |
| NST < 560 | 39.00 ± 1.07 ef | 1.14 ± 0.11 efg |
| NST 560 to 650 | 37.79 ± 0.65 f | 1.13 ± 0.06 g |
| NST > 650 | 32.12 ± 0.11 h | 0.94 ± 0.10 hi |
| NSK < 560 | 41.80 ± 0.65 de | 1.36 ± 0.08 bc |
| NSK 560 to 650 | 36.57 ± 0.80 fg | 1.18 ± 0.09 def |
| NSK > 650 | 37.10 ± 0.23 f | 1.11 ± 0.07 fg |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

From Table 7 it can be explained that the three varieties grown in six locations produced fruit weight per tree between 0.93 kg and 1.62 kg. The salak nangka variety planted in Karangasem at an altitude of 560 to 650 m asl (NK 560 to 650) produced the heaviest fruit weight of 1.62 kg tree$^{-1}$, followed by NK < 560 and NT 560 to 650 with fruit weights of 1.48 and 1.29 kg. While the nenas variety produces the best fruit at altitudes < 560 m asl (NSK < 560 and NT < 560). Salak 'Gulapasir' var. gondok is ideal when planted at altitudes < 560 m asl (GK < 560 and GT < 560), although the two growing locations showed a different yields.

Nenas and gondok varieties showed a trend of decreasing fruit weight in line with increasing altitude, both planted in Karangasem and Tabanan. The reverse occurred in the salak nangka variety, an increase in altitude from 550 m asl to 550 to 650 m asl caused an increase in fruit weight and after that the fruit weight decreased when planted at altitudes > 650 m asl. This finding is in line with the results of research that has been reported by Sumantra *et al*. (2014). However, for the gondok and nenas varieties, this is a new finding.

Apart from being influenced by environmental factors, the production of salak 'Gulapasir' fruit is also influenced by internal plant factors (Adelina *et al*., 2021b: Lestari *et al*. 2011). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019), and rainfall (Ritonga *et al*., 2018). Altitude increases, the average daily air temperature decreases and monthly rainfall increases (Table 3). Nuary *et al.* (2019) stated that the distribution and adaptation of salak plants is strongly influenced by temperature and rainfall. It was further stated, the contribution of daily temperature accounts for nearly 38.6 % while rainfall is 27.8 %. Kanzaria *et al.* (2015) reported that mango plants planted at an altitude of 229 m flowered slower than those at an altitude of 148 m and 81 m asl. The temperature regime at higher altitudes is colder than at lower altitudes. Lower temperatures accumulate less growing degree day (GDD) and may result in late flowering. Table 7 shows that the 'Gulapasir' salak planted in Karangasem produced a higher fruit weight in the three salak varieties tested. This is related to the level of soil fertility. The soil nitrogen and phosphate nutrient content at three locations in Karangasem was higher than at three locations in Tabanan. Meanwhile, the potassium content in the six research locations was low (Table 3). Therefore it is necessary to make improvements by providing fertilizers containing elements of N, P and K to meet ideal conditions for growth, although more data is needed to fully support this conclusion (Hailu *et al.*, 2015).

*3.4 Quality characteristics of salak varieties*

The interaction between varieties and altitude significantly affected sugar/total acid and vitamin C content. The three varieties grown in Tabanan (T < 560, T 560 to 650 and T > 650) showed a lower TSS/acid ratio. The fruit flavour planted in three locations in Tabanan is sourer than the three locations in Karangasem. Sugar content is greatly affected by the geographical. The geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity, and rainfall (Ritonga *et al*., 2018). Table 8 also shows that the increase in altitude from 550 m to 700 m asl in Tabanan and the addition in altitude from 550 to 650 m asl in Karangasem causes the sugar/acid ratio decrease in all three varieties, and the lowest sugar/acid value occurs in nenas variety in all locations. Each salak variety has an adaptation to an elevation closely related to plant tolerance to temperature (Sumantra and Martiningsih, 2016; 2018). Many factors influence fruit quality, but the most dominant are climate factors, especially temperature and rainfall. High rainfall and low air temperature during the fruit ripening phase can cause the dissolved solids in the fruit to become watery so that the TSS value is low (Singh *et al*., 2011).

Salak fruits from three different varieties grown in low lands in Karangasem (K < 560 m asl) showed the highest vitamin C content and were significantly different from the three cultivars when planted in other locations. In both areas land increased by > 650 m asl effects to vitamin C decrease, nangka and gondok varieties showed higher levels of vitamin C between < 550 m to < 650 m asl. (Table 8).

**Table 8.** TSS/acid ratio and levels of vitamin C of nangka, gondok, and nenas varieties in six locations.

| Treatment | TSS/T.Acid | Vit. C (mg /100g) |
|---|---|---|
| NT < 560 | 56.20 ± 0.16 abc | 27.50 ± 0.41 bde |
| NT 560 to 650 | 59.18 ± 0.82 a | 25.45 ± 0.37 defgl |
| NT > 650 | 37.89 ± 0.91 f | 22.52 ± 0.39 j |
| NK < 560 | 51.41 ± 0.33 cde | 27.74 ± 0.47 bd |
| NK 560 to 650 | 53.52± 0.82 abcd | 29.61 ± 0.50 ab |
| NK > 650 | 47.76 ± 0.11 de | 24.25 ± 0.20 fghij |
| GT < 560 | 34.88± 0.72 fg | 25.50 ± 0.41 defgl |
| GT 560 to 650 | 34.80 ± 0.65 fg | 25.75 ± 0.20 defgl |
| GT > 650 | 30.24 ± 0.20 gh | 23.34 ± 0.28 hij |
| GK < 560 | 51.28 ± 0.23 cde | 30.31 ± 0.25 a |
| GK 560 to 650 | 58.44 ± 0.36 ab | 27.63 ± 0.30 bd |
| GK > 650 | 53.04 ± 0.82 bcde | 25.07 ± 0.33 efgh |
| NST < 560 | 31.50 ± 0.41 gh | 26.71± 0.21 cdef |
| NST 560 to 650 | 30.44 ± 0.36 gh | 25.88 ± 0.41 defg |
| NST > 650 | 26.13 ± 0.11 h | 23.65 ± 0.29 ghij |
| NSK < 560 | 53.73 ± 0.60 abc | 24.42 ± 0.34 fghij |
| NSK 560 to 650 | 52.63 ± 0.51 bcde | 22.82 ± 0.15 ij |
| NSK > 650 | 47.60 ± 0.49 e | 25.16 ± 0.13 efgh |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

The results showed that the varieties of the ‘Gulapasir’ salak needs different environmental requirements to optimize yields. Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al*., 2021, 2022). Therefore, variety differences may depend on growing requirements and cultivation techniques. Vitamin C in the ‘Gulapasir’ salak is strongly influenced by the altitude of the land. To produce high levels of vitamin C, the nangka and gondok varieties are ideal for planting at an altitude of 560 m to 650 m asl, while the nenas variety is ideal at a land altitude

of < 560 m asl. However, changes in ascorbate levels during fruit ripening are species-dependent and environmental factors especially temperature and light (Fenech *et al*., 2019).

There was no interaction between varieties and altitude to the flesh thickness, edible fruit portion, and fruit sugar content. The nangka salak variety showed fruit quality, including TSS, edible parts of the fruit, and higher flesh thickness (Table 9).

**Table 9.** The effect of a single factor of varieties on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment | TSS (°Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| Nangka | 16.59a | 72.50a | 0.63a |
| Gondok | 16.42a | 70.66ab | 0.59b |
| Nenas | 15.64b | 69.22b | 0.52c |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Salak grown in Karangasem both from the lowlands and the middle lands produces fruit thickness, and the edible portion of fruits is higher than plants in the highlands. This study indicates that the ideal growing place for salak plants is between 450 m to 650 m asl. This study is in line with several previous studies which explained that altitude affects the flowering process and fruit enlargement (Sophie *at al*., 2017; Spinardi *et al*., 2019; Widyastuti *et al*., 2022).

**Table 10.** The effect of a single factor of planting location on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment (m asl) | TSS (°Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| T < 550 | 16.28a | 73.13a | 0.54c |
| T 550 to 650 | 16.27a | 69.89a | 0.58bc |
| T > 650 | 16.14a | 63.87b | 0.49d |
| K 550 | 16.81a | 73.15a | 0.61b |
| K 550 to 650 | 16.11a | 72.29a | 0.66a |
| K > 650 | 15.69a | 72.44a | 0.61b |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Further research can be applied using sustainable salak organic agriculture (Budiasa, 2014; Handayani, 2022; Nurhidayat *et al*., 2022; Rahmah *et al*., 2022; Wimatsari *et al*., 2019). Table 3 shows that salak cultivation in the research location still needs to implement sustainable farming (Prasetyo *et al*., 2022b; 2022a). There are indications some of decrease in soil fertility, especially potassium available in the six planting locations that shows a very low value. Potassium levels in Table 3 are lower than the observations of Ashari (2013) and Woran *et al.* (2018) in salak cultivation areas in Swaru – Malang (very high), Sleman – Yogya (moderate), Bangkalan – Madura (very high), and Pangu – Minahasa (moderate).

Potassium helps produce good fruit quality, such as bigger, heavier, and sweeter fruit. Another benefit of the nutrient potassium in plants is to increase the growth of meristem tissue and regulate the movement of stomata. Potassium also helps the development of plant roots so that plant stems can stand upright and do not collapse easily (Adinurani *et al.,* 2018; Budiono *et al*., 2019). Therefore, Nasution (2022) recommends more $K_20$ fertilizer than $P_20_5$ fertilizer and N fertilizer. In addition, salak needs 70 kg of $K_2O$ because this nutrient is found in the leaves at an amount (12.2 to 14.7) mg $g^{-1}$ (Ashari, 2013).

The chemical fertilizers (e.g., KCl) are too expensive for Salak farmers and do not support the salak organic. Therefore, the application of sustainable farming should apply local wisdom including the use of the pruning of salak midrib. Consider this policy because C organic is essential to soil fertility (Budiono *et al*. 2021; Goenadi *et al*. 2021). The success of this midrib decomposition is demonstrated by the C organic in Table 3, which is classified as medium to high. This finding support Faizah and Fauzan (2021), Saputra *et al.* (2018) in salak plantation of Purwosari District - Pasuruan Regency, and Wonosalam District – Jombang Regency.

But, in the next stage, some of the salak midribs should be burned into ashes which can be used as a source of potassium nutrients (Ekawati and Purwanto, 2012; Vincevica-Gaile *et al*., 2021a, 2021b). Another organic source of potassium is the pulp/husk of coffee cherries. Karangasem and Tabanan districts are coffee cultivation areas in Bali, so they should take advantage of this coffee processing waste. Several researchers stated that coffee pulp/husk contains higher potassium than nitrogen or phosphorus nutrients (Bahri *et al*., Falahuddin *et al*., 2016; Novita *et al.*, 2018; Setyobudi *et al*., 2018).

Several researchers (Analianasari *et al*. 2022; Ningsih, 2020; Wachisbu, 2020) recommend soaking the pulp/husk coffee cherries and uses as liquid organic fertilizer with benefits for various plants. To develop this idea, salak farmers in Karangasem and Tabanan Regency should create biogas as household or communal scale digesters (Prespa *et al*., 2020; Setyobudi *et al.* 2021b; Susanto *et al*., 2020a) or use digesters from used drums (Adinurani *et al*., 2017; Hendroko *et al*., 2013). All household organic waste is processed in the digester, including kitchen waste, leftover food, and human excrement from pit latrines and septic tank (Anukam and Nyamukamba, 2022; Somorin, 2020; Susanto *et al*., 2020b; Zhou *et al*., 2022). This action has various advantages, namely reducing global warming, obtaining clean - renewable energy, and two kinds of organic fertilizer, i.e., liquid and solid (Abdullah *et al*., 2020; Burlakovs *et al*., 2022; Hendroko *et al*., 2014; Prespa *et al*., 2020; Setyobudi, *et al*., 2018). In addition, many researchers have reported (among other things Benyahya *et al*., 2022; Baştabak and Koça, 2020; Li *et al*., 2021) the benefits of organic fertilizers from biogas digesters.

Another measure to increase and maintain land fertility is in salak cultivation, namely the application of Plant Growth Promoting Rhizobacteria (PGPR) or biological fertilizer (Basu *et al*., 2021; Ekawati, *et al.,* 2019). Several researchers (Adinurani *et al*., 2021; Kumalawati *et al*., 2021; Muhammad *et al*. 2021) have reported using mycorrhiza, which positively impacts various plants, including salak cultivation (Amnah and Friska, 2018; Dewi *et al*., 2020; Rai *et al*., 2021). Multiplication of mycorrhiza is relatively simple (Sportes *et al*., 2021; Sukmawati *et al*., 2021) and can be done by farmer groups with initial guidance from universities.

**4. Conclusion and Recommendation**

Different cultivars caused different fruit weights, fruit bunches, and the sugar/acid ratio at various locations. The three varieties showed lower fruit weight and fruit quality in Tabanan (low, medium, and highlands) than the salak originating from Karangasem. The nangka variety in Karangasem showed higher fruit weight, vitamin C content, and sugar/ acid ratio, while the nenas salak showed the highest number of fruit bunches$^{-1}$ in six locations. Nangka salak are very suitable to be planted at an altitude of 550 m to 650 m asl. In contrast, the nenas and gondok varieties are developed naturally at low altitudes < 550 m asl. In order tofor enable all cultivars to be able to produce optimally, efforts to improve the cultivation system are needed through fertilization and the provision of calcium is highly recommended. Further research can be applied using sustainable salak organic agriculture to maintain soil fertility.

**Commented [ES9]:** Please be consistent, using cultivars or varieties, unless both categories are included in the study

**Commented [ES10]:** The wording in the Conclusion must be difefrent from the Result, it should connect the best result due to something…., for example

**Commented [ES11]:** In the Conclusion also need to include the problems raised in the Introduction whether the results could solve the problem or partly solved, before the recommendation sentence.

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**Title:**

Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Various Planted in Different Agro-Ecosystems

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**Running Title:**

Assessment of Salak cv Gulapasir Fruit Quality and Agronomic Characters Planted in Different Various Agro-Ecosystems

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# Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Various Different Agro-Ecosystems

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## ABSTRACT

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir has been officially released by the Minister of Agriculture of the Republic of Indonesia since 1994. Salak 'Gulapasir' is one of five types of fruit that have been designated as the superior fruit of the Bali Province. Salak 'Gulapasir' preferred by consumers due to its specific fruit flesh taste. Salak 'Gulapasir' was propagated using seeds so that a new types of salak emerged. However, the characters of this new type of salak 'Gulapasir' is not yet known. The research objective was to obtain the superior of some Salak 'Gulapasir' both in production and fruit quality. The research used a Randomized Block Design with three replications. The non-independent variable was the three of Salak 'Gulapasir' (SGP): SGP var. nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 to 650 m asl, and K > 650 m asl) and Tabanan (T): (T < 560 m asl, T 560 to 650 m asl, T > 650 m asl). Observations were made on the agronomic characters and fruit quality. Data were analyzed using variance analysis, and if the planting location and varieties show a difference, then it is followed by the LSD test at the 5 % level. The results showed that different varieties caused different fruit weights, fruit bunches, TSS, and total acid ratio. In Karangasem and in Tabanan, SGP var. nangka grows ideally at an altitude of 560 to 650 m asl with fruit weight per tree of 1.62 kg$^{-1}$ and 1.29 kg$^{-1}$, respectively. SGP var. nenas and SGP var. gondok are ideal for cultivating at an altitude of <560 m asl both in Karangasem and Tabanan, but the fruit production of SGP var. nenas and SGP var. gondok is higher, respectively 19.29% and 15.31% when planted in Karangasem.

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In Tabanan (in the low, medium, and highlands), the three varieties showed lower fruit weight and fruit quality than the salak originating from Karangasem. The SGP var. nangka in Karangasem showed higher fruit weight, vitamin C content, and TSS/total acid ratio, Wwhile the SGP var. nenas showed the highest number of fruit bunches$^{-1}$ in six locations. Further research can be applied using sustainable salak organic agriculture to maintain soil fertility.


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**Keywords :** Altitude, *Salacca zalacca* (Gaertn.) Voss, Salak 'Gulapasir' var. gondok, Salak 'Gulapasir' var. nangka, Salak 'Gulapasir' var. nenas, Salak sustainable agriculture, Snake fruit, Quality, Tropical fruit


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## 1. Introduction

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir is one of the important fruits in Indonesia and the plant can be found in most regions of Indonesia (Rai *et al*. 2016; Ritonga *et al*., 2018). The salak fruit belong to the family Palmae or Arecaceae, and are native to the Indonesian-Malaysian region (Hakim *et al.*, 2019; Zumaidar *et al*., 2014). One of the extraordinary strengths of this fruit commodity for Indonesia is the possession of high genetic diversity (Budiyanti *et al*., 2019). Also, the nutrition of salak fruit is rich in antioxidants, phenolics, vitamins, and minerals (Cepkova *et al.*, 2021; Mazumdar *et al*., 2019), and a good source of income and provides livelihood opportunities on seasonal days (Khan and Idrees, 2021). The fruit flesh and peel have shown some tremendous anti-inflammatory, anticancer and antidiabetic (Saleh *et al*., 2018), and anti-ageing agents (Girsang *et al*., 2019). Antioxidants are chemical compounds that play an essential role in protecting cells due to attacks against free radicals-induced damage to biomolecules (Damat *et al*., 2019, 2020; Puspitasari and Ningsih, 2016; Setyobudi *et al*., 2019). Despite its incredible food and medicinal benefits, salak fruit is still underutilized and unknown globally. So that this underutilized fruit remains an issue for future sustainable utilization and commercial value enhancement market (Mazumdar *et al*., 2019). Fruit quality is an important issue, especially for products that are consumed raw and fresh. One of the problems is the lack of fruit quality because of inadequate information about superior salak (Budiyanti *et al*., 2019; Herawati *et al*., 2018). Therefore, it is necessary to select superior salak to meet market demand and fulfil community nutrition.

Salak ‘Bali’ is quite a lot, based on the shape, aroma, taste, and skin colour of the location where the plants are cultivated (Sumantra *et al*., 2012, 2014; Sumantra and Martiningsih, 2016, 2018). Under the Decree of the Minister of Agriculture of the Republic of Indonesia in 1994, Balinese zalacca was grouped into two superior zalacca: Salak ‘Bali’ (SK Mentan, 1994a) and Salak ‘Gulapasir’ (SK Mentan, 1994b). The second type, the salak ‘Gulapasir’ (SGP) is the most superior salak because of its sweet fruit taste; even though the age of the fruit is still young, thick fruit flesh and seeds are not attached to the fruit flesh (Rai *et al*., 2014; Sumantra *et al*., 2016). The nature of this fruit is ideal for meeting market demands for both the domestic and export markets (Martiningsih *et al*., 2018). Salak 'Bali' is monoecious, so crossing does not need human help (Herawati *et al*., 2018), and can quickly develop using seeds (Sumantra and Martiningsih, 2016). Another advantage of salak plants in Indonesia compared to other fruits is harvest fruit 2 to 3 times a year if management is good (Rai *et al*., 2016; Warnita *et al.*, 2019). The expansion of salak 'Gulapasir' planting causes variations in phenotypic diversity. People can find two to three types of salak plants with a marker, fruit shape, aroma, flesh colour, and fruit weight (Martiningsih *et al*., 2018). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seeds so that new varieties of salak 'Gulapasir' (SGP) appear, as reported by Sumantra and Martiningsih (2016). Based on the marker that can be used as a differentiator, salak farmers give it the name of SGP var. nenas, SGP var. gondok, and SGP var. nangka. The three varieties have not yet identified their advantages in meeting market needs in line with the results of research (Sumantra and Martiningsih, 2016). The performance and produce are influenced by the characteristics of the agricultural ecosystem, particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status (Adelina *et al.,* 2021a; Kumar *et al*., 2020) and growth hormone (Prihastanti and Haryanti. 2022; Rai *et al.,* 2016).

The salak 'Gulapasir' plantation in the District of Bebandem is the main producer of salak 'Gulapasir' in Bali is located in the southern part of Mount Agung with an altitude of 450 m to 700 m above sea level (m asl). The effect of altitude on plant growth and production is related to plant adaptation to temperature (Sumantra, *et al*., 2014), full sunlight (Sukawijaya *et al*., 2009), water status and soil quality (Raharjo *et al*., 2022; Rai *et al*., 2014; Ritonga *et al.,* 2018). Salak plants are not resistant to full sun but 50 % to 70 % enough, therefore it is necessary to have shade plants (Sukawijaya *et al*., 2009; Sumantra *et al*., 2012). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019). Water status and soil quality really determine the fruit set on the salak 'Gulapasir'. Low rainfall reduces the Relative Water Content in leaves (RWC), leaf chlorophyll content, and plant nutrient uptake (Rai *et al*., 2014). soil quality included the suitability of the physical, chemical and biological properties (Raharjo *et al*., 2022). Nuary *et al*. (2019) stated that the distribution of the salak 'Pondoh' plantation area in Sleman (Yogyakarta, Special Region) was greatly influenced by temperature and rainfall. The contribution of temperature in the modelling reached 38.6 % while the rainfall was 27.8 %. Furthermore, taking into account the probability of the temperature variable, the average temperature ranges from 17.41 °C to 25.65 °C, and the ideal month's rainfall ranges from 385.24 mm to 505.01 mm.

Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al*., 2021, 2022). Therefore, varieties differences may depend on growing requirements and cultivation techniques. Likewise, Puspitasari *et al*. (2016) stated that tannin content, fruit size and flesh colour of salak fruit are strongly influenced by where it grows. Other studies also explain that salak 'Gulapasir' var. nangka which is grown 570 m asl, would result in a higher quality of fruit that includes thickness of the mesocarpium, edible portion of fruit then compared to above and below 570 m asl (Sumantra *et al*., 2014; Sumantra and Martiningsih, 2016). Meanwhile, fruit weight and fruit quality of var. gondok and var. nenas have not been reported. Therefore, one way of handling salak quality is by undertaking severe studies for factors such as land and climate and adjusting agricultural patterns according to local climate conditions (Nassar *et al*., 2018). The success of each species to occupy the environment of an area is influenced by its ability to adapt optimally to all physical environmental factors (temperature, light, soil structure, humidity), biotic factors (interaction between species, competition, parasitism), and chemical factors including the availability of water, oxyge, pH, and nutrients (Nassar *et al*., 2018; Widyastuti *et al*., 2022). Moreover, a broad genetic variability would lead to wide phenotypic variability due to the effect of genetic-environment interaction (Ritonga *et al*., 2018). The research objective was to obtain several the superior of some salak 'Gulapasir' both in production and fruit quality (sugar and acid ratio, vitamin C and tannin) in six different agricultural ecosystems in Bali. This research was important to do to get the suitability and adaptation of the types of salak based on the altitude where it grows so that in the future, its development will be able to provide maximum results according to existing agro-ecosystem conditions.

## 2. Materials and Methods

### *2.1 Experimental site*

The research was conducted in Tabanan and Karangasem Regencies. Tabanan and Karangasem were selected as research locations because the domination of salak 'Gulapasir' in these two regencies was the highest. In 2021, the salak 'Gulapasir' population in Tabanan is 84 % of all salak species, while in Karangasem Regency the dominance of the salak 'Gulapasir' is more than 63 % (Sumantra *et al*., 2022).

The study was carried out in six different locations, three sites in Karangasem Regency and three sites in the district of Tabanan. Locations in Karangasem (K) are lowlands (K < 560 m asl) which include several places, namely Telaga, Dukuh, and Karanganyar. Karangasem in the moderate plains (K 560 m to 650 m asl) has several areas, namely Kecing and Kutabali and highlands (K > 650 m asl), namely Tanah Apo and Kresek (Figure 1).

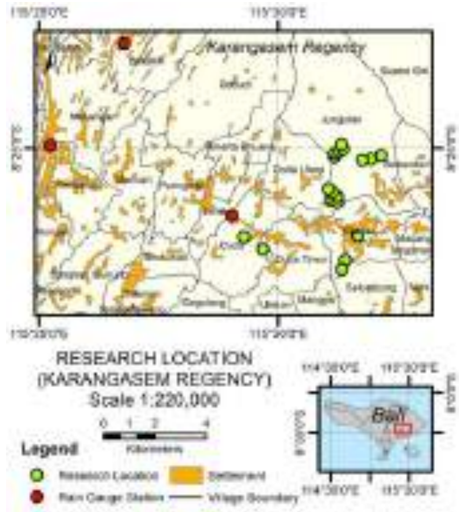


**Fig 1.** Research map and sampling point in Karangasem (K)

The research location is in Tabanan (T) in the lowlands (T < 560 m asl), including Wanagiri, Sari Buana, and Mundeh Kauh. Tabanan in the medium lands (T 560 m to 650 m asl) includes several places, namely Pajahan, Kebon Jero, and Angseri. Tabanan in the highlands (T > 650 m asl), namely Munduk Temu, Pempatan, and Batungsel (Figure 2).

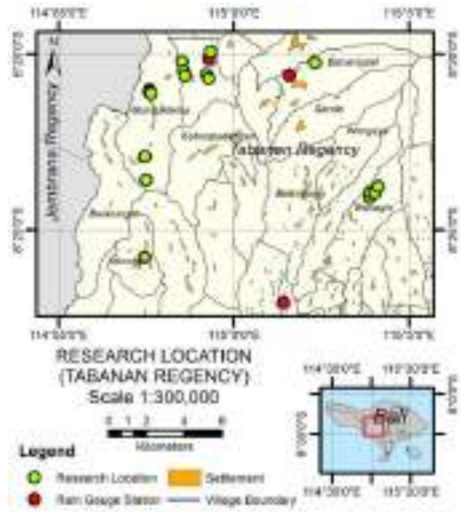

**Fig 2.** Research map and sampling point in Tabanan (T)

The non-independent variable was the three varieties of Salak 'Gulapasir' (SGP): SGP var.nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem (K) : (K < 560 m asl, K 560 m to 650 m asl, and K > 650 m asl) and Tabanan (T) : (T < 560 m asl, T 560 m to 650 m asl, T > 650 m) Repetition was carried out three times with the number of sample plants in each location, and cultivars were seven plants. The treatment tested is as shown in Table 1

**Table 1**. Treatment of plant location and three varieties of 'Gulapasir' salak

| No | Treatment | Explanation |
|---|---|---|
| 1 | NT< 560 m asl | Salak GP.var. nangka Tabanan < 560 m asl. |
| 2 | NT 560 m to 650 m asl | Salak GP.var. nangka Tabanan 560 m to 650 m asl. |
| 3 | NT > 650 m asl. | Salak GP.var. nangka Tabanan > 650 m asl. |
| 4 | NK < 560 m asl. | Salak GP.var. nangka Karangasem < 560 m asl. |
| 5 | NK 560 m to 650 m asl | Salak GP.var. nangka Karangasem 560 m to 650 m asl. |
| 6 | NK > 650 m asl. | Salak GP.var. nangka Karangasem > 650 m asl. |
| 7 | GT< 560 m asl | Salak GP var. gondok Tabanan < 560 m asl. |
| 8 | GT.560 to 650 m asl | Salak GP var. gondok Tabanan 560 m to 650 m asl. |
| 9 | GT > 650 m asl | Salak GP var. gondok Tabanan > 650 m asl. |
| 10 | GK.< 560 m asl | Salak GP var. gondok Karangasem < 560 m asl. |
| 11 | GK 560 m to 650 m asl | Salak GP var. gondok Karangasem 560 m to 650 m asl. |
| 12 | GK > 650 m asl | Salak GP var. gondok Karangasem > 650 m asl. |
| 13 | NST < 560 m asl | Salak GP var. nenas Tabanan < 560 m asl. |
| 14 | NST.560 m to 650 m asl | Salak GP var. nenas Tabanan 560 m to 650 m asl. |

| | | |
|---|---|---|
| 15 | NST > 650 m asl | Salak GP var. nenas Tabanan > 650 m asl. |
| 16 | NSK .< 560 m asl | Salak GP var. nenas Karangasem < 560 m asl. |
| 17 | NSK 560 m to 650 m asl | Salak GP var. nenas Karangasem 560 m to 650 m asl.. |
| 18 | NSK > 650 m asl | Salak GP var. nenas Karangasem > 650 m asl. |

The study used a Composite Analysis of Variance (Andinurani, 2016, 2022) with the model determined using Equation (1) below:

$$Yjk = u + L\ i + \delta\ ik + Pj + (LP)\ ij + \mathcal{E}\ ijk \quad (1)$$

Where:

Yijk = The observation value of the treatment (j) in the group (k), which is repeated at the location (i).

u = the actual average value

Li = additive effect from location i

δ ik = the error effect in group k at location i

Pj = additive effect of the next treatment

(LP) ij = the effect of treatment (j) at the location (i)

Ɛ ijk = the effect of error from the treatment (j) in the group (k) which was carried out at the location (i).

*2.2 Preparation of study materials*

The material used is the salak 'Gulapasir' plant with uniform growth, plants have been fruitful with uniform on morphological, age of plants and cultivation action. The intentional practice is that the plant only receives treatment in the midrib, tillers, and weed cleaning. In this study, the plants were not fertilized. The provision of water was only from rainfall following the habits applied by salak farmers. The sample plant maintains by trimming unproductive leaf midribs and removing young shoots. Plant material was taken

from the Salak Development Centre in six locations, namely at the Centre of Salak Development in the Bebandem sub-districts, Karangasem district (K-lowland < 560 m asl, K-medium 560 m to 650 m asl and K-highland > 650 m asl), Bajre, West Slemadeg and Pupuan sub-districts, Tabanan district (T-lowland < 560 m asl, T-medium 560 to 650 m asl and T-highland > 650 m asl).

2.*3 Analysis of physicochemical properties of soil sample and climate*

Soil analysis was carried out to determine the physical and chemical properties of the soil. Soil sampling was carried out under sample plant trees, carried out in a composite manner at a depth of 0 cm to 40 cm. Chemical analysis was carried out on total N (Kjeldahl method), available P by Bray I method and $K_2O$ by the Bray I method, organic C, pH, soil physical properties in the form of texture by pipette method (Eviati and Sulaeman. 2009; Hailu *et al*., 2015; Prasetyo *et al*., 2022a; Rzasa and Owczarzak, 2013).

Rainfall data was taken for five years from 2015 to 2019. Rainfall data has been collected from six nearby stations to the research site (Figure 1, Figur 2Table 2). Daily temperature data obtained from the Denpasar Meteorology Climatology Agency.

**Table 2**. Research locations and place of climatology stations

| Research Locations | Climate observation station | Latitude and altitude |
|---|---|---|
| Tabanan Lowlands (< 560 m asl) | Ampadan, Tiyinggading No.St. 439 m | 8°27'5.0688"S/ 115°1'25.086 "E; 400 m asl. |
| Tabanan Moderate (560 m to 650 m asl) | Coffee Breeding Center, Sai Pupuan No. St. 439 h | 08°20'08.6"S/ 114° 59'17.4" E; 580 m asl. |
| Tabanan Highlands (> 650 m asl) | Agricultural Extension Center, Pupuan. No St.441 h | 08°20'38.1" S/ 115°01'35.2" E; 750 m asl. |

| | | |
|---|---|---|
| Karangasem Lowlands (< 560 m asl) | Agricultural Extension Center, Selat. No. St. 444 d | 08°26'25" S / 115°29'02" E; 450 m asl. |
| Karangasem Moderate (560 m to 650 m asl) | Horticulture Seed Center, Singerata No.St. 442 | 08°24'57"S / 115°25'14"E; 580 m asl. |
| Karangasem Highlands (> 650 m asl) | Besakih Station. No.St.442 a | 08°22'49"S / 115°26'47"E; 800 m asl. |

*2.4 Observation of fruit and fruit quality*

Salak fruit can be harvested when it is ready for consumption. Consumable ripe fruit is a fruit that is ready to be consumed, characterized by a change in skin colour from dark brown to light brown, the thorns on the skin have reduced and are not sharp, and in general, at this stage, the fruit easily falls when shaken.

Observation and measurement of agronomic characters follow the method that has been done by Sumantra *et al*. (2014) including fruit weight, number of fruit bunches, the thickness of fruit flesh and fruit shape. The fruit characters from six-observed locations include the numbers of fruits per bunch, which is calculated manually on the formed fruits. The fruit weight per fruit and the fruit weight per tree is weighed after the fruits were removed from the bunch. The thickness of the mesocarpium is obtained by measuring the mesocarpium after it is cut vertically. The length of the flower sheath is measured on the stem of the sheath from the base to the tip of the sheath.

While fruit quality includes sugar content, tannins, titrated acid, sugar content and vitamin C. Titrated acid was analyzed by titration (Sripakdee *et al*., 2015). The fruit which was weighed 10 g of sample was added to 100 mL of distilled water, then was homogenized using a slow spin blender, and filtered using an aseptic filter. The filtrate obtained was taken as much as 25 mL, then titrated with 0.1 N NaOH solution with phenolphthalein indicator until red in colour appeared. The results obtained are calculated as the percentage tartaric acid is determined using Equation (2) below :

$$A = \frac{\text{mL NaOH} \times \text{N NaOH} \times P \times BM}{Y \times 1\,000 \times 2} \times 100\ \% \qquad (2)$$

where:

A = percentage of total acid

P = amount of dilution

BM = molecular weight of tartaric acid

Y = sample weight (g).

Tannis content was analyzed as done by Thakur *et al*. (2021), Setyobudi *et al*. (2022). Amount of 100 mg of the sample was homogenized by 2 mL of methanol. Centrifuged for 10 min at 10 000  rpm (1 rpm = 1/60 Hz) and collected the supernatant. Amount of 1 mL of supernatant mixed with 0.5 mL Folin's phenol reagent and 35 % $Na_2CO_3$ of 5 mL added and the mixture was kept at room temperature for 5 min. The blue colour of the reaction mixture was observed at 640 nm by UV/visible spectrophotometer (Shimadzu UV-1800, Japan). The content of tannin was calculated by calibration curve equation and determined using Equation (3) below:

$$Y = 0.0073x - 0.0071 : R^2 = 0.9973 \qquad (3)$$

Vitamin C was determined by titration like the method used by Asamara (2016), Setyobudi *et al.* (2021a, 2022). The material is weighed as much as 10 g and crushed in mortal. Then put into a 250 mL volumetric flask, set to the mark and filtered. Take 25 mL of the filtrate and titrate with 0.01 N Yod solution equivalent to 0.88 mg of ascorbic acid. The calculation of ascorbic acid content per 100 g of material is determined using Equation (4) below:

$$A = \frac{mL\ Yod\ 0.01\ N \times 0.88 \times P \times 100}{Y} \quad (4)$$

where: A = mg of ascorbic acid per 100 g of material

P = amount of dilution

Y = gram sample weight

Sugar content as TSS is calculated using a hand refractometer (Bellingham and Stanley Ltd., London) at 20 $^{o}$C.

The ratio of sugar content (TSS) and total acid is calculated by the sugar content divided by the acid content multiplied by 100 %.

The materials used in this study were Folin-Ciocalteu reagent (Pro Analytic, Merck), NaOH (Pro Analytic, Merck), $Na_2CO_3$ (Pro Analytic, Merck), Phenolphereagent ascorbic acid (Pro Analytic, Merck), Phosphoric Acid (Pro Analytic, Merck), Sodium Phosphate (Pro Analytic, Merck) and Ammonium Molybdate (Pro Analytic, Merck).

The tools used in this study were analytical balances (Shimadzu ATY224, Japan), centrifuge tubes, Erlenmeyer flasks (pyrex), dropper pipettes (pyrex), volume pipettes (pyrex), vortex (Maxi Mix II Type 367000), measuring flask (pyrex), water bath (Memmert), blender (Miyako), and centrifuge (Damon /IEC Division). Whatman filter paper No 1 (Sigma – Aldrich, USA), measuring cup (Pyrex, USA), micropipette (Dragon Lab, Indonesia), spectrophotometer (Biochromsn 133467, UK), test tube (Pyrex¸ USA), vortex (Barnsteadl Thermolyne Type 37600 Mixer, USA), aluminum foil (Klin Pak, Indonesia).

*2.5 Study design*

This study used a randomized block design with the data analyzed using a Composite Analysis of Variance. If the variance test is significantly different, then it is continued with a different test with LSD at the 5 % level. Data analysis was performed using SPSS-IBM 18 (Adinurani, 2016, 2022). Each experimental treatment was repeated three times.

## 3. Results and Discussion

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### *3.1 Agroclimate characteristic*

The low production level and quality of salak fruit are caused by environmental factors that do not support growth or because the physiological processes of the plant are not optimal due to insufficient nutrients and water. The suitability of climatic and soil conditions at six locations of the centres for the development of the 'Gulapasir' salak was evaluated. The evaluation results show that the air temperature decreases as the altitude increases. The average air temperature at the 'Gulapasir' salak plantation in Tabanan is 22.90 °C, while the air temperature at the Karangasem salak plantation is around 23.24 °C. (Tabel 23)

**Table 23.** Soil and climate characteristics of the research site in Tabanan and Karangasem in three subzones

| Parameter | Tabanan (T) | | | Karangasem (K) | | |
|---|---|---|---|---|---|---|
| | Lowlands (< 560 m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) | Lowlands (< 560m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) |
| Temp. (° C) | 23.82 | 22.75 | 22.12 | 24.29 | 23.35 | 22.09 |
| Rainfall (mm $mo^{-1}$) | 188.24 | 199.91 | 231.008 | 237.242 | 254.183 | 289.216 |
| Soil texture | loamy clay | loamy clay | loamy clay | clay | clay | sandy loam |
| pH ($H_2O$) | 5.64(sa) | 5.75 (sa) | 5.84 (sa) | 6.08 (sa) | 6.05 (sa) | 6.03(sa) |
| C- organic (%) | 2.94(m) | 3.40 (h) | 3.25 (h) | 2.77 (m) | 3.63 (h) | 3.32 (h) |
| Nutrients available | | | | | | |
| N total (%) | 0.18 (l) | 0.16 (l) | 0.18 (l) | 0.24(m) | 0.23 (m) | 0.29 (m) |
| $P_2O_5$ (mg $g^{-1}$) | 9.38 (vl) | 9.12 (vl) | 13.50 (l) | 22.55 (m) | 24.18 (m) | 23.04 (m) |
| $K_2O$ (mg $g^{-1}$)) | 18.47 (vl) | 22.05 (vl) | 17.23 (vl) | 24.17 (vl) | 19.93 ( vl ) | 18.37 ( vl ) |

Notes: sa: slightly acidic; h: high; m: medium; l: low; vh: very high; h: high; asl: above sea level (The assessment criteria refer to Eviati and Sulaeman. 2009; PPT, 1983).

In addition toLikewise monthly rainfall, the average rainfall over the 5 years is presented in Table Table 4Figure 3. Annual rainfall in Tabanan (T < 560, T 560 to 650 and T > 650) is lower with an average of 2515.05 mm while in Karangasem (K < 560, K 560 to 650 and K > 650) it is — 3 122.05 mm. However, the six locations show

Commented [ES7]: Should not be shortened a trend of increasing rainfall as altitude increases. The salak plantation area in Karangasem is in the southern part of Mount Agung. Meanwhile in Tabanan, the dominant salak plantation area is behind Mount Batukaru with a lower elevation than Mount Agung. Mount Agung with an altitude of 3 142 m asl (Andaru and Rau, 2019), while the Batukaru mountains area with an elevation 2 250 m asl (Asmiwyati *et al*., 2015). Mount Batukaru as a barrier, causing this area to be a rain shadow. Enyew and Steenveld (2014) state that rainfall in an area is influenced by topographical factors and mountain ranges. Decreasing the height of the mountains, provides a reduction in the maximum level of rainfall over the mountains and foothills by 50 % (Flesch and Reuter, 2012). Topographical factors and regional weather systems have an important role in the amount and spatial pattern of rainfall in an area (Enyew and Steenveld, 2014).

~~**Table 4.** The annual rainfall in the six study sites (2015 to 2019)~~

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| ~~Year~~ | ~~Tabanan: T (mm yr$^{-1}$)~~ | | | ~~Karangasem: K (mm yr$^{-1}$)~~ | | |
|---|---|---|---|---|---|---|
| | ~~T < 560~~ | ~~T 560 to 650~~ | ~~T > 650~~ | ~~K < 560~~ | ~~K 560 to 650~~ | ~~K > 650~~ |
| ~~2015~~ | ~~2 001.0~~ | ~~2 462.7~~ | ~~2 633.0~~ | ~~2 470.5~~ | ~~2 714.0~~ | ~~3 291.0~~ |
| ~~2016~~ | ~~2 095.0~~ | ~~2 453.5~~ | ~~3 049.5~~ | ~~2 659.0~~ | ~~2 885.0~~ | ~~3 800.0~~ |
| ~~2017~~ | ~~1 958.0~~ | ~~2 152.5~~ | ~~2 135.0~~ | ~~2 903.0~~ | ~~3 173.0~~ | ~~3 500.0~~ |
| ~~2018~~ | ~~2 335.5~~ | ~~2 463.9~~ | ~~2 955.0~~ | ~~3 002.0~~ | ~~3 057.0~~ | ~~3 200.0~~ |
| ~~2019~~ | ~~2 905.0~~ | ~~2 462.0~~ | ~~3 088.0~~ | ~~3 200.0~~ | ~~3 422.0~~ | ~~3 562.0~~ |
| ~~Average~~ | ~~2 258.9~~ | ~~2 398.92~~ | ~~2 772.1~~ | ~~2846.9~~ | ~~3 050.2~~ | ~~3 470.6~~ |

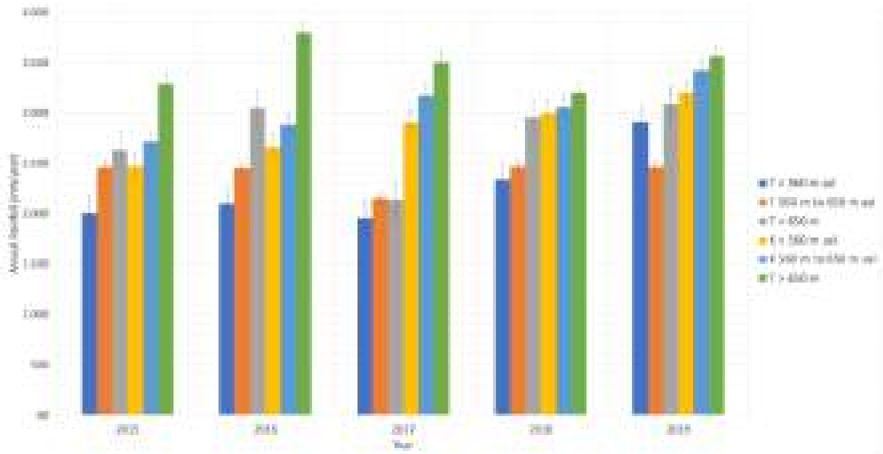

**Fig. 3.** The annual rainfall in the six study sites

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Based on the growing requirements of salak plants, rainfall and air temperature in the six locations evaluated were in the very suitable range to support plant growth and development. A good air temperature for the growth of salak plants is between 20 °C to 30 °C and an average rainfall of (200 to 400) mm $mo^{-1}$ (Nuary *et al*., 2019).

Soil C-organic content in six planting sites was in the medium to high range. Availability of N and P nutrients in salak plantations in Tabanan in the lowlands, medium and highlands in low to very low conditions. Salak planting land in Karangasem, both in the lowlands, medium and highlands, these two nutrients are available in moderate conditions (Table 3). The nutrient content of potassium available in the six planting locations that have been evaluated shows a very low value. The results of this study indicate that the cultivation techniques carried out by farmers are very low. Farmers do not apply an fertilizers that only rely on litter from the pruning of salak midrib as reported by Ilmiah *et al*. (2021), Rai *et al.* (2014), and Warnita *et al.* (2019). To cultivate sustainable agriculture, especially in agroecosystems salak in Bali. The authors will discuss this issue more in the future research paragraph.

*3.2 Fruit Characteristics of Salak 'Gulapasir'*

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The salak 'Gulapasir' his monoecius plant, namely male and female flowers arranged on the same bunches, the shape of the bunches is compound, and the position of the flower is on the back of the midrib. The salak 'Gulapasir' is classified as special because of its sweet fruit taste and the price per unit weight is four times more expensive than the salak 'Bali' (Rai *et al*., 2014; Sumantra *et al*., 2012). The expansion of the cultivation of the salak 'Gulapasir' from its area of origin, Sibetan, Karangasem, has resulted in phenotypic diversity with a phenotypic similarity level of 58.62 % to 93.10 % (Sumantra and Martiningsih, 2016). In the same garden, more than one type of 'Gulapasir' salak appears, depending on fruit shape, aroma, color of fruit flesh and fruit weight (Sumantra and Martiningsih, 2016). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seed, so new variants of salak 'Gulapasir' appear with local names such as salak 'Gulapasir' nenas, salak 'Gulapasir' gondok and salak 'Gulapasir' nangka. The striking difference between these three varieties lies in the shape and flesh of the fruit. The number of fruit branches of salak 'Gulapasir' nangka, 1 to 2 branches, salak 'Gulapasir' nenas amount of 2 to 4 branches and salak 'Gulapasir' gondok the fruit bunches that do not form fruit branches. Salak 'Gulapasir', which is ready to harvest, has fruit flesh attached to the seed, and the fruit flesh is 0.63 cm thick. Meanwhile, the flesh of the salak 'Gulapasir' nenas is the thinnest and the seeds are attached to the flesh. Meanwhile, when the salak 'Gulapasir' gondok is ready to harvest, the seeds make a sound when shaken (Figure 4 and 5 ~~3~~).


**Fig. 4~~3~~.** The shape  and the thickness of the fruit flesh of SGP.var.nenas, gondok and nangka


**Fig. 5~~4~~.** The shape of the bunch and the number of fuits  of SGP var. gondok,nenas, and nangka

*3.3* Agronomic characteristics of 'Gulapasir' Salak

Analysis of variance showed that the interaction between planting locations and varieties of 'Gulapasir' salak  had significant effect on the number of fruits per bunch, fruit weight per tree, fruit weight per fruit, number of fruits per bunch, the ratio of sugar and acid and vitamin C content. Meanwhile, the thick fruit flesh and tannins content was not significant (Table 4~~5~~)

**Table 4~~5~~.** Recapitulation of the effects of varieties and growing locations on agronomic and fruits quality of 'Gulapasir' salak

| No. | Character agronomic and fruits quality | Planting location | Varieties | Varieties x Location |
|---|---|---|---|---|
| 1 | Length of the flower sheath | ** | ** | * |
| 2 | Number of fruit bunches $^{-1}$ | ** | ** | * |
| 3 | Fruit tree weight $^{-1}$ | ** | ** | * |
| 4 | Fruit weight $^{-1}$ | ** | ** | * |
| 5 | TSS ratio and total acid | ** | ** | ** |
| 6 | Thick fruit flesh | ** | ** | Ns |
| 7 | Vitamin C | Ns | Ns | * |
| 8 | Tannins | Ns | Ns | Ns |
| 9 | Edible portion | ** | ** | Ns |

Notes: *) significant $P < 0.05$, **) very significant $P < 0.01$ and Ns) not significantly different $P > 0.05$

The interaction of varieties and planting location had a significant effect on the length of the flower sheath and the number of fruit bunches $^{-1}$. Nenas variety grown in Tabanan (T < 560, T 560 to 650, and T > 650 ) and Karangasem (K < 560, K560 to 650, and K > 650) showed higher sheath length and a number of fruit bunches$^{-1}$ than with nangka and gondok varieties (Table 5~~6~~). Tabanan (T 560 to 650) and Karangasem (K<560 m asl) are ideal conditions for flower sheath development and fruit development of nenas.

**Table 5~~6~~.** Flower sheath length (cm) and a number of fruit bunches $^{-1}$ (fruit) of nangka, gondok and nenas varieties at six locations.

| Treatment | Sheath length (cm) | Amount fruit bunches $^{-1}$ |
|---|---|---|
| NT < 560 | 27.50 ± 0.34 bcd | 19.55 ± 0.82 hij |
| NT 560 to 650 | 28.83 ± 1.31 b | 20.39 ± 1.00 g |
| NT > 650 | 27.17 ± 0.96 cde | 19.02 ± 0.82 j |
| NK < 560 | 26.00 ± 0.82 e | 21.13 ± 0.82 ef |
| NK 560 to 50 | 27.17 ± 0.14 cde | 22.28± 2.45 c |
| NK > 650 | 26.67 ± 1.36 cde | 21.13 ± 0.74 ef |
| GT < 560 | 26.67 ± 2.18 cde | 20.22 ± 0.31 gh |
| GT 560 to 650 | 27.50 ± 1.22 bcd | 20.55 ± 0.62 fg |
| GT > 650 | 27.70 ± 1.98 bc | 19.22 ± 0.74 ij |
| GK< 560 | 25.83 ± 1.41 e | 21.89 ± 0.82 cd |
| GK 560 to 650 | 26.83 ± 0.75 cde | 20.5 ± 1.63 fg |
| GK > 650 | 27.5 ± 0.82 bcd | 21.28 ± 0.78 def |
| NST < 560 | 27.5 ± 0.82 bcd | 21.41 ± 0.91 de |
| NST 560 to 650 | 27.67 ± 0.82 bc | 22.00 ± 1.56 cd |
| NST > 650 | 26.17 ± 2.16 de | 19.91 ± 1.36 ghi |

| | | |
|---|---|---|
| NSK < 560 | 32.00 + 1.63 a | 25.27+ 1.41 a |
| NSK 560 to 650 | 30.90 + 2.10 a | 24.00 + 0.82 b |
| NSK > 650 | 27.00 + 1.47 cde | 21.86 + 0.82 cde |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

From Table 56 above it can be explained that the three varieties planted in six locations produced a number of fruits between 19.02 to 25.27 fruits per bunch. The nenas variety planted in Karangasem at an altitude of < 560 m asl (treatment NSK < 560) produced the highest number of fruits of 25.27 per bunch, followed by NSK 560 to 650 and NST 560 to 650 with 24.00 and 22.00 fruits per bunch. In order for the salak plants to bear much fruit, the nangka variety is ideal in Karangasem 560 to 650 m asl (NK 560 to 650), while the gondok variety is very good when planted below 560 m asl (GK < 560) although the number of fruits is not significantly different from the same altitude for NT 560 to 650 and GT < 560. The results of this study are in line with the findings of Sumantra and Martiningsih (2016) that the 'Gulapasir' salak var. nenas produces the highest number of fruits both in the on season (*gadu* season) and -off-season (*sela* season). Sumantra *et al*. (2014) reported that the emergence of new sheaths occurred on the third or fourth leaf midrib from the growing point depending on the altitude and plant conditions. The time for new sheaths to appear ranges from 129.00 d to145.10 d with the required heat units between (1 233.62 to 1 047.90) Degree-Day (DD). The higher altitude, the longer the sheath appears, as well as the harvest time.

The interaction of varieties and planting location had a significant effect on the fruit weigh (fruit tree$^{-1}$ and fruit$^{-1}$). Nangka variety grown in Tabanan (T < 560, T 560 to 650, and T > 650) and Karangasem (K < 560, K 560 to 650, and K > 650) showed higher of weight of fruit tree$^{-1}$ and fruit-$^{1}$ than with nenas and gondok (Table 7).

**Table 67**. Fruit weight of nangka, gondok, and nenas varieties in six locations

| Treatment | Fruit$^{-1}$ (g) | Fruit tree$^{-1}$ (kg) |
|---|---|---|
| NT < 560 | 45.32 + 1.08 cd | 1.19 + 0.08 def |
| NT 560 to 650 | 48.56 + 0.71 c | 1.29 + 0.07 cd |
| NT > 650 | 38.22 + 0.46 ef | 1.03 + 0.06 ghi |
| NK < 560 | 55.84 + 1.37 a | 1.48 + 0.02 b |
| NK 560 to 650 | 59.43 + 0.71 a | 1.62 + 0.07 a |
| NK > 650 | 49.4 +1.65 b | 1.34 + 0.05 c |
| GT < 560 | 40.14 + 0.11 e | 1.11+ 0.09 fg |
| GT 560 to 650 | 38.67 + 0.55 ef | 1.09 + 0.07 fg |
| GT > 650 | 32.95 + 0.73 gh | 0.93 + 0.10 i |
| GK < 560 | 44.22 + 0.18 d | 1.27 + 0.06 cde |
| GK 560 to 650 | 38.20 + 0.78 ef | 1.16 + 0.05 defg |
| GK > 650 | 36.20 + 0.75 fg | 1.07 + 0.11 fgh |
| NST < 560 | 39.00 + 1.07 ef | 1.14 + 0.11 efg |
| NST 560 to 650 | 37.79 + 0.65 f | 1.13 + 0.06 g |
| NST > 650 | 32.12 + 0.11 h | 0.94 + 0.10 hi |
| NSK < 560 | 41.80 + 0.65 de | 1.36 + 0.08 bc |
| NSK 560 to 650 | 36.57 + 0.80 fg | 1.18 + 0.09 def |
| NSK > 650 | 37.10 + 0.23 f | 1.11 + 0.07 fg |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

From Table 67 it can be explained that the three varieties grown in six locations produced fruit weight per tree between 0.93 kg and 1.62 kg. The salak nangka variety planted in Karangasem at an altitude of 560 to 650 m asl (NK 560 to 650) produced the heaviest fruit weight of 1.62 kg tree$^{-1}$, followed by NK < 560 and NT 560 to 650 with fruit weights of 1.48 and 1.29 kg. While the nenas variety produces the best fruit at altitudes < 560 m asl (NSK < 560 and NT < 560). Salak 'Gulapasir' var. gondok is ideal when planted at altitudes < 560 m asl (GK < 560 and GT < 560), although the two growing locations showed a different yields.

Nenas and gondok varieties showed a trend of decreasing fruit weight in line with increasing altitude, both planted in Karangasem and Tabanan. The reverse occurred in the salak nangka variety, an increase in altitude from 550 m asl to 550 to 650 m asl caused an increase in fruit weight and after that the fruit weight decreased when planted at altitudes >

650 m asl. This finding is in line with the results of research that has been reported by Sumantra *et al*. (2014). However, for the gondok and nenas varieties, this is a new finding.

Apart from being influenced by environmental factors, the production of salak 'Gulapasir' fruit is also influenced by internal plant factors (Adelina *et al*., 2021b: Lestari *et al*. 2011). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019), and rainfall (Ritonga *et al*., 2018). Altitude increases, the average daily air temperature decreases and monthly rainfall increases (Table 3). Nuary *et al.* (2019) stated that the distribution and adaptation of salak plants is strongly influenced by temperature and rainfall. It was further stated, the contribution of daily temperature accounts for nearly 38.6 % while rainfall is 27.8 %. Kanzaria *et al.* (2015) reported that mango plants planted at an altitude of 229 m flowered slower than those at an altitude of 148 m and 81 m asl. The temperature regime at higher altitudes is colder than at lower altitudes. Lower temperatures accumulate less growing degree day (GDD) and may result in late flowering. Table 7 shows that the 'Gulapasir' salak planted in Karangasem produced a higher fruit weight in the three salak varieties tested. This is related to the level of soil fertility. The soil nitrogen and phosphate nutrient content at three locations in Karangasem was higher than at three locations in Tabanan. Meanwhile, the potassium content in the six research locations was low (Table 3). Therefore it is necessary to make improvements by providing fertilizers containing elements of N, P and K to meet ideal conditions for growth, although more data is needed to fully support this conclusion (Hailu *et al.*, 2015).

*3.4 Quality characteristics of salak varieties*

The interaction between varieties and altitude significantly affected sugar/total acid and vitamin C content. The three varieties grown in Tabanan (T < 560, T 560 to 650 and T

> 650) showed a lower TSS/acid ratio. The fruit flavour planted in three locations in Tabanan is sourer than the three locations in Karangasem. Sugar content is greatly affected by the geographical. The geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity, and rainfall (Ritonga *et al*., 2018). Table 8 also shows that the increase in altitude from 550 m to 700 m asl in Tabanan and the addition in altitude from 550 to 650 m asl in Karangasem causes the sugar/acid ratio decrease in all three varieties, and the lowest sugar/acid value occurs in nenas variety in all locations. Each salak variety has an adaptation to an elevation closely related to plant tolerance to temperature (Sumantra and Martiningsih, 2016; 2018). Many factors influence fruit quality, but the most dominant are climate factors, especially temperature and rainfall. Rainfall has a negative correlation with fruit weight-1 (r = -0.991 **), TSS/acid ratio (r = -0.875 **) and vitamin C (r = -1.000**). However, the air temperature has a positive and significant correlation with fruit weight-1, TSS/acid ratio, and vitamin C with correlations, respectively: r = 0.930 **, r = 0.733 **, and r = 0.964**..High rainfall and low air temperature during the fruit ripening phase can cause the dissolved solids in the fruit to become watery so that the TSS value is low (Singh *et al*., 2011).

Salak fruits from three different varieties grown in low lands in Karangasem (K < 560 m asl) showed the highest vitamin C content and were significantly different from the three cultivars when planted in other locations. In both areas land increased by > 650 m asl effects to vitamin C decrease, nangka and gondok varieties showed higher levels of vitamin C between < 550 m to < 650 m asl. (Table 78).

**Table 78.** TSS/acid ratio and levels of vitamin C of nangka, gondok, and nenas varieties in six locations.

| Treatment | TSS/T.Acid | Vit. C (mg /100g) |
|---|---|---|
| NT < 560 | 56.20 ± 0.16 abc | 27.50 ± 0.41 bde |
| NT 560 to 650 | 59.18 ± 0.82 a | 25.45 ± 0.37 defgl |
| NT > 650 | 37.89 ± 0.91 f | 22.52 ± 0.39 j |
| NK < 560 | 51.41 ± 0.33 cde | 27.74 ± 0.47 bd |
| NK 560 to 650 | 53.52± 0.82 abcd | 29.61 ± 0.50 ab |
| NK > 650 | 47.76 ± 0.11 de | 24.25 ± 0.20 fghij |
| GT < 560 | 34.88± 0.72 fg | 25.50 ± 0.41 defgl |
| GT 560 to 650 | 34.80 ± 0.65 fg | 25.75 ± 0.20 defgl |
| GT > 650 | 30.24 ± 0.20 gh | 23.34 ± 0.28 hij |
| GK < 560 | 51.28 ± 0.23 cde | 30.31 ± 0.25 a |
| GK 560 to 650 | 58.44 ± 0.36 ab | 27.63 ± 0.30 bd |
| GK > 650 | 53.04 ± 0.82 bcde | 25.07 ± 0.33 efgh |
| NST < 560 | 31.50 ± 0.41 gh | 26.71± 0.21 cdef |
| NST 560 to 650 | 30.44 ± 0.36 gh | 25.88 ± 0.41 defg |
| NST > 650 | 26.13 ± 0.11 h | 23.65 ± 0.29 ghij |
| NSK < 560 | 53.73 ± 0.60 abc | 24.42 ± 0.34 fghij |
| NSK 560 to 650 | 52.63 ± 0.51 bcde | 22.82 ± 0.15 ij |
| NSK > 650 | 47.60 ± 0.49 e | 25.16 ± 0.13 efgh |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

The results showed that the varieties of the ‘Gulapasir’ salak needs different environmental requirements to optimize yields. Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al*., 2021, 2022). Therefore, variety differences may depend on growing requirements and cultivation techniques. Vitamin C in the ‘Gulapasir’ salak is strongly influenced by the altitude of the land. To produce high levels of vitamin C, the nangka and gondok varieties are ideal for planting at an altitude of 560 m to 650 m asl, while the nenas variety is ideal at a land altitude

of < 560 m asl. However, changes in ascorbate levels during fruit ripening are species-dependent and environmental factors especially temperature and light (Fenech *et al*., 2019).

There was no interaction between varieties and altitude to the flesh thickness, edible fruit portion, and fruit sugar content. The nangka salak variety showed fruit quality, including TSS, edible parts of the fruit, and higher flesh thickness (Table 89).

**Table 89.** The effect of a single factor of varieties on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment | TSS ($^{o}$Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| Nangka | 16.59a | 72.50a | 0.63a |
| Gondok | 16.42a | 70.66ab | 0.59b |
| Nenas | 15.64b | 69.22b | 0.52c |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Salak grown in Karangasem both from the lowlands and the middle lands produces fruit thickness, and the edible portion of fruits is higher than plants in the highlands. This study indicates that the ideal growing place for salak plants is between 450 m to 650 m asl (Tabel 9). This study is in line with several previous studies which explained that altitude affects the flowering process and fruit enlargement (Sophie *at al*., 2017; Spinardi *et al*., 2019; Widyastuti *et al*., 2022).

**Table 910.** The effect of a single factor of planting location on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment (m asl) | TSS ($^{o}$Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| T < 550 | 16.28a | 73.13a | 0.54c |
| T 550 to 650 | 16.27a | 69.89a | 0.58bc |
| T > 650 | 16.14a | 63.87b | 0.49d |
| K 550 | 16.81a | 73.15a | 0.61b |
| K 550 to 650 | 16.11a | 72.29a | 0.66a |
| K > 650 | 15.69a | 72.44a | 0.61b |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

The soil analysis results showed that the total N and P2O5 contents at three locations in Tabanan were very low to low, while the K2O content at the six study sites was very low (Table 3). The low nutrient values of the three nutrients above are thought to be a factor causing the three types of salak planted in Tabanan at different altitudes to produce low fruit. The correlation results showed that N and P2O5 content negatively correlated with fruit weight (r = -0.855** and -0.992**), while K2O content had a positive and highly significant correlation (r = 0.997**) with fruit weight. The quality of zalacca land is low because farmers practice very simple in zalacca cultivation, most fertilization only uses submerged salacca midrib (Sumantra, et al., 2014; Tamba and Sumantra, 2022). Therefore, the utilization and processing of plant waste need to be optimized to improve land quality. Further research can be applied using sustainable salak organic agriculture (Budiasa, 2014; Handayani, 2022; Nurhidayat *et al*., 2022; Rahmah *et al*., 2022; Wimatsari *et al*., 2019). Table 3 shows that salak cultivation in the research location still needs to implement sustainable farming (Prasetyo *et al*., 2022b; 2022a). There are indications some of decrease in soil fertility, especially potassium available in the six planting locations that shows a very low value. Potassium levels in Table 3 are lower than the observations of Ashari (2013) and Woran *et al.* (2018) in salak cultivation areas in Swaru – Malang (very high), Sleman – Yogya (moderate), Bangkalan – Madura (very high), and Pangu – Minahasa (moderate).

Potassium helps produce good fruit quality, such as bigger, heavier, and sweeter fruit. Another benefit of the nutrient potassium in plants is to increase the growth of meristem tissue and regulate the movement of stomata. Potassium also helps the development of plant roots so that plant stems can stand upright and do not collapse easily (Adinurani *et al.*, 2018; Budiono *et al*., 2019). Therefore, Nasution (2022) recommends more $K_20$ fertilizer than $P_20_5$ fertilizer and N fertilizer. In addition, salak needs 70 kg of $K_2O$ because this nutrient is found in the leaves at an amount (12.2 to 14.7) mg $g^{-1}$ (Ashari, 2013).

The chemical fertilizers (e.g., KCl) are too expensive for Salak farmers and do not support the salak organic. Therefore, the application of sustainable farming should apply local wisdom including the use of the pruning of salak midrib. Consider this policy because C organic is essential to soil fertility (Budiono *et al*. 2021; Goenadi *et al*. 2021). The success of this midrib decomposition is demonstrated by the C organic in Table 3, which is classified as medium to high. This finding support Faizah and Fauzan (2021), Saputra *et al.* (2018) in salak plantation of Purwosari District - Pasuruan Regency, and Wonosalam District – Jombang Regency.

But, in the next stage, some of the salak midribs should be burned into ashes which can be used as a source of potassium nutrients (Ekawati and Purwanto, 2012; Vincevica-Gaile *et al*., 2021a, 2021b). Another organic source of potassium is the pulp/husk of coffee cherries. Karangasem and Tabanan districts are coffee cultivation areas in Bali, so they should take advantage of this coffee processing waste. Several researchers stated that coffee pulp/husk contains higher potassium than nitrogen or phosphorus nutrients (Bahri *et al*., Falahuddin *et al*., 2016; Novita *et al.*, 2018; Setyobudi *et al*., 2018).

Several researchers (Analianasari *et al*. 2022; Ningsih, 2020; Wachisbu, 2020) recommend soaking the pulp/husk coffee cherries and uses as liquid organic fertilizer with benefits for various plants. To develop this idea, salak farmers in Karangasem and Tabanan Regency should create biogas as household or communal scale digesters (Prespa *et al*., 2020; Setyobudi *et al.* 2021b; Susanto *et al*., 2020a) or use digesters from used drums (Adinurani *et al*., 2017; Hendroko *et al*., 2013). All household organic waste is processed in the digester, including kitchen waste, leftover food, and human excrement from pit latrines and septic tank (Anukam and Nyamukamba, 2022; Somorin, 2020; Susanto *et al*., 2020b; Zhou *et al*., 2022). This action has various advantages, namely reducing global warming, obtaining clean - renewable energy, and two kinds of organic fertilizer, i.e., liquid and solid

(Abdullah *et al*., 2020; Burlakovs *et al*., 2022; Hendroko *et al*., 2014; Prespa *et al*., 2020; Setyobudi, *et al*., 2018). In addition, many researchers have reported (among other things Benyahya *et al*., 2022; Baştabak and Koça, 2020; Li *et al*., 2021) the benefits of organic fertilizers from biogas digesters.

Another measure to increase and maintain land fertility is in salak cultivation, namely the application of Plant Growth Promoting Rhizobacteria (PGPR) or biological fertilizer (Basu *et al*., 2021; Ekawati, *et al.*, 2019). Several researchers (Adinurani *et al*., 2021; Kumalawati *et al*., 2021; Muhammad *et al*. 2021) have reported using mycorrhiza, which positively impacts various plants, including salak cultivation (Amnah and Friska, 2018; Dewi *et al*., 2020; Rai *et al*., 2021). Multiplication of mycorrhiza is relatively simple (Sportes *et al*., 2021; Sukmawati *et al*., 2021) and can be done by farmer groups with initial guidance from universities.

**4. Conclusion and Recommendation**

Different cultivars caused different fruit weights, fruit bunches, and the sugar/acid ratio at various locations. The three varieties showed lower fruit weight and fruit quality in Tabanan (low, medium, and highlands) than the salak originating from Karangasem. The SGP var. nangka in Karangasem showed higher fruit weight, vitamin C content, and sugar/acid ratio. In Karangasem and Tabanan, SGP var. nangka grows ideally at an altitude of 560 to 650 m asl with fruit weight per tree of 1.62 $kg^{-1}$ and 1.29 $kg^{-1}$, respectively. While the SGP var. nenas showed the highest number of fruit $bunches^{-1}$ in six locations. In contrast, SGP var. nenas and SGP var.gondok are ideal for cultivating at an altitude of <560 m asl both in Karangasem and Tabanan, but the fruit production of SGP var. nenas and SGP var.gondok is higher, respectively, 19.29 % and 15.31 % when planted in Karangasem.

In order to obtain ideal fruit production and quality, SGP var. nangka is very suitable to be planted at an altitude of 550 m to 650 m asl. In contrast, the SGP var. nenas and var.gondok are developed naturally at low altitudes < 550 m asl.

The nangka variety in Karangasem showed higher fruit weight, vitamin C content, and sugar/ acid ratio, while the nenas salak showed the highest number of fruit $bunches^{-1}$ in six

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~~locations. Nangka salak are very suitable to be planted at an altitude of 550 m  to  650 m asl. In contrast, the nenas and gondok varieties are developed naturally at low altitudes < 550 m asl~~. In order to~~for~~ enable all cultivars ~~to be able to~~ produce optimally, efforts to improve the cultivation system are needed through fertilization and the provision of calcium is highly recommended. Further research can be applied using sustainable salak organic agriculture to maintain soil fertility.

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**Commented [ES12]:** In the Conclusion also need to include the problems raised in the Introduction whether the results could solve the problem or partly solved, before the recommendation sentence.

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# Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Various Agro-Ecosystems

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**Abstract**

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir has been officially released by the Minister of Agriculture of the Republic of Indonesia since 1994. Salak 'Gulapasir 'is one of five types of fruit that have been designated as the superior fruit of the Bali Province. Salak 'Gulapasir' is preferred by consumers due to its specific fruit flesh taste. Salak 'Gulapasir' was propagated using seeds so that a new type of salak emerged. However, the characters of this new type of salak 'Gulapasir' are not yet known. The research objective was to obtain the superior products of Salak 'Gulapasir' both in quantity and quality. The research used a Randomized Block Design with three replications. The non-independent variable was the three of Salak 'Gulapasir' (SGP): SGP var. nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem: (K < 560 m asl, K 560 m to 650 m asl, and K > 650 m asl) and Tabanan: (T < 560 m asl, T 560 m to 650 m asl, T > 650 m asl). Observations were made on the agronomic characters and fruit quality. Data were analyzed using variance analysis, and if the planting location and varieties show a difference, then it is followed by the LSD test at the 5 % level. The results showed that different varieties caused different fruit weights, fruit bunches, TSS, and total acid ratio. In Karangasem and in Tabanan, SGP var. nangka grows ideally at an altitude of 560 m to 650 m asl with fruit weight per tree of 1.62 $kg^{-1}$ and 1.29 $kg^{-1}$, respectively. SGP var. nenas and SGP var. gondok are ideal for cultivating at an altitude of < 560 m asl both in Karangasem and Tabanan, but the fruit production of SGP var. nenas and SGP var. gondok is higher, respectively 19.29 % and 15.31 % when planted in Karangasem, while the SGP var. nenas showed the highest number of fruit $bunches^{-1}$ in six locations. Further research can be applied using sustainable salak organic agriculture to maintain soil fertility.

**Keywords:** Altitude, Improve soil fertility, Organic potassium fertilizer, Organic salak, *Salacca zalacca* (Gaertn.) Voss, Salak sustainable agriculture, Snake fruit, Tropical fruit

## Introduction

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir is one of the essensial fruits in Indonesia, and the plant can be found in most regions of Indonesia (Rai *et al*., 2016; Ritonga *et al*., 2018). The salak fruit belongs to the family Palmae or Arecaceae and is native to the Indonesian-Malaysian region (Hakim *et al.*, 2019; Zumaidar *et al*., 2014). One of the extraordinary strengths of this fruit commodity for Indonesia is the possession of high genetic diversity (Budiyanti *et al*., 2019). Also, the nutrition of salak fruit is rich in antioxidants, phenolics, vitamins, and minerals (Cepkova *et al*., 2021; Mazumdar *et al*., 2019), and a good source of income and provides livelihood opportunities on seasonal days (Khan and Idrees, 2021). Furthermore fruit flesh and peel have shown tremendous anti-inflammatory, anticancer, antidiabetic (Saleh *et al*., 2018), and anti-aging agents (Girsang *et al*., 2019). Antioxidants are chemical compounds that play an essential role in protecting cells due to attacks against free radicals-induced damage to biomolecules (Damat *et al*.,

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2019, 2020; Puspitasari and Ningsih, 2016; Setyobudi *et al*., 2019). Despite its incredible food and medicinal benefits, salak fruit is still underutilized and unknown globally so that this underutilized fruit remains an issue for future sustainable utilization and commercial value enhancement market (Mazumdar *et al*., 2019). Fruit quality is an important issue, especially for products that are consumed raw and fresh. One of the problems is the lack of fruit quality because of inadequate information about superior salak (Budiyanti *et al*., 2019; Herawati *et al*., 2018). Therefore, it is necessary to select superior salak to meet market demand and serve community nutrition.

Salak 'Bali' is quite a lot, based on the shape, aroma, taste, and skin colour of the location where the plants are cultivated (Sumantra *et al*., 2012, 2014; Sumantra and Martiningsih, 2016, 2018). Under the Decree of the Minister of Agriculture of the Republic of Indonesia in 1994, Balinese zalacca was grouped into two superior zalacca: Salak 'Bali' (SK Mentan, 1994a) and Salak 'Gulapasir' (SK Mentan, 1994b). The second type, the salak 'Gulapasir' (SGP) is the most superior salak because of its sweet fruit taste; even though the age of the fruit is still young, thick fruit flesh and seeds are not attached to the fruit flesh (Rai *et al*., 2014; Sumantra *et al*., 2016). The nature of this fruit is ideal for meeting market demands for both the domestic and export markets (Martiningsih *et al*., 2018). Salak 'Bali' is monoecious, so crossing does not need human help (Herawati *et al*., 2018), and can quickly develop using seeds (Sumantra and Martiningsih, 2016). Another advantage of salak plants in Indonesia compared to other fruits is harvest 2 to 3 times a year if management is good (Rai *et al*., 2016; Warnita *et al.*, 2019). The expansion of salak 'Gulapasir' planting causes variations in phenotypic diversity. People can find two to three types of salak plants with a marker, fruit shape, aroma, flesh colour, and fruit weight (Martiningsih *et al*., 2018). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seeds so that new varieties of salak 'Gulapasir' (SGP) appear, as reported by Sumantra and Martiningsih (2016). Based on the marker that can be used as a differentiator, salak farmers give it the name of SGP var. nenas, SGP var. gondok, and SGP var. nangka. The three varieties have not yet identified their advantages in meeting market needs in line with the results of research (Sumantra and Martiningsih, 2016). The performance and produce are influenced by the characteristics of the agricultural ecosystem, particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status (Adelina *et al.*, 2021a; Kumar *et al*., 2020) and growth hormone (Prihastanti and Haryanti. 2022; Rai *et al.*, 2016).

The salak 'Gulapasir' plantation in the District of Bebandemis the main producer of salak 'Gulapasir' in Bali is located in the southern part of Mount Agung with an altitude of 450 m to 700 m above sea level (m asl). The effect of altitude on plant growth and production is related to plant adaptation to temperature (Sumantra, *et al*., 2014), full sunlight (Sukawijaya *et al*., 2009), water status and soil quality (Raharjo *et al*., 2022; Rai *et al*., 2014; Ritonga *et al.*,2018). Salak plants are not resistant to full sun but 50 % to 70 % enough, therefore it is necessary to have shade plants (Sukawijaya *et al*., 2009; Sumantra *et al*., 2012). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019). Water status and soil quality really determine the fruit set on the salak 'Gulapasir'. Low rainfall reduces the Relative Water Content in leaves (RWC), leaf chlorophyll content, and plant nutrient uptake (Rai *et al*., 2014). Soil quality included the suitability of the physical, chemical and biological properties (Raharjo *et al*., 2022). Nuary *et al*. (2019) stated that the distribution of the salak 'Pondoh' plantation area in Sleman (Yogyakarta, Special Region) was greatly influenced by temperature and rainfall. The contribution of temperature in the modelling reached 38.6 % while the rainfall was 27.8 %. Furthermore, taking into account the probability of the temperature variable, the average temperature ranges from 17.41 °C to 25.65 °C, and the ideal month's rainfall ranges from 385.24 mm to 505.01 mm.

Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al.*, 2021, 2022). Therefore, variety differences may depend on growing requirements and cultivation techniques. Likewise, Puspitasari *et al*. (2016) stated that tannin content, fruit size and flesh colour of salak fruit are strongly influenced by where it grows. Other studies also explain that salak 'Gulapasir' var. nangka which is grown 570 m asl, would result in a higher quality of fruit that includes thickness of the mesocarpium, edible portion of fruit than compared to above and below 570 m asl (Sumantra *et al*., 2014; Sumantra and Martiningsih, 2016). Meanwhile, fruit weight and fruit quality of var. gondok and var. nenas have not been reported. Therefore, one way of handling salak quality is by undertaking severe studies for factors such as land and climate and adjusting agricultural patterns according to local climate conditions (Nassar *et al*., 2018). The success of each species to occupy the environment of an area is influenced by its ability to adapt optimally to all physical environmental factors (temperature, light, soil structure, humidity), biotic factors (interaction between species, competition, parasitism), and chemical factors including the availability of water, oxygen, pH, and nutrients (Nassar *et al*., 2018; Widyastuti *et al*., 2022). Moreover, a broad genetic variability would lead to wide phenotypic variability due to the effect of genetic-environment interaction (Ritonga *et al*., 2018). The research objective was to obtain several superior salak 'Gulapasir' both in production and fruit quality (sugar and acid ratio, vitamin C and tannins) in six different agricultural ecosystems in Bali. This research was important to do to get the suitability and adaptation of the types of salak based on the altitude where it grows so that in the future, its development will be able to provide maximum results according to existing agro-ecosystem conditions.

## Materials and Methods

### *Experimental site*

The research was conducted in Tabanan and Karangasem Regencies. Tabanan and Karangasem were selected as research locations because the domination of salak 'Gulapasir' in these two regencies was the highest. In 2021, the salak 'Gulapasir' population in Tabanan was 84 % of all salak species, while in Karangasem Regency the dominance of the salak 'Gulapasir' was more than 63 % (Sumantra *et al*., 2022).

The study was carried out in six different locations, three sites in Karangasem Regency and three sites in the district of Tabanan. Locations in Karangasem (K) are lowlands (K < 560 m asl) which include several places, namely Telaga, Dukuh, and Karanganyar. Karangasem in the moderate plains (K 560 m to 650 m asl) has several areas, namely Kecing and Kutabali and highlands (K > 650 m asl), namely Tanah Apo and Kresek (Figure 1).

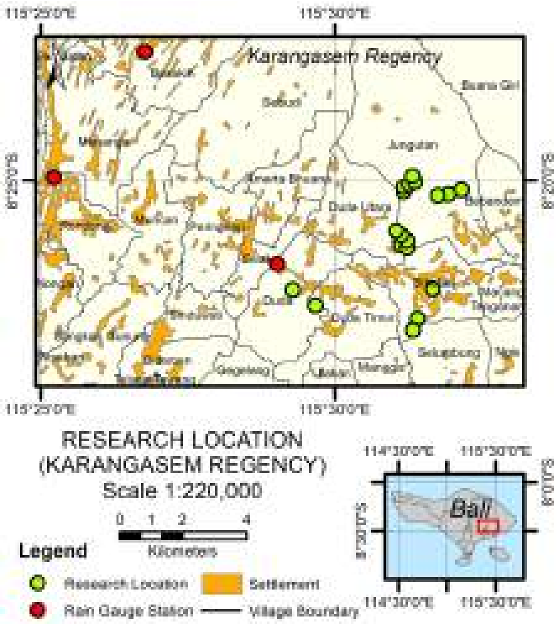


Fig. 1. Research map and sampling point in Karangasem (K)

The research location is in Tabanan (T) in the lowlands (T < 560 m asl), including Wanagiri, Sari Buana, and Mundeh Kauh. Tabanan in the medium lands (T 560 m to 650 m asl) includes several places, namely Pajahan, Kebon Jero, and Angseri. Tabanan in the highlands (T > 650 m asl), namely Munduk Temu, Pempatan, and Batungsel (Figure 2).

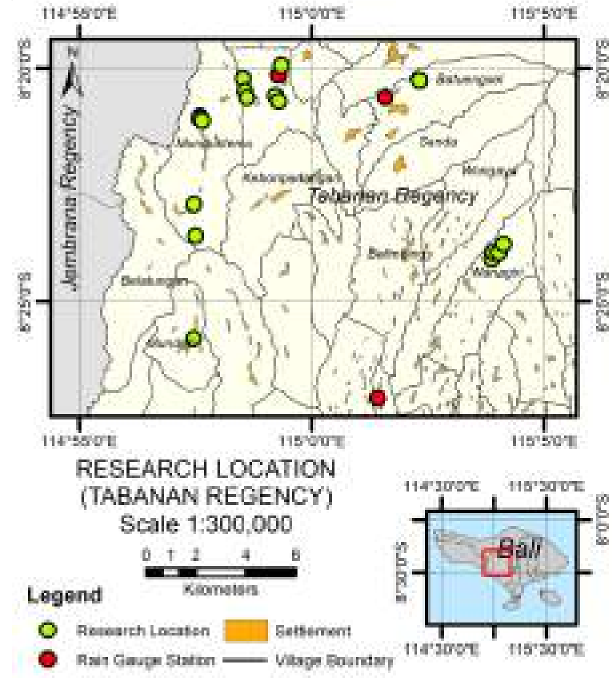


**Fig 2.** Research map and sampling point in Tabanan (T)

The non-independent variable was the three varieties of Salak 'Gulapasir' (SGP): SGP var. nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem (K): (K < 560 m asl, K 560 m to 650 m asl, and K > 650 m asl) and Tabanan (T): (T < 560 m asl, T 560 m to 650 m asl, T > 650 m). Repetition was carried out three times with the number of sample plants in each location, and cultivars were seven plants. The treatment tested is as shown in Table 1.

**Table 1**. Treatment of plant location and three varieties of 'Gulapasir' salak

| No | Treatment | Explanation |
|---|---|---|
| 1 | NT < 560 m asl | Salak GP var. nangka Tabanan < 560 m asl. |
| 2 | NT 560 m to 650 m asl | Salak GP var. nangka Tabanan 560 m to 650 m asl. |
| 3 | NT > 650 m asl. | Salak GP var. nangka Tabanan > 650 m asl. |
| 4 | NK < 560 m asl. | Salak GP var. nangka Karangasem < 560 m asl. |
| 5 | NK 560 m to 650 m asl | Salak GP var. nangka Karangasem 560 m to 650m asl. |
| 6 | NK > 650 m asl. | Salak GP var. nangka Karangasem > 650 m asl. |
| 7 | GT < 560 m asl | Salak GP var. gondok Tabanan < 560 m asl. |
| 8 | GT.560 to 650 m asl | Salak GP var. gondok Tabanan 560 m to 650 m asl. |
| 9 | GT > 650 m asl | Salak GP var. gondok Tabanan > 650 m asl. |
| 10 | GK.< 560 m asl | Salak GP var. gondok Karangasem < 560 m asl. |
| 11 | GK 560 m to 650 m asl | Salak GP var. gondok Karangasem 560 m to 650 m asl. |
| 12 | GK >650 m asl | Salak GP var. gondok Karangasem > 650 m asl. |
| 13 | NST < 560 m asl | Salak GP var. nenas Tabanan < 560 m asl. |
| 14 | NST.560 m to 650 m asl | Salak GP var. nenas Tabanan 560 m to 650 m asl. |
| 15 | NST > 650 m asl | Salak GP var. nenas Tabanan > 650 m asl. |
| 16 | NSK .< 560 m asl | Salak GP var. nenas Karangasem < 560 m asl. |
| 17 | NSK 560 m to 650 m asl | Salak GP var. nenas Karangasem 560 m to 650 m asl.. |
| 18 | NSK > 650 m asl | Salak GP var. nenas Karangasem > 650 m asl. |

The study used a Composite Analysis of Variance (Andinurani, 2016, 2022) with the model determined using Equation (1) below:

$$Yjk = U + Li + \delta ik + Pj + (LP) ij + \varepsilon ijk \quad (1)$$

Where:

Yijk = The observation value of the treatment (j) in the group (k), which is repeated at the location (i).

u = the actual average value

Li = additive effect from location i

δ ik = the error effect in group k at location i

Pj = additive effect of the next treatment

(LP) ij = the effect of treatment (j) atthe location (i)

Ɛ ijk = the effect of error from the treatment (j) in the group (k) which was carriedout at the location (i).

*Preparation of study materials*

The material used is the salak 'Gulapasir' plant with uniform growth; plants have been fruitful with uniform on morphological, age of plants and cultivation action. The intentional practice is that the plant only receives treatment in the midrib, tillers, and weed cleaning. In this study, the plants were not fertilized. The provision of water was only from rainfall following the habits applied by salak farmers. The sample plant was maintained by trimming unproductive leaf midribs and removing young shoots. Plant material was taken from the Salak Development Centre in six locations, namely at the Centre of Salak Development in the Bebandem sub-districts, Karangasem district (K-lowland < 560 m asl, K-medium 560 m to 650 m asl and K-highland > 650 m asl), Bajre, West Slemadeg and Pupuan sub-districts, Tabanan district (T-lowland < 560 m asl, T-medium 560 to 650 m asl and T-highland > 650 m asl).

*Analysis of physicochemical properties of soil sample and climate*

Soil analysis was carried out to determine the physical and chemical properties of the soil. Soil sampling was carried out under sample plant trees, in a composite manner at a depth of 0 cm to 40 cm. Chemical analysis was carried out on total N (Kjeldahl method), available P by Bray I method and $K_2O$ by the Bray I method, organic C, pH, soil physical properties in the form of texture by pipette method (Eviati and Sulaeman. 2009; Hailu *et al*., 2015; Prasetyo *et al*., 2022a; Rzasa and Owczarzak, 2013).

Rainfall data was taken for 5 yr from 2015 to 2019. Rainfall data has been collected from six nearby stations to the research site (Figure 1 and Figure 2). Daily temperature data was obtained from the Denpasar Meteorology Climatology Agency.

*Observation of fruit and fruit quality*

Salak fruit can be harvested when it is ready for consumption. Consumable ripe fruit is a fruit that is ready to be consumed, characterized by a change in skin colour from dark brown to light brown, the thorns on the skin being reduced and not sharp, and in general, at this stage, the fruit easily falling when shaken.

Observation and measurement of agronomic characters follow the method that has been done by Sumantra *et al*. (2014) including fruit weight, number of fruit bunches, the thickness of fruit flesh and fruit shape. The fruit characters from six-observed locations include the numbers of fruits per bunch, which is calculated manually on the formed fruits. The fruit weight per fruit and the fruit weight per tree is weighed after the fruits were removed from the bunch. The thickness of the mesocarpium is obtained by measuring the mesocarpium after it is cut vertically. The length of the flower sheath is measured on the stem of the sheath from the base to the tip of the sheath.

While fruit quality includes sugar content, tannins, titrated acid, sugar content and vitamin C. Titrated acid was analyzed by titration (Sripakdee *et al*., 2015). The fruit which was weighed 10 g of sample was added to 100 mL of distilled water, then was homogenized using a slow spin blender, and filtered using an aseptic filter. The filtrate obtained was taken as much as 25 mL, then titrated with 0.1 N NaOH solution with phenolphthalein indicator until red colour appeared. The results obtained are calculated as the percentage tartaric acid as per Equation (2) below :

$$A = \frac{\text{mL NaOH} \times \text{N NaOH} \times P \times BM}{Y \times 1\,000 \times 2} \times 100\ \% \quad (2)$$

where:

A = percentage of total acid
P = amount of dilution
BM = molecular weight of tartaric acid
Y = sample weight (g).

Tannins content was analyzed as done by Thakur *et al*. (2021), Setyobudi *et al*. (2022). Amount of 100 mg of the sample was homogenized by 2 mL of methanol, centrifuged for 10 min at 10 000 rpm (1 rpm = 1/60 Hz), and then the supernatant was collected. Amount of 1 mL of the aforementioned supernatant was mixed with 0.5 mL Folin's phenol reagent and 35 % $Na_2CO_3$ of 5 mL was added, and the mixture was kept at room temperature for 5 min. The blue colour of the reaction mixture was observed at 640 nm by UV/visible spectrophotometer (Shimadzu UV-1800, Japan). The content of tannins was calculated by calibration curve equation and determined using Equation (3) below:

$$Y = 0.007\,3\times - 0.007\,1 : R^2 = 0.997\,3 \quad (3)$$

Vitamin C was determined by titration like the method used by Asamara (2016), Setyobudi *et al*. (2021a, 2022). The material is weighed as much as 10 g and crushed in mortal, then put into a 250 mL volumetric flask, set to the mark and filtered. Take 25 mL of the filtrate and titrate with 0.01 N Yod solution equivalent to 0.88 mg of ascorbic acid. The calculation of ascorbic acid content per 100 g of material is determined using Equation (4) below:

$$A = \frac{\text{mL Yod } 0.01\text{ N} \times 0.88 \times P \times 100}{Y} \quad (4)$$

where: A = mg of ascorbic acid per 100 g of material
P = amount of dilution
Y = gram sample weight

Sugar content as TSS is calculated using a hand refractometer (Bellingham and Stanley Ltd., London) at 20 ºC (Adinurani *et al*., 2018). The ratio of sugar content (TSS) and total acid is calculated by the sugar content divided by the acid content multiplied by 100 %.

The materials used in this study were Folin-ciocalteu reagent (Pro Analytic, Merck), NaOH (pro analytic, Merck), $Na_2CO_3$ (pro analytic, Merck), Phenol reagent (pro analytic, Merck), Ascorbic acid (pro analytic, Merck), Phosphoric acid (Pro Analytic, Merck), Sodium phosphate (pro analytic, Merck) and Ammonium molybdate (pro analytic, Merck).

The tools used in this study were analytical balances (Shimadzu ATY224, Japan), centrifuge tubes, Erlenmeyer flasks (Pyrex), dropper pipettes (pyrex), volume pipettes (Pyrex), vortex (Maxi Mix II Type 367000), measuring flask (Pyrex), water bath (Memmert), blender (Miyako), and centrifuge (Damon /IEC Division). Whatman filter paper No 1 (Sigma – Aldrich, USA), measuring cup (Pyrex, USA), micropipette (Dragon Lab, Indonesia), spectrophotometer (Biochromsn 133467, UK), test tube (Pyrex¸ USA), vortex (Barnsteadl Thermolyne Type 37600 Mixer, USA), aluminum foil (Klin Pak, Indonesia).

*Study design*

This study used a randomized block design with the data analyzed using a Composite Analysis of Variance. If the variance test is significantly different, then it is continued with a different test with LSD at the 5 % level. Data analysis was performed using SPSS-IBM 18 (Adinurani, 2016, 2022). Each experimental treatment was repeated three times.

## Results and Discussion

*Agroclimate characteristic*

The low production level and the quality of salak fruit are caused by environmental factors that do not support growth or because the physiological processes of the plant are not optimal due to insufficient nutrients and water. The suitability of climatic and soil conditions at six locations of the centres for the development of the 'Gulapasir' salak was evaluated. The evaluation results show that the air temperature decreases as the altitude increases. The average air temperature at the 'Gulapasir' salak plantation in Tabanan is 22.90 ºC, while the air temperature at the Karangasem salak plantation is around 23.24 ºC. (Tabel 2)

**Table 2.** Soil and climate characteristics of the research site in Tabanan and Karangasem in three subzones

| Parameter | Tabanan (T) | | | Karangasem (K) | | |
|---|---|---|---|---|---|---|
| | Lowlands (< 560 m asl) | Moderate ((560 m to 650 m asl) | Highlands (> 650 m asl) | Lowlands (< 560m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) |
| Temp. (ºC) | 23.82 | 22.75 | 22.12 | 24.29 | 23.35 | 22.09 |
| Rainfall (mm $mo^{-1}$) | 188.24 | 199.91 | 231.008 | 237.242 | 254.183 | 289.216 |
| Soil texture | loamy clay | loamy clay | loamy clay | clay | Clay | sandy loam |
| pH ($H_2O$) | 5.64 (sa) | 5.75 (sa) | 5.84 (sa) | 6.08 (sa) | 6.05 (sa) | 6.03(sa) |
| C- organic (%) | 2.94 (m) | 3.40 (h) | 3.25 (h) | 2.77 (m) | 3.63 (h) | 3.32 (h) |
| Nutrients available | | | | | | |
| N total (%) | 0.18 (l) | 0.16 (l) | 0.18 (l) | 0.24(m) | 0.23 (m) | 0.29 (m) |
| $P_2O_5$ (mg $g^{-1}$) | 9.38 (vl) | 9.12 (vl) | 13.50 (l) | 22.55 (m) | 24.18 (m) | 23.04 (m) |
| $K_2O$ (mg $g^{-1}$)) | 18.47 (vl) | 22.05 (vl) | 17.23 (vl) | 24.17 (vl) | 19.93 ( vl ) | 18.37 ( vl ) |

Notes: sa: slightly acidic; h: high; m: medium; l: low; vh: very high; h: high; asl: above sea level (The assessment criteria refer to Eviati and Sulaeman. 2009; PPT, 1983).

In addition to monthly rainfall, the average rainfall over 5 yr is presented in Figure 3. Annual rainfall in Tabanan (T < 560, T 560 to 650 and T > 650) is lower with an average of 2515.05 mm, while in Karangasem (K < 560, K 560 to 650 and K > 650) it is 3 122.05 mm. However, the six locations show a trend of increasing rainfall as altitude increases. The salak plantation area in Karangasem is in the southern part of Mount Agung. Meanwhile, in Tabanan, the dominant salak plantation area is behind Mount Batukaru with a lower elevation than Mount Agung. Mount Agung has an altitude of 3 142 m asl (Andaru and Rau, 2019), while Batukaru mountains area of 2 250 m asl (Asmiwyati *et al*., 2015). Mount Batukaru serves as a barrier from the rain, causing this area to be a rain shadow. Enyew and Steenveld (2014) state that rainfall in an area is influenced by topographical factors and mountain ranges. Decreasing the height of the mountains provides a reduction in the maximum level of rainfall over the mountains and foothills by 50 % (Flesch and Reuter, 2012). Topographical factors and regional weather systems have an important role in the amount and spatial pattern of rainfall in an area (Enyew and Steenveld, 2014).

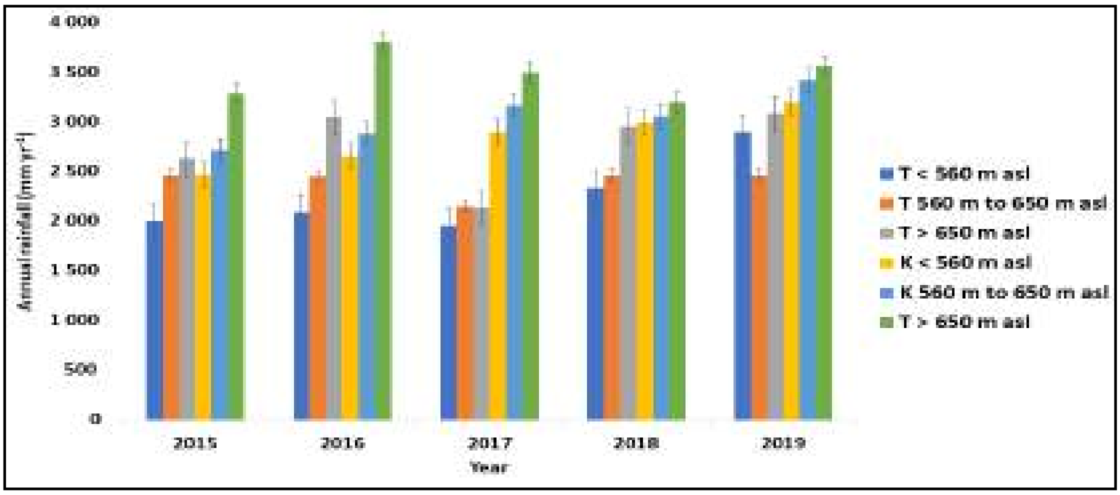


**Fig. 3.** The annual rainfall in the six study sites

Based on the growing requirements of salak plants, rainfall and air temperature in the six locations evaluated were in the very suitable range to support plant growth and development. A good air temperature for the growth of salak plants is between 20 °C to 30°C and an average rainfall of (200 to 400) mm $mo^{-1}$ (Nuary *et al*., 2019).

Soil C-organic content in six planting sites was in the medium to high range. Availability of N and P nutrients in salak plantations in Tabanan in the lowlands, medium and highlands is of low to very low conditions. In salak planting land in Karangasem - both in the lowlands, medium and highlands - these two nutrients are available in moderate conditions (Table 3). The nutrient content of potassium available in the six planting locations that have been evaluated shows a very low value. The results of this study indicate that the cultivation techniques carried out by farmers are very low. Farmers do not apply fertilizers that only rely on litter from the pruning of salak midrib as reported by Ilmiah *et al*. (2021), Rai *et al.* (2014), and Warnita *et al.* (2019). To cultivate sustainable agriculture, especially in agroecosystems salak in Bali, the authors will discuss this issue more in the future research paragraph.

*Fruit Characteristics of Salak 'Gulapasir'*

The salak 'Gulapasir' his monoecius plant, namely male and female flowers arranged on the same bunches, the shape of the bunchesis compound, and the position of the flower is on the back of the midrib. The salak 'Gulapasir' is classified as special because of its sweet fruit taste and the price per unit weight is four times more expensive than the salak 'Bali' (Rai *et al*., 2014; Sumantra *et al*., 2012). The expansion of the cultivation of the salak 'Gulapasir' from its area of origin, Sibetan, Karangasem, has resulted in phenotypic diversity with a phenotypic similarity level of 58.62 % to 93.10 % (Sumantra and Martiningsih, 2016). In the same garden, more than one type of 'Gulapasir'salak appears, depending on fruit shape, aroma, color of fruit flesh and fruit weight (Sumantra and Martiningsih, 2016).The results of this study mean that the emergence of plant diversity due to plant propagation is done by seed, so new variants of salak 'Gulapasir' appear with local names such as salak 'Gulapasir' nenas, salak 'Gulapasir' gondok and salak 'Gulapasir' nangka. The striking difference between these three varieties lies in the shape and flesh of the fruit. The number of fruit branches of salak 'Gulapasir' nangka, 1 to 2 branches, salak 'Gulapasir' nenas amount of 2 to 4 branchesand salak 'Gulapasir' gondok the fruit bunches that do not form fruit branches. Salak 'Gulapasir', which is ready to harvest, has fruit flesh attached to the seed, and the fruit flesh is 0.63 cm thick. However, the flesh of the salak 'Gulapasir' nenas is the thinnest and the seeds are attached to the flesh. And when the salak 'Gulapasir' gondok is ready to harvest, the seeds make a sound when shaken (Figure 4 and Figure 5).


**Fig. 4.** The shape and the thickness of the fruit flesh of SGP.var.nenas, gondok and nangka


**Figure 5.**The shape of the bunch andthe number of fuits of SGPvar. gondok,nenas, and nangka

*Agronomic characteristics of 'Gulapasir' Salak*

Analysis of variance showed that the interaction between planting locations and varieties of 'Gulapasir' salak had significant effect on the number of fruits per bunch, fruit weight per tree, fruit weight per fruit, number of fruits per bunch, the ratio of sugar and acid and vitamin C content. Meanwhile, the thick fruit flesh and tannins content was not significant (Table 4)

**Table 4.** Recapitulation of the effects of varieties and growing locations on agronomic and fruits quality of 'Gulapasir' salak

| No. | Character agronomic and fruits quality | Planting location | Varieties | Varieties x Location |
|---|---|---|---|---|
| 1 | Length of the flower sheath | ** | ** | * |
| 2 | Number of fruit bunches $^{-1}$ | ** | ** | * |
| 3 | Fruit tree weight $^{-1}$ | ** | ** | * |
| 4 | Fruit weight $^{-1}$ | ** | ** | * |
| 5 | TSS ratio and total acid | ** | ** | ** |
| 6 | Thick fruit flesh | ** | ** | Ns |
| 7 | Vitamin C | Ns | Ns | * |
| 8 | Tannins | Ns | Ns | Ns |
| 9 | Edible portion | ** | ** | Ns |

Notes: *) significant $P < 0.05$, **) very significant $P < 0.01$ and Ns) not significantly different $P > 0.05$

The interaction of varieties and planting location had a significant effect on the length of the flower sheath and the number of fruit bunches$^{-1}$. Nenas variety grown in Tabanan (T < 560, T 560 to 650, and T > 650 ) and Karangasem (K < 560, K 560 to 650, and K> 650) showed higher sheath length and a number of fruit bunches$^{-1}$ than with nangkaand gondok varieties (Table 5). Tabanan (T 560 to 650) and Karangasem (K < 560 m asl) are ideal conditions for flower sheath development and fruit development of nenas.

**Table 5.** Flower sheath length (cm) and a number of fruit bunches $^{-1}$ (fruit) of nangka, gondok and nenasvarieties at six locations**.**

| Treatment | Sheath length (cm) | Amount fruit bunches $^{-1}$ |
|---|---|---|
| NT< 560 | 27.50 ± 0.34 bcd | 19.55± 0.82 hij |
| NT 560 to 650 | 28.83± 1.31 b | 20.39± 1.00 g |
| NT > 650 | 27.17± 0.96 cde | 19.02± 0.82 j |
| NK < 560 | 26.00± 0.82 e | 21.13± 0.82 ef |
| NK 560 to 50 | 27.17± 0.14 cde | 22.28± 2.45 c |
| NK > 650 | 26.67± 1.36 cde | 21.13± 0.74 ef |
| GT<560 | 26.67± 2.18 cde | 20.22± 0.31 gh |
| GT560 to 650 | 27.50 ± 1.22 bcd | 20.55± 0.62 fg |
| GT>650 | 27.70 ± 1.98 bc | 19.22± 0.74 ij |
| GK<560 | 25.83± 1.41 e | 21.89± 0.82 cd |
| GK 560 to 650 | 26.83± 0.75 cde | 20.5± 1.63 fg |
| GK >650 | 27.5± 0.82 bcd | 21.28± 0.78 def |
| NST <560 | 27.5± 0.82 bcd | 21.41± 0.91 de |
| NST560 to 650 | 27.67± 0.82 bc | 22.00 ± 1.56 cd |
| NST >650 | 26.17± 2.16 de | 19.91± 1.36 ghi |
| NSK <560 | 32.00 ± 1.63 a | 25.27± 1.41 a |
| NSK560 to 650 | 30.90± 2.10 a | 24.00 ± 0.82 b |
| NSK >650 | 27.00 ± 1.47 cde | 21.86± 0.82 cde |

Remarks : Numbers followed by the same letter in the samecolumn and parameter indicate a non-significant difference in LSD 5 %.

From Table 5 above, it can be explained that the three varieties planted in six locations produced a number of fruits between 19.02 to 25.27 fruits per bunch. The nenas variety planted in Karangasem at an altitude of < 560 m asl (treatment NSK < 560) produced the highest number of fruits of 25.27 per bunch, followed by NSK 560 to 650 and NST 560 to 650 with 24.00 and 22.00 fruits per bunch. In order for the salak plants to bear much fruit, the nangka variety is ideal in Karangasem 560 to 650 m asl (NK 560 to 650), while the gondok variety is very good when planted below 560 m asl (GK < 560) although the number of fruits is not significantly different from the same altitude for NT 560 to 650 and GT < 560.The results of this study are in line with the findings of Sumantra and Martiningsih (2016) that the 'Gulapasir' salak var. nenas produces the highest number of fruits both in the on season (*gadu* season) and -off-season (*sela* season).Sumantra *et al*. (2014) reported that the emergence of new sheaths occurred on the third or fourth leaf midrib from the growing point depending on the altitude and plant conditions. The time for new sheaths to appear ranges from 129.00 d to 145.10 d with the required heat units between (1 233.62 to 1 047.90) Degree-Day (DD). The higher altitude causes the longer the sheath appears as well as the harvest time.

The interaction of varieties and planting location had a significant effect on the fruit weigh (fruit tree$^{-1}$ and fruit$^{-1}$). Nangka variety grown in Tabanan (T < 560, T 560 to 650, and T > 650) and Karangasem (K < 560, K 560 to 650, and K > 650) showed higher of weight of fruit tree$^{-1}$ and fruit-$^{1}$ than with nenas and gondok (Table 7).

**Table 6**. Fruit weight of nangka, gondok, and nenas varieties in six locations

| Treatment | Fruit$^{-1}$ (g) | Fruit tree-$^{1}$ (kg) |
|---|---|---|
| NT < 560 | 45.32±1.08 cd | 1.19± 0.08 def |
| NT 560 to 650 | 48.56±0.71 c | 1.29± 0.07 cd |
| NT > 650 | 38.22±0.46 ef | 1.03± 0.06 ghi |
| NK < 560 | 55.84±1.37 a | 1.48 ± 0.02 b |
| NK 560 to 650 | 59.43±0.71 a | 1.62 ± 0.07 a |
| NK > 650 | 49.4±1.65 b | 1.34 ± 0.05 c |
| GT < 560 | 40.14± 0.11 e | 1.11± 0.09 fg |
| GT 560 to 650 | 38.67± 0.55 ef | 1.09 ± 0.07 fg |
| GT > 650 | 32.95± 0.73 gh | 0.93 ± 0.10 i |
| GK <5 60 | 44.22± 0.18 d | 1.27 ± 0.06 cde |
| GK 560 to 650 | 38.20 ± 0.78 ef | 1.16 ± 0.05 defg |
| GK > 650 | 36.20 ± 0.75 fg | 1.07 ± 0.11 fgh |
| NST < 560 | 39.00 ± 1.07 ef | 1.14 ± 0.11 efg |
| NST560 to 650 | 37.79± 0.65 f | 1.13 ± 0.06 g |
| NST >650 | 32.12± 0.11 h | 0.94 ± 0.10 hi |
| NSK < 560 | 41.80 ± 0.65 de | 1.36 ± 0.08 bc |
| NSK 560 to 650 | 36.57± 0.80 fg | 1.18 ± 0.09 def |
| NSK > 650 | 37.10 ± 0.23 f | 1.11 ± 0.07 fg |

Remarks : Numbers followed by the same letter in the samecolumn and parameter indicate a non-significant difference in LSD 5 %.

From Table 6, it can be explained that the three varieties grown in six locations produced fruit weight per tree between 0.93 kg and 1.62 kg. The salak nangka variety planted in Karangasem at an altitude of 560 to 650 m asl (NK 560 to 650) produced the heaviest fruit weight of 1.62 kg tree$^{-1}$, followed by NK < 560 and NT 560 to 650 with fruit weights of 1.48 and 1.29 kg, while the nenas variety produces the best fruit at altitudes < 560 m asl (NSK < 560 and NT < 560). Salak 'Gulapasir' var.gondok is ideal when planted at altitudes < 560 m asl (GK < 560 and GT < 560), although the two growing locations showed different yields.

Nenas and gondok varieties showed a trend of decreasing fruit weight in line with increasing altitude, both planted in Karangasem and Tabanan. The reverse occurred in the salak Nangka variety, an increase in altitude from 550 m asl to 650 m asl caused an increase in fruit weight and after that the fruit weight decreased when planted at altitudes > 650 m asl. This finding is in line with the results of research that have been reported by Sumantra *et al*. (2014). However, for the gondok and nenas varieties, this is a new finding.

Apart from being influenced by environmental factors, the production of salak 'Gulapasir' fruit is also influenced by internal plant factors (Adelina *et al*., 2021b: Lestari *et al*. 2011). The effect of altitude on plant growth and production is related to plant adaptability and tolerance to temperature (Fenech *et al*., 2019) and rainfall (Ritonga *et al*., 2018). Altitude increases, the average daily air temperature decreases and monthly rainfall increases (Table 3). Nuary *et al*. (2019) stated that the distribution and adaptation of salak plants is strongly influenced by temperature and rainfall. It was further stated that the contribution of daily temperature accounts for nearly 38.6% while rainfall is 27.8 %. Kanzaria *et al.* (2015) reported that mango plants planted at an altitude of 229 m flowered slower than those at an altitude of 148 m and 81 m asl. The temperature regime at higher altitudes is colder than at lower altitudes. Lower temperatures accumulate less growing degree day (GDD) and may result in late flowering. Table 7 shows that the 'Gulapasir' salak planted in Karangasem produced a higher fruit weight in the three salak varieties tested. This is related to the level of soil fertility. The soil nitrogen and phosphate nutrient content at three locations in Karangasem was higher than at three locations in Tabanan. Meanwhile, the potassium content in the six research locations was low (Table 3). Therefore, it is necessary to make improvements by providing fertilizers containing elements of N, P and K to meet ideal conditions for growth, although more data is needed to fully support this conclusion (Hailu *et al.*, 2015).

*Quality characteristics of salak varieties*

The interaction between varieties and altitude significantly affected sugar/total acid and vitamin C content. The three varieties grown in Tabanan (T < 560, T 560 to 650 and T > 650) showed a lower TSS/acid ratio. The fruit flavour planted in three locations in Tabanan is more sour than the three locations in Karangasem. Sugar content is greatly affected by the geographical conditions. The geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity, and rainfall (Ritonga*et al*., 2018). Table 8 also shows that the increase in altitude from 550 m to 700 m asl in Tabanan and the addition in altitude from 550 to 650 m asl in Karangasem causes the sugar/acid ratio decrease in all three varieties, and the lowest sugar/acid value occurs in nenas variety in all locations. Each salak variety has an adaptation to an elevation closely related to plant tolerance to temperature (Sumantra and Martiningsih, 2016; 2018). Many factors influence fruit quality, but the most dominant are climate factors, especially temperature and rainfall. Rainfall has a negative correlation with fruit weight-1 (r = -0.991 **), TSS/acid ratio (r = -0.875 **) and vitamin C (r = -1.000**). However, the air temperature has a positive and significant correlation with fruit weight$^{-1}$, TSS/acid ratio, and vitamin C with correlations, respectively: r = 0.930 **, r = 0.733 **, and r = 0.964**. High rainfall and low air temperature during the fruit ripening phase can cause the dissolved solids in the fruit to become watery so that the TSS value is low (Singh *et al*., 2011).

Salak fruits from three different varieties grown in low lands in Karangasem (K < 560 m asl) showed the highest vitamin C content and were significantly different from the three cultivars when planted in other locations. In both areas, land increased by > 650 m asl effects to vitamin C decrease; nangka and gondok varieties showed higher levels of vitamin C between < 550 m to < 650 m asl. (Table 7).

**Table 7.** TSS/acid ratio and levels of vitamin C of nangka, gondok, and nenas varieties in six locations.

| Treatment | TSS/T acid | Vit. C (mg 100 g-1) |
|---|---|---|
| NT < 560 | 56.20 ± 0.16 abc | 27.50 ± 0.41 bde |
| NT 560 to 650 | 59.18± 0.82 a | 25.45±0.37 defgh |
| NT > 650 | 37.89± 0.91 f | 22.52± 0.39 j |
| NK < 560 | 51.41± 0.33 cde | 27.74± 0.47 bd |
| NK 560 to 650 | 53.52± 0.82 abcd | 29.61± 0.50 ab |
| NK > 650 | 47.76± 0.11 de | 24.25± 0.20 fghij |
| GT<560 | 34.88±0.72 fg | 25.50 ± 0.41 defgh |
| GT5 60 to 650 | 34.80 ± 0.65 fg | 25.75± 0.20 defgh |
| GT > 650 | 30.24± 0.20 gh | 23.34± 0.28 hij |
| GK< 560 | 51.28± 0.23 cde | 30.31± 0.25 a |
| GK 560 to 650 | 58.44± 0.36 ab | 27.63± 0.30 bd |
| GK > 650 | 53.04± 0.82 bcde | 25.07± 0.33 efghi |
| NST < 60 | 31.50 ±0.41 gh | 26.71± 0.21 cdef |
| NST 560 to 650 | 30.44± 0.36 gh | 25.88± 0.41 defg |
| NST > 650 | 26.13± 0.11 h | 23.65± 0.29 ghij |
| NSK < 560 | 53.73± 0.60 abc | 24.42± 0.34 fghij |
| NSK 560 to 650 | 52.63± 0.51 bcde | 22.82± 0.15 ij |
| NSK > 650 | 47.60 ± 0.49 e | 25.16± 0.13 efghi |

Remarks : Numbers followed by the same letter in the samecolumn and parameter indicate a non-significant difference in LSD 5 %.

The results showed that the varieties of the 'Gula pasir'salak need different environmental requirements to optimize yields. Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al*., 2021, 2022). Therefore, variety differences may depend on growing requirements and cultivation techniques. Vitamin C in the 'Gula pasir'salak is strongly influenced by the altitude of the land. To produce high levels of vitamin C, the nangka and gondok varieties are ideal for planting at an altitude of 560 m to 650 m asl, while the nenas variety is ideal at a land altitude of < 560 m asl. However, changes in ascorbate levels during fruit ripening are species-dependent and environmental factors, especially temperature and light (Fenech *et al*., 2019).

There was no interaction between varieties and altitude to the flesh thickness, edible fruit portion, and fruit sugar content. The nangka salak variety showed fruit quality, including TSS, edible parts of the fruit, and higher flesh thickness (Table 8).

**Table 8.** The effect of a single factor of varieties on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment | TSS (° Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| Nangka | 16.59a | 72.50a | 0.63a |
| Gondok | 16.42a | 70.66ab | 0.59b |
| Nenas | 15.64b | 69.22b | 0.52c |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Salak grown in Karangasem both from the lowlands and the middle lands produces fruit thickness, and the edible portion of fruits is higher than plants in the highlands. This study indicates that the ideal growing place for salak plants is between 450 m to 650 m asl (Tabel 9). This study is in line with several previous studies which explained that altitude affects the flowering process and fruit enlargement (Sophie *at al*., 2017; Spinardi *et al*., 2019; Widyastuti *et al*., 2022).

**Table 9.** The effect of a single factor of planting location on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment (m asl) | TSS (° Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| T< 550 | 16.28a | 73.13a | 0.54c |
| T550 to 650 | 16.27a | 69.89a | 0.58bc |
| T >650 | 16.14a | 63.87b | 0.49d |
| K550 | 16.81a | 73.15a | 0.61b |
| K550 to 650 | 16.11a | 72.29a | 0.66a |
| K>650 | 15.69a | 72.44a | 0.61b |

Remarks : Numbers followed by the same letter in the samecolumn and parameter indicate a non-significant difference in LSD 5 %.

The soil analysis results showed that the total N and $P_2O_5$ contents at three locations in Tabanan were very low to low, while the $K_2O$ content at the six study sites was very low (Table 3). The low nutrient values of the three nutrients above are thought to be a factor causing the three types of salak planted in Tabanan at different altitudes to produce low fruit. The correlation results showed that N and $P_2O_5$ content negatively correlated with fruit weight (r = -0.855** and -0.992**), while $K_2O$ content had a positive and highly significant correlation (r = 0.997**) with fruit weight. The quality of salak land is low because farmers practice very simple technique in salak cultivation, where most fertilization only uses buried salak midrib (Sumantra, *et al*., 2014; Tamba and Sumantra, 2022). Therefore, the utilization and processing of plant waste need to be optimized to improve land quality.

Further research can be applied using sustainable salak organic agriculture (Budiasa, 2014; Handayani, 2022; Nurhidayat *et al*., 2022; Rahmah *et al*., 2022; Sukewijaya *et al*., 2009; Wimatsari *et al*., 2019). Table 3 shows that salak cultivation in the research location still needs to implement sustainable farming (Prasetyo *et al*., 2022b; 2022a). There are indications on decrease in soil fertility, especially potassium availability, as the six planting locations came out with very low values. Potassium levels in Table 3 are lower than the observations of Ashari (2013) and Woran *et al.* (2018) in salak cultivation areas in Swaru – Malang (very high), Sleman – Yogyakarta (moderate), Bangkalan – Madura (very high), and Pangu – Minahasa (moderate).

The low availability of potassium (Table 3) in the nine study areas deserves attention, especially since the authors stated that the $K_2O$ content had a positive and highly significant correlation (r = 0.997**) with fruit weight. Potassium helps produce good fruit quality, such as bigger, heavier, and sweeter fruit. Another benefit of the nutrient potassium in plants is to increase the growth of meristem tissue and regulate the movement of stomata. Potassium also helps the development of plant roots so that plant stems can stand upright and do not collapse easily (Adinurani *et al.,* 2018; Budiono *et al*., 2019). Therefore, Nasution (2022) recommends more $K_20$ fertilizer than $P_20_5$ fertilizer and N fertilizer. In addition, salak needs 70 kg of $K_2O$ because this nutrient is found in the leaves at an amount (12.2 to 14.7) mg $g^{-1}$ (Ashari, 2013).

The chemical fertilizers (*e.g*., KCl) are too expensive for Salak farmers and do not support the salak organic. Therefore, the application of sustainable farming should apply local wisdom including the use of the pruning of salak midrib. Consider this policy because C organic is essential to soil fertility (Budiono*et al*. 2021; Goenadi *et al*. 2021). The success of this midrib decomposition is demonstrated by the C organic in Table 3, which is classified as medium to high. This finding supports Faizah and Fauzan (2021), Saputra *et al.* (2018) in salak plantation of Purwosari District - Pasuruan Regency, and Wonosalam District – Jombang Regency.

But, in the next stage, some of the salak midribs should be burned into ashes which can be used as a source of potassium nutrients (Ekawati and Purwanto, 2012; Vincevica-Gaile *et al*., 2021a, 2021b). Another organic source of potassium is the pulp/husk of coffee cherries. Karangasem and Tabanan districts are coffee cultivation areas in Bali, so they should take advantage of this coffee processing waste. Several researchers stated that coffee pulp/husk contains higher potassium than nitrogen or phosphorus nutrients (Bahri *et al*., Falahuddin *et al*., 2016; Novita *et al.*, 2018; Setyobudi *et al*., 2018).

Several researchers (Analianasari *et al*. 2022; Ningsih, 2020; Wachisbu, 2020) recommend soaking the pulp/husk of coffee cherries and using it as liquid organic fertilizer, which is beneficial for various plants. To develop this idea, salak farmers in Karangasem and Tabanan Regency should create biogas as household or communal scale digesters (Prespa *et al*., 2020; Setyobudi *et al*. 2021b; Susanto *et al*., 2020a) or use digesters from used drums (Adinurani *et al*., 2013, 2017; Hendroko *et al*., 2013). All household organic waste is processed in the digester, including kitchen waste, leftover food, and human excrement from pit latrines and septic tank (Anukam and Nyamukamba, 2022; Somorin, 2020; Susanto *et al*., 2020b; Zhou *et al*., 2022). This action has various advantages, namely reducing global warming, obtaining clean - renewable energy, and two kinds of organic fertilizer, *i.e*., liquid and solid (Abdullah *et al*., 2020; Burlakovs *et al*., 2022; Hendroko *et al*., 2014; Prespa *et al*., 2020; Setyobudi, *et al*., 2018). In addition, many researchers have reported (among other things Benyahya *et al*., 2022; Baştabak and Koça, 2020; Li *et al*., 2021) the benefits of organic fertilizers from biogas digesters.

Another measure to increase and maintain land fertility is in salak cultivation, namely the application of Plant Growth Promoting Rhizobacteria (PGPR) or biological fertilizer (Afzal *et al*., 2017; Basu *et al*., 2021; Ekawati, *et al.,* 2019; Nguyen *et al.,* 2020; 2022, Sukorini *et al.*, 2023). Several researchers (Adinurani *et al*., 2021; Kumalawati *et al*., 2021; Muhammad *et al*. 2021) have reported using mycorrhiza, which positively impacts various plants, including salak cultivation (Amnah and Friska, 2018; Dewi *et al*., 2020; Rai *et al*., 2021). Multiplication of mycorrhiza is relatively simple (Sportes *et al*., 2021; Sukmawati *et al*., 2021) and can be done by farmer groups with initial guidance from universities.

## Conclusion and Recommendation

The SGP var. nangka in Karangasem showed higher fruit weight, vitamin C content, and sugar/acid ratio. In Karangasem and Tabanan, SGP var. nangka grows ideally at an altitude of (560 to 650) m asl with fruit weight per tree of 1.62 $kg^{-1}$ and 1.29 $kg^{-1}$, respectively, while the SGP var. nenas showed the highest number of fruit $bunches^{-1}$ in six locations. In contrast, SGP var. nenas and SGP var.gondok are ideal for cultivating at an altitude of < 560 m asl both in Karangasem and Tabanan, but the fruit production of SGP var. nenas and SGP var. gondok is higher, respectively, 19.29 % and 15.31 % when planted in Karangasem. In order to obtain ideal fruit production and quality, SGP var. nangka is very suitable to be planted at an altitude of 550 m to 650 m asl. In contrast, the SGP var. nenas and var.gondok are developed naturally at low altitudes < 550 m asl.

In order to enable all cultivars produce optimally, efforts to improve the cultivation system are needed through fertilization; mainly potassium is highly recommended. Further research can be applied using sustainable salak organic agriculture to maintain soil fertility.

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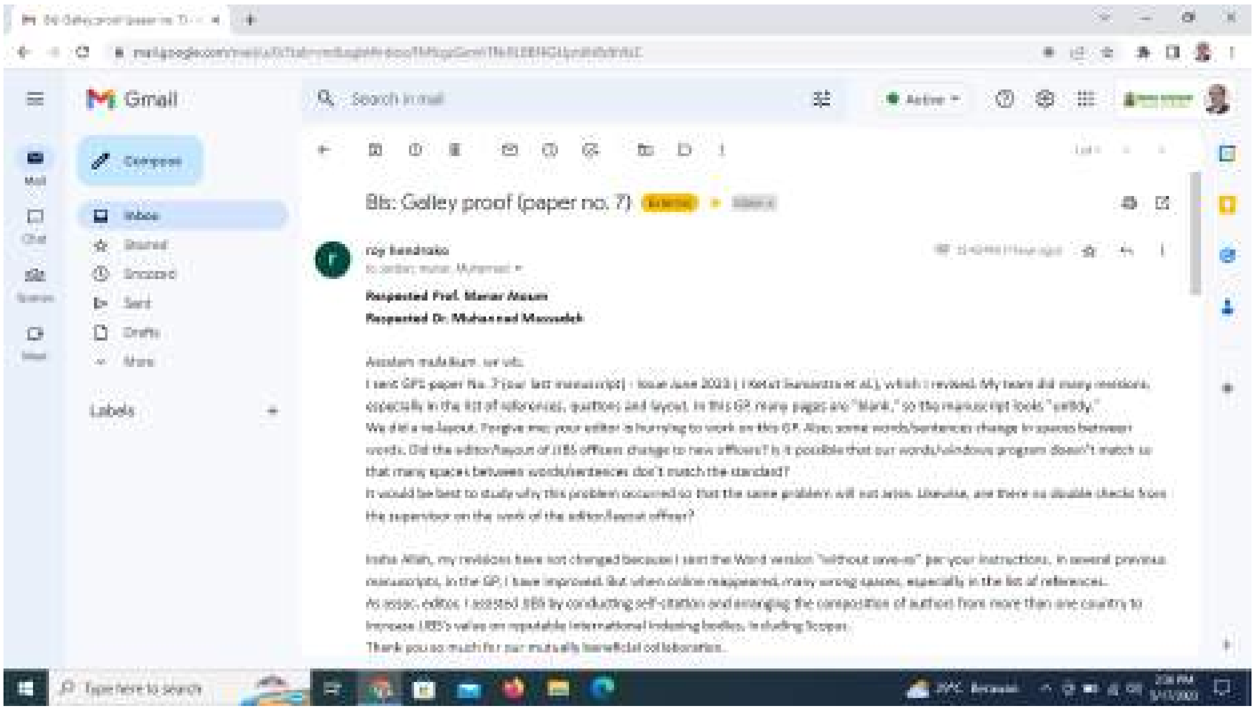
Final revision




Respected Prof. Manar Atoum

Respected Dr. Muhannad Massadeh

Assalam mulaikum wr wb.

I sent GP1 paper No. 7 (our last manuscript) - Issue June 2023 ( I Ketut Sumantra et al.), which I revised. My team did many revisions, especially in the list of references, quations and layout. In this GP, many pages are "blank," so the manuscript looks "untidy."

We did a re-layout. Forgive me; your editor is hurrying to work on this GP. Also, some words/sentences change in spaces between words. Did the editor/layout of JJBS officers change to new officers? Is it possible that our words/windows program doesn't match so that many spaces between words/sentences don't match the standard?

It would be best to study why this problem occurred so that the same problem will not arise. Likewise, are there no double checks from the supervisor on the work of the editor/layout officer?

Insha Allah, my revisions have not changed because I sent the Word version "without save-as" per your instructions. In several previous manuscripts, in the GP, I have improved. But when online reappeared, many wrong spaces, especially in the list of references.

As assoc. editor, I assisted JJBS by conducting self-citation and arranging the composition of authors from more than one country to increase JJBS's value on reputable international indexing bodies, including Scopus.

Thank you so much for our mutually beneficial collaboration.

Wassalam salam wr wb

Roy

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# Agronomic Characters and Quality of Fruit of Salak cv. Gulapasir Planted in Various Agro-Ecosystems

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**Abstract**

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir has been officially released by the Minister of Agriculture of the Republic of Indonesia since 1994. Salak 'Gulapasir 'is one of five types of fruit that have been designated as the superior fruit of the Bali Province. Salak 'Gulapasir' is preferred by consumers due to its specific fruit flesh taste. Salak 'Gulapasir' was propagated using seeds so that a new type of salak emerged. However, the characters of this new type of salak 'Gulapasir' are not yet known. The research objective was to obtain the superior products of Salak 'Gulapasir' both in quantity and quality. The research used a Randomized Block Design with three replications. The non-independent variable was the three of Salak 'Gulapasir' (SGP): SGP var. nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem: (K < 560 m asl, K 560 m to 650 m asl, and K > 650 m asl) and Tabanan: (T < 560 m asl, T 560 m to 650 m asl, T > 650 m asl). Observations were made on the agronomic characters and fruit quality. Data were analyzed using variance analysis, and if the planting location and varieties show a difference, then it is followed by the LSD test at the 5 % level. The results showed that different varieties caused different fruit weights, fruit bunches, TSS, and total acid ratio. In Karangasem and in Tabanan, SGP var. nangka grows ideally at an altitude of 560 m to 650 m asl with fruit weight per tree of 1.62 $kg^{-1}$ and 1.29 $kg^{-1}$, respectively. SGP var. nenas and SGP var. gondok are ideal for cultivating at an altitude of < 560 m asl both in Karangasem and Tabanan, but the fruit production of SGP var. nenas and SGP var. gondok is higher, respectively 19.29 % and 15.31 % when planted in Karangasem, while the SGP var. nenas showed the highest number of fruit $bunches^{-1}$ in six locations. Further research can be applied using sustainable salak organic agriculture to maintain soil fertility.

**Keywords:** Altitude, Improve soil fertility, Organic potassium fertilizer, Organic salak, *Salacca zalacca* (Gaertn.) Voss, Salak sustainable agriculture, Snake fruit, Tropical fruit

## 1. Introduction

Salak [*Salacca zalacca* (Gaertn.) Voss] var. amboinensis cv. Gulapasir is one of the essensial fruits in Indonesia, and the plant can be found in most regions of Indonesia (Rai *et al*., 2016; Ritonga *et al*., 2018). The salak fruit belongs to the family Palmae or Arecaceae and is native to the Indonesian-Malaysian region (Hakim *et al.*, 2019; Zumaidar *et al*., 2014). One of the extraordinary strengths of this fruit commodity for Indonesia is the possession of high genetic diversity (Budiyanti *et al*., 2019). Also, the nutrition of salak fruit is rich in antioxidants, phenolics, vitamins, and minerals (Cepkova *et al.,* 2021; Mazumdar *et al*., 2019), and a good source of income and provides livelihood opportunities on seasonal days (Khan and Idrees, 2021). Furthermore fruit flesh and peel have shown tremendous anti-inflammatory, anticancer, antidiabetic (Saleh *et al*., 2018), and anti-aging agents (Girsang *et al*., 2019). Antioxidants are chemical compounds that play an essential role in protecting cells due to attacks against free radicals-induced damage to biomolecules (Damat *et al*., 2019, 2020; Puspitasari and Ningsih, 2016; Setyobudi *et al*., 2019). Despite its incredible food and medicinal benefits, salak fruit is still underutilized and unknown globally so that this

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underutilized fruit remains an issue for future sustainable utilization and commercial value enhancement market (Mazumdar *et al*., 2019). Fruit quality is an important issue, especially for products that are consumed raw and fresh. One of the problems is the lack of fruit quality because of inadequate information about superior salak (Budiyanti *et al*., 2019; Herawati *et al*., 2018). Therefore, it is necessary to select superior salak to meet market demand and serve community nutrition.

Salak 'Bali' is quite a lot, based on the shape, aroma, taste, and skin colour of the location where the plants are cultivated (Sumantra *et al*., 2012, 2014; Sumantra and Martiningsih, 2016, 2018). Under the Decree of the Minister of Agriculture of the Republic of Indonesia in 1994, Balinese zalacca was grouped into two superior zalacca: Salak 'Bali' (SK Mentan, 1994a) and Salak 'Gulapasir' (SK Mentan, 1994b). The second type, the salak 'Gulapasir' (SGP) is the most superior salak because of its sweet fruit taste; even though the age of the fruit is still young, thick fruit flesh and seeds are not attached to the fruit flesh (Rai *et al*., 2014; Sumantra *et al*., 2016). The nature of this fruit is ideal for meeting market demands for both the domestic and export markets (Martiningsih *et al*., 2018). Salak 'Bali' is monoecious, so crossing does not need human help (Herawati *et al*., 2018), and can quickly develop using seeds (Sumantra and Martiningsih, 2016). Another advantage of salak plants in Indonesia compared to other fruits is harvest 2 to 3 times a year if management is good (Rai *et al*., 2016; Warnita *et al*., 2019). The expansion of salak 'Gulapasir' planting causes variations in phenotypic diversity. People can find two to three types of salak plants with a marker, fruit shape, aroma, flesh colour, and fruit weight (Martiningsih *et al*., 2018). The results of this study mean that the emergence of plant diversity due to plant propagation is done by seeds so that new varieties of salak 'Gulapasir' (SGP) appear, as reported by Sumantra and Martiningsih (2016). Based on the marker that can be used as a differentiator, salak farmers give it the name of SGP var. nenas, SGP var. gondok, and SGP var. nangka. The three varieties have not yet identified their advantages in meeting market needs in line with the results of research (Sumantra and Martiningsih, 2016). The performance and produce are influenced by the characteristics of the agricultural ecosystem, particularly microclimate and endogenic factors such as carbohydrate contents, nutrient status (Adelina *et al*., 2021a; Kumar *et al*., 2020) and growth hormone (Prihastanti and Haryanti. 2022; Rai *et al*., 2016).

The salak 'Gulapasir' plantation in the District of Bebandemis the main producer of salak 'Gulapasir' in Bali is located in the southern part of Mount Agung with an altitude of 450 m to 700 m above sea level (m asl). The effect of altitude on plant growth and production is related to plant adaptation to temperature (Sumantra, *et al*., 2014), full sunlight (Sukawijaya *et al*., 2009), water status and soil quality (Raharjo *et al*., 2022; Rai *et al*., 2014; Ritonga *et al*.,2018). Salak plants are not resistant to full sun but 50 % to 70 % enough, therefore it is necessary to have shade plants (Sukawijaya *et al*., 2009; Sumantra *et al*., 2012). The effect of altitude on plant growth and production is related to plant adaptation to plant tolerance to temperature (Fenech *et al*., 2019). Water status and soil quality really determine the fruit set on the salak 'Gulapasir'. Low rainfall reduces the Relative Water Content in leaves (RWC), leaf chlorophyll content, and plant nutrient uptake (Rai *et al*., 2014). Soil quality included the suitability of the physical, chemical and biological properties (Raharjo *et al*., 2022). Nuary *et al*. (2019) stated that the distribution of the salak 'Pondoh' plantation area in Sleman (Yogyakarta, Special Region) was greatly influenced by temperature and rainfall. The contribution of temperature in the modelling reached 38.6 % while the rainfall was 27.8 %. Furthermore, taking into account the probability of the temperature variable, the average temperature ranges from 17.41 °C to 25.65 °C, and the ideal month's rainfall ranges from 385.24 mm to 505.01 mm.

Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al*., 2021, 2022). Therefore, variety differences may depend on growing requirements and cultivation techniques. Likewise, Puspitasari *et al*. (2016) stated that tannin content, fruit size and flesh colour of salak fruit are strongly influenced by where it grows. Other studies also explain that salak 'Gulapasir' var. nangka which is grown 570 m asl, would result in a higher quality of fruit that includes thickness of the mesocarpium, edible portion of fruit than compared to above and below 570 m asl (Sumantra *et al*., 2014; Sumantra and Martiningsih, 2016). Meanwhile, fruit weight and fruit quality of var. gondok and var. nenas have not been reported. Therefore, one way of handling salak quality is by undertaking severe studies for factors such as land and climate and adjusting agricultural patterns according to local climate conditions (Nassar *et al*., 2018). The success of each species to occupy the environment of an area is influenced by its ability to adapt optimally to all physical environmental factors (temperature, light, soil structure, humidity), biotic factors (interaction between species, competition, parasitism), and chemical factors including the availability of water, oxygen, pH, and nutrients (Nassar *et al*., 2018; Widyastuti *et al*., 2022). Moreover, a broad genetic variability would lead to wide phenotypic variability due to the effect of genetic-environment interaction (Ritonga *et al*., 2018). The research objective was to obtain several superior salak 'Gulapasir' both in production and fruit quality (sugar and acid ratio, vitamin C and tannins) in six different agricultural ecosystems in Bali. This research was important to do to get the suitability and adaptation of the types of salak based on the altitude where it grows so that in the future, its development will be able to provide maximum results according to existing agro-ecosystem conditions.

## 2. Materials and Methods

### *2.1. Experimental site*

The research was conducted in Tabanan and Karangasem Regencies. Tabanan and Karangasem were selected as research locations because the domination of salak 'Gulapasir' in these two regencies was the highest. In 2021, the salak 'Gulapasir' population in Tabanan was 84 % of all salak species, while in Karangasem Regency the dominance of the salak 'Gulapasir' was more than 63 % (Sumantra *et al*., 2022).

The study was carried out in six different locations, three sites in Karangasem Regency and three sites in the district of Tabanan. Locations in Karangasem (K) are lowlands (K < 560 m asl) which include several places, namely Telaga, Dukuh, and Karanganyar. Karangasem in the moderate plains (K 560 m to 650 m asl) has several areas, namely Kecing and Kutabali and highlands (K > 650 m asl), namely Tanah Apo and Kresek (Figure 1).

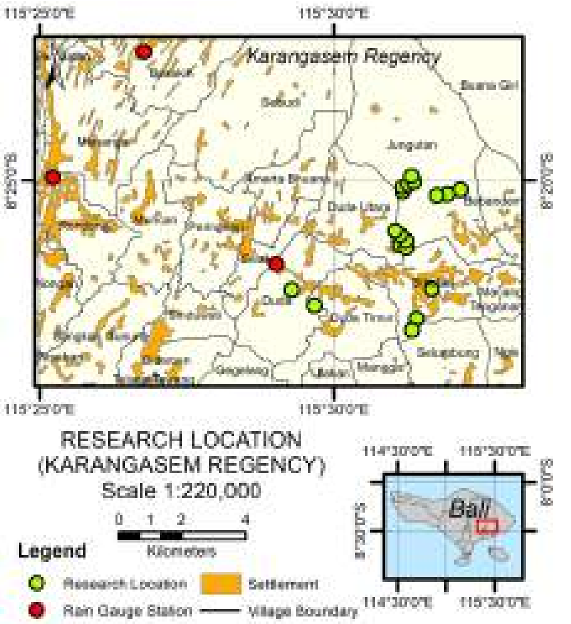


Fig. 1. Research map and sampling point in Karangasem (K)

The research location is in Tabanan (T) in the lowlands (T < 560 m asl), including Wanagiri, Sari Buana, and Mundeh Kauh. Tabanan in the medium lands (T 560 m to 650 m asl) includes several places, namely Pajahan, Kebon Jero, and Angseri. Tabanan in the highlands (T > 650 m asl), namely Munduk Temu, Pempatan, and Batungsel (Figure 2).

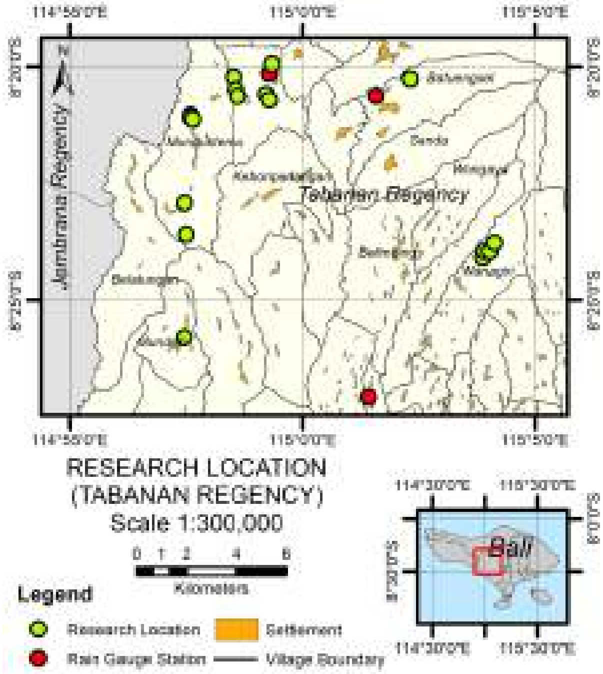


**Fig 2.** Research map and sampling point in Tabanan (T)

The non-independent variable was the three varieties of Salak 'Gulapasir' (SGP): SGP var. nangka (N), SGP var. nenas (NS), SGP var. gondok (G), and six sites, namely Karangasem (K): (K < 560 m asl, K 560 m to 650 m asl, and K > 650 m asl) and Tabanan (T): (T < 560 m asl, T 560 m to 650 m asl, T > 650 m). Repetition was carried out three times with the number of sample plants in each location, and cultivars were seven plants. The treatment tested is as shown in Table 1.

**Table 1**. Treatment of plant location and three varieties of 'Gulapasir' salak

| No | Treatment | Explanation |
|---|---|---|
| 1 | NT < 560 m asl | Salak GP var. nangka Tabanan < 560 m asl. |
| 2 | NT 560 m to 650 m asl | Salak GP var. nangka Tabanan 560 m to 650 m asl. |
| 3 | NT > 650 m asl. | Salak GP var. nangka Tabanan > 650 m asl. |
| 4 | NK < 560 m asl. | Salak GP var. nangka Karangasem < 560 m asl. |
| 5 | NK 560 m to 650 m asl | Salak GP var. nangka Karangasem 560 m to 650m asl. |
| 6 | NK > 650 m asl. | Salak GP var. nangka Karangasem > 650 m asl. |
| 7 | GT < 560 m asl | Salak GP var. gondok Tabanan < 560 m asl. |
| 8 | GT.560 to 650 m asl | Salak GP var. gondok Tabanan 560 m to 650 m asl. |
| 9 | GT > 650 m asl | Salak GP var. gondok Tabanan > 650 m asl. |
| 10 | GK.< 560 m asl | Salak GP var. gondok Karangasem < 560 m asl. |
| 11 | GK 560 m to 650 m asl | Salak GP var. gondok Karangasem 560 m to 650 m asl. |
| 12 | GK >650 m asl | Salak GP var. gondok Karangasem > 650 m asl. |
| 13 | NST < 560 m asl | Salak GP var. nenas Tabanan < 560 m asl. |
| 14 | NST.560 m to 650 m asl | Salak GP var. nenas Tabanan 560 m to 650 m asl. |
| 15 | NST > 650 m asl | Salak GP var. nenas Tabanan > 650 m asl. |
| 16 | NSK .< 560 m asl | Salak GP var. nenas Karangasem < 560 m asl. |
| 17 | NSK 560 m to 650 m asl | Salak GP var. nenas Karangasem 560 m to 650 m asl.. |
| 18 | NSK > 650 m asl | Salak GP var. nenas Karangasem > 650 m asl. |

The study used a Composite Analysis of Variance (Andinurani, 2016, 2022) with the model determined using Equation (1) below:

$$Yjk = U + Li + \delta ik + Pj + (LP) ij + \varepsilon ijk \quad (1)$$

Where:

Yijk = The observation value of the treatment (j) in the group (k), which is repeated at the location (i).

u = the actual average value

Li = additive effect from location i

δ ik = the error effect in group k at location i

Pj = additive effect of the next treatment

(LP) ij = the effect of treatment (j) atthe location (i)

Ɛ ijk = the effect of error from the treatment (j) in the group (k) which was carriedout at the location (i).

## 2.2. Preparation of study materials

The material used is the salak 'Gulapasir' plant with uniform growth; plants have been fruitful with uniform on morphological, age of plants and cultivation action. The intentional practice is that the plant only receives treatment in the midrib, tillers, and weed cleaning. In this study, the plants were not fertilized. The provision of water was only from rainfall following the habits applied by salak farmers. The sample plant was maintained by trimming unproductive leaf midribs and removing young shoots. Plant material was taken from the Salak Development Centre in six locations, namely at the Centre of Salak Development in the Bebandem sub-districts, Karangasem district (K-lowland < 560 m asl, K-medium 560 m to 650 m asl and K-highland > 650 m asl), Bajre, West Slemadeg and Pupuan sub-districts, Tabanan district (T-lowland < 560 m asl, T-medium 560 to 650 m asl and T-highland > 650 m asl).

## 2.3. Analysis of physicochemical properties of soil sample and climate

Soil analysis was carried out to determine the physical and chemical properties of the soil. Soil sampling was carried out under sample plant trees, in a composite manner at a depth of 0 cm to 40 cm. Chemical analysis was carried out on total N (Kjeldahl method), available P by Bray I method and $K_2O$ by the Bray I method, organic C, pH, soil physical properties in the form of texture by pipette method (Eviati and Sulaeman. 2009; Hailu *et al*., 2015; Prasetyo *et al*., 2022a; Rzasa and Owczarzak, 2013).

Rainfall data was taken for 5 yr from 2015 to 2019. Rainfall data has been collected from six nearby stations to the research site (Figure 1 and Figure 2). Daily temperature data was obtained from the Denpasar Meteorology Climatology Agency.

## 2.4. Observation of fruit and fruit quality

Salak fruit can be harvested when it is ready for consumption. Consumable ripe fruit is a fruit that is ready to be consumed, characterized by a change in skin colour from dark brown to light brown, the thorns on the skin being reduced and not sharp, and in general, at this stage, the fruit easily falling when shaken.

Observation and measurement of agronomic characters follow the method that has been done by Sumantra *et al*. (2014) including fruit weight, number of fruit bunches, the thickness of fruit flesh and fruit shape. The fruit characters from six-observed locations include the numbers of fruits per bunch, which is calculated manually on the formed fruits. The fruit weight per fruit and the fruit weight per tree is weighed after the fruits were removed from the bunch. The thickness of the mesocarpium is obtained by measuring the mesocarpium after it is cut vertically. The length of the flower sheath is measured on the stem of the sheath from the base to the tip of the sheath.

While fruit quality includes sugar content, tannins, titrated acid, sugar content and vitamin C. Titrated acid was analyzed by titration (Sripakdee *et al*., 2015). The fruit which was weighed 10 g of sample was added to 100 mL of distilled water, then was homogenized using a slow spin blender, and filtered using an aseptic filter. The filtrate obtained was taken as much as 25 mL, then titrated with 0.1 N NaOH solution with phenolphthalein indicator until red colour appeared. The results obtained are calculated as the percentage tartaric acid as per Equation (2) below :

$$A = \frac{mL\ NaOH \times N\ NaOH \times P \times BM}{Y \times 1\,000 \times 2} \times 100\ \% \quad (2)$$

where:

A = percentage of total acid
P = amount of dilution
BM = molecular weight of tartaric acid
Y = sample weight (g).

Tannins content was analyzed as done by Thakur *et al*. (2021), Setyobudi *et al*. (2022). Amount of 100 mg of the sample was homogenized by 2 mL of methanol, centrifuged for 10 min at 10 000 rpm (1 rpm = 1/60 Hz), and then the supernatant was collected. Amount of 1 mL of the aforementioned supernatant was mixed with 0.5 mL Folin's phenol reagent and 35 % $Na_2CO_3$ of 5 mL was added, and the mixture was kept at room temperature for 5 min. The blue colour of the reaction mixture was observed at 640 nm by UV/visible spectrophotometer (Shimadzu UV-1800, Japan). The content of tannins was calculated by calibration curve equation and determined using Equation (3) below:

$$Y = 0.007\,3 \times -0.007\,1 : R^2 = 0.997\,3 \quad (3)$$

Vitamin C was determined by titration like the method used by Asamara (2016), Setyobudi *et al.* (2021a, 2022). The material is weighed as much as 10 g and crushed in mortal, then put into a 250 mL volumetric flask, set to the mark and filtered. Take 25 mL of the filtrate and titrate with 0.01 N Yod solution equivalent to 0.88 mg of ascorbic acid. The calculation of ascorbic acid content per 100 g of material is determined using Equation (4) below:

$$A = \frac{mL\ Yod\ 0.01\ N \times 0.88 \times P \times 100}{Y} \quad (4)$$

where: A = mg of ascorbic acid per 100 g of material
P = amount of dilution
Y = gram sample weight

Sugar content as TSS is calculated using a hand refractometer (Bellingham and Stanley Ltd., London) at 20 ºC (Adinurani *et al.*, 2018). The ratio of sugar content (TSS) and total acid is calculated by the sugar content divided by the acid content multiplied by 100 %.

The materials used in this study were Folin-ciocalteu reagent (Pro Analytic, Merck), NaOH (pro analytic, Merck), $Na_2CO_3$ (pro analytic, Merck), Phenol reagent (pro analytic, Merck), Ascorbic acid (pro analytic, Merck), Phosphoric acid (Pro Analytic, Merck), Sodium phosphate (pro analytic, Merck) and Ammonium molybdate (pro analytic, Merck).

The tools used in this study were analytical balances (Shimadzu ATY224, Japan), centrifuge tubes, Erlenmeyer flasks (Pyrex), dropper pipettes (pyrex), volume pipettes (Pyrex), vortex (Maxi Mix II Type 367000), measuring flask (Pyrex), water bath (Memmert), blender (Miyako), and centrifuge (Damon /IEC Division). Whatman filter paper No 1 (Sigma – Aldrich, USA), measuring cup (Pyrex, USA), micropipette (Dragon Lab, Indonesia), spectrophotometer (Biochromsn 133467, UK), test tube (Pyrex¸ USA), vortex (Barnsteadl Thermolyne Type 37600 Mixer, USA), aluminum foil (Klin Pak, Indonesia).

### 2.5. Study design

This study used a randomized block design with the data analyzed using a Composite Analysis of Variance. If the variance test is significantly different, then it is continued with a different test with LSD at the 5 % level. Data analysis was performed using SPSS-IBM 18 (Adinurani, 2016, 2022). Each experimental treatment was repeated three times.

## 3. Results and Discussion

### 3.1. Agroclimate characteristic

The low production level and the quality of salak fruit are caused by environmental factors that do not support growth or because the physiological processes of the plant are not optimal due to insufficient nutrients and water. The suitability of climatic and soil conditions at six locations of the centres for the development of the 'Gulapasir' salak was evaluated. The evaluation results show that the air temperature decreases as the altitude increases. The average air temperature at the 'Gulapasir' salak plantation in Tabanan is 22.90 ºC, while the air temperature at the Karangasem salak plantation is around 23.24 ºC. (Tabel 2)

**Table 2.** Soil and climate characteristics of the research site in Tabanan and Karangasem in three subzones

| Parameter | Tabanan (T) | | | Karangasem (K) | | |
|---|---|---|---|---|---|---|
| | Lowlands (< 560 m asl) | Moderate ((560 m to 650 m asl) | Highlands (> 650 m asl) | Lowlands (< 560m asl) | Moderate (560 m to 650 m asl) | Highlands (> 650 m asl) |
| Temp. (º C) | 23.82 | 22.75 | 22.12 | 24.29 | 23.35 | 22.09 |
| Rainfall (mm $mo^{-1}$) | 188.24 | 199.91 | 231.008 | 237.242 | 254.183 | 289.216 |
| Soil texture | loamy clay | loamy clay | loamy clay | clay | Clay | sandy loam |
| pH ($H_2O$) | 5.64 (sa) | 5.75 (sa) | 5.84 (sa) | 6.08 (sa) | 6.05 (sa) | 6.03(sa) |
| C- organic (%) | 2.94 (m) | 3.40 (h) | 3.25 (h) | 2.77 (m) | 3.63 (h) | 3.32 (h) |
| Nutrients available | | | | | | |
| N total (%) | 0.18 (l) | 0.16 (l) | 0.18 (l) | 0.24(m) | 0.23 (m) | 0.29 (m) |
| $P_2O_5$ (mg $g^{-1}$) | 9.38 (vl) | 9.12 (vl) | 13.50 (l) | 22.55 (m) | 24.18 (m) | 23.04 (m) |
| $K_2O$ (mg $g^{-1}$)) | 18.47 (vl) | 22.05 (vl) | 17.23 (vl) | 24.17 (vl) | 19.93 ( vl ) | 18.37 ( vl ) |

Notes: sa: slightly acidic; h: high; m: medium; l: low; vh: very high; h: high; asl: above sea level (The assessment criteria refer to Eviati and Sulaeman. 2009; PPT, 1983).

In addition to monthly rainfall, the average rainfall over 5 yr is presented in Figure 3. Annual rainfall in Tabanan (T < 560, T 560 to 650 and T > 650) is lower with an average of 2515.05 mm, while in Karangasem (K < 560, K 560 to 650 and K > 650) it is 3 122.05 mm. However, the six locations show a trend of increasing rainfall as altitude increases. The salak plantation area in Karangasem is in the southern part of Mount Agung. Meanwhile, in Tabanan, the dominant salak plantation area is behind Mount Batukaru with a lower elevation than Mount Agung. Mount Agung has an altitude of 3 142 m asl (Andaru and Rau, 2019), while Batukaru mountains area of 2 250 m asl (Asmiwyati *et al*., 2015). Mount Batukaru serves as a barrier from the rain, causing this area to be a rain shadow. Enyew and Steenveld (2014) state that rainfall in an area is influenced by topographical factors and mountain ranges. Decreasing the height of the mountains provides a reduction in the maximum level of rainfall over the mountains and foothills by 50 % (Flesch and Reuter, 2012). Topographical factors and regional weather systems have an important role in the amount and spatial pattern of rainfall in an area (Enyew and Steenveld, 2014).

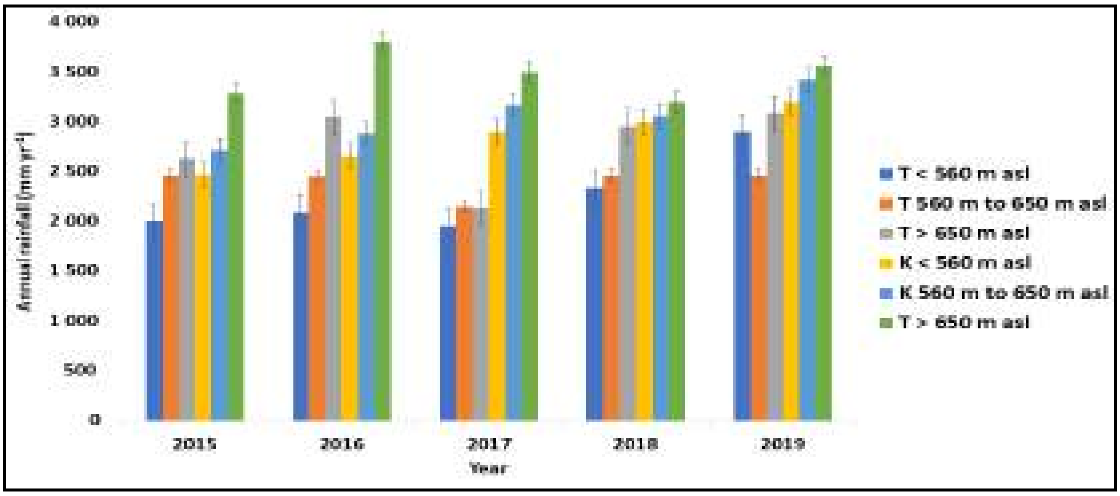


**Fig. 3.** The annual rainfall in the six study sites

Based on the growing requirements of salak plants, rainfall and air temperature in the six locations evaluated were in the very suitable range to support plant growth and development. A good air temperature for the growth of salak plants is between 20 °C to 30°C and an average rainfall of (200 to 400) mm mo$^{-1}$ (Nuary *et al*., 2019).

Soil C-organic content in six planting sites was in the medium to high range. Availability of N and P nutrients in salak plantations in Tabanan in the lowlands, medium and highlands is of low to very low conditions. In salak planting land in Karangasem - both in the lowlands, medium and highlands - these two nutrients are available in moderate conditions (Table 3). The nutrient content of potassium available in the six planting locations that have been evaluated shows a very low value. The results of this study indicate that the cultivation techniques carried out by farmers are very low. Farmers do not apply fertilizers that only rely on litter from the pruning of salak midrib as reported by Ilmiah *et al*. (2021), Rai *et al.* (2014), and Warnita *et al.* (2019). To cultivate sustainable agriculture, especially in agroecosystems salak in Bali, the authors will discuss this issue more in the future research paragraph.

*3.2. Fruit Characteristics of Salak 'Gulapasir'*

The salak 'Gulapasir' his monoecius plant, namely male and female flowers arranged on the same bunches, the shape of the bunchesis compound, and the position of the flower is on the back of the midrib. The salak 'Gulapasir' is classified as special because of its sweet fruit taste and the price per unit weight is four times more expensive than the salak 'Bali' (Rai *et al*., 2014; Sumantra *et al*., 2012). The expansion of the cultivation of the salak 'Gulapasir' from its area of origin, Sibetan, Karangasem, has resulted in phenotypic diversity with a phenotypic similarity level of 58.62 % to 93.10 % (Sumantra and Martiningsih, 2016). In the same garden, more than one type of 'Gulapasir'salak appears, depending on fruit shape, aroma, color of fruit flesh and fruit weight (Sumantra and Martiningsih, 2016).The results of this study mean that the emergence of plant diversity due to plant propagation is done by seed, so new variants of salak 'Gulapasir' appear with local names such as salak 'Gulapasir' nenas, salak 'Gulapasir' gondok and salak 'Gulapasir' nangka. The striking difference between these three varieties lies in the shape and flesh of the fruit. The number of fruit branches of salak 'Gulapasir' nangka, 1 to 2 branches, salak 'Gulapasir' nenas amount of 2 to 4 branchesand salak 'Gulapasir' gondok the fruit bunches that do not form fruit branches. Salak 'Gulapasir', which is ready to harvest, has fruit flesh attached to the seed, and the fruit flesh is 0.63 cm thick. However, the flesh of the salak 'Gulapasir' nenas is the thinnest and the seeds are attached to the flesh. And when the salak 'Gulapasir' gondok is ready to harvest, the seeds make a sound when shaken (Figure 4 and Figure 5).


**Fig. 4.** The shape and the thickness of the fruit flesh of SGP.var.nenas, gondok and nangka


**Figure 5.**The shape of the bunch andthe number of fuits of SGPvar. gondok,nenas, and nangka

*3.3. Agronomic characteristics of 'Gulapasir' Salak*

Analysis of variance showed that the interaction between planting locations and varieties of 'Gulapasir' salak had significant effect on the number of fruits per bunch, fruit weight per tree, fruit weight per fruit, number of fruits per bunch, the ratio of sugar and acid and vitamin C content. Meanwhile, the thick fruit flesh and tannins content was not significant (Table 4)

**Table 4.** Recapitulation of the effects of varieties and growing locations on agronomic and fruits quality of 'Gulapasir' salak

| No. | Character agronomic and fruits quality | Planting location | Varieties | Varieties x Location |
|---|---|---|---|---|
| 1 | Length of the flower sheath | ** | ** | * |
| 2 | Number of fruit bunches $^{-1}$ | ** | ** | * |
| 3 | Fruit tree weight $^{-1}$ | ** | ** | * |
| 4 | Fruit weight $^{-1}$ | ** | ** | * |
| 5 | TSS ratio and total acid | ** | ** | ** |
| 6 | Thick fruit flesh | ** | ** | Ns |
| 7 | Vitamin C | Ns | Ns | * |
| 8 | Tannins | Ns | Ns | Ns |
| 9 | Edible portion | ** | ** | Ns |

Notes: *) significant $P < 0.05$, **) very significant $P < 0.01$ and Ns) not significantly different $P > 0.05$

The interaction of varieties and planting location had a significant effect on the length of the flower sheath and the number of fruit bunches$^{-1}$. Nenas variety grown in Tabanan (T < 560, T 560 to 650, and T > 650 ) and Karangasem (K < 560, K 560 to 650, and K> 650) showed higher sheath length and a number of fruit bunches$^{-1}$ than with nangkaand gondok varieties (Table 5). Tabanan (T 560 to 650) and Karangasem (K < 560 m asl) are ideal conditions for flower sheath development and fruit development of nenas.

**Table 5.** Flower sheath length (cm) and a number of fruit bunches $^{-1}$ (fruit) of nangka, gondok and nenasvarieties at six locations**.**

| Treatment | Sheath length (cm) | Amount fruit bunches $^{-1}$ |
|---|---|---|
| NT< 560 | 27.50 ± 0.34 bcd | 19.55± 0.82 hij |
| NT 560 to 650 | 28.83± 1.31 b | 20.39± 1.00 g |
| NT > 650 | 27.17± 0.96 cde | 19.02± 0.82 j |
| NK < 560 | 26.00± 0.82 e | 21.13± 0.82 ef |
| NK 560 to 50 | 27.17± 0.14 cde | 22.28± 2.45 c |
| NK > 650 | 26.67± 1.36 cde | 21.13± 0.74 ef |
| GT<560 | 26.67± 2.18 cde | 20.22± 0.31 gh |
| GT560 to 650 | 27.50 ± 1.22 bcd | 20.55± 0.62 fg |
| GT>650 | 27.70 ± 1.98 bc | 19.22± 0.74 ij |
| GK<560 | 25.83± 1.41 e | 21.89± 0.82 cd |
| GK 560 to 650 | 26.83± 0.75 cde | 20.5± 1.63 fg |
| GK >650 | 27.5± 0.82 bcd | 21.28± 0.78 def |
| NST <560 | 27.5± 0.82 bcd | 21.41± 0.91 de |
| NST560 to 650 | 27.67± 0.82 bc | 22.00 ± 1.56 cd |
| NST >650 | 26.17± 2.16 de | 19.91± 1.36 ghi |
| NSK <560 | 32.00 ± 1.63 a | 25.27± 1.41 a |
| NSK560 to 650 | 30.90± 2.10 a | 24.00 ± 0.82 b |
| NSK >650 | 27.00 ± 1.47 cde | 21.86± 0.82 cde |

Remarks : Numbers followed by the same letter in the samecolumn and parameter indicate a non-significant difference in LSD 5 %.

From Table 5 above, it can be explained that the three varieties planted in six locations produced a number of fruits between 19.02 to 25.27 fruits per bunch. The nenas variety planted in Karangasem at an altitude of < 560 m asl (treatment NSK < 560) produced the highest number of fruits of 25.27 per bunch, followed by NSK 560 to 650 and NST 560 to 650 with 24.00 and 22.00 fruits per bunch. In order for the salak plants to bear much fruit, the nangka variety is ideal in Karangasem 560 to 650 m asl (NK 560 to 650), while the gondok variety is very good when planted below 560 m asl (GK < 560) although the number of fruits is not significantly different from the same altitude for NT 560 to 650 and GT < 560.The results of this study are in line with the findings of Sumantra and Martiningsih (2016) that the 'Gulapasir' salak var. nenas produces the highest number of fruits both in the on season (*gadu* season) and -off-season (*sela* season).Sumantra *et al*. (2014) reported that the emergence of new sheaths occurred on the third or fourth leaf midrib from the growing point depending on the altitude and plant conditions. The time for new sheaths to appear ranges from 129.00 d to 145.10 d with the required heat units between (1 233.62 to 1 047.90) Degree-Day (DD). The higher altitude causes the longer the sheath appears as well as the harvest time.

The interaction of varieties and planting location had a significant effect on the fruit weigh (fruit tree$^{-1}$ and fruit$^{-1}$). Nangka variety grown in Tabanan (T < 560, T 560 to 650, and T > 650) and Karangasem (K < 560, K 560 to 650, and K > 650) showed higher of weight of fruit tree$^{-1}$ and fruit-$^{1}$ than with nenas and gondok (Table 7).

**Table 6**. Fruit weight of nangka, gondok, and nenas varieties in six locations

| Treatment | Fruit$^{-1}$ (g) | Fruit tree-$^{1}$ (kg) |
|---|---|---|
| NT < 560 | 45.32±1.08 cd | 1.19± 0.08 def |
| NT 560 to 650 | 48.56±0.71 c | 1.29± 0.07 cd |
| NT > 650 | 38.22±0.46 ef | 1.03± 0.06 ghi |
| NK < 560 | 55.84±1.37 a | 1.48 ± 0.02 b |
| NK 560 to 650 | 59.43±0.71 a | 1.62 ± 0.07 a |
| NK > 650 | 49.4±1.65 b | 1.34 ± 0.05 c |
| GT < 560 | 40.14± 0.11 e | 1.11± 0.09 fg |
| GT 560 to 650 | 38.67± 0.55 ef | 1.09 ± 0.07 fg |
| GT > 650 | 32.95± 0.73 gh | 0.93 ± 0.10 i |
| GK <5 60 | 44.22± 0.18 d | 1.27 ± 0.06 cde |
| GK 560 to 650 | 38.20 ± 0.78 ef | 1.16 ± 0.05 defg |
| GK > 650 | 36.20 ± 0.75 fg | 1.07 ± 0.11 fgh |
| NST < 560 | 39.00 ± 1.07 ef | 1.14 ± 0.11 efg |
| NST560 to 650 | 37.79± 0.65 f | 1.13 ± 0.06 g |
| NST >650 | 32.12± 0.11 h | 0.94 ± 0.10 hi |
| NSK < 560 | 41.80 ± 0.65 de | 1.36 ± 0.08 bc |
| NSK 560 to 650 | 36.57± 0.80 fg | 1.18 ± 0.09 def |
| NSK > 650 | 37.10 ± 0.23 f | 1.11 ± 0.07 fg |

Remarks : Numbers followed by the same letter in the samecolumn and parameter indicate a non-significant difference in LSD 5 %.

From Table 6, it can be explained that the three varieties grown in six locations produced fruit weight per tree between 0.93 kg and 1.62 kg. The salak nangka variety planted in Karangasem at an altitude of 560 to 650 m asl (NK 560 to 650) produced the heaviest fruit weight of 1.62 kg tree$^{-1}$, followed by NK < 560 and NT 560 to 650 with fruit weights of 1.48 and 1.29 kg, while the nenas variety produces the best fruit at altitudes < 560 m asl (NSK < 560 and NT < 560). Salak 'Gulapasir' var.gondok is ideal when planted at altitudes < 560 m asl (GK < 560 and GT < 560), although the two growing locations showed different yields.

Nenas and gondok varieties showed a trend of decreasing fruit weight in line with increasing altitude, both planted in Karangasem and Tabanan. The reverse occurred in the salak Nangka variety, an increase in altitude from 550 m asl to 650 m asl caused an increase in fruit weight and after that the fruit weight decreased when planted at altitudes > 650 m asl. This finding is in line with the results of research that have been reported by Sumantra *et al*. (2014). However, for the gondok and nenas varieties, this is a new finding.

Apart from being influenced by environmental factors, the production of salak 'Gulapasir' fruit is also influenced by internal plant factors (Adelina *et al*., 2021b: Lestari *et al*. 2011). The effect of altitude on plant growth and production is related to plant adaptability and tolerance to temperature (Fenech *et al*., 2019) and rainfall (Ritonga *et al*., 2018). Altitude increases, the average daily air temperature decreases and monthly rainfall increases (Table 3). Nuary *et al.* (2019) stated that the distribution and adaptation of salak plants is strongly influenced by temperature and rainfall. It was further stated that the contribution of daily temperature accounts for nearly 38.6% while rainfall is 27.8 %. Kanzaria *et al.* (2015) reported that mango plants planted at an altitude of 229 m flowered slower than those at an altitude of 148 m and 81 m asl. The temperature regime at higher altitudes is colder than at lower altitudes. Lower temperatures accumulate less growing degree day (GDD) and may result in late flowering. Table 7 shows that the 'Gulapasir' salak planted in Karangasem produced a higher fruit weight in the three salak varieties tested. This is related to the level of soil fertility. The soil nitrogen and phosphate nutrient content at three locations in Karangasem was higher than at three locations in Tabanan. Meanwhile, the potassium content in the six research locations was low (Table 3). Therefore, it is necessary to make improvements by providing fertilizers containing elements of N, P and K to meet ideal conditions for growth, although more data is needed to fully support this conclusion (Hailu *et al.*, 2015).

### *3.4. Quality characteristics of salak varieties*

The interaction between varieties and altitude significantly affected sugar/total acid and vitamin C content. The three varieties grown in Tabanan (T < 560, T 560 to 650 and T > 650) showed a lower TSS/acid ratio. The fruit flavour planted in three locations in Tabanan is more sour than the three locations in Karangasem. Sugar content is greatly affected by the geographical conditions. The geographical difference is usually followed by overall climate and weather differences, particularly temperature, humidity, and rainfall (Ritonga*et al*., 2018). Table 8 also shows that the increase in altitude from 550 m to 700 m asl in Tabanan and the addition in altitude from 550 to 650 m asl in Karangasem causes the sugar/acid ratio decrease in all three varieties, and the lowest sugar/acid value occurs in nenas variety in all locations. Each salak variety has an adaptation to an elevation closely related to plant tolerance to temperature (Sumantra and Martiningsih, 2016; 2018). Many factors influence fruit quality, but the most dominant are climate factors, especially temperature and rainfall. Rainfall has a negative correlation with fruit weight-1 (r = -0.991 **), TSS/acid ratio (r = -0.875 **) and vitamin C (r = -1.000**). However, the air temperature has a positive and significant correlation with fruit weight$^{-1}$, TSS/acid ratio, and vitamin C with correlations, respectively: r = 0.930 **, r = 0.733 **, and r = 0.964**. High rainfall and low air temperature during the fruit ripening phase can cause the dissolved solids in the fruit to become watery so that the TSS value is low (Singh *et al*., 2011).

Salak fruits from three different varieties grown in low lands in Karangasem (K < 560 m asl) showed the highest vitamin C content and were significantly different from the three cultivars when planted in other locations. In both areas, land increased by > 650 m asl effects to vitamin C decrease; nangka and gondok varieties showed higher levels of vitamin C between < 550 m to < 650 m asl. (Table 7).

**Table 7.** TSS/acid ratio and levels of vitamin C of nangka, gondok, and nenas varieties in six locations.

| Treatment | TSS/T acid | Vit. C (mg 100 g$^{-1}$) |
|---|---|---|
| NT < 560 | 56.20 ± 0.16 abc | 27.50 ± 0.41 bde |
| NT 560 to 650 | 59.18± 0.82 a | 25.45±0.37 defgh |
| NT > 650 | 37.89± 0.91 f | 22.52± 0.39 j |
| NK < 560 | 51.41± 0.33 cde | 27.74± 0.47 bd |
| NK 560 to 650 | 53.52± 0.82 abcd | 29.61± 0.50 ab |
| NK > 650 | 47.76± 0.11 de | 24.25± 0.20 fghij |
| GT<560 | 34.88±0.72 fg | 25.50 ± 0.41 defgh |
| GT5 60 to 650 | 34.80 ± 0.65 fg | 25.75± 0.20 defgh |
| GT > 650 | 30.24± 0.20 gh | 23.34± 0.28 hij |
| GK< 560 | 51.28± 0.23 cde | 30.31± 0.25 a |
| GK 560 to 650 | 58.44± 0.36 ab | 27.63± 0.30 bd |
| GK > 650 | 53.04± 0.82 bcde | 25.07± 0.33 efghi |
| NST < 60 | 31.50 ± 0.41 gh | 26.71± 0.21 cdef |
| NST 560 to 650 | 30.44± 0.36 gh | 25.88± 0.41 defg |
| NST > 650 | 26.13± 0.11 h | 23.65± 0.29 ghij |
| NSK < 560 | 53.73± 0.60 abc | 24.42± 0.34 fghij |
| NSK 560 to 650 | 52.63± 0.51 bcde | 22.82± 0.15 ij |
| NSK > 650 | 47.60 ± 0.49 e | 25.16± 0.13 efghi |

Remarks : Numbers followed by the same letter in the samecolumn and parameter indicate a non-significant difference in LSD 5 %.

The results showed that the varieties of the 'Gula pasir'salak need different environmental requirements to optimize yields. Ascorbate content is influenced by abiotic factors, especially temperature and light (Fenech *et al*., 2019; Setyobudi *et al*., 2021, 2022). Therefore, variety differences may depend on growing requirements and cultivation techniques. Vitamin C in the 'Gula pasir'salak is strongly influenced by the altitude of the land. To produce high levels of vitamin C, the nangka and gondok varieties are ideal for planting at an altitude of 560 m to 650 m asl, while the nenas variety is ideal at a land altitude of < 560 m asl. However, changes in ascorbate levels during fruit ripening are species-dependent and environmental factors, especially temperature and light (Fenech *et al*., 2019).

There was no interaction between varieties and altitude to the flesh thickness, edible fruit portion, and fruit sugar content. The nangka salak variety showed fruit quality, including TSS, edible parts of the fruit, and higher flesh thickness (Table 8).

**Table 8.** The effect of a single factor of varieties on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment | TSS (° Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| Nangka | 16.59a | 72.50a | 0.63a |
| Gondok | 16.42a | 70.66ab | 0.59b |
| Nenas | 15.64b | 69.22b | 0.52c |

Remarks : Numbers followed by the same letter in the same column and parameter indicate a non-significant difference in LSD 5 %.

Salak grown in Karangasem both from the lowlands and the middle lands produces fruit thickness, and the edible portion of fruits is higher than plants in the highlands. This study indicates that the ideal growing place for salak plants is between 450 m to 650 m asl (Tabel 9). This study is in line with several previous studies which explained that altitude affects the flowering process and fruit enlargement (Sophie *at al*., 2017; Spinardi *et al*., 2019; Widyastuti *et al*., 2022).

**Table 9.** The effect of a single factor of planting location on TSS, the portion of edible flesh, and the thickness of salak fruits

| Treatment (m asl) | TSS (° Brix) | Edible portion (%) | Flesh thickness (cm) |
|---|---|---|---|
| T< 550 | 16.28a | 73.13a | 0.54c |
| T550 to 650 | 16.27a | 69.89a | 0.58bc |
| T >650 | 16.14a | 63.87b | 0.49d |
| K550 | 16.81a | 73.15a | 0.61b |
| K550 to 650 | 16.11a | 72.29a | 0.66a |
| K>650 | 15.69a | 72.44a | 0.61b |

Remarks : Numbers followed by the same letter in the samecolumn and parameter indicate a non-significant difference in LSD 5 %.

The soil analysis results showed that the total N and $P_2O_5$ contents at three locations in Tabanan were very low to low, while the $K_2O$ content at the six study sites was very low (Table 3). The low nutrient values of the three nutrients above are thought to be a factor causing the three types of salak planted in Tabanan at different altitudes to produce low fruit. The correlation results showed that N and $P_2O_5$ content negatively correlated with fruit weight (r = -0.855** and -0.992**), while $K_2O$ content had a positive and highly significant correlation (r = 0.997**) with fruit weight. The quality of salak land is low because farmers practice very simple technique in salak cultivation, where most fertilization only uses buried salak midrib (Sumantra, *et al*., 2014; Tamba and Sumantra, 2022). Therefore, the utilization and processing of plant waste need to be optimized to improve land quality.

Further research can be applied using sustainable salak organic agriculture (Budiasa, 2014; Handayani, 2022; Nurhidayat *et al*., 2022; Rahmah *et al*., 2022; Sukewijaya *et al*., 2009; Wimatsari *et al*., 2019). Table 3 shows that salak cultivation in the research location still needs to implement sustainable farming (Prasetyo *et al*., 2022b; 2022a). There are indications on decrease in soil fertility, especially potassium availability, as the six planting locations came out with very low values. Potassium levels in Table 3 are lower than the observations of Ashari (2013) and Woran *et al.* (2018) in salak cultivation areas in Swaru – Malang (very high), Sleman – Yogyakarta (moderate), Bangkalan – Madura (very high), and Pangu – Minahasa (moderate).

The low availability of potassium (Table 3) in the nine study areas deserves attention, especially since the authors stated that the $K_2O$ content had a positive and highly significant correlation (r = 0.997**) with fruit weight. Potassium helps produce good fruit quality, such as bigger, heavier, and sweeter fruit. Another benefit of the nutrient potassium in plants is to increase the growth of meristem tissue and regulate the movement of stomata. Potassium also helps the development of plant roots so that plant stems can stand upright and do not collapse easily (Adinurani *et al.,* 2018; Budiono *et al*., 2019). Therefore, Nasution (2022) recommends more $K_20$ fertilizer than $P_20_5$ fertilizer and N fertilizer. In addition, salak needs 70 kg of $K_2O$ because this nutrient is found in the leaves at an amount (12.2 to 14.7) mg $g^{-1}$ (Ashari, 2013).

The chemical fertilizers (*e.g*., KCl) are too expensive for Salak farmers and do not support the salak organic. Therefore, the application of sustainable farming should apply local wisdom including the use of the pruning of salak midrib. Consider this policy because C organic is essential to soil fertility (Budiono*et al*. 2021; Goenadi *et al*. 2021). The success of this midrib decomposition is demonstrated by the C organic in Table 3, which is classified as medium to high. This finding supports Faizah and Fauzan (2021), Saputra *et al.* (2018) in salak plantation of Purwosari District - Pasuruan Regency, and Wonosalam District – Jombang Regency.

But, in the next stage, some of the salak midribs should be burned into ashes which can be used as a source of potassium nutrients (Ekawati and Purwanto, 2012; Vincevica-Gaile *et al*., 2021a, 2021b). Another organic source of potassium is the pulp/husk of coffee cherries. Karangasem and Tabanan districts are coffee cultivation areas in Bali, so they should take advantage of this coffee processing waste. Several researchers stated that coffee pulp/husk contains higher potassium than nitrogen or phosphorus nutrients (Bahri *et al*., Falahuddin *et al*., 2016; Novita *et al.*, 2018; Setyobudi *et al*., 2018).

Several researchers (Analianasari *et al*. 2022; Ningsih, 2020; Wachisbu, 2020) recommend soaking the pulp/husk of coffee cherries and using it as liquid organic fertilizer, which is beneficial for various plants. To develop this idea, salak farmers in Karangasem and Tabanan Regency should create biogas as household or communal scale digesters (Prespa *et al*., 2020; Setyobudi *et al.* 2021b; Susanto *et al*., 2020a) or use digesters from used drums (Adinurani *et al*., 2013, 2017; Hendroko *et al*., 2013). All household organic waste is processed in the digester, including kitchen waste, leftover food, and human excrement from pit latrines and septic tank (Anukam and Nyamukamba, 2022; Somorin, 2020; Susanto *et al*., 2020b; Zhou *et al*., 2022). This action has various advantages, namely reducing global warming, obtaining clean - renewable energy, and two kinds of organic fertilizer, *i.e*., liquid and solid (Abdullah *et al*., 2020; Burlakovs *et al*., 2022; Hendroko *et al*., 2014; Prespa *et al*., 2020; Setyobudi, *et al*., 2018). In addition, many researchers have reported (among other things Benyahya *et al*., 2022; Baştabak and Koça, 2020; Li *et al*., 2021) the benefits of organic fertilizers from biogas digesters.

Another measure to increase and maintain land fertility is in salak cultivation, namely the application of Plant Growth Promoting Rhizobacteria (PGPR) or biological fertilizer (Afzal *et al*., 2017; Basu *et al*., 2021; Ekawati, *et al.,* 2019; Nguyen *et al.,* 2020; 2022, Sukorini *et al.,* 2023). Several researchers (Adinurani *et al*., 2021; Kumalawati *et al*., 2021; Muhammad *et al*. 2021) have reported using mycorrhiza, which positively impacts various plants, including salak cultivation (Amnah and Friska, 2018; Dewi *et al*., 2020; Rai *et al*., 2021). Multiplication of mycorrhiza is relatively simple (Sportes *et al*., 2021; Sukmawati *et al*., 2021) and can be done by farmer groups with initial guidance from universities.

## 4. Conclusion and Recommendation

The SGP var. nangka in Karangasem showed higher fruit weight, vitamin C content, and sugar/acid ratio. In Karangasem and Tabanan, SGP var. nangka grows ideally at an altitude of (560 to 650) m asl with fruit weight per tree of 1.62 $kg^{-1}$ and 1.29 $kg^{-1}$, respectively, while the SGP var. nenas showed the highest number of fruit $bunches^{-1}$ in six locations. In contrast, SGP var. nenas and SGP var.gondok are ideal for cultivating at an altitude of < 560 m asl both in Karangasem and Tabanan, but the fruit production of SGP var. nenas and SGP var. gondok is higher, respectively, 19.29 % and 15.31 % when planted in Karangasem. In order to obtain ideal fruit production and quality, SGP var. nangka is very suitable to be planted at an altitude of 550 m to 650 m asl. In contrast, the SGP var. nenas and var.gondok are developed naturally at low altitudes < 550 m asl.

In order to enable all cultivars produce optimally, efforts to improve the cultivation system are needed through fertilization; mainly potassium is highly recommended. Further research can be applied using sustainable salak organic agriculture to maintain soil fertility.

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