International Journal of
TROPICAL Drylands

| Intl J Trop Drylands | vol. 5 | no. 2 | December 2021 | E-ISSN: 2580-2828 |

Liang Bua Cave, Manggarai, Indonesia; photo by Rosino

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Published semiannually **PRINTED IN INDONESIA**

E-ISSN: 2580-2828

9 772580 282107

International Journal of
Tropical Drylands

| Intl J Trop Drylands | vol. 5 | no. 2 | December 2021 |

ONLINE
http://smujo.id/td

e-ISSN
2775-6130

PUBLISHER
Society for Indonesian Biodiversity

CO-PUBLISHER
Universitas Nusa Cendana, Kupang, Indonesia

OFFICE ADDRESS
Archipelagic Dryland Center of Excellence, Universitas Nusa Cendana.
Jl. Adisucipto Penfui, Kupang 85001, East Nusa Tenggara, Indonesia. Tel.: +62-380-881580, Fax.: +62-380-881674, email: editors@smujo.id

PERIOD OF ISSUANCE
June, December

Society for Indonesian Biodiversity

Universitas Nusa Cendana Kupang, Indonesia

Published by Smujo International for The Society for Indonesian Biodiversity and Universitas Nusa Cendana Kupang, Indonesia

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Abstract:

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Proceeding:

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Thesis, Dissertation:

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Information from the internet:

Balagadde FK, Song H, Ozaki J, Collins CH, Barnet M, Arnold FH, Quake SR, You L. 2008. A synthetic *Escherichia coli* predator-prey ecosystem. Mol Syst Biol 4: 187. DOI: 10.1038/msb.2008.24. www.molecularsystembiology.com.

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INTL J TROP DRYLANDS
Volume 5, Number 2, December 2021
Pages: 41-47
E-ISSN: 2775-6130
DOI: 10.13057/tropdrylands/t050201

A screening of resistance to sweet potato weevil (*Cylas formicarius* Fab.) in a collection of sweet potato clones under laboratory conditions

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Manuscript received: 21 August 2021. Revision accepted: 25 September 2021.

Abstract. *Mau YS, Wadu MN, Ndiwa ASS, Markus JER, Arsa IGBA. 2021. A screening of resistance to sweet potato weevil (*Cylas formicarius *Fab.) in a collection of sweet potato clones under laboratory conditions. Intl J Trop Drylands 5: 41-47.* Sweet potato is a potential carbohydrate source as a rice substitute in Indonesia, especially in East Nusa Tenggara (ENT). However, the productivity of this crop is still low at the farmer level due to, among others, the use of low-yielding varieties and yield loss caused by sweet potato weevil (SPW), *Cylas formicarius*. The use of SPW resistant varieties is considered the most effective and eco-friendly way of controlling the pest. However, the availability of resistant varieties is currently limited. This study aimed to evaluate the SPW-induced damage intensity and SPW-resistance level in a collection of sweet potato clones. The study was conducted in the laboratory of Universitas Nusa Cendana, Kupang, Indonesia. Observed variables included the percentage of damaged roots, the intensity of root damage, the number of *C. formicarius* per root, the number of feeding tunnels per root, root epidermal thickness, and root latex level. Observed data were subjected to analysis of variance followed by Duncan's post hoc test of 5%, except root latex level that was subjected to descriptive analysis. A correlation analysis was also performed. The damaged root percentage ranged from 77.8% to 100%, and the intensity of root damage was from 14.0% to 76.6%. The laboratory assay categorized the tested genotypes into Moderately Resistant, Moderately Susceptible, and Susceptible levels, with the Resistant category being absent. The SPWs ranged from 1.4 to 31.9 per root, while the number of feeding tunnels ranged from 1.4 to 31.1 per root. The observed sweet potato genotypes possessed root epidermal thickness between 1 mm to 4 mm, and the root latex was low to a high level. The study revealed a strong correlation between the damaged root intensity and the number of feeding tunnels per root or SPWs per root. A highly positive correlation was also observed between the number of SPWs and the number of feeding tunnels per root. A weak and positive correlation was found between root epidermal thickness and the number of SPWs or feeding tunnels per root.

Keywords: *Cylas formicarius*, resistance, sweet potato hybrid, sweet potato weevil

INTRODUCTION

Crop production and productivity are affected by factors such as the genetic potentials of the crop, environment (growing) condition, and biotic factors. In addition, the agronomical practices applied also play an essential role in crop productivity. Suboptimal conditions of at least one of these factors may lead to low crop production and productivity. In practice, more than one of these factors may occur altogether in suboptimal conditions. Thus, managing a crop cultivar to produce genetic potential is a challenging task. Therefore, driving all these factors close to their optimal conditions is necessary for maximum crop productivity.

Pests and diseases are generally considered as biotic factors hampering crop production. In sweet potato (*Ipomoea batatas* L. (Lam)), sweet potato weevil/SPW (*Cylas formicarius* (Fab.)) is known as the most devastating pest of the crop (Talekar 1982; Chalfant et al. 1990; Smith and Beuzelin 2015; Chen 2017) as its infestation directly implicates in high storage root damage intensity, and hence, high storage root yield loss is inevitable (Jansson et al. 1987; Alcazar et al. 1997; Nderitu et al. 2009).

Chemical control is the most popular way of controlling the SPW (Smith and Beuzelin 2015; Chen 2017), but this method is considered not environmentally safe. Thus, reducing the use of chemical pesticides and promoting more ecologically safe control measures are strongly encouraged. In addition, the use of chemical control strategy is also sometimes ineffective because the weevils are subterranean and spend most of their life cycles inside the roots (Anyanga 2015). Thus, the use of resistant varieties is considered an efficient and more environmentally friendly control method of SPW. Furthermore, resistant varieties are also more appropriate for the subsistent sweet potato farmers as they lack the chemical control strategy (Chen 2017). Nonetheless, SPW resistant varieties are hardly available (Mao et al. 2001; Mau et al. 2011).

Sweet potato is the second most important root crop in East Nusa Tenggara (ENT) Province, Indonesia, after cassava (BPS NTT 2020). It has been used as a substitute for rice and maize as a staple food. However, the productivity of the crop in the ENT province is still low (~9 t ha-1) as compared to that of the national level (~17 t ha-1) (BPS Pusat 2020). This low productivity is caused by many factors such as common-yielding variety, poor cropping techniques, drought stress, and also pests and diseases infestations, most specifically the SPW. Developing sweet potato cultivars with the high-yielding ability and good resistance to SPW is a promising approach to tackle the problem. This can be achieved by breeding using the existing and introduced sweet potato germplasm and selecting at the early stages of crop cultivar development. The desirable traits can be introgressed in the earlier generation chosen clones. The incorporated features appear in advanced ages among candidate clones for registration as superior varieties, where SWP resistance is among the unique traits of the candidate variety.

Several purple, orange and yellow-fleshed sweet potato hybrid clones that have been generated and evaluated for yield potential and drought tolerance (Mau et al. 2019) are potential sources of SPW resistance. Evaluation of these clones at an early generation would allow the selection of clones that exhibit the desirable agronomical traits and SPW resistance. Therefore, this study aimed to evaluate the response of yellow and purple-fleshed sweet potato clones to SPW infestation in the laboratory and identify sweet potato clones with good resistance to the weevil.

MATERIALS AND METHODS

Study site and plant materials

The study was carried out at the Integrated Field Laboratory of Archipelagic Dryland of Universitas Nusa Cendana, from August to November 2019. Nineteen sweet potato clones were used in the study, consisted of 15 hybrids and four Indonesian released varieties (Table 1). The hybrid clones were produced from crossing between local cultivars and national varieties. The Indonesian released types were provided by the Indonesian Legume and Tuber Research Institute (ILETRI), Malang, East Java.

Experimental design and procedures

The laboratory experiment was done by an artificial infestation of sweet potato storage roots using adult *Cylas formicarius* collected from a rearing experiment. The laboratory assays were carried out following Supriyatin and Rahayuningsih (1994) and Zuraida et al. (2005).

The roots of tested sweet potato clones were harvested in the field 18 weeks after planting. The harvested roots were washed under running water and air-dried at room temperature for about one hour. Three fresh roots of about 250-300 g each were put into a plastic container of 4 L volume covered with a plastic mesh. Each clone consisted of three replicates.

Five pairs of newly emerged sweet potato weevils (SPWs) were introduced into each plastic container and kept at room temperature for five days to allow the female SPW to oviposit. After five days of infestation, the SPW pairs were replaced from the plastic containers. Next, the containers were kept at room temperature for 30 days, after which the roots were taken out from the plastic containers and observed for the research variables.

Observation

Observed variables included percentage of damaged storage roots, storage root damage intensity, number of weevils (adult + immature) per root, number of feeding tunnels per root, root epidermal thickness, and root latex level.

Percentage of damaged roots

The tested roots were examined for damage related to SPW feeding, as shown by feeding punctures or feeding cavities in the root surface. Root with damage symptoms was classified as damaged, and that without any damage symptom was considered undamaged by SPW.

The percentage of the damaged root was calculated as:

$$I = \frac{a}{a+b} x\, 100\%$$

Where: I: Percentage of the damaged root, a: damaged root, b. undamaged root

Table 1. Sweet potato genotypes evaluated for resistance to sweet potato weevil

Genotype code	Flesh colour	Origin of population
UNC2016.CIL/JPV.01	Purple	Hybrid Clone
UNC2016.CIL/JPV.02	Light purple	Hybrid Clone
UNC2016.CIL/JPV.04	Light purple	Hybrid Clone
UNC2016.CIL/JPV.05	Purple	Hybrid Clone
UNC2016.KDL/NPL.02	Purple	Hybrid Clone
UNC2016.JPV/KDL.08	Light orange	Hybrid Clone
UNC2016.JPV/KDL.11	Pale orange	Hybrid Clone
UNC2016.JPV/KDL.02	Light purple	Hybrid Clone
UNC2016.NPL/JPV//KDL.02	Orange	Hybrid Clone
UNC2016.KDL/NPL.01	Orange	Hybrid Clone
UNC2016.NPL/PSOL.16	Purple	Hybrid Clone
UNC2016.JPV/KDL/NPL-04-1	Light purple	Hybrid Clone
UNC2016.JPV/KDL/NPL-04-2	Purple	Hybrid Clone
UNC2016.PSOL/NPL-15	Orange	Hybrid Clone
UNC2016.KDL/V1-CIL-01	Light orange	Hybrid Clone
Antin-1	Purple	ILETRI*
Beta-1	Orange	ILETRI*
Beta-2	Orange	ILETRI*
Kidal	Yellow	ILETRI*

Note: * Indonesian released variety

Table 2. Percentage and score of root damage intensity (Amalin 1994)

% Damage symptom	Damage score
< 1 %	1
1-25 %	2
26-50 %	3
51-75 %	4
76-100 %	5

Storage root damage intensity

All roots in the plastic container were observed for root damage intensity. The root was cut lengthwise into two parts of the same size, and the internal damage was observed for the damage intensity. The damage intensity was determined by visually estimated the percent area of damage of the internal root surface and then was given a damage score (Amalin 1994). Roots with 0% to < 1% damage intensity were scored 1, and those exhibiting internal damage of ≥ 1% were given a score as presented in Table 2. The damage intensity scores were then used to classify the SPW resistance level of the tested genotypes into; Resistant (R) (scores 1.0-< 1.5), Moderately Resistant (MR) (scores 1.5-< 2.5), Moderately Susceptible (MS) (scores 2.5-< 3.5) and Susceptible (S) (scores 3.5-5.0).

Number of SPWs (imago + immature) per root

The number of SPWs per root was observed inside and outside the root within the plastic container. The observation was done after the roots were examined for root damage intensity.

Number of feeding tunnels per root

The number of feeding tunnels was observed on the root surface, and the average was taken.

Root epidermal thickness

Freshly harvested roots from the field of about 250-300 g each were cut crosswise into the same size, and the epidermal thickness was measured. Three replicates were done in each genotype.

Root latex level

Freshly harvested roots were broken into two by using a knife to allow the flow of the latex. The latex was collected from the broken, exposed surface with a tube. The amount of latex was then classified into low, medium, and high.

Data analysis

Arcsine transformed the percentage of damaged root and root damage intensity data. Those of the total SPWs and the number of tunnels per root were changed by square root + 0.5 before ANOVA. Root epidermal thickness was subjected to ANOVA without transformation. Variables significantly affected by the treatments were subjected to post hoc Duncan Multiple Range Test (DMRT) at the 5% significant level to see the difference between the treatment means. The root damage intensity score data was used to group the SPW resistance level of tested sweet potato clones. Root latex production was subjected to descriptive analysis. Correlation analysis was carried out to see the relationship between the observed variables.

RESULTS AND DISCUSSION

Percentage of damaged root and root damage intensity

Fresh roots harvested from the field experiment were used for the laboratory assay. After one month of SPW infestation, the roots were examined for the percentage of the damaged roots and the intensity of root damage, as presented in Table 3.

Table 3. Means of the percentage of the damaged root, root damage intensity, root damage score, and SPW resistance level of tested sweet potato genotypes

Sweet potato genotype/code	Damaged root (%)	Root damage intensity (%)	Root damage score	SPW resistance level*
UNC2016.CIL/JPV-01	88.89 [a]	46.72 [cde]	3.10	MS
UNC2016.CIL/JPV-02	100.00 [b]	54.84 [cdef]	3.05	MS
UNC2016.CIL/JPV-04	100.00 [b]	14.09 [a]	2.08	MR
UNC2016.CIL/JPV-05	88.89 [b]	13.95 [a]	1.77	MR
UNC2016.KDL/NPL-02	77.78 [a]	39.60 [cd]	3.03	MS
UNC2016.JPV/KDL-08	88.89 [b]	65.33 [defg]	3.94	S
UNC2016.JPV/KDL-11	88.89 [b]	47.08 [cde]	3.07	MS
UNC2016.JPV/KDL-02	77.78 [a]	41.10 [cde]	2.89	MS
UNC2016.NPL/JPV/KDL-02	77.78 [a]	50.06 [cde]	3.23	MS
UNC2016.KDL/NPL-01	100.00 [b]	76.60 [g]	3.72	S
UNC2016.NPL/PSOL-16	88.89 [b]	72.17 [efg]	3.53	S
UNC2016.JPV/KDL/NPL-04-1	100.00 [a]	41.90 [cde]	2.65	MS
UNC2016.JPV/KDL/NPL-04-2	100.00 [a]	51.23 [cde]	3.04	MS
UNC2016.PSOL/NPL-15	100.00 [a]	52.92 [cde]	3.06	MS
UNC2016.KDL/V1-CIL-01	88.89 [b]	32.62 [bc]	2.60	MS
Antin-1	88.89 [b]	67.46 [fg]	3.95	S
Beta-1	66.67 [a]	41.69 [cde]	2.55	MS
Beta-2	66.67 [a]	19.27 [ab]	2.18	MR
Kidal	100.00 [a]	11.37 [a]	1.72	MR
Coefficient of Variation (%)	14.40	13.37		
Standard Error	2.69	2.90		

Note: Different superscripts letters within the same column denotes significant difference (DMRT 0.05) among means. MR: Moderately Resistant, MS: Moderately Susceptible, S: Susceptible. *Resistance level was determined based on Score of Root Damage Intensity (Amalain 1994)

Table 3 reveals that most tested SPW damaged sweet potato clones, ranging from 66.7-100% of the evaluated roots. For example, about 66.7% of storage roots of the check varieties Beta-1 and Beta-2 were damaged by SPW, while three hybrid clones (UNC2016.KDL/NPL-2, UNC2016.JPV/KDL-2, and UNC2016.NPL/JPV/KDL-2) had 77.8% of their storage roots been damaged by SPW. The remaining sweet potato clones had 88.9-100% of their roots damaged by the SPW.

The percentage of the damaged root as described above was determined based on SPW damage on the surface of tested roots, regardless of the damage intensity. In contrast, the root damage intensity was determined based on visual observation of internal root damage described in Table 3. The root damage intensity of the evaluated sweet potato clones varied significantly, ranging from 11.4% to 76.6%. Table 3 shows that 10 of the tested clones suffered root damage intensity of less than 50%, while the rest nine clones had more than 50% root damage intensity. Sweetpotato genotypes suffering the least (< 20% root damage intensity) included the check varieties Kidal and Beta-2 and the hybrid clones UNC2016.CIL/JPV-4 and UNC2016.CIL/JPV-5. While the highest root damage intensity was observed in the hybrid clone UNC2016.KDL/NPL-1, which was not significantly different from that of Antin 1, UNC2016.NPL/PSOL-16, and UNC2016.JPV/KDL-8. These data presumably indicate varying resistance levels of the tested sweet potato clones against *C. formicarius*.

Storage root damage score and SPW resistance level

The storage root damage intensity was assigned with root damage scores before the SPW resistance level of the tested sweet potato genotypes. The root damage intensity was scored 1 to 5 (Amalin 1994; Mau et al. 2011) as presented in Table 3 and used to classify the resistance level of the tested clones. The damage scores ranged from 1.72 to 3.72, which organized the tested clones into three categories, i.e., moderately resistant (MR), moderately susceptible (MS), and Susceptible (S). Only two hybrid clones (UNC2016.CIL/JPV-4 and UNC2016.CIL/JPV-5) were relatively resistant to SPW, while the remaining hybrid clones were either moderately susceptible or susceptible to SPW. Meanwhile, of the four check varieties, Beta-2 and Kidal were relatively resistant and the remaining two checks, i.e., Beta-1 and Antin-1, were moderately susceptible and susceptible, respectively. Thus, none of the 17 tested clones was resistant to SPW.

Number of SPWs and feeding tunnels, root epidermal thickness, and root latex level

In addition to the percentage of damaged root and root damage intensity, other variables assumed to be correlated with these two variables were also observed. These included the number of SPWs per root, number of feeding tunnels per root, root epidermal thickness, and root latex level. Data of these variables are presented in Table 4.

The results demonstrated that the number of SPWs varied significantly among the tested sweet potato clones. The highest number of SPWs (31.9) was observed on UNC2016.JPV/KDL-11 while the lowest (1.4) was observed in UNC2016.CIL/JPV-04. One-half of tested sweet potato clones had more than 10 SPWs per root during 30 days of infestation.

Table 4. Means of number of sweet potato weevils (SPWs) per root, number of feeding tunnels per root, root epidermal thickness, and root latex level

Sweet potato genotype/code	Number of SPWs per root	Number of feeding tunnels per root	Root epidermal thickness (mm)	Root latex level
UNC2016.CIL/JPV-01	4.9 ^{cd}	4.61 ^{cd}	2.49 ^{bc}	+
UNC2016.CIL/JPV-02	2.8 ^{bc}	2.93 ^{abc}	2.83 ^{cd}	++
UNC2016.CIL/JPV-04	1.4 ^{a}	1.36 ^{a}	2.00 ^{b}	+
UNC2016.CIL/JPV-05	2.9 ^{bc}	2.76 ^{abc}	1.08 ^{a}	+
UNC2016.KDL/NPL-02	3.8 ^{bc}	3.72 ^{bc}	3.00 ^{cd}	++
UNC2016.JPV/KDL-08	27.3 ^{h}	26.83 ^{i}	2.83 ^{cd}	++
UNC2016.JPV/KDL-11	31.9 ^{h}	31.11 ^{i}	4.00 ^{f}	+
UNC2016.JPV/KDL-02	15.0 ^{fg}	15.65 ^{fgh}	2.00 ^{b}	+
UNC2016.NPL/JPV/KDL-02	7.8 ^{de}	8.03 ^{de}	3.67 ^{ef}	++
UNC2016.KDL/NPL-01	17.2 ^{g}	16.94 ^{h}	3.00 ^{cd}	++
UNC2016.NPL/PSOL-16	15.8 ^{g}	16.03 ^{gh}	2.83 ^{cd}	+
UNC2016.JPV/KDL/NPL-04-1	1.8 ^{b}	2.07 ^{ab}	1.92 ^{b}	++
UNC2016.JPV/KDL/NPL-04-2	13.1 ^{fg}	13.34 ^{fgh}	2.83 ^{cd}	++
UNC2016.PSOL/NPL-15	6.4 ^{d}	6.31 ^{d}	2.17 ^{b}	++
UNC2016.KDL/V1-CIL-01	12.3 ^{fg}	12.17 ^{fg}	3.33 ^{de}	+
Antin-1	10.9 ^{ef}	10.76 ^{ef}	3.00 ^{cd}	+
Beta-1	13.8 ^{fg}	13.22 ^{fgh}	3.00 ^{cd}	+++
Beta-2	1.7 ^{ab}	12.57 ^{a}	2.87 ^{cd}	++
Kidal	2.4 ^{b}	2.51 ^{abc}	3.10 ^{cde}	++
Coefficient of Variation (%)	8.91	9.91	10.15	
Standard Error	0.29	0.29	0.15	

Note: Different superscripts letters within the same column denotes significant difference (DMRT 0.05) among means. $^{+}$Low, $^{++}$Medium, and $^{+++}$ High

Table 5. Correlation between observed variables of tested sweet potato genotypes

Observed variables	Percentage of damaged root	Root damage intensity	Number of SPWs per root	Number of feeding tunnels per root	Root epidermal thickness
Percentage of damaged root		0.56	0.75	0.36	0.39
Root damage intensity	0.14 ns		0.02	0.04	0.17
Number of SPW per root	-0.08 ns	0.54 *		0.00	0.04
Number feeding tunnels per root	-0.22 ns	0.47 *	0.96**		0.03
Root epidermal thickness	-0.21 ns	0.33 ns	0.48*	0.50 *	

Note: Numbers below the dashed-box diagonal are Pearson's correlation coefficient values, and those above the diagonal are the p-values. nsNot Significant (P>0.05), *Significant (P<0.05), **Highly Significant (P<0.01).

The number of feeding tunnels per root also differed significantly among the clones. Generally, roots with lower SPW numbers also had fewer feeding tunnels per root and vice versa (Table 4). The number of SPWs also corresponded strongly with the number of feeding tunnels per root. This indicates a strong correlation between the two variables.

Root epidermal thickness also varied among the tested clones, ranging from 1.08 mm to 4.0 mm. Eight of the tested clones had root epidermal thickness between 3.0-4.0 mm, while the rest had < 3 mm epidermal thickness. The root epidermal thickness seems to be corresponding well with either number of SPWs or the number of feeding tunnels per root, indicating a significant correlation among them. The qualitative assessment also showed that roots of the tested sweet potato clones produced varying levels of latex, ranging from low to high levels (Table 4).

Correlations among observed variables

The observed variables were subjected to correlation analysis to reveal their association. The results (Table 5) showed a differential correlational pattern among variables. The percentage of damaged roots was not correlated with other observed variables. At the same time, root damage intensity was positively correlated with the number of SPWs per root (r = 0.54) and the number of feeding tunnels per root (r = 0.47). Furthermore, a highly significant and positive correlation (r = 96) was observed between the number of SPW per root and the number of feeding tunnels per root (r = 0.96). The results also showed that root epidermal thickness had a positive and moderate correlation with either number of SPW per root (r = 0.48) or the number of feeding tunnels per root (r = 0.50).

Discussion

The present study results revealed variable responses of sweet potato genotypes against SPW. Both the percentage of damaged root and root damage intensity differed significantly among the tested sweet potato genotypes. Most of the roots of the sweet potato genotypes were damaged by SPW as in the present no choice bioassay. The weevils were forced to feed on the roots for their survival and also for oviposition. For completing their life cycle, the weevils cause feeding destruction to sweet potato roots, vines, stems, and leaves (Kyereko et al. 2019). In roots, after mating, the female weevils create feeding punctures on the roots to lay eggs (Matthews 2002; Muyinza 2010), and the developing larvae will make tunnels in holes inside the roots, feed and develop into adults within the roots.

Both the percentage of damaged roots and root damage intensity in this study (77.8-100% and 14.0-76.6%, respectively) differed in range as compared to those of the previous research by Mau et al. (2011) (24.1-88.3 and 3.8-67.9%, respectively) on local and released sweet potato genotypes from Indonesia. These differences may have been caused by differences in genotypes being tested and the sweet potato root production sites. This is supported by the findings of Jackson et al. (2012), who also found different percentages of damaged roots among plant introduction (PI) sweet potato accessions on multi-year and multi-site experiments. In addition, the effect of genotype by location on the percentage of SPW damage on sweet potato genotypes has also been reported by Mao et al. (2001).

Consistent with the percentage of damaged root and root damage intensity, the root damage score, and hence, the resistant level of tested sweet potato genotypes also significantly differed among tested sweet potato clones. Of the 19 genotypes tested, none was found to be resistant to SPW. Only four clones were moderately resistant, and the rest of the genotypes were moderately susceptible and susceptible to SPW. This finding confirmed previous study results (Zuraida et al. 2005; Mau et al. 2011), where SPW resistant genotypes were hardly encountered. Zuraida et al. (2005) identified only one SPW resistant clone out of 50 genotypes tested, while Mau et al. (2011) found only one out of 10 tested clones to be resistant to SPW. In addition, using a bionomic of the sweet potato weevil, Adom et al. (2018) identified one out of four sweet potato genotypes tested to be less susceptible to *C. puncticollis*.

Rais et al. (2004) identified 10 SPW resistant sweet potato genotypes out of 70 accessions tested. Further, Jackson et al. (2012) identified several SPW resistant genotypes out of 55 sweet potato PI accessions. All these findings imply that the success of finding sweet potato genotypes with good SPW resistance is very much dependent on the genetic background of the germplasm evaluated, and is to some extent, on the effect of planting environments that influence the nutritional quality of sweet potato storage root that influence the preference of SPW (Parr et al. 2016).

The present study classified the tested sweetpotato genotypes into three categories of resistance level, i.e., moderately resistant (four genotypes), moderately susceptible (11 genotypes) and susceptible (four genotypes). The mechanism of resistance was not elucidated in detail in the present study. Still, the observed variables related to SPWs and the root morphology may provide insights into the resistance mechanism in the studied genotypes.

In addition to the percentage of damaged root and root damage intensity, SPW per root, number of feeding tunnels per root, root epidermal thickness, and root latex level also varied among tested sweet potato genotypes. Differences in the number of SPWs and number of feeding tunnels per root may imply differences in SPW preference toward the sweet potato genotypes, which determine the oviposition preference that in turn determines the number of eggs laid, and hence the number of the following growth stages such as larvae, pupae and imago (Kyereko et al. 2019). The SPWs will determine the number of feeding tunnels created as shown by a highly significant and positive correlation between the two variables (r = 0.96). Correlation analysis results also revealed that root damage intensity was positively and significantly correlated with the number of SPWs and the number of feeding tunnels per root. The positive correlation indicates that an increase in the number of SPWs and, hence the number of feeding tunnels per root will also be accompanied by an increase in root damage intensity as the higher the number of SPWs, the more the requirement for food. Thus, the root will be damaged for food provision. A similar result of a highly significant and positive correlation between root damage intensity and the number of SPWs was also observed by Mau et al. (2011) on Indonesian local and released sweet potato varieties. These results imply that the tested genotypes possess different resistance mechanisms against the SPW.

A moderately positive correlation was observed between root epidermal thickness with either number of SPWs (r = 0.48) and the number of feeding tunnels (r = 0.50), indicating that the thicker the root epidermis, the higher the number of SPWs and number of feeding tunnels per root. However, the association of the root epidermal thickness with the two variables is biologically unexplainable in this study. It contradicts Korada et al. (2010) statement that epidermal thickness could affect cultivar preference by inhibiting the SPW mouthpart penetration. This, in turn, will affect the feeding site decision of SPW. Alternatively, the observed association between epidermal thickness and the number of SPWs found in this study could have randomly occurred and not related to the SPW resistance mechanism. Further, Mau et al. (2011) observed no correlation between root epidermal thickness with either number of SPWs or the number of feeding tunnels per root.

The tested sweet potato genotypes also differed in latex production level. Although the latex production was assessed qualitatively, the observed data seems not strongly associated with resistance level as two of the moderately resistant (MR) genotypes produced only a low latex level. In contrast, the other two MR genotypes had a moderate latex level. On the contrary, a high latex production level was observed on a moderately susceptible (MS) genotype (Table 4). Thus, the latex production levels observed in the present study seem unrelated to SPW resistance. This finding contrasts the previous reports (Data et al. 1996; Stevenson et al. 2009; Rukarwa et al. 2013; Anyanga 2015), who found that chemical differences in periderm and epidermal latex could mediate resistance to SPW. The chemical compounds in root surface, periderm, and epidermal latex that may mediate resistance include hydroxycinnamic acid esters such as hexadeyl caffeic acid, heptadecyl caffeic acid, octadecyl caffeic acid, and octadecyl coumaric acid (Harrison et al. 2003; Muyinza 2010; Anyanga et al. 2013; Anyanga 2015).

Overall, the present study results revealed a variable SPW resistance among the tested sweet potato genotypes; four genotypes were moderately resistant (MR). The remaining 15 genotypes were either moderately susceptible or susceptible to SPW. The MR genotypes included two-hybrid purple-fleshed clones, i.e., UNC2016.CIL/JPV-04, UNC2016.CIL/JPV-05 and two released varieties, i.e., Beta 2 and Kidal. Kidal has also been moderately resistant to SPW in the previous study (Mau et al. 2011), thus, expressing its actual resistance instead of being an escape. Therefore, the SPW-MR genotypes are potential sources for developing sweet potato superior varieties with high SPW resistance. The hybrid clone UNC2016.CIL/JPV-05 has also been recorded to have a high yield (23 t ha-1) in the previous study (Mau et. 2019). Thus it is promising for varietal release.

ACKNOWLEDGEMENTS

We are very thankful to the Directorate of Research and Community Services (DRPM) of the Indonesian Ministry of Research, Technology and Higher Education for supporting this research through *Penelitian Terapan* research scheme, the financial year 2019. Special thanks are also addressed to Teroci Lake for providing the selected roots from the field.

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INTL J TROP DRYLANDS
Volume 5, Number 2, December 2021
Pages: 48-60
E-ISSN: 2775-6130
DOI: 10.13057/tropdrylands/t050202

Insecticidal activities of indigenous plants from Volta Region, Ghana in managing *Sitophilus zeamais* and *Prostephanus truncatus* in stored maize

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Manuscript received: 5 December 2021. Revision accepted: 24 October 2021.

Abstract. *Ankutse DK, Eziah VY, Afreh-Nuamah K. 2021. Insecticidal activities of indigenous plants from Volta Region, Ghana in managing* Sitophilus zeamais *and* Prostephanus truncatus *in stored maize. Intl J Trop Drylands 5: 48-60.* The rising rate of pest resistance, and the high expense and health risks associated with insecticide use, have become a source of public concern. This study aimed to discover and evaluate plant species used by farmers in the Volta Region to control *Sitophilus zeamais* (Motschulsky, 1855) and *Prostephanus truncatus* (Horn, 1878) in stored maize grains. In a survey, *Azadirachta indica, Clausena anisata, Phyllanthus amarus, Picralima nitida, Vernonia amygdalina, Nauclea latifolia,* and *Momordica charantia* were discovered to be grain protectants against stored insect pests. All of the plants indicated above were employed in the experiment, except for *A. indica*, which has a long history of being used to combat grain storage pests. The insecticidal activity of dried powders (5 and 10%) and aqueous extracts (0.1 and 0.2 g/mL) of plants against *P. truncatus* and *S. zeamais* was examined. Plant species and dose rate influenced repellency. In the *V. amygdalina* treatment, plant powders and methanol extracts were the most poisonous to insects. The toxicity of *V. amygdalina* to *P. truncatus* and *S. zeamais* was 83.3 and 86.7%, respectively, at higher concentrations of 0.2 g/mL. At 0.2 g/mL, all plant extracts exhibited a significant difference in Actellic repellent (P0.05); nevertheless, *C. anisata* had the highest repellent action against *P. truncatus* and *S. zeamais*, with 80.0 and 66.7%, respectively. As grains were treated with plant extracts, oviposition and egg emergence were reduced compared to the control. When embryonic stages of insects were treated with methanol extracts of botanicals, the number of adult insects decreased. These findings show that the studied plants have the potential to aid in the development of post-harvest protection technology against the principal pests of stored grains, *P. truncatus* and *S. zeamais*. As a result, farmers should use it to control *P. truncatus* and *S. zeamais* in stored maize grains.

Keywords: Indigenous plants, insecticidal, *Prostephanus truncatus*, *Sitophilus zeamai*s, *Zea mays*

INTRODUCTION

Maize (*Zea mays* L.) is a member of the Gramineae family and is one of the most significant cereal crops grown in various agro-ecological environments around the world (Owusu-Sekyere et al. 2011). Maize is produced in greater quantities than any other grains, and statistics reveal that maize accounts for 37% of total cereal consumption in Sub-Saharan Africa (Quandzie 2011). In Ghana, it is grown in all ten regions of the country with the Eastern Region being the most prolific producer. Maize is only third in production after roots & tubers and plantain (MOFA 2008). Maize farming takes up less space than wheat or rice, but produces a higher average output per unit area of roughly 5.5 tons per hectare (Obeng-Ofori and Dankwah 2004).

Maize is used for three main purposes: human food, industrial raw materials, and livestock feed. According to IITA (2003), globally, 66% of all maize is utilized for livestock feed, 25% for human consumption, and 9% for industrial purposes. However, in poor countries such as Ghana, around half of all maize is consumed as food, while the remaining 43% is given to livestock and the rest is used for industrial purposes. Whole grains are either mature or immature (fresh corn) or various processed forms, depending on the location or ethnic group. It can also be processed into a wide range of intermediate goods, including different-sized maize grits, maize meal, maize flour, and flaking grits.

Despite maize's importance, storage losses are still relatively substantial. According to FAO (2008), global grain losses amount to about 10% of all stored grain, i.e., 13 million tons of grain are lost owing to insect pest damage and 100 million tons are lost due to improper storage. According to Cornelius et al. (2008) estimates, losses in developing countries might be as high as 50% of what is produced. In contrast to perishable crops, maize can be stored for extended periods of time; however, preservation quality during long-term storage is an issue in many regions of the world, as quality decreases with storage duration. Losses in storage might occur as a result of over-drying of grains, weight loss owing to respiration, or the incorrect application of synthetic pesticides. In addition, infestation by rodents and insects, as well as feeding damage, contamination with mycotoxins caused by molds and bacteria, and dead insect parts, can all lead to storage loss (Boxall 2001).

The most common insect pests on maize are *Prostephanus truncatus* (Horn, 1878) (Coleoptera: Bostrichidae) and *Sitophilus zeamais* (Motschulsky, 1855) (Coleopteran Curculionidae). The larvae and adults of both insects feed on the grain, reducing its viability, quality, and value, as well as its weight and nutrients (Cornelius et al. 2008). Food insecurity and poverty levels among farmers have increased as a result of this predicament, particularly in developing nations like Ghana.

Synthetic pesticides are currently commonly utilized to control insect pests of stored foodstuffs in most developing countries, such as Ghana. However, indiscriminate use of synthetic pesticides has resulted in food poisoning, the extinction of natural enemies and non-target species, pest resistance, the transformation of harmless species into pests, food contamination and air pollution all, of which pose a health risk to humans and animals (Gill and Garg 2014).

As a result, most academics are now focusing on non-chemical grain storage systems in order to limit the usage of synthetic insecticides. Plants have significant economic and health benefits for users, consumers, and the environment (Elhag 2000; Talukder and Howse 2000). The usage of plant extracts has a variety of impacts on insects. They are non-toxic to warm-blooded animals and act as antifeedants, growth regulators, sterilants, oviposition deterrents, repellents, and impair insect fitness (Saxena et al. 1989; Schmutterer 1990). According to Obeng-Ofori (2007), the application of plants as grain protectants from insect damage is gaining traction and yielding favorable results in recent years.

Under these conditions, laboratory and field bioassays were undertaken to determine the efficiency of six indigenous Ghanaian plant powders and extracts against *S. zeamais* and *P. truncatus* in the Volta Region's Jasikan, Afadjato, and South Dayi Districts. The objectives of this research were (i) To identify the various plant species used to preserve corn in the selected districts. (ii) To determine the antimicrobial efficacy of six potential plant powders against *S. zeamais* and *P. truncatus* in preserved maize. (iii) To determine the toxicity and repellency of the best plant's methanol extract against *S. zeamais* and *P. truncatus* in stored maize. (iv) To determine the optimal concentration of the most effective plant methanol extract against *S. zeamais* and *P. truncatus* in stored maize. (v) To determine the effective concentration of potential plant extract against *S. zeamais* and *P. truncatus* in a bioassay.

MATERIALS AND METHODS

The study area

A survey was done in three districts of Ghana's Volta Region (Jasikan, Afadjato, and South Dayi) to ascertain the plants used by farmers to protect maize grains from insect pests. The Jasikan District is one of the Volta Region's twenty-five (25) municipalities and districts. Jasikan serves as the administrative capital. The district is bounded on the east by the Republic of Togo, on the west by the Volta River, on the north by Biakoye District, and on the south by Afadjato District and Kpandu Municipal. It has an area of 1355 km^2 and comprises 33 villages and 33 sub-towns. The primary activity of their inhabitants is farming, with the majority of them being women engaged in small-scale production (Ghanaditricts.com 2013).

In 2012, the Afadjato District was carved out of Hohoe Municipality. Ve-Golokwati serves as the administrative capital of the District. The District is bounded on the north by Hohoe Municipality, on the west by Kpando Municipality, on the east by the Republic of Togo, and on the south by Ho West District and South Dayi District. It comprises around 238,533 km^2 and the majority of its inhabitants are peasant farmers who cultivate corn primarily on subsistence scales (ghanaditricts.com 2013).

South Dayi District is located between latitudes 3.020'N and 3.5005'N, with longitude 0017'E. It is bordered on the north by Kpando and Afadjato South, east by Ho West, and south by Asougyaman District, with the Volta Lake forming the western boundary. The District has a total size of 1,000 km^2, with the Volta Lake submerging around 20% of it. The yearly rainfall averages between 900 and 1300 millimeters. The District's vegetation is dominated by Guinea woodland and deciduous forests. The human population of South Dayi District in September 2010 was 46,661, according to the 2010 Population and Housing Census. Farming and fishing activities employ approximately 62% of the economically active population (Ghanaditricts.com 2013).

The laboratory and final field trials were done at the University of Ghana Farm and the Entomology Laboratory at the Crop Science Department. A ventilated crib of 3 x 1.5 x 1.5 m was built with a wooden framework at the University farm of Ghana-Legon. The efficacy of plant extracts against *S. zeamais* and *P. truncatus* in bioassay was determined by storing grains treated with four extracts at two concentration levels in the crib.

Field survey

The Volta Region's field survey was done in three districts: Jasikan, Afadjato, and South Dayi. Three villages were chosen at random in each district to represent villages, and ten maize farmers in each village were picked with the help of extension officers. Ninety (90) farmers from the three districts were asked open-ended and closed-ended questions. Farmers' demographics, storage methods, maize varieties and effectiveness, and customer acceptability of grain treated with plant extracts were all covered in the questionnaires. The data was examined using the SPSS storage method.

Culturing of insects

Sitophilus zeamais

Sitophilus zeamais was isolated from contaminated maize grains collected from a maize farmer in the Volta Region's Kpeve. In the Crop Science Laboratory, one hundred adult insects of mixed sexes were infested in 500 g of sterilized grains in a glass jar covered with muslin cloth. The culture was stored on the laboratory shelf for one week to allow for oviposition. Adult insects were removed, and emerging generations were used to establish the experimental cultures. To get enough insects for the studies, the culturing of *S. zeamais* was repeated four times.

Prostephanus truncatus

Prostephanus truncatus samples were collected from infested maize grain stock at Baika in the Jasikan District of the Volta Region and from old stock at the Crop Science Laboratory. First, whole maize grains were sterilized for 3 hours at 60°C and then allowed to cool for 12 hours before being utilized in the culture. Then, in a glass jar, one hundred insects of mixed sexes were injected into 500 g of sterilized maize grains using an aspirator in a controlled room at 28 ± 2°C and 65% relative humidity (Osafo 1998; Weaver et at. 1998; Udo et al. 2009). Adult insects have sieved away after one week of oviposition and the culture was left to stand for emerging progeny employed to establish the experimental cultures (Udo et al. 2009).

Selection of plants

The plant species employed in grain storage in this study were chosen based on the following parameters by farmers during a field survey. These considerations include the efficiency of the plant against stored insects, its availability, how frequently it is employed in the area, and whether or not the plant has been utilized or properly researched in the country to store grains.

Seven plants were detected in total (*Azadirachta indica, Clausena anisata, Phyllanthus amarus, Picralima nitida, Vernonia amygdalina, Nauclea latifolia,* and *Momordica charantia*), although *A. indica* was not picked due to its considerable research in the country. The synthetic reference pesticide Actellic was chosen since it is one of Ghana's most frequently utilized synthetic chemicals for grain storage. The names of the plants, their local names in the location where they were collected, and the portions used to prepare the plant powders and extracts are listed in Table 1.

Preparation of plant powders

The components of the six plant species were gathered from Baika in the Volta Region's Jasikan District. They were brought to the Crop Science Laboratory of the University of Ghana-Legon, where they were prepared for identification at the university's herbarium in the Botany Department. After washing the plant specimens with tap water to remove sand and other undesirable particles, they were air-dried for 15 days at room temperature. Next, the specimens of the chosen plants were beaten using a mortar and pestle before being processed into a fine powder. To achieve homogeneous size particles, the powders were sieved with an Impact Test Sieve with a mesh size of 70. A day before being employed for grain treatment, the crushed powders were kept in six distinct airtight containers.

Preparation of methanol extract of plants

Six conical flasks containing 430 mL each of 100% methanol were filled with approximately 100 g of the plant powders. For 48 hours, the flasks were covered with Parafilm and shaken. The solution was filtered through a 2.5-mesh filter and concentrated at 60°C using a rotary evaporator, following which the residues were dissolved in acetone to obtain concentrations of 0.1 g/mL and 0.2 g/mL for the various bioassays.

Screening of the six plant powders

Effect of plant powders on adult insects

Four kg of whole grains was placed on a metal tray and sterilized in a 60°C oven for 3 hours. For 24 hours, the sterilized grains were equilibrated at 28 ± 2°C and 65% relative humidity in a controlled atmosphere. Sterilized whole maize grains (100 g) were placed in glass jars, and two sets of plant powders (5% and 10%) were combined in with the grains. Actellic 25 EC was administered in acetone at a concentration of 2 mL/L, while the control treatment included no botanical powder. Before introducing 20 adult *S. zeamais* and *P. truncatus* (5-10 days old) into the treated and untreated maize grains, the setups were let to stand for one hour. Under a randomized design, the treatments were replicated four times. For seven days, the daily mortality of insects was recorded. It was declared dead if an insect did not respond to poking with a blunt probe.

Effect of methanol extracts on adult insect in treated grains

Sterilized maize grains (50 g) were placed in Kilner glass jars, and four botanicals (*C. anisata, P. amarus, P. nitida,* and *V. amygdalina*) were administered to each jar in two concentrations (0.1 g/mL and 0.2 g/mL). In addition, grain was treated with Actellic (2 mL/L) and control-treated with acetone. The treated grains were air-dried for one hour to evaporate the solvent. After introducing twenty adult *S. zeamais* and *P. truncatus* (5-10 days old) into the treated and untreated maize grains, the jars were covered with muslin cloth held in place with rubber bands. The treatments were repeated four times and kept for one week in a controlled chamber at 28 ± 2°C and 65% relative humidity. Insects were declared dead if they did not respond to three probes with a blunt probe.

Table 1. Plant species used for the experiment

Plant species	Local name	Common name	Parts use	Stage of collection
Clausena anisata	Ayira	Horsewood	Leaves	Before flowering
Phyllanthus amarus	Kpavideme	Phyllantus	Leaves	During flowering
Picralima nitida	Quinine	Akuamma plant	Seed	Matured seed
Vernonia amygdalina	Gbɔti	Bitter Leaf	Leaves	Before flowering
Nauclea latifolia	Nyimɔke	African peach	Root	Maturity
Momordica charantia	Kakle	Bitter gourd	Leaves	During flowering

Contact toxicity by topical application

The procedure described by Obeng-Ofori and Reichmuth (1997) was used in this test. Ten adults of each *S. zeamais* and *P. truncatus* (5-10 days old) were placed in a separate petri dish lined with damp filter paper for three minutes. Using a micro-pipette, one microlitre of four plant extracts, Actellic, and a control (water) were applied to the dorsal surface of the thorax of insects. The experiment was carried out four times in all. The mortality of insects was measured during five days.

Effect of methanol extracts on oviposition

50 g maize grains were weighed into glass jars and given four different herbal treatments. Another jar was given Actelic at a concentration of 2 mL/L, whereas the control received no treatment. The treated grains were infested with mixed sexes of 20 adults of *S. zeamais* and *P. truncatus* (5-10 days old) after being left for one hour. To allow for oviposition, the jars were covered with muslin cloth kept in place with rubber bands and put in a controlled atmosphere at 28 ± 2°C and 65% relative humidity for seven days. The experiment was set up in a completely randomized design with three repetitions. The adult insects were sieved on the eighth day, and the number of eggs laid was calculated using egg plug staining procedures (acid fuchsin method) FAO (2008).

Effect of methanol extracts of plants on eggs and immature stages

Effect on eggs

Six glass jars were filled with sterilized maize grains (100 g) with a moisture content of 12%. To allow for egg laying, the grains were infested with 20 adult *S. zeamais* and *P. truncatus* (5-10 days old) of mixed sexes in each set of jars. After seven days of oviposition, the adult insects were collected and the percentage of oviposition was calculated before grains were treated with methanol extracts of *C. anisata, P. amarus, P. nitida,* and *V. amygdalina* at 0.1 g/mL and 0.2 g/mL, respectively. Water and Actellic were used to treat the control and reference groups, and each treatment was repeated three times. In addition, the number of newly emerged adults was counted and recorded.

Toxicity of methanol extracts to larva.

Twenty adults of *S. zeamais* and *P. truncatus* (5-10 days old) of mixed sexes were infested with 100 g of sterilized maize in each glass jar, and oviposition was allowed for seven days. On the seventh day, the adult insects have sieved away, and the grains were permitted to stay for another seven days to allow the eggs to develop into larva. The grains were subsequently treated with two concentrations of plant extracts and Actellic (0.1 g/mL and 0.2 g/mL), with the control being treated with acetone. Under a completely randomized design, the experiment was repeated four times. The number of newly emerged adults was counted and recorded.

Effect of methanol extracts on the pupa

In this experiment, 100 g of sterilized maize grains was placed in twelve glass jars, with twenty adults of *S. zeamais* (5-10 days old) of mixed sexes delivered into six jars and twenty adults of *P. truncatus* introduced into the remaining six jars. On the seventh day following oviposition, the mature insects have sieved. The grains were treated with four different botanical extracts and Actellic at two concentrations (0.1 g/mL and 0.2 g/mL) on the 22nd day, whereas the control was given water. The emerged adults were numbered and documented after each treatment was reproduced three times in a completely randomized method.

Repellency assay

The repellency of methanol extracts of plants on *S. zeamais* and *P. truncatus* was determined in the laboratory using Obeng-Ofori and Reichmuth's (1997) approach carried out at 28 ± 2°C and 68-73% relative humidity. Full disc filter sheets were separated into two halves, with one half being treated with the test solutions (0.1 g/mL and 0.2 g/mL) and the other half being treated with water using a micropipette. The modified filter sheets were air-dried for three hours in the laboratory. The treated and untreated filter papers of the same dimension were joined together to produce a whole disc using sellotape. Each filter paper was placed in a petri dish, and 10 adults (5-10 days old) mixed sexed *S. zeamais* and *P. truncatus* were placed in the center of each filter paper and covered. Three times the experiment was carried out. The number of insects present on the treated (Nt) and control (Nc) groups were counted and recorded 30 minutes after the insects were introduced. PR = [(Nc – Nt)/ [(Nc + Nt)] X 100 was used to calculate the percentage repellency (PR) values.

Damage assessment

An approach of Cornelius et al. (2008) for assessing grain damage was used. Methanol extracts of four plants treated sterile whole maize grains (2 kg) each. The control group received simply methanol treatment. The treated grains were then air-dried for three hours before being placed in 30 x 40 cm sacks. One hundred *S. zeamais* and *P. truncatus* adults (5-10 days old) of mixed sexes were discharged into two separate bags. Three times each therapy was carried out. The bags were then placed in a crib at the University of Ghana farm for ten weeks, following which the amount of weight lost was calculated using the count and weigh method. 1000 grain samples were taken from each of the treatments, and 500 grains were counted from each sample. Damaged and undamaged grains were isolated from the 500 grains. They were all weighed and counted. The percentage weight loss was calculated using the FAO approach, as updated by Cornelius et al. (2008):

$$\text{Percent Weight Loss} = (UNd)-(DNu)/ U(Nd + Nu) \times 100$$

Where: *Nu* is the number of undamaged grains; *Nd* is the number of damaged grains; *U* is the weight of undamaged grains; and *D* is weight of damaged grains.

Separate sieves were used to separate the grains, and the frass from each treatment was weighed and the means compared.

RESULTS AND DISCUSSION

Survey

A summary of survey results from the three districts of the Volta Region

Respondent profile: this section covers the respondent's gender, age group, marital status, educational level, dependents, and farming experience. The study discovered that both men and women were active in utilizing plants to manage pests of stored products, albeit the demographics indicated a higher proportion of female respondents (72%). Farmers' ages and educational levels did not differ significantly across the three districts. While all respondents were adults, 60% were between the ages of 40-60, 94% of farmers had some level of schooling, and 85% were married with dependents (Table 2). At least 70% of respondents reported had 10-20 years of expertise growing and utilizing botanicals to conserve their produce.

Type of crops grown and storage method by farmers in Volta Region

Although a variety of crops were planted, 90% of respondents cultivated maize for subsistence farming, primarily during the minor season for storing. Farmers harvest and store their crops manually in the majority of cases. For example, 50% of farmers stored their corn in cribs, while the other half stored grains in 15 L oil gallon (hermetic) containers with plant parts, barns, and sacks (Figure 1).

Table 2. A summary of survey results from the three districts of the Volta Region, Ghana

	Frequency	Percentage
Sex		
Male	25	28
Female	65	72
Age of farmers (range)		
Under 21	0	0
21-40	22	25
41-60	54	60
Above 60	14	15
Educational level		
None	5	6
Basic	49	54
Secondary	27	30
Tertiary	9	10
Method of storage		
Crib	45	50
Barn	15	17
Hermetic	30	33
Total	60	100

Figure 1. Methods of maize storage with plant parts in Jasikan, Afadjato and South Dayi Districts, Volta Region, Ghana. A. Integrated storage method, B. Crib, C. Barn, D. Integrated Storage Method

The use of plant elements, effectiveness and marketing of grains treated with botanicals

According to the survey, 90% of respondents utilized just plant elements, while 10% used plant elements and synthetic chemicals (Actellic). Farmers utilized a total of seven plant species to prevent their wheat from insect pest infestation (Table 3). From 73.5% respondents agreed that *A. indica, C. anisata, P. nitida,* and *V. amygdalina* were more effective at managing stored insect pests than the other plant species. All respondents agreed that there were no issues with the sale of grains preserved with plant elements.

Effect of plant powder on *Sitophilus zeamais and Prostephanus truncatus* in treated maize

Figure 2 illustrates the reaction of all six plant powders at 5% and 10% against adult *P. truncatus* and *S. zeamais* after seven days. After seven days of treatment with all six plant powders at 5% and 10%, *S. zeamais* survival ranged between 54-86% and 41-64%, respectively, while *P. truncatus* survival ranged between 55-86% and 42-71%. All of the readings were significantly (P and < 0.05) less than what Actellic induced.

Contact toxicity by topical application

Table 4 shows the adult mortality of *P. truncatus* and *S. zeamais* after contact toxicity with methanol extracts of *C. anisata, P. amarus, P. nitida,* and *V. amygdalina* at concentrations of 0.1 g/mL and 0.2 g/mL. The results revealed that the type of plant and the concentration of extract applied had a substantial (P < 0.05) impact on the toxicity of methanol extracts of various plants. In the lower (0.1g/mL) concentration, mortality in *P. truncatus* and *S. zeamais* was 36.7-60% and 50-70%, respectively, whereas, in the higher (0.2/mL) concentration, mortality was 50-83% and 56.7-86.7% in *P. truncatus* and *S. zeamais*, respectively. Insect mortality was higher in the higher concentration than in the lower concentration.

Toxicity of extracts to *Sitophilus zeamais* and *Prostephanus truncatus* in treated grain.

Figure 3 shows the effects of methanol extracts of *C. anisata, P. amarus, P. nitida,* and *V. amygdalina* at concentrations of 0.1 g/mL and 0.2 g/mL on adult insects in treated grains. In both treatments, the survival of both insects rose as the concentration increased. However, at 0.1 g/mL, *P. truncatus* and *S. zeamais* had the lowest survival rates of 35% and 38%, respectively, while at 0.2 g/mL, they had even worse survival rates of 28% and 23%. In almost all of the treatments, the reference product had zero survival.

Table 3. Botanicals used by farmers in Volta Region, Ghana to store maize grains.

Botanicals	Local name	Common name
Azadirachta indica	*Liliti*	Neem
Clausena anisata	*Ayira*	Horsewood
Phyllanthus amarus	*Kpavideme*	Phyllantus
Picralima nitida	*Quinine*	Akuamma plant
Vernonia amygdalina	*Gbɔti*	Bitter Leaf
Nauclea latifolia	*Nyimɔke*	African peach
Momordica charantia	*Kakle*	Bitter gourd

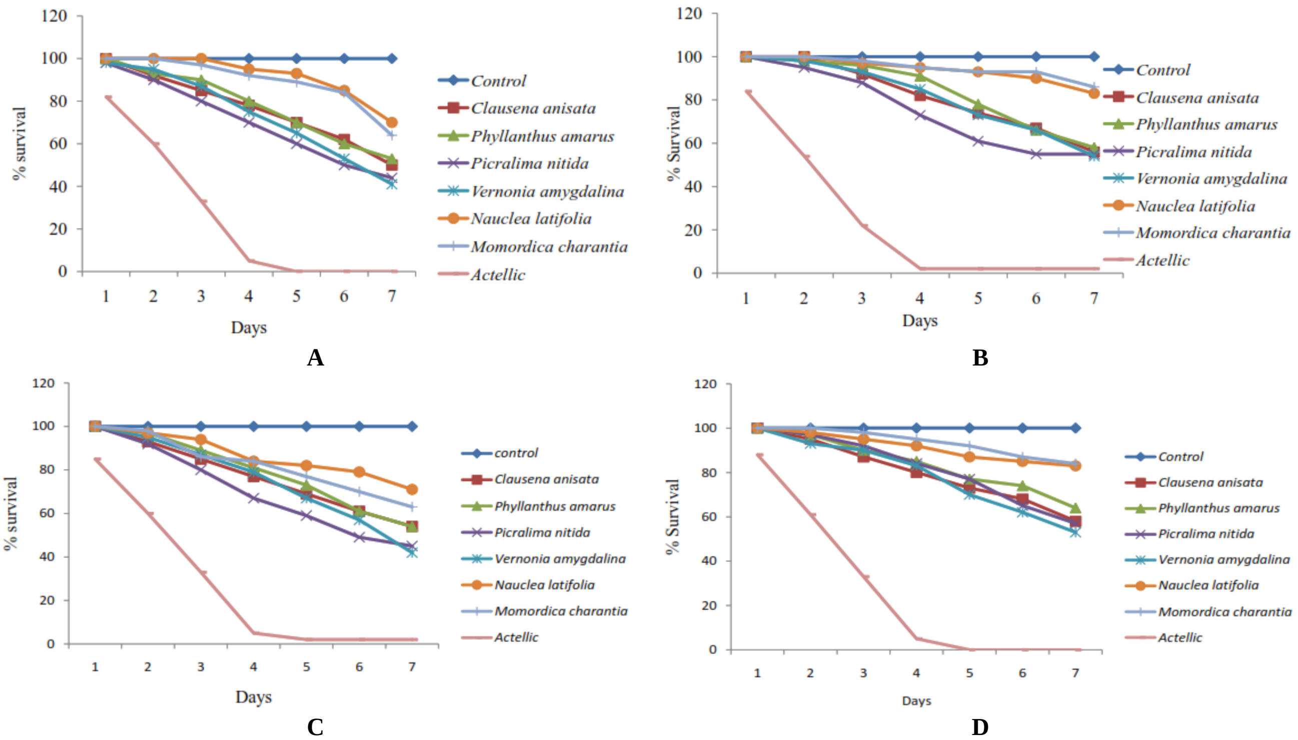

Figure 2. Effect of the powders of six plant species at: A. 10% on the survival of adult *Sitophilus zeamais*, B. 5% on the survival of adult *S. zeamais*, C. 10% on the survival of adult *Prostephanus truncatus*. D. 5% on the survival of adult *P. truncatus*

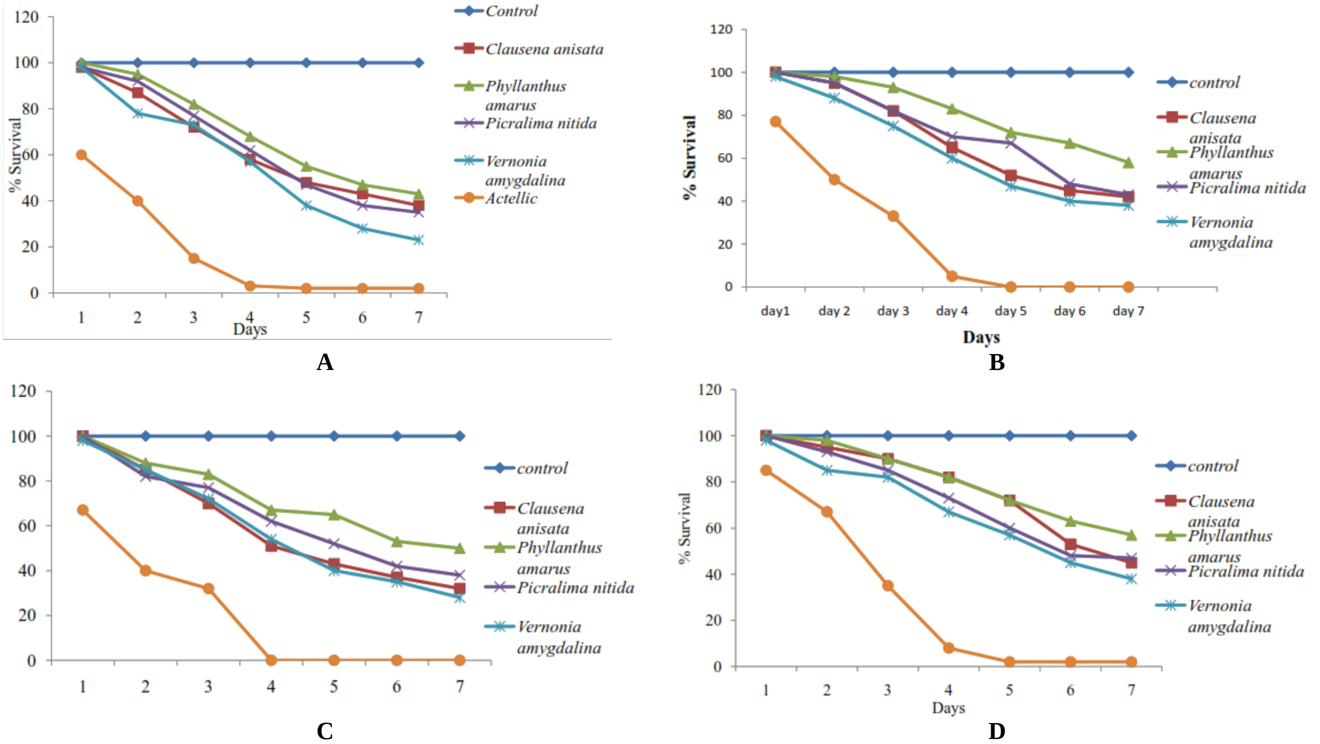

Figure 3. Effect of methanol extract of four plant species at: A. 0.2 g/mL on the survival of adult *Sitophilus zeamais* in treated grain, B. 0.1 g/mL on the survival of adult *S. zeamais* in treated grain, C. 0.2 g/mL on the survival of adult *Prostephanus truncatus* in treated grain, D. 0.1 g/mL on the mortality of adult *P. truncatus* in treated grain

Effect of methanol extract of plants on oviposition of Prostephanus truncatus *and* Sitophilus zeamais

In Figure 4, the number of eggs laid by *P. truncatus* and *S. zeamais* on grains (50 g) treated with *C. anisata, P. amarus, P. nitida, V. amygdalina* at concentrations of 0.1 g/mL and 0.2 g/mL, and Actellic (2 mL/L) are shown. When compared to the lower concentration, the higher concentration had the fewest eggs (3.0 and 4.0) laid by *P. truncatus* and *S. zeamais*, respectively (4.5 and 5.3). The difference between the eggs placed on the treated grains and the control was significant ($P < 0.5$). The reference product (Actellic) was found to be more effective than other treatments in reducing the quantity of eggs laid on grains.

Effect of methanol extract of four botanicals on eggs and immature stages

Effect of methanol extracts of four botanicals on eggs of Prostephanus truncatus *and* Sitophilus zeamais

The emergence of *P. truncatus* and *S. zeamais* in treated grain was reduced by methanol extracts of *C. anisata, P. amarus, P. nitida,* and *V. amygdalina* (0.1 g/mL and 0.2 g/mL) (Table 5). The difference between the extract-treated grains and the control grains was significant ($P<0.05$). Insects did not emerge from grains treated with Actellic, *C. anisata*, or *V. amygdalina* at a higher concentration (0.2 g/L).

Effect of methanol extract of four botanicals on the larvae of Prostephanus truncatus *and* Sitophilus zeamais

The effect of leaf extracts from *C. anisata, P. amarus, P. nitida, V. amygdalina,* and Actellic on grains containing *P. truncatus* and *S. zeamais* larvae was shown in Table 6. There was a significant difference ($P<0.05$) between the emergence of insects in grains treated with extract and the control at both concentrations. Insect emergence was lowest at the highest concentration (0.2 g/mL), and in some cases none at all.

Effect of methanol extract of four plants on the pupae Prostephanus truncatus *and* Sitophilus zeamais

When grains were treated with plants, the extracts of *C. anisata, P. amarus, P. nitida,* and *V. amygdalina* were considerably ($P<0.05$) harmful to pupae of *P. truncatus* and *S. zeamais* when compared to the control (Table 7). At both concentrations, there was no significant ($P<0.05$) difference between botanicals and Actellic. The botanical extracts with the highest concentration (0.2 g/mL) had the lowest survival on both insects and no pupae survival after 35 days of storage in *V. amygdalina* and *C. anisata.*

Repellency

Table 8 illustrates the repellent activity of *C. anisata, P. amarus, P. nitida,* and *V. amygdalina* against *P. truncatus* and *S. zeamais* in stored maize grains at concentrations of 0.1 g/mL and 0.2 g/mL. Compared to Actellic, all plant extracts were more repellant to *P. truncatus* and *S. zeamais.* However, *P. truncatus* was more resistant to the plant extracts than *S. zeamais* in general. Furthermore, all treatments had a greater repellent effect on both insects at higher concentrations (0.2 g/mL) than at lower concentrations (0.1 g/mL).

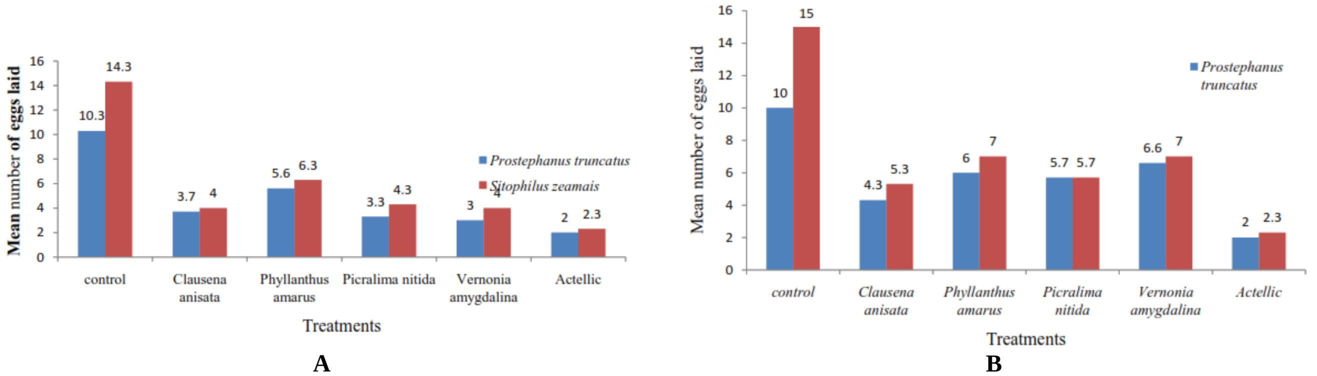

Figure 4. Effect of methanol extract of four plant species at: A. 0.2 g/mL and B. 0.1 g/mL on oviposition *Postephanus truncatus* and *Sitophilus zeamais*

Table 4. Contact toxicity of methanol extract of four plant species by topical application to *Sitophilus zeamais* and *Prostephanus truncatus* after 96 hrs

Treatment	Percentage mean mortality (±SE) after 96 hrs	
	P. truncatus	***S. zeamais***
0.1 g/mL		
Clausena anisata	53.3±0.67	63.3 ± 0.67
Phyllanthus amarus	36.7±0.33	50.0 ± 0.57
Picralima nitida	50.0±1.00	56.7 ± 1.20
Vernonia amygdalina	60.0±0.58	70.0 ± 0.16
Actellic	100±0.00	100 ± 0.00
Control	00.0±0.00	00.0 ±0.00
LSD(P<0.05)	19.66	19.66
0.2 g/mL		
Clausena anisata	70.0 ±1.16	80.0±1.16
Phyllanthus amarus	50.0 ±0.16	56.7±1.20
Picralima nitida	73.3±1.90	73.3±1.80
Veroniaamydalima	83.3 ±0.89	86.7±0.33
Actellic	96.7±0.33	100 ±0.00
Control	00.0 ± 0.00	00.0±0.00
LSD(P<0.05)	20.64	20.6

Table 6. Effect of methanol extract of four plant species on the larvae of *Prostephanus truncatus* and *Sitophilus zeamais*

Treatment	Mean number of adults that emerged (±SE)	
	P. truncatus	***S. zeamais***
0.1 g/mL		
Clausena anisata	2.00±0.89	1.00±0.33
Phyllanthus amarus	2.00±1.20	2.00±0.88
Picralima nitida	1.00±0.88	2.00±0.58
Vernonia amygdalina	1.00±0.33	0.00±0.33
Actellic	0.00±0.00	0.00±0.00
Control	6.00 ±0.89	4.00±0.33
LSD(P<0.05)	1.12	1.12
0.2 g/mL		
Clausena anisata	0.00±0.00	0.00±0.00
Phyllanthus amarus	1.00±0.66	1.00±0.33
Picralima nitida	1.00±1.33	1.00±0.00
Vernonia amydalina	0.00±0.00	0.00±0.00
Actellic	0.00±0.00	0.00±0.00
Control	6.00±1.20	4.00±0.88
LSD(P<0.05)	1.61	1.61

Table 5. Effect of methanol extract of four plant species on eggs of *Prostephanus truncatus* and *Sitophilus zeamais*

Treatment	Mean number of adults emerged (±SE)	
	P. truncatus	***S. zeamais***
0.1 g/mL		
Clausena anisata	2.0±0.33	2.0±0.00
Phyllanthus amarus	3.0±0.33	2.0±0.33
Picralima nitida	2.0±0.00	1.0±0.33
Vernonia amygdalina	1.0±0.33	0.0±0.00
Actellic	0.0±0.00	0.0±0.00
Control	8.0±1.15	5.0±0.33
LSD(P<0.05)	1.22	1.22
0.2 g/mL		
Clausena anisata	0.0±0.00	0.0±0.00
Phyllanthus amarus	1.0±1.16	1.0±0.33
Picralima nitida	1.0±0.58	1.0±0.33
Vernonia amydalina	0.0±0.00	0.0±0.00
Actellic	0.0±0.00	0.0±0.00
Control	7.0±1.15	8.0±0.33
LSD(P<0.05)	1.12	1.12

Table 7. Effect of methanol extracts of four plant species on pupae of *Prostephanus truncatus* and *Sitophilus zeamais*

Treatment	Percentage mean mortality (±SE) after 96 hrs	
	P. truncatus	***S. zeamais***
0.1 g/mL		
Clausena anisata	1.00±0.00	1.00±0.33
Phyllanthus amarus	2.00±0.00	1.00±0.67
Picralima nitida	1.00±0.58	1.00±0.66
Vernonia amygdalina	0.00±0.00	0.00±0.00
Actellic	0.00±0.00	0.00±0.00
Control	7.00±0.88	6.00±0.33
LSD(P<0.05)	1.46	1.46
0.2 g/mL		
Clausena anisata	0.00±0.33	0.00±0.00
Phyllanthus amarus	2.00±0.33	2.00±0.33
Picralima nitida	1.00±0.66	1.00±0.33
Vernonia amygdalina	0.00±0.00	0.00±0.00
Actellic	0.00±0.00	0.00±0.00
Control	6.00±0.88	6.00±0.60
LSD(P<0.05)	1.22	1.22

Table 8. Percentage mean repellency of methanol extract of four plant species on *Prostephanus truncatus* and *Sitophilu zeamais*

Treatment	Percentage mean repellency (PR) ± SE	
	P. truncatus	*S. zeamais*
0.1 g/mL		
Clausena anisata	60.0 ±1.56	53.3 ±1.33
Phyllanthus amarus	33.3 ± 0.65	26.7 ±0.65
Picralima nitida	46.7 ± 1.76	40.0 ±1.55
Vernonia amygdalina	53.3 ± 1.33	46.7 ±1.76
Actellic	33.3 ±1.33	6.7 ± 0.67
LSD(P<0.05)	20.63	20.63
0.2 g/mL		
Clausena anisata	80.0± 1.56	66.7 ±2.40
Phyllanthus amarus	53.3± 0.67	46.7 ±1.76
Picralima nitida	60.0± 1.56	46.7 ±0.67
Vernonia amygdalina	73.3± 0.56	66.7 ±1.76
Actellic	33.3± 1.33	26.7±0.67
LSD(P<0.05)	20.63	20.63

Table 9. Effect of methanol extract of four plant species on grain loss (powder) caused by *Prostephanus truncatus* and *Sitophilus zeamais* after 10 weeks of treatment

Treatment	Percentage mean weight loss (±SE) after 10 weeks	
	P. truncatus	*S. zeamais*
0.1 g/mL		
Clausena anisata	18.6±2.37	18.0±1.60
Phyllanthus amarus	24.2±2.23	22.8±1.42
Picralima nitida	14.5±1.66	12.4±1.84
Vernonia amygdalina	11.5±1.53	8.0±0.52
Actellic	1.4±0.06	1.4±0.07
Control	30.0±0.58	31.0±0.86
LSD(P<0.05)	4.22	4.22
0.2 g/mL		
Clausena anisata	13.5±1.52	11.9±0.54
Phyllanthus amarus	22.0±0.99	23.0±1.94
Picralima nitida	13.4±0.58	11.4±1.16
Vernonia amydalina	10.5±0.33	7.2±0.69
Actellic	1.4± 0.12	1.4±0.07
Control	30.0±0.58	31.0±0.86
LSD(P<0.05)	2.75	2.75

Loss assessment

When grains were treated with methanol extract of plants after 10 weeks of infestation, there was a significant (P<0.05) difference in the weight of powder produced by *S. zeamais* and *P. truncatus*. When applied to the grains at a 0.2 g/mL concentration of plant extract, the least mean weight of powder was reported in *V. amygdalina*, with a mean value of 10.5 and 7.2 g in *P. truncatus* and *S. zeamais*, respectively. At a 0.1 g/mL concentration, *P. amarus* lost the most weight (24.2 g) (Table 9). Compared to the lower concentration, the greater concentration created very little powder.

Damage assessment

In general, all grains treated with plant extracts provided better pest protection than untreated grains. However, there was no statistically significant difference (P>0.05) between all four plants and Actellic (Table 10). In terms of lowering weight loss, all of the plant extracts examined were more effective at higher (0.2 g/mL) dosages than at lower (0.1 g/mL) dosages. Compared to *S. zeamais, P. Truncatus* produced higher weight loss in grains treated with botanical extracts.

Damage assessment

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Table 10. Effect of methanol extract of botanicals on damage caused by *Prostephanus truncatus* and *Sitophilus zeamais* after 10 weeks of treatment

Treatment	Percentage mean weight loss (±SE) after 10 weeks	
	P. truncatus	*S. zeamais*
0.1 g/mL		
Clausena anisata	1.41±2.28	2.1±0.14
Phyllanthus amarus	5.28±1.32	4.18±0.59
Picralima nitida	2.60±2.25	3.34±0.83
Vernonia amygdalina	1.14±0.69	0.59±0.12
Actellic	0.69±0.27	0.52±0.09
Control	13.33±2.99	11.02±4.19
LSD(P<0.05)	6.46	6.46
0.2 g/mL		
Clausena anisata	0.69±0.45	0.49±0.23
Phyllanthus amarus	3.66±1.45	3.47±1.19
Picralima nitida	1.89±0.45	1.88±0.60
Veronica amygdalina	0.66±0.96	0.39±0.18
Actellic	0.32±0.23	0.41±0.27
Control	11.56±2.07	9.91±1.68
LSD(P<0.05)	3.64	3.64

Discussion

Survey

The survey revealed that both men and women are involved in farming and mostly employ plants to protect stored maize grains from insect pests. However, most respondents were female, confirming previous research by Cornelius et al. (2008) indicating approximately 70% of women generated 80% of household food in Africa. Matobola (2014) also noted that while more women were engaged in rural agricultural economic sub-sectors, they lacked access to assets, limiting their ability to acquire inputs. As a result, such households were forced to rely on indigenous materials to produce and preserve crops on a big scale.

The seven plant species used were *A. indica, V. amygdalina, P. nitida, C. anisata, P. amarus, N. latifolia,* and *M. charantia,* decreasing order of efficiency in pest control. *A. indica* was not chosen for the research since its efficacy against grain storage pests has been well known for an extended time.

Effect of plant powders on Prostephanus truncatus *and* Sitophilus zeamais

After seven days of treatment, the crushed powders of *C. anisata, P. amarus, P. nitida, V. amygdalina, N. latifolia,* and *M. charantia* showed varying efficiency degrees against *P. truncatus* and *S. zeamais* in treated grains. Insect survival decreased when the powder concentration increased from 5% to 10%.

The survival of *P. truncatus* and *S. zeamais* in grains treated with 10% *V. amygdalina* powder demonstrated that the plant is a promising control agent against the two insects due to its alkaloid content, which included caffeine, cocaine, morphine, and nicotine Irvine (1961). However, these chemicals are harmful to both insects and may have contributed to the insects' low survival rates in the treated grains. This finding confirms Irvine's (1961) earlier finding that the biter principle, vernonine, in *V. amygdalina* is toxic to mites. Similarly, Bouda et al. (2001) and Asawalam and Hassanali (2006) previously stated that the toxicity of *V. amygdalina* essential oil against *S. zeamais* was ascribed to the primary component terpenoids, which act as neurotoxins in insects.

The results of this study showed that *P. nitida* powder had a protective effect against two insect species that feed on stored maize grains (Ojo and Ogunleye 2013). The high lethality of the aqueous leaf and seed extract of *P. nitida* against *Anopheline* larvae and several kinds of fungi may be due to the presence of bioactive substances such as alkaloids, cardiac glycosides, saponins, tannins, flavonoids, terpenes, and steroids in the studied plant (Mujeeb et al. 2014). These chemicals may have contributed to the decreased survival of *P. truncatus* and *S. zeamais* in treated grains, explaining the efficacy of *P. nitida* in our investigation.

When *P. amarus* powder was administered at a 5% concentration, it was found to be effective in reducing *S. zeamais* and *P. truncatus* survival to 56%. The survival rate of insects was further reduced to 52% when the powder dosage was increased to 10%. Jayakumar (2010) previously demonstrated that greater concentrations of plant extracts were more efficient at reducing oviposition and increasing the death of target insect pests than lower concentrations.

Clausena anisata leaf powder's efficacy against the two insects suggested a possible contact action. This could be because the leaf oil contains the highly poisonous chemical component "estragole" (Sentilkumar and Venkatesalu 2009). The leaf powder of *C. anisata* may have contained additional chemical components that inhibited insects from eating on grains treated with the powder.

The use of *N. latifolia* and *M. charantia* powder as grain protectants against *S. zeamais* and *P. truncatus* resulted in a much greater survival rate than the other four plant species discussed previously.

While, *N. latifolia* and *M. charantia* contain alkaloids, terpenoid, morphine, and phenol, their concentrations may be lower in the plant portions utilized in the experiment than in the other four plant species (Akinkurolere 2012). This could explain why *P. truncatus* and *S. zeamais* survived so well in the treated grains. This observation contradicts Akinkurolere's (2012) conclusion that *M. charantia* is extremely poisonous to *S. zeamais* and *C. maculatus*. The difference in efficacy of these plants could also be attributed to changes in meteorological and soil variables, as well as the parts used and harvesting time (Jorge et al. 2009; Ndomo et al. 2009).

Toxicity of extracts applied topically to insects

After 96 hours of topical application, all plant extracts were harmful to insects at varying concentrations compared to the control. The greater concentration (0.2 g/mL) was more effective against both insects than the lower concentration (0.1 g/mL) in all treatments. Due to the presence of chemical substances such as alkaloids, flavonoids, lignans, and vernonine in *V. amygdalina*, it was very harmful to both insects (Irvine 1961). At 0.2 g/mL, *V. amygdalina* was 83.3 percent lethal to *P. truncatus* and 86.7% lethal to *S. zeamais*. This confirms previous studies undertaken by Asawalam and Hassanali (2006), who discovered that essential oil of *V. amygdalina* contained a variety of terpenoids and triggered 82 percent mortality in *S. zeamais* after 7 days of treatment with 750 mg/250 g of essential oil. *Prostephanus truncatus* was more resistant to methanol extract than *S. zeamais*, which may be explained by its more robust character, high feeding ability, and heavily sclerotized cuticle, which may have limited the active component of the extract's physical absorption through the cuticle.

Toxicity of extracts to Sitophilus zeamais *and* Prostephanus truncatus *in treated grain*

After seven days, the methanol extracts at both concentrations were applied to adult insects in treated grain, causing a substantial ($P<0.05$) reduction in survival for both insects compared to the control. The species of plant, the dose administered, and the time of contact all had an effect on the toxicity of the extract applied to adult insects in treated grain (days). *Vernonia amygdalina* was the most effective plant species, whereas *P. amarus* was the least effective. Although *P. amarus* includes similar chemical elements such as lignans, flavonoids, and phyllanthin, they may not have been as effective as *V. amygdalina* at killing insect pests. They can, however, be employed to prevent fungus from attacking stored grains (Oudhia 2008). The higher concentration of the herb resulted in a reduction in insect survival. Due to the continual buildup of the botanical's chemical component in the insects, the period of contact (days) had a substantial effect on the percentage survivability of adult *P. truncatus* and *S. zeamais*. While the standard (Actellic) caused 100% death or no survivorship after five days of contact, *V. amygdalina* at 0.2 g/mL caused 62% mortality or 38% survival in *P. truncatus* after five days off treatment. As a result, the extracts killed insects more slowly than the manufactured toxin (Actellic). This finding corroborates an earlier observation by Obeng-Ofori and Dankwah (2004) that Actellic had a quick knockdown effect, instantly killing adult insects on contact.

Effect of methanol extract of plants on oviposition of Prostephanus truncates *and* Sitophilus zeamais

After seven days of treatment, all plant extracts successfully lowered the quantity of eggs laid by both insects compared to the control. At a 0.2 g/mL dosage, *C. anisata* was the most efficient of all the plant extracts against both insects. This suggests that *C. anisata* may have repellant and/or oviposition deterrent properties, resulting in alterations in the adult insects' physiology and behavior, as indicated in their egg laying capacity. This supports the findings of Schmuttere (1990) and Ndomo et al. (2009) that plant extracts and essential oils reduce oviposition and fecundity in a variety of insects. *Sitophilus zeamais* lay more eggs than *P. truncatus* in all of the treatments. This could be due to *S. zeamais* having a higher fecundity level than *P. truncatus.*

Effect of methanol extract of plants on eggs and immature stages of Prostephanus truncatus *and* Sitophilus zeamais

In comparison to the control, the methanol extracts of all plants were effective against the eggs, larvae, and pupae of *P. truncatus* and *S. zeamais* at both doses. This supports the findings of Jayakumar et al. (2003), who found that plant extracts had a clear effect on postembryonic survival of the insect, resulting in a reduction in adult emergence when different plants are used. Because of the toxicity of extracts to eggs, larvae, and pupae, the number of adults emerging from treated seeds was significantly reduced. The potency could be owing to the extract's bitter antinutritive secondary metabolites acting as a barrier on the seed coat, preventing the eggs from developing into adults (Tchinda 2011). After 35 days of treatment, a 0.2 g/mL methanol extract of *V. amygdalina* and *C. anisata* completely blocked the development of eggs, larvae, and pupae of both insects into adults. This is on par with the gold standard (Actellic), which also completely inhibited adults.

When compared to the juvenile stages developing inside cowpea seed, the eggs of *P. truncatus* and *S. sitophilus* in treated grains were more vulnerable to the extracts of *V. amygdalina*. This could be due to the extract's reduced action to pupae compared to larvae due to relative inactivity, reduced metabolism, and superior exoskeleton growth in both insects. This supports Law-Ogbomo and Enobakhare's (2007) findings that 1 to 5 g of *V. amygdalina* dry leaf powder suppressed the growth of *S. zeamais* and *S. oryzae* on stored maize grains and rice. The total prevention of the development of eggs and immature stages within the treated grain increases the ability of *V. amygdalina* and *C. anisata* to protect stored grains from insect damage.

Repellency

All four plant extracts were found to resist *P. truncatus* and *S. zeamais* better than the synthetic commercial pesticide (Actellic). *C. anisata*, on the other hand, was found to be very repellent to the two insects tested, with overall mean repellency of 80.0% and 66.7% for *P. truncatus* and *S. zeamais*, respectively, at 0.2 g/mL. Tchinda (2011) discovered that dried leaves of *C. anisata* were utilized as insect repellents throughout tropical Africa, and that the leaves were used as mattress filling in Kenya, because they were scented and repelled insects. Carbazole alkaloids, peptide derivatives, and phytosterol are the main chemical components of *C. anisata*, which may explain the strong insect repellent properties of the plant (Songue et al. 2012).

Damaged assessment

The greater concentration (0.2 g/mL) of evaluated plants resulted in lower mean weight loss in the treated grains than the lower concentration (0.1 g/mL). The number of damaged seeds in maize treated with plant extracts was significantly lower than control. Law-Ogbomo and Enobakhare (2007) concurred that the proportion of pierced grain in the treated grain with *V. amygdalina* was lower than the untreated control grain. *Vernonia amygdalina* is also an efficient grain protestant against *S. zeamais*, according to Enobakhare and Law-Ogbomo (2002). *Sitophilus zeamais* was able to inflict greater damage to grains than *P. truncatus*. Due to the high humidity in the bioassay, some of the plant extract-treated grains, excluding *V. amygdalina*, were attacked by *Aspergillus flavus*. According to Ogbebor et al. (2007), inhibitory activity of *V. amygdalina* is due to secondary metabolites that are resistant to fungus

In terms of plant and bug kind, the powder generated after ten weeks of storage varies. *Prostephanus truncatus* produced more powder than *S. Sitophilus*, according to the findings. This could be attributed to its hardy nature, exploratory nature, and capacity to feed and breed in dry environments, including maize with a moisture level of 9% (Cornelius et al. 2008).

In conclusion, the bioactivity of six indigenous plants in the management of *S. zeamais* and *P. truncatus* in stored maize was identified and analyzed in this study. *Azadirachta indica, C. anisata, P. amarus, P. nitida, V. amygdalina, N. latifolia,* and *M. charantia* were identified as plant species utilized by farmers in the Volta Region to manage insect pests in maize. *Azadirachta indica*, on the other hand, was not chosen because it has already undergone significant research. When applied at 5% and 10% concentrations, the powders of the other six botanicals were poisonous to *P. truncatus* and *S. zeamais*, lowering insect survival. The botanical *V. amygdalina* was shown to be the most promising in terms of safeguarding maize grains from the two insects. Insecticides, antifeedants, anti-ovipositant, ovicidal, and repellent activities are all present in the methanol extract of *V. amygdalina*. After 96 hours, contact treatment of a methanol extract of *V. amygdalina* at 0.2 g/mL eradicated 83.3% of *P. truncatus* and 86.7% of *S. zeamais*, respectively. This did not differ significantly ($P<0.05$) from the standard (Actellic). In comparison to the control, insect mortality in maize grains treated with *V. amygdalina* methanol extract was extremely high. After 10 weeks, insect damage to maize grains treated with *V. amygdalina* in a crib was minor, and it did not differ much from Actellic. Both insects laid a few eggs in maize grains treated with *C. anisata* extract. When grains were treated with extract of *V. amygdalina* and the standard, adult emergence from eggs, larvae, and pupa was completely inhibited (Actellic). The repellency of *C. anisata* extract (0.2 g/mL) to insects was significantly significant in comparison to the standard. The presence of toxicants and growth inhibitors in *V. amygdalina* when applied to *P. truncatus* and *S. zeamais* suggests that they have a lot of promise for storage pest management, particularly in farm stored grains of peasant farmers. The investigation also confirmed the scientific reality that farmers utilize *V. amygdalina* as a grain protectant.

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INTL J TROP DRYLANDS
Volume 5, Number 2, December 2021 E-ISSN: 2580-2828
Pages: 61-74 DOI: 10.13057/tropdrylands/t050203

Review: A descriptive study of karst conditions and problems in Indonesia and the role of karst for flora, fauna, and humans

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Manuscript received: 4 September 2021. Revision accepted: 29 November 2021.

Abstract. *Aprilia D, Arifiani KN, Sani MF, Jumari, Wijayanti F, Setyawan AD. 2021. Review: A descriptive study of karst conditions and problems in Indonesia and the role of karst for flora, fauna, and humans. Intl J Trop Drylands 5: 61-74.* The karst area in Indonesia covers an area of about 15.4 million hectares and is spread almost throughout Indonesia. It is estimated the age of karst in Indonesia started from 470 million years ago to the most recent about 700,000 years. The existence of this area shows that many of the Indonesian islands were once seabed but were later uplifted and hardened. Most of the karst areas in Indonesia are composed of carbonate rocks, and almost none are composed of other rocks such as gypsum, salt rock, and evaporite rocks. Karst in Indonesia can be classified based on its development and climate. The amount of water available in the karst area plays an important role in human life and so do flora and fauna around the karst area. The karst area functions as an ecosystem for the habitat of various animals and plants. The richness of flora and fauna of this karst area is extraordinary. Karst area plays an important role in economy, science, and human culture. In addition, karst areas have an important role in the ecosystem, such as providing clean water, limestone-based natural materials, and controlling climate change. Its role in ecological function is that karst areas can also be a source of CO_2 gas absorption. About 9.5% (155,000 km^2) of the total karst area of Indonesia was damaged due to limestone mining activities, logging of vegetation, and land conversion. Given the importance of karst and limestone ecosystems as non-renewable natural resources, it is necessary to do conservation to maintain the ecological function. Steps that can be taken for conservation efforts in karst areas include limiting the sale of raw limestone to outside the area, clarifying protected areas and cultivation areas, socializing the importance of preserving karst areas, providing skills or developing other business opportunities, and reclaiming used land and mining according to the level and type of damage. This study aims to describe the geographical conditions and karst problems in Indonesia so that the conservation measures taken are known and identify the role of the karst area for flora, fauna, and humans.

Keywords: Karst, karst conservation, karst problems, karst types, role of karst

INTRODUCTION

Karst is a German term derived from the Slovenian language kras, which means rocky arid land (Faida et al. 2011). Karst is a limestone area with a typical landscape shape in Slovenia that spreads to Italy. The area then becomes a type locality in a karst landscape (Milanovic 1981) in (Puradimaja 2006). Karst area is a landscape that was formed a very long time. Karst is a landform composed of carbonate rock (limestone) that undergoes a solutional process to form a unique and distinctive morphological and hydrological order.

Wuspada (2012) defines karst as a field with typical hydrological conditions resulting from soluble rock and a well-developed secondary porosity. The characteristics of karst are the presence of closed basins, dry valleys of various sizes and shapes, rare surface drainage/rivers, and the presence of caves from underground drainage systems. Karst occurs not only in carbonate rocky areas but also in other easily soluble rocks and has secondary porosity (joints and intensive faults), such as gypsum rock and salty rock (Juliani 2015). In Indonesia, the karst area has an area of approximately 15.4 million hectares (Candra 2011). The dissolution process (solutional/karstification) causes the formation of a unique hydrological system. The hydrological system is strongly influenced by secondary porosity (flow of groundwater through dissolution gaps) which causes water to enter the underground flow system and causes dry conditions at the soil surface (Cahyadi et al. 2013). Karst area is an area that can capture and store rainwater (Haryono 2000).

The karst area is closely related to the presence of caves. These caves are unique from the karst area. The existence of karst caves is an indicator of the development of karst landforms. The formation of the cave occurs by the ongoing process of dissolving and widening of limestone cracks (Ashari 2013). Caves have various characteristics, including vertical caves, horizontal caves, caves that flow underground rivers, dry caves, and various kinds of ornaments contained in them (Harmony and Pitoyo 2012). These caves are generally terraced with less than one meter to hundreds of square meters with a vertical tilt or horizontal shape. Almost all of the karst caves are decorated with ornaments (speleothems) that vary from very small to very large (columns) with varying shapes and colors (Adji et al. 1999). Caves have both direct and indirect benefits. The direct benefits of the cave include the development of the cave as a tourist attraction.

According to Wiyanata et al. (2018), a karst area has three functions, namely ecological functions, economic functions, and educational and cultural functions. The ecological function of the karst area is as a place for flora and fauna to live, store groundwater, and absorb carbon. Meanwhile, the function of regional education and culture is, among others, a medium of learning and cultural wisdom. The economic function of the area is as a tourist place. As an ecological function, the karst area has a wealth of biodiversity. In Indonesia, 17 locations can be categorized as biodiversity karst areas. Karst biodiversity is divided into biodiversity based on the surface (exokarst) and below the surface (endokarst), also known as caves. Organisms in caves are grouped into terrestrial and aquatic organisms (Prakarsa and Ahmadin 2017). Caves in karst areas are home to various fauna communities such as bat communities (Wijayanti et al. 2010; Wijayanti and Maryanto 2017). Biological resources in the karst area are not too abundant due to the thin soil and scarcity of groundwater in the area. Karst areas are known for their low resistance to change or disturbance (Gillieson 1997). As an economic function, the karst area also contains non-biological natural resources, limestone, a group excavation material. The karst area also has the potential as a mining area because of its hilly physiography formed from limestone (Haryono and Adjie 2004).

The karst ecosystem has a very important function in the environment and its social, cultural, and economic values. Seeing its uniqueness and strategic function, this ecosystem is categorized as a protected area in Indonesian laws and regulations. Some karst areas have tourist activities in them. Still, this activity can disrupt the surrounding ecosystem and it is feared that the fauna population in it and the cave ecosystem will decline, considering that the ecosystem, especially in the cave, is related to the ecosystem outside the cave (Tamasuki et al. 2015). Currently, the operationalization of the "protected area" status has not been carried out properly, thus causing most of the karst ecosystems in Indonesia to be potentially exploited (Widyaningsih 2017). Karst, especially caves, is increasingly threatened by traditional limestone mining (Prakarsa 2013) and land use for housing (Mijiarto et al. 2014). Mining activities can hurt the karst ecosystem, for example, the destruction of the hydrological system that can cause drought (Widiyastuti 2018). Karst area is a non-renewable natural resource, so these conditions need to be protected in the form of Geological Heritage (Geoheritage), this term implies protection of natural heritage which can later be passed down to the next generation in the future (Irianto et al. 2020). This study aims to describe the geographical conditions and karst problems in Indonesia so that the conservation measures taken are known and identify the role of the karst area for flora, fauna, and humans.

GEOGRAPHY OF KARST IN INDONESIA

Indonesia is one of the countries with a fairly large karst area, estimated at ± 15.4 million hectares (BAPPENAS 2016). Indonesia has a variety of karst landforms found in almost all islands and archipelagos in Indonesia (Jayanto et al. 2017). Karst areas are scattered almost throughout the island, from Papua to Aceh. Most of the southern coast of Java Island is a karst area, with an elongated shape from west to east. There are seventeen major karst areas in Indonesia. Among these karst areas, two karst areas are the best and are considered prototypes of tropical karst, namely the Maros karst and Gunung Sewu karst (Adji et al. 1999). Karst area is a typical landscape with high natural resource wealth (Raguz 2008).

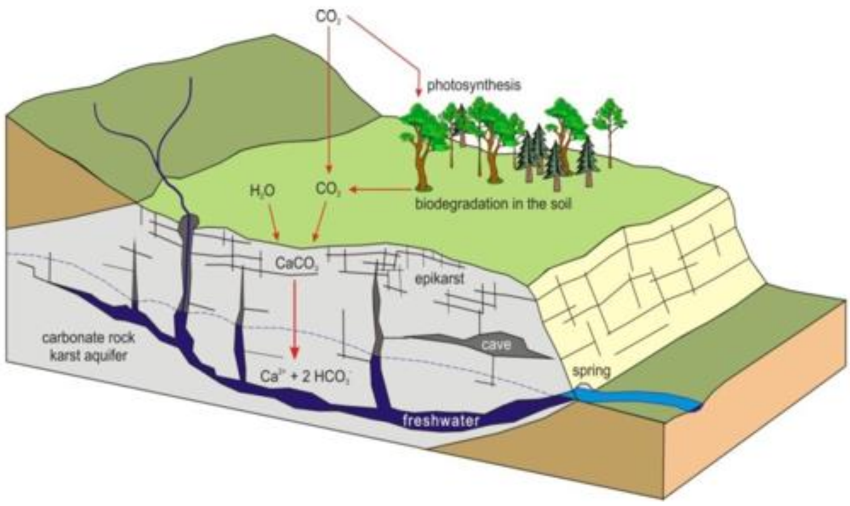


Figure 1. Illustration of the process of karstification (carbonate rock dissolution) (Goeppert and Goldscheider 2019)

The existence of karst areas in Indonesia has a very strategic value. In addition to the potential area of Indonesia's karst landscape of 154,000 km^2, equivalent to 0.08% of Indonesia's land area, karst has potential that is not unique and distinctive but is also very rich in natural resources, both biological and non-biological. The estimated age of Indonesian karts started from 470 million years ago to the most recent about 700,000 years. The existence of this area shows that many of the Indonesian islands were once seabed but were later uplifted and hardened. Karst areas are usually hilly with many caves (Sukandarrumidi and Maulana 2014). Most of the karst areas in Indonesia are composed of carbonate rocks, and almost nothing is composed of other rocks such as gypsum, salt rock, or evaporite rock. Nearly every island in Indonesia has carbonate rocks, but not all are karstified into karst areas. Karstification will be more intense when these rocks are overwritten by rainwater containing a lot of CO_2 (Goldscheider et al. 2007).

The existence of karst areas in Indonesia is currently considered very strategic values. The karst area reaches almost 20% of the total area throughout the Indonesian archipelago. The strategic values in question, apart from being an area as a supplier and reservoir of water for domestic purposes (the UN estimates that around 25% of the world's population is a source of karst water, Ko 1997), also have natural resources that can be used to increase the country's foreign exchange such as tourism, mining of minerals, producing swallow's nests, and even closely related to the field of defense and security/military, and intelligence (Adji et al. 1999).

Karst area, according to Ford and Williams (1989), is an area that has distinctive relief and drainage characteristics and occurs in rocks that are easily soluble and have well-developed secondary porosity, such as carbonate rocks (usually limestone, dolomite, or marble), although there are also what happens not in carbonate rocks. The karst area has various features. In terms of endokarst (subsurface morphology division), the formation of underground caves, rivers, and underground springs, complex underground drainage systems (Maulana 2011), and exokarst (distribution of surface morphology) the area is manifested in the form of basins. In the form of small hills, hillsides, and rock carvings on the karst surface, valley curves, and the mouth of the cave formed from the dissolution of rocks by rainwater, which has a typical relief and drainage in the form of limestone. Limestone has a high porosity value as a result when rainwater falls on the karst area, the rainwater will penetrate through the cracks of the rocks that make up the area so that the karst area has a lot of beauty. Several features above result from a very long natural process (Hutomo et al. 2016). The karst area is a landscape with steep slopes. There are many basins, prominent and irregular limestones, caves, a continuous underground flow system, and forests with different soil surface textures and compositions at each altitude. The unique condition of this karst area causes the biota living in the karst area to be unique (Ko 2003). The International Union for The Conservation of Natural Resources (Williams 2008) defines karst areas as protected areas because of their function as storage of groundwater and biodiversity in karst areas and non-renewable karst resources. Karst areas have quite real potential in an ecosystem.

Under certain environmental conditions, each type of plant spreads with varying degrees of adaptation, thus causing the presence or absence of a plant species in the environment. Environmental factors can affect the structure and composition of vegetation formed in an area (Haryono and Adji 2004). One of the environmental factors that can affect a vegetation community is altitude. Altitude has a very strong influence on tree species distribution (Kurniawan and Parikesit 2008).

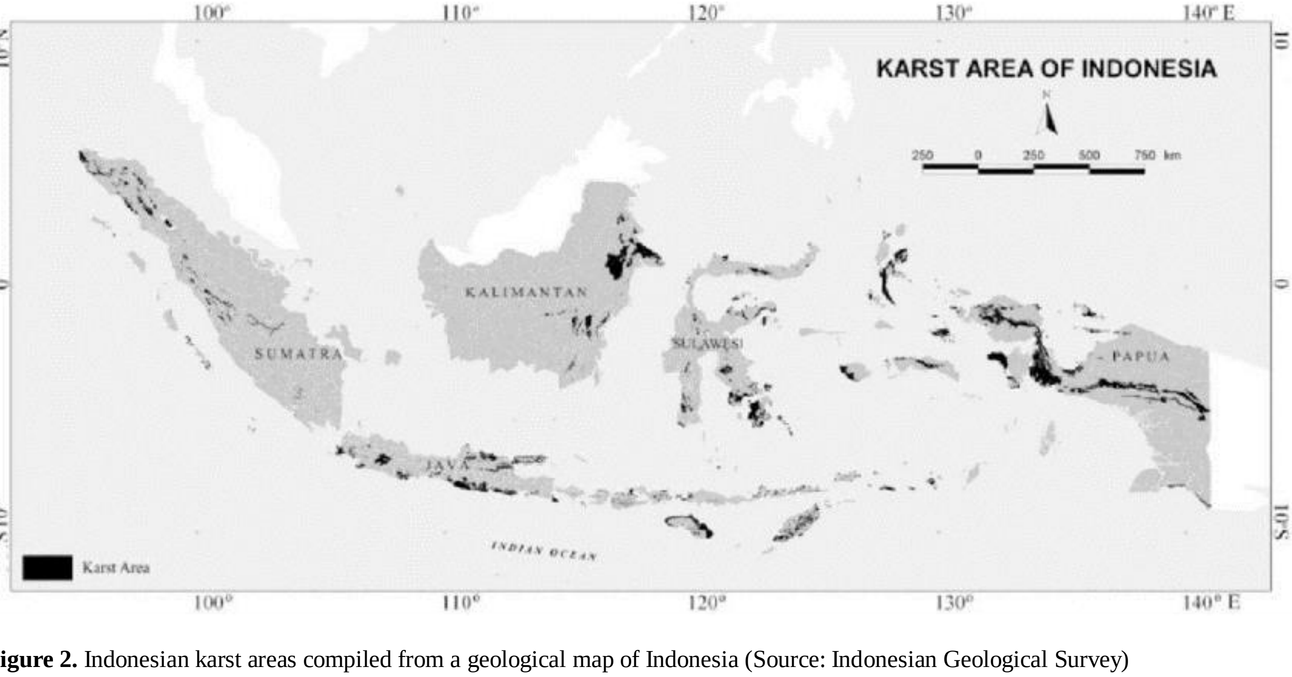


Figure 2. Indonesian karst areas compiled from a geological map of Indonesia (Source: Indonesian Geological Survey)

Karst area is a non-renewable natural resource with high natural resource function and potential (Beynen and Townsend 2005). Forest ecologists classify limestone hill forests as one forest ecosystem (Achmad 2011). There is rarely living vegetation or only vegetation in limestone hills such as weeds that can live and there is no strong and deep vegetation, the limestone mountain area will be prone to an avalanche. Karst area is a very unfavorable area for most plants. It can be seen from the thin soil conditions, limited nutrients, very limited water, very limited water, unfriendly weather, hot conditions, especially in the dry season. Plants that live in this area will, of course, undergo a process of adaptation to the environment (Rahmanizah et al. 2019). The soil in the karst area is formed from limestone with low nutrient content except for calcium and magnesium, making the vegetation in the karst area unique. The appearance and composition of vegetation species in karst areas are different from other vegetation types. Many plant species in the karst area are endemic and several species have economic value. This is in addition to the high calcium and magnesium content due to extreme climatic conditions such as sunlight, rainfall, dry periods, underground drainage systems (Vermeulen and Whitten 1999), and differences in plant tolerance to physical factors karst areas (Whitten et al. 1999). Vegetation in karst areas can protect water catchment areas, work well and provide protection for the function of springs in underground rivers (Sugita et al. 2015). Given the function of the karst area as a water reservoir.

TYPES OF KARST IN INDONESIA

Karst area is mostly composed of carbonate rocks, especially limestone $CaCO_3$ and dolomite CaMg $(CO_3)_2$ (Sulastoro 2013). Karst area is a complex geological phenomenon with unique and specific hydrological conditions. The karst area has a unique topography where Indonesia itself has several types of karst (Endah et al. 2017). Classification of karst in Indonesia can be categorized into two groups, namely (i) classification based on development (Cvijić 1914) and (ii) classification based on climate (Sweeting 1972). Based on its development, there are two types of karst, it is merokarst and holokarst. Merokarst is karst with incomplete or partial development with only some characteristics of karst landforms. Merokarst develops in relatively thin and impure limestones, and especially when limestone is interspersed with layers of marl. Examples of merokarst in Indonesia include the karst around Rengel, Tuban District. Then there is the holokarst type. The holokarst area is the opposite of merokarst, characterized by almost no surface river flow and which then turns into sub-drainage so that the effective exogenic process is only dissolving, the topographic surface is almost decorated with various karst cones (karst conicals). Among them are karst depressions of various types and sizes (Kusumayudha 2005). Examples of holokarst in Indonesia include the Gunung Sewu Karst (Gunungkidul, Wonogiri, and Pacitan) (Haryono and Adji 2004).

According to Sweeting (1972), karst can be categorized based on climate into (i) Fluviokarst is karst formed by a combination of fluvial processes and dissolution processes generally occurs in limestone rocky areas traversed by allogeneic rivers (river downstream of non-karst areas). Limestone distribution laterally and vertically is much smaller than the true karst. The development of underground circulation is also limited due to the local groundwater table. Fluviokarst caves are formed at the boundary between limestone and underlying impermeable rock by allogeneic rivers and are associated with river development in the karst areas. Limestone surfaces in fluvio karsts are generally covered by soil formed by erosion and sedimentation by fluvial processes. Examples of kegelkarst in Indonesia are several types of karts in the Gunung Sewu Karst area. (ii) Glaciokarst is karst formed as the result of karstification that is dominated by glaciation and glacial processes in limestone areas, an example of glaciokarst in Indonesia is the karst in the Jaya Wijaya Mountain area. (iii) Nivalkarst is karst formed due to karstification by snow in glacial and periglacial environments. Glaciokarst is found in limestone areas that have experienced glaciation or have experienced glaciation. Glaciokarst is characterized by glacier burning, erosion, and sedimentation. Dolines are formed mainly by snowfall. Another characteristic of glaciokarst is the caves filled with ice and snow. An example of glaciokarst is the Carstensz Pyramid karst area, also known as Puncak Jaya in the Jayawijaya Mountains, (iv) Tropical karst differs from karst in temperate and polar mainly due to high precipitation and evaporation in the tropics. Tropical karst is further divided into two groups, namely (i) Kegelkarst (synoid karst, cone karst, or karst a python), and (ii) Turmkarst (tower karst, innacles karst, or karst a tourelles).

A collection of continuous conical hills characterizes Kegelkarst. The gap between the conical hills forms a basin with a star-like shape known as the cockpit. Examples of kegelkarst in Indonesia include the Gunungsewu Karst and the Karangbolong Karst. And those in Java in the Gunung Kidul area (Fahmi et al. 2017). Turmkarst/tower karst/eclepinacle karst is the second type of karst often found in the tropics. Hills characterize this type of karst with steep slopes, usually found in groups separated by rivers or alluvial plains. Tower karst is formed when lateral dissolution by a very shallow groundwater table or allogeneic rivers passes through limestone outcrops. Joints or faults generally control the distribution of tower hills. The size of the tower hills varies greatly from small pinnacles to blocks of several square kilometers in size. Karst towers can be divided into two groups. First, the tower hill is a hill of limestone remnants isolated between limestone flats that have been covered with alluvium deposits. Second, the tower hill is a remnant hill of limestone located on a plain with non-carbonate rocks. Some of the tower karsts in Indonesia can be found on the edge of the Maros Karst bordering the alluvial plain (west side). The hydrological value of cone-shaped (kegelkarst) and tower-shaped (turmkarst) are similar in the dissolving process. Dissolution produces cavities that are interconnected to form secondary porosity. The greatest dissolution occurs near the surface due to the decreasing solubility of water on its way down due to the increase in dissolved carbonate concentration until it reaches saturation at a depth of 30 to 50 m (Kunardi et al. 2019).

THE ROLE OF KARST FOR FLORA AND FAUNA

The karst area is an area that has unique hydrological characteristics due to the development of dissolving tunnels. This area is formed by the dissolution process of soluble rocks such as carbonate rocks and salty rocks (Ford and William 1992). The unique condition of this karst area causes the biota living in the karst area to be unique (Ko 2003). The presence of light in the cave environment is also very important. Light concentration can affect the cave ecosystem directly, and indirectly affect the cave fauna (Simon et al. 2007). Another uniqueness of the karst area lies in the presence of caves in the karst area which forms a microclimate that is different from the area outside (PPLH 2007). The International Union for The Conservation of Natural Resources (Williams 2008) defines the karst area as a protected area because of its function as a reservoir of groundwater and biodiversity in karst areas, and karst resources that cannot be renewed. Therefore, Karst areas have quite real potential in an ecosystem (White et al. 2019). The existence of karst areas in Indonesia has recently been considered very strategic values. Apart from covering almost 20% of the total area in Indonesia. Karst has potential that is unique and very rich in natural resources, both biological and non-biological. At this point, tension arises, namely the use of natural resources (Kartodihardjo 2012).

The Karst area can store a lot of water because of its unique characteristics and has a hollow soil structure. The suspended aquifer in the epikarst provides a habitat for permanent troglobitic aquatic fauna (William 2008). Karst areas with limestone constituent rocks correlate with small to moderate groundwater continuity and limited groundwater availability (ESDM 1995; Milsom 2003; Fetter 2004; Singhal and Gupta 2010). The amount of water available in the karst area plays an important role in human life and flora and fauna around the karst area. Water resources are a basic need for humans and living creatures (Kurniaty and Danu 2012; Febriarta et al. 2018). In addition, the karst area functions as an ecosystem for the habitat of various animals and plants. As a result, the richness of flora and fauna of this karst area is extraordinary (Jumari 2011).

Fauna

Most of the cave fauna have adapted to the cave environment. The invertebrate fauna in the cave remaining groups comprising molluscs, diplopods, chilopods, annelids, platyhelminths and nematodes. The diversity of troglobite species is fairly typical for karst areas (Eberhard et al. 2014). The fauna found in every cave is crickets (Figure 3). This is in accordance with Kamal et al. (2011) statement that the most numerous Insect groups (both species and numbers) are crickets. This opinion is reinforced by Rahmadi (2005) which states that Hexapoda/Insecta is one of the dominant classes of cave fauna after Crustacea and Arachnida, 25%.

One type of fauna in the cave of the Arachnida class is a spider (Figure 4). Cave spiders will adapt by changing the function of the front legs to become organs of touch, such as the spider's antennae, it will also reduce its eyes and use the sense of taste as a smell. Eyeless spiders can navigate the web and rely on vibrations to detect prey. The sense of touch is generally located in the hairs on his feet. Then the fauna of the class Crustacea, such as shrimp and crab (Figure 5A-B). Cave Crayfish live in deep and dark caves. Almost no light can penetrate where the shrimp live. The environment without light makes the creatures that live in deep and dark holes in the earth's bowels able to adapt without eyes and pigment. Living in a cave causes shrimp to have translucent skin, so they look white (Marin 2021).

Although it is facultative, one of the successful karst vertebrate species is the bat, where the cave is used for resting, nesting, and raising young. Meanwhile, food is obtained from outside the cave. Factors that influence the abundance of bats are the physical structure of the habitat, microhabitat climate, food and water availability, security from predators, competition, and nest availability (Wilkelman 1999).

The other two groups of vertebrates that have successfully colonized and adapted to the subterranean cave environment are fish and salamander (Figure 5C). Still, cave salamander is not recorded yet in Indonesia. In the extreme conditions of the cave, in the absence of light, very high humidity, and constant temperature throughout the year, the cave-dwelling organisms adapt to their environment. Adaptations in sensory compensation occur, pigmentation, eyes are reduced or completely lost, and slow metabolism. Some species of cave exhibit limb weakness. It has been hypothesized that the limb attenuation function to elevate the body and head above the substrate allows more efficient prey detection by the lateral line system (Rahmadi 2002). This proves the physiological changes of animals in the cave.

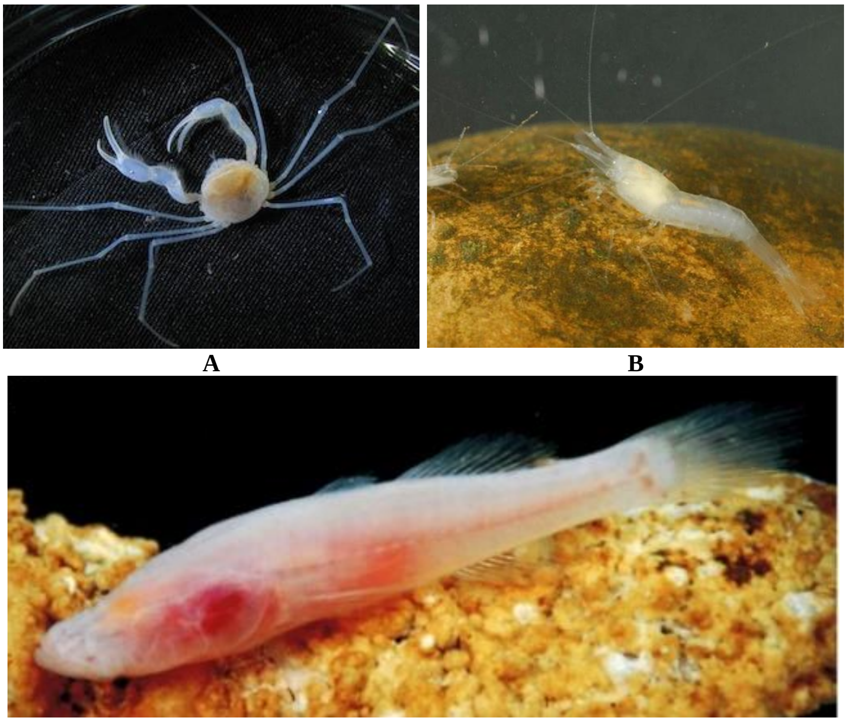
Flora

Many plant species in the karst area are endemic and several species have economic value. This is not only due to the high calcium and magnesium content but also due to extreme climatic conditions such as sunlight, rainfall, dry periods, underground drainage systems (Vermeulen and Whitten et al. 1999), and differences in plant tolerance to physical factors in karst areas (Whitten et al. 1999; Lio and Dewi 2018). Vegetation in karst areas can protect water catchment areas, work well and provide protection for the function of springs in underground rivers (Sugita et al. 2015). Considering the function of the karst area as water storage, it is necessary to cover vegetation that can absorb a lot of water (Tanjung 2004).

A B

Figure 3. Some species of Gryllidae (cricket family) from Dopaam cave, Enggano Island, Indonesia. A. *Charon grayi*, B. *Rhaphidophora oophaga* (Puspita et al. 2020)

Figure 4. *Amauropelma matakecil*, a new colorless spider from Nguwik Cave, Central Java, Indonesia (Photograph by S. Harjanto) (Miller and Rahmadi 2012)



A B

C

Figure 5. Some aquatic species from Indonesian karst area. A. *Sulaplax ensifera,* an endemic crab from Muna Island, Indonesia (Photograph by C. Rahmadi) (Rahmadi 2016), B. *Marosina longirostris,* an enemic shrimp from Maros cave karst, Indonesia (Photograph by Rasplus) (Rahmadi 2016), C. *Oxyeleotris colasi*, a blint-colorless fish from Sewiki lake, Kaimana karst area, West Papua, Indonesia (Photo by RK Hadiaty and P. Keith) (Pouyaud et al. 2012)

Priyanti et al. (2011) explained that the most common plant species found in the karst area are Asteraceae and Poaceae. This is due to the nature of the two tribes which have fast reproduction and light seeds, so they are easily carried by the wind (Piji 1982).

The high and low community similarity index can be influenced by environmental conditions both physical, chemical, and interactions between species (Setiadi 2005). In addition to physical and chemical factors, other factors that affect plant communities are animal and human activities (Loveless 1989). According to Marwiyati et al. (2012), the environmental conditions of the karst area that are less supportive of growth and reproduction can be the cause of the low diversity of tree species in the karst area. The existing plant species can adapt and tolerate unique karst environmental conditions. The soil layer that tends to be thin can also affect the number of tree species that grow in the karst area so that in general the number of tree species will be less than the forest with a thicker soil layer. In addition, the high human activity in the karst area impacts the low value of tree species diversity (Whitten et al. 1999).

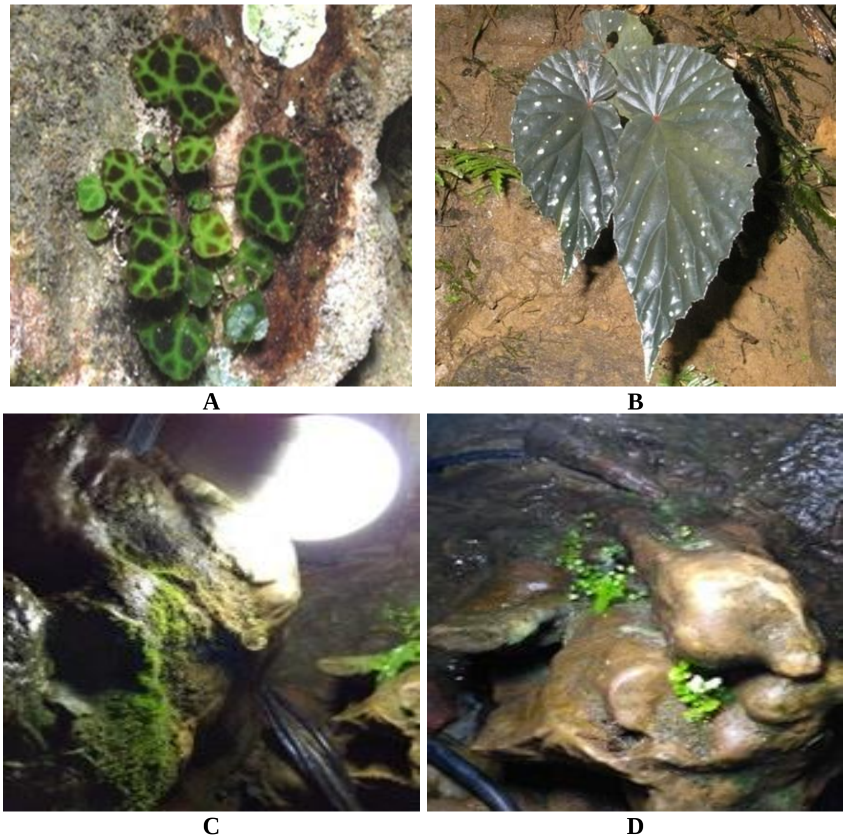


Figure 6. A. *Begonia droopiae* (Ardi 2010), B. *Begonia atricha* (Girmansyah 2017), C. Lampenflora (Bryophyta) (Kurniawan et al. 2018), D. Lampenflora (Pteridophyta) (Kurniawan et al. 2018)

Publications regarding the diversity of endemic plant species in Indonesia's karst areas are still rare. In the karst area of Sumatra, there are plants typical of the karst area, namely *Begonia* spp., that are supposedly endemic species (Figure 6A-B). Publications regarding the diversity of endemic plant species in Indonesia's karst areas are still rare. In the karst area of Sumatra, there are plants typical of the karst area. *Begonia droopiae* (Ardi 2010) was found in Perkaulan Cave, West Sumatra. *Begonia atricha* (Girmansyah 2017) was found in the cave area of Palembayan, West Sumatra. Hughes (2008), stated that there are about 45 species of Begonias from Sumatra. Out of 1500 species of Begonias are scattered in Southeast Asia. About 33 species of *Begonia* in West Sumatra are divided into six sections. One species has not been included in the existing section because it has a generative character that has not been recorded in the publication Doorenbos et al. (1998). Begonias that live in karst areas generally have unique characteristics, namely thicker leaves and the ability to do dormancy in the dry season (Girmansyah 2017).

There is another distinctive species, namely Lampenfllora. This is a complex community of autotrophic photosynthetic organisms in illuminated areas like rocky rocks, and sediments. Lampenflora also thrives in nature and artificial caves around artificial light sources. Mosses and ferns, also part of the lampenflora (Figure 6C-D). Lampenflora is a community relative to the aerophytic phototrophs of the cave entrance, which is completely independent of sunlight and external climate or other factors (Priyanti et al. 2011).

THE ROLE OF KARST FOR HUMANS

Ecology

Carbon sequestration. Karst areas have a role in ecology, economy, and human culture. Purnaweni (2014) stated that karst areas have an important role in the ecosystem by providing clean water, limestone-based natural materials, and controlling climate change. Its role in the ecological function of karst areas can also be a source of CO_2 gas absorption. CO_2 is a molecule composed of the elements carbon and oxygen. CO_2 is one of the causes of global warming and several other gases such as CH_4, CFC, N_2O, and O_3. The karst area's absorption of CO_2 occurs due to the karstification process. The process begins with the dissolution of CO_2 in water and then forms H_2CO_3. The H_2CO_3 solution is unstable, so it decomposes into $(HCO_3)^{2-}$ and H^+. This H^+ ion will decompose limestone ($CaCO_3$) into Ca^{2+} and HCO^{3-}. The absorption of CO_2 gas occurs because of Indonesia's position in the tropics, which is influenced by the global atmospheric movement system. Global atmospheric movements that affect CO_2 levels in the tropics are caused by the Intertropical Convergence Zone (ITCZ) phenomenon. The existence of this phenomenon causes the movement of air masses from 300 LU and 300

LS towards the tropics which not only carries air masses but also carries water vapor, gases that cause the greenhouse effect, and others. Therefore, the absorption of CO_2 by karst areas in the tropics becomes very important to prevent or reduce excessive concentrations of CO_2 that have an impact on global warming (Cahyadi 2010).

Water conservation. The hydrological cycle is the role of karst areas in the social and environmental fields in people's lives. The role of the karst is important for its extraordinary water cycle (Khairurrahman 2021). The karst area is a source of life for local residents. Water sources in the karst area can be used as springs and residents' agriculture. Some of the lakes called "lakes" become a source of water supply. The potential of these water resources is influenced by the input of rainfall and karstified limestone and the morphology of the karst hills. Most of the water from rainfall in the karst area will enter the cracks (epikarst) on the surface and then be stored in the cavities resulting from the dissolving. Karst hills can store water three to four months after the rainy season, by releasing water slowly into underground river systems. So that karst hills must be protected to face drought in the dry season. Conservation actions that can be taken include maintaining and managing karst hills according to their designation by referring to the type of karst area, regulating limestone mining, rehabilitating ex-mining land, and managing epikarst and ponor/luweng zones (Haryono and Day 2004).

Economics

Mining. The large number of natural resources in the karst area, ultimately makes the area a potential land that provides many advantages (Amalia et al. 2016). The economic role of the karst area in the economic field is divided into two parts, namely the non-renewable role and the renewable role. The non-renewable role is the karst area as a mining area. The current policy of the Indonesian government is the development of infrastructure in various regions. In line with that, the need for building materials such as limestone will increase. (Sarwanto and Sari 2017). The abundant natural resources of lime have become the mining center for cement production. This area is a source of livelihood for the surrounding community who work with companies established around the karst area. Although it plays a very important role in people's lives, karst areas are vulnerable to disturbances from the undirected socio-economic dynamics of the community. Limestone mining will change the landscape significantly and has the potential to damage the environment, the losses can even outweigh the benefits that can be obtained from mining activities; and to overcome the damage to karst areas, it takes decades of ecological compensation and very large costs (Zhou et al. 2014).

Agriculture. The economic role of renewable karst is its existence as a source of irrigation. There are slopes of the karst area which have been converted into terraced agricultural land. It serves to maintain soil moisture, prevent erosion, and so on. Most of the slopes and terraces play a role in supporting permanent dry land without the aid of irrigation, making it possible to establish rural agriculture spread over the many karst basins (Setyawan 2007).

Ecotourism. Another socio-economic role that is also the role of education is that the karst area becomes a tourist spot. With the existence of tourist attractions, the economic level of the community will increase both from the source of profits from the management of the tourist area and because of opening a business around the karst area. For example, the karst area of Gunung Sewu muntains, southern Java. UNESCO recognizes this area as one of the global geoparks with enormous geological potential. This area has built a tourist attraction in the form of a karst museum in the Pracimantoro Sub-district, Wonogiri District (Wicaksono et al. 2021).

Socio-culture

The karst area is one of the earliest places for human civilization to develop. Modern humans, *Homo sapiens*, are not the only hominids inhabiting the Indonesian archipelago, previously *Homo erectus* (1.6 million-100,000 years ago) and *Homo floresiensis* (100,000-60,000 years ago). Modern humans arrived in Indonesia in several waves. First, the Austro-Melanesian arrived 60,000-45,000 years ago from mainland Asia. Their genetics and language are preserved in Eastern Indonesian, such as East Nusa Tenggara, Maluku, and Papua. Second, the Austroasiatic arrived 6,300-5,000 years ago from Yunnan, inhabited Western Indonesia, such as Sumatra, Kalimantan, Java and Bali. Third, Austronesian arrived 4,000 years ago from Taiwan, mainly inhabited Sulawesi. Although Austronesian people are sea nomads, the language is widespread and even adopted by the Austroasiatic people in Western Indonesia. In Eastern Indonesia, the Austronesian language family replaced or assimilated to the local language, especially in coastal areas. Austronesian even spread west to Madagascar to the east to Hawaii, New Zealand (Aotearoa) and Rapa Nui (Easter Island) (Ooi 2004; Lipson et al. 2014).

The existence of caves is a strong reason for hominids to settle by making them temporary or permanent shelter (Mulec and Goraxd 2009). In addition, the karst area was rich in plants and animals as a source of food (Sugiyanto 2013). Furthermore, the rocks in the karst region make it possible to make tools. This is found almost evenly in all karst areas in Indonesia, as can be seen from traces of past civilizations, such as tools and flakes, jewelry, animal bones, plant foods, even the remains of human skeletons and early burial cultures (van den Bergh et al. 2016; Yondri 2019). Under certain conditions, art is also found in caves, such as paintings, drawings, and engravings on immobile rock surfaces and carved figurines (Aubert et al. 2014, 2018). At least 20 cave arts were found in Indonesia (Fauzi et al. 2019). Relics of cave art in the karst areas of South Sulawesi and East Kalimantan indicate that humans had been present in these caves 40,000-52,000 years ago. Even during excavations at Talepu (northeast of Maros), stone artifacts associated with the fossil remains of megafauna (*Bubalus, Stegodon* and *Celebochoerus*) have been found from layered deposits accumulated from 200,000-100,000 years ago, indicating that the users were not modern humans (van den Bergh et al. 2016). In the last century, modern human fossils were found in the Wajak karst area, Tulungagung, East Java from 40,000 years ago (Aziz and de Vos 1989). Meanwhile, excavations at Liang Bua, Flores, found *H. floresiensis*, a hobbit (Brown et al. 2004; Aiello 2013), about 100,000 years old (Sutikna et al. 2016). This new hominid had a different morphology from its predecessor *H. erectus* and modern humans, *H. sapiens* (Jungers et al. 2009; Brown 2012; Westaway et al. 2015).

Several human roles in karst environments are shown in Figure 7.

KARST PROBLEMS IN INDONESIA

About 9.5% of the total karst area of Indonesia with a total area of 155,000 km^2 was damaged (Ika 2016). Karst damage can be caused by natural and anthropogenic factors (Endarto et al. 2015). Natural factors that threaten karst can be triggered by natural factors like natural disasters and natural activities such as climate change. Climate change, causing effects such as rising temperatures and longer hot periods. Anthropogenic factors are factors related to things caused by human activities. One of the anthropogenic activities that threaten the karst environment is the occurrence of karst mining. Human activities can cause disruption of the hydrological system and a decrease in the quantity and quality of water.

Human activities such as mining and deforestation will cause less water to seep, decrease biodiversity, and other damage. Meanwhile, human activities such as agriculture, sanitation management, and so on will cause a decrease in water quality. Damage to the karst landscape, among others, is the result of limestone mining activities and land conversion. The main problem in the management of karst areas in Indonesia arises from the consequences of decentralization of authority, in particular, the authority to permit limestone mining. The decentralization of authority has made the regulations for karst management issued by the central government ineffective. Although there are regulations regarding the determination of karst areas, in their implementation they often contradict the political policies of regional heads who hold management authority.

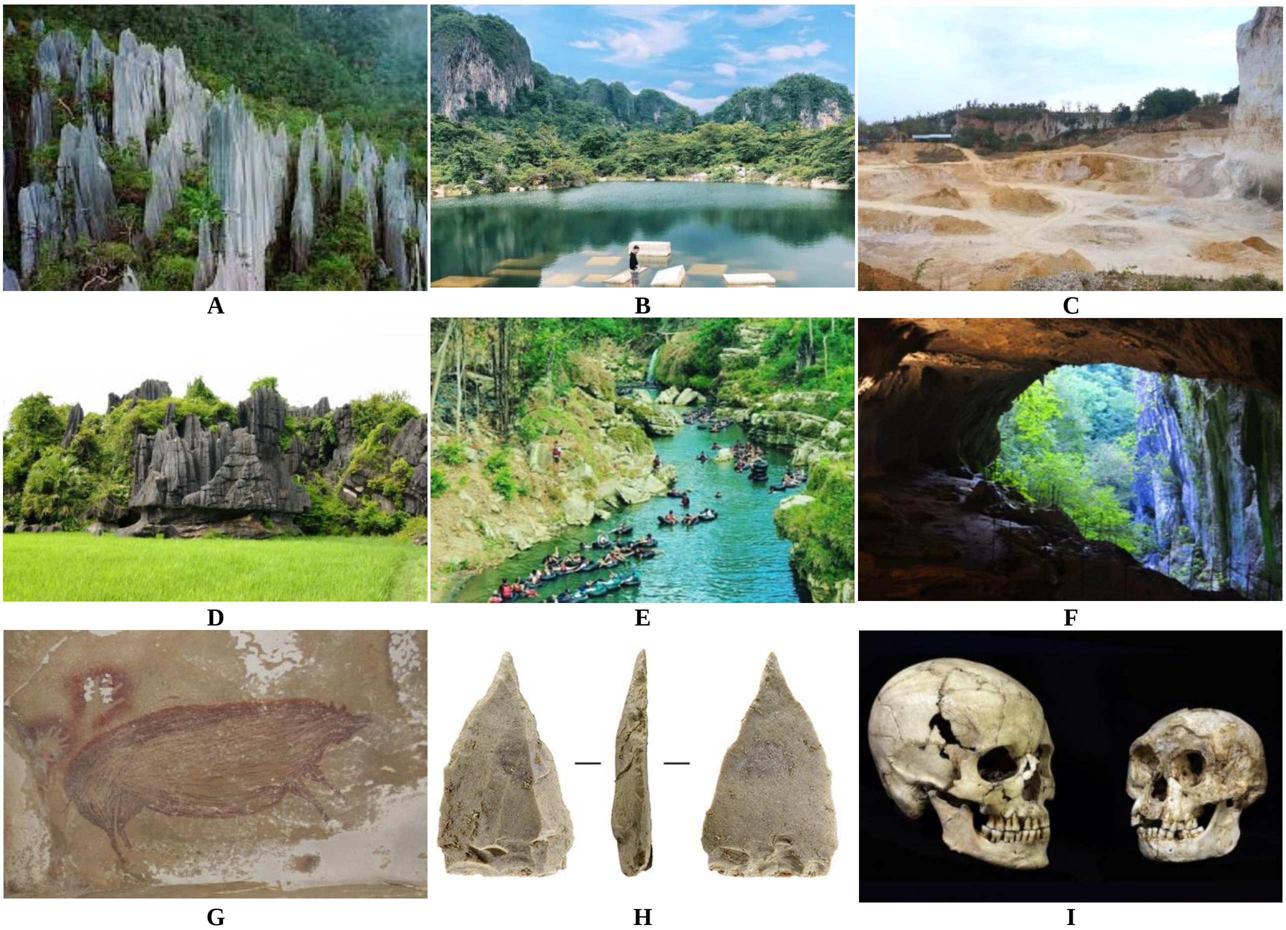


Figure 7. Human role on karst environment. A. Tropical rainforest in Berau karst area as carbon sequestration, East Kalimantan. B. Water conservation in Ramang-Ramang karst area of Maros, South Sulawesi. C. Karst quarry in Tuban for cement, East Java. D. Paddy fied in Maros karst area, South Sulawesi. E-F. Ecosystem base tourism in Gua Pindul, Gunung Sewu, Yogyakarta and Pati, Gunung Kendeng, Central Java. G. The world-oldest human cave painting, a warty pig in Leang Tedongnge cave, Maros, South Sulawesi from 45.500 year ago. H. Pangkep point type for arrow/spear, South Sulawesi. I. Skull of *Homo florisiensis* (*right*) from Liang Bua, Flores, East Nusa Tenggara (compared with modern human, *left*)

Karst area is known as an environment that has a very low carrying capacity, and cannot be repaired if it has been damaged. Karst areas are very vulnerable to various natural and human disturbances (Budiyanto 2015). Because of its nature, karst areas can be called very vulnerable areas, or sensitive to pollution. This is due to the large number of fractures in limestone that make up the karst topography so its large pores, high secondary permeability, high degree of rock dissolution cloud, cause conduit tunnels in forms of underground rivers so that any small input will be accepted and percolated through pores and enter underground river passages and disperse easily. Karst area can be seen as an ecosystem, in which there are interactions and interdependencies between the physical, non-physical, biological, and non-biological environments, as well as biogeochemistry both in exokarst and endokarst which are always in contact. This shows that it is very easy for the karst environment to be damaged if one of its constituent components is damaged or polluted. In other words, it can be concluded that the karst environment has a very low carrying capacity. Due to its nature, the Gunung Sewu karst area has a very high vulnerability

Conflicts of interest to conserve and pressure from the population to utilize karst natural resources eventually led to several problems of degradation of the karst lands as follows:

Mining activities

Mining activities in the karst area are very intensive. Mining in karst areas has become an industrial activity, in small, medium, and large scale such as cement factories. Generally, mining activities are mining of limestone which erodes karst domes. The effects that occur as a result of mining activities include a decrease in the biodiversity index erosion and sedimentation, decrease in soil fertility, changes in landscape/land, and pollution of air and water bodies. The function of CO_2 absorption in karst areas in Indonesia is currently being disrupted, including due to limestone mining. Limestone mining in karst areas in Indonesia is often done by overburdening (peeling) the karst cones either manually (with human power) or by using heavy equipment. This mining process causes the loss of the epikarst layer in limestone so that the karstification process cannot occur (Cahyadi 2010).

Cutting of vegetation

Logging activities in the Gunung Sewu karst have been going on for decades. As a result, most of this area is currently degraded and deforested land. Logging vegetation is decreased evaporation (*evapotranspiration),* increased levels of CO_2 in the soil, increased permeability of surface soil (topsoil), and decreased permeability of subsoil.

Conversion of land functions has partially damaged the existing karst ecosystem. Existing degradation will reduce the level of resources, both water resources, and land resources. Based on the existing problems, there is a need for problems, an inventory of land resources, water resources, and then the grouping according to their level and intensity. Another problem is related to the absence of laws and regulations governing the operation of landscape conservation in Indonesia. The existing regulations are more regulated on biodiversity and cultural conservation. In addition, the number of applications for limestone mining permits in Java has contributed to the increasingly massive damage to the karst landscape. At least 20% of the total area of 1,228,538.5 h of karst landscapes in Java was damaged. The damage occurred in several karst areas in Java with the largest damage are occurring in East Java, followed by West Java, then Central Java and Yogyakarta. Karst conservation efforts are important because, in addition to functioning as a storage bag for clean water reserves, the karst area is also an area for carbon absorption. The karst landscape is capable of absorbing large amounts of carbon that pollutes the air, which is 13,482 Giga grams per year.

KARST CONSERVATION IN INDONESIA

People who lack understanding of the karst area will think that karst is an arid, barren area, deficit of water, and has inadequate and unattractive infrastructure. The karst area holds a lot of potentials that can be utilized for the welfare of the community. It is emphasized in Article 33 paragraph (3) of the 1945 Constitution, which states "the earth, water and natural resources contained therein are controlled by the state and used for the prosperity of the people." However, an inaccurate interpretation of the meaning of the Constitution, as well as the pressure of economic needs will trigger uncontrolled exploitation of limestone hills. This causes the karst ecosystem to be damaged.

Karst is not a mining area because it is a buffer zone for water availability. Mining is one of the activities that cause quite a lot of environmental damage and pollution. This is because all mining sub-sectors have the potential to cause environmental problems in the form of environmental destruction and environmental pollution of waters, land, and air (Supriadi 2006). This pollution will then have the next impact which can eventually lead to negative public perceptions of mining activities. Considering the importance of karst and limestone ecosystems as non-renewable natural resources, conservation is necessary to maintain ecological functions.

The steps that can be taken for conservation karst areas include:

Limiting sales of raw limestone to outside regions

Damage of the Karst Area by the mining of limestone is due to the uncertainty of which plots are allowed to be mined and which are not. In general, this limestone is used for a mixture of wall paint and several other building materials, making chalk and others. The sale of raw materials tends to be cheaper than if the limestone product is processed into other materials with a higher selling value. In addition, sales of raw materials are usually carried out in large quantities to meet the needs of consumers for raw materials. This results in a lot of natural resources that must be taken. The speed of taking resources will be directly proportional to the depletion of these resources.

Therefore, then suppliers need to process limestone into processed materials so that their selling power is higher and the rate of resource depletion can also be slowed down. One form of processing that has high selling power iswhen the stone has been carved into an ornament that is good for home decoration (Tyas et al. 2016).

Clarifying protected areas and cultivation areas

Damage of the Karst Area by the mining of limestone is due to the uncertainty of which plots are allowed to be mined and which are not. So that what happens is rampant illegal mining in areas that should not be allowed to be mined. The magnitude of the estimated impact of damage to the karst environment caused by mining activities, in reality, does not reduce mining activities, on the contrary, in recent years mining activities have increased. So that what happens is rampant illegal mining in areas that should not be allowed to be mined (Amalia et al. 2016). With mining activities, there is a reduction in water absorption and damage to water systems and the habitat of endemic animals such as bats, snakes, swallows, and long-tailed macaques (Wuspada 2012). Areas that are allowed and prohibited to be mined should be assessed immediately, including estimating the impact if an area is cleared to become a mining area. Re-evaluating or revising the Regional Spatial Planning (RT/RW) can beused as a way to find solutions for regulating mining areas. This is important to do consider that mining karst areas will damage the environment, but stopping all mining activities will also have a major impact on the community's economy. Some people depend on the livelihood of karst miners for their livelihoods.

Conducting socialization on the importance of maintaining the sustainability of the karst area

In general, residents do not know that some of the areas should not be mined. Large population pressure (> 1) will cause environmental damage (Sartohadi and Putri 2008). In their understanding, the limestone hills are privately owned, so the owner has the right to mine or sell their limestone hills. This is one of the weak points of efforts to reduce environmental damage due to limestone hill mining. The government becomes a little heavy if it will prohibit illegal mining because miners dig limestone on their land which has been passed down from generation to generation from their parents. Therefore, it is important to carry out socialization efforts to the community as one of the preventive measures to contain the widespread damage to the karst ecosystem.

Providing skills or developing other business opportunities

The booming mining activities are driven by the economic needs of the community, where people who make a living as farmers cannot depend all their needs on agricultural products. Based on these reasons, people often switch professions to become illegal limestone miners or work in limestone mining factories. Wild limestone miners tend to be dangerous to the safety of miners because they mine with traditional tools. Excavations usually leave marks in the form of holes in the limestone walls, making them prone to collapse. However, mining like this tends to be slower, so even though it is damaging to the environment, the results obtained by miners are not much. Based on these considerations, the government should provide other skills for the community. However.

Reclaiming ex-mining land according to the level and type of damage

Every mining activity will certainly cause damage to the environment. Especially at the production operation stage, the environment is damaged and the social order is damaged. This happens when the extraction of minerals will damage the earth's landscape, although karst areas should not be allowed to be mined, for areas that have already been mined, conservation needs to be done. The conservation carried out is intended to restore the ecological function of the damaged landscape. Although these ecological functions cannot be fully restored to their initial conditions before being mined. What can be done is to plant suitable vegetation for ex-mined land. There are still very few ex-excavated lands that are reclaimed, what exists is that the land is left as open land without returning its ecological function. Moreover, the karst area as a reservoir for underground springs is a water storage area. Mining can stockpile these springs so that it has an impact on water shortages during the dry season. Therefore, reclamation is important to maintain the function of the area as a water buffer area. Another thing that needs to be emphasized is that it is not only the environment that needs to be reclaimed but also the social risks that arise due to the opening of the mining area. For example, the risk of public health problems around the limestone factory. The mining company should allocate reclamation funds as a form of compensation for the environment and the surrounding community. This results in water shortages during the dry season. Therefore, reclamation is important to maintain the function of the area as a water buffer area. Another thing that needs to be emphasized is that it is not only the environment that needs to be reclaimed but also the social risks that arise due to the opening of the mining area. For example, the risk of public health problems around the limestone factory. The mining company should allocate reclamation funds as a form of compensation for the environment and the surrounding community. This results in water shortages during the dry season. Therefore, reclamation is important to maintain the function of the area as a water buffer area. Another thing that needs to be emphasized is that it is not only the environment that needs to be reclaimed but also the social risks that arise dueto the opening of the mining area. For example, the risk of public health problems around the limestone factory. The mining company should allocate reclamation funds as a form of compensation for the environment and the surrounding community. but also the social risks that arise as a result of the opening of the mining area. For example, the risk of public health problems around the limestone factory. The mining company should allocate reclamation funds as a form of compensation for the environment and the surrounding community. but also the social risks that arise as a result of the opening of the mining area. For example, the risk of public health problems around the limestone factory. The mining company should allocate reclamation funds as a form of compensation for the environment and the surrounding community.

CONCLUDING REMARKS

The karst area in Indonesia covers an area of about 15.4 million hectares and is spread almost throughout Indonesia. Most of the karst areas in Indonesia are composed of carbonate rocks, and almost none are composed of other rocks such as gypsum, salt rock, and evaporite rocks. Damage to the karst landscape, among others, is the result of limestone mining activities, logging of vegetation, and land conversion. To overcome the damage that exists in the karst environment, conservation can be done. The steps that can be taken for conservation efforts in karst areas include limiting the sale of raw limestone outside the area, clarifying protected areas and cultivation areas, socializing the importance of preserving karst areas, providing skills, or developing other business opportunities, and reclaiming land. Mining sites according to the level and type of damage. The amount of water available in the karst area plays an important role in human life and also the flora and fauna around the karst area. The karst area functions as an ecosystem for the habitat of various animals and plants. The richness of flora and fauna of this karst area is extraordinary. Karst area plays an important role in terms of economy, science, and human culture. In addition, karst areas have an important role in the ecosystem, such as providing clean water, limestone-based natural materials, and controlling climate change. Its role in ecological function is that karst areas can also be a source of CO_2 gas absorption.

ACKNOWLEDGEMENTS

We want to thank all parties for their contributions in completing this review article.

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INTL J TROP DRYLANDS
Volume 5, Number 2, December 2021
Pages: 75-83
E-ISSN: 2580-2828
DOI: 10.13057/tropdrylands/t050204

Identification and potential of vascular plants in the karst ecosystem of Somopuro Cave, Pacitan, East Java, Indonesia

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Manuscript received: 2 December 2021. Revision accepted: 28 December 2021.

Abstract. *Septiasari A, Balgis M, Lathifah MN, Hanugroho PD, Setyawan AD. 2021. Identification and potential of vascular plants in the karst ecosystem of Somopuro Cave, Pacitan, East Java, Indonesia. Intl J Trop Drylands 5: 75-83.* Karst areas are composed of limestone hills or mountains formed over hundreds or even millions of years. Karst landforms vary according to the formation process. With a unique formation, karst land is a place to live for unique organisms. The karst area is like a natural laboratory that contains various phenomena of living organisms and plays an important role in the progress of science. One of the plants that live in the karst environment is a vascular plant and is rarely discussed among researchers. No one has ever investigated the vascular plants around Somopuro Cave, so this research became interesting to discuss. This paper aims to know the diversity of vascular plants in the Somopuro Karst Cave, Pacitan, East Java, Indonesia area, and the potential species. The research was conducted in November 2021, using a survey method. Based on observations around Somopuro Cave, vascular plants are grouped based on their habitus; there are 5 groups, namely trees, shrubs, herbs, vines, and epiphytes. The collection of plants in the karst area of the Somopuro Cave contains 103 species from 51 families. Results revealed that the most common vascular plants are Asteraceae, Araceae, Fabaceae, and Euphorbiaceae family. Six potentials can be utilized from vascular plants in the Somopuro Cave Area: medicinal plants, ornamental plants, foodstuffs, wood-producing plants, animal feed, and energy sources.

Keywords: Biodiversity, karst caves, Somopuro Cave, vascular plants

INTRODUCTION

Karst is a specific area consisting of relief surfaces and underground hydrographic tissue surfaces resulting from chemical and mechanical water circulation that will create cracks along with soluble rock layers, such as limestone, dolomite as well as gypsum, and salt (Kurniati and Siswanto 2020). The karst region is composed mostly of carbonate rocks, especially $CaCO_3$ limestone and CaMg dolomite $(CO_3)_2$ (Sulastoro 2013). The formation of cracks on the surface causes the water directly into the underground flow system resulting in dry conditions on the surface (Murti 2009). Karst has a unique topographic form that if there is a change in the karst, it will cause water balance, solar energy flow system, and reduction of carbon dioxide absorption (Hartono et al. 2020).

The karst ecosystem is the karst landscape's abiotic, biotic, and cultural components (Nugroho and Kristanto 2020). Karst ecosystem is a region that can capture and store rainwater as a habitat for several species of special living things and potentially mining due to hilly physiographs formed from limestone (Purnaweni 2014). Karst ecosystem is a unique landscape with a fragile or irreversible nature (Widyaningsih 2017). If the karst ecosystem is affected by a strong disturbance, there will be reverse succession, and recovery will take a long time. Biodiversity plays a role in maintaining the karst landscape and the process of restoring damaged karst ecosystems (Li et al., 2013).

Karst areas in Indonesia can be categorized based on climate and development. Karst has an important role, namely as a habitat for various flora and fauna. The biodiversity in karst is very rich and unique. So that the karst area has 3 functions: economic, ecological, and educational & cultural (Aprilia et al. 2021). Based on research by Balazs (1971), karst areas in Indonesia can be categorized into 17 locations. Not all of them developed well; from the 17 locations, 2 areas developed the best, namely the Maros karst and Gunung Sewu karst areas.

Karst landforms vary according to the formation process. With a unique formation, karst land is a place to live for unique organisms. Karst in Indonesia holds many unique potentials and is very rich in natural resources, both biological and non-biological. The phenomenon is also amazing and has never finished being researched. Therefore, this research aims to know the diversity of vascular plants in the Somopuro karst cave area and the potential species.

MATERIALS AND METHODS

Study area

The observation is at Somopuro Cave area, Bungur Village, Tulakan, Pacitan, East Java, Indonesia (Figure 1). Somopuro Cave has located ±30 km east of the city center and is still part of the Southern Mountains karst area. Somopuro Cave's formations are stalactites and stalagmites hanging in beautiful curves. This cave is the outlet of an underground river. Around the cave, there is diverse and interesting vegetation to be investigated further. The research was conducted in November 2021.

Methods

This research was conducted using a survey method. All vascular plants that grow around the cave (*goa/gua*) will be recorded for further identification (Nasution et al., 2015). Direct observations were made in the area of the object under study as primary research data. The results were obtained to describe the conditions in the Somopuro Cave area. Then proceed with the identification of vascular plants species while collecting additional literature as supporting data. After primary data are collected, the research is focused on knowing the potential of each plant.

Procedures

Observation

Direct observations were made by exploring the Somopuro Cave area to find out the conditions around the cave and observing the diversity of the vegetation. Vascular plants were recorded and documented for further identification.

Plant identification

After the list of plants found in Somopuro Cave was compiled, the research continued with plant identification. Plants are identified based on their taxonomy and habitus. The identification data uses open web access, including plantamor.com, theplantlist.org, identify.plantnet.org, gbif.org, and powo.science.kew.org. After that, the potential of each plant was recorded based on the literature (see Table 1 for a list of references).

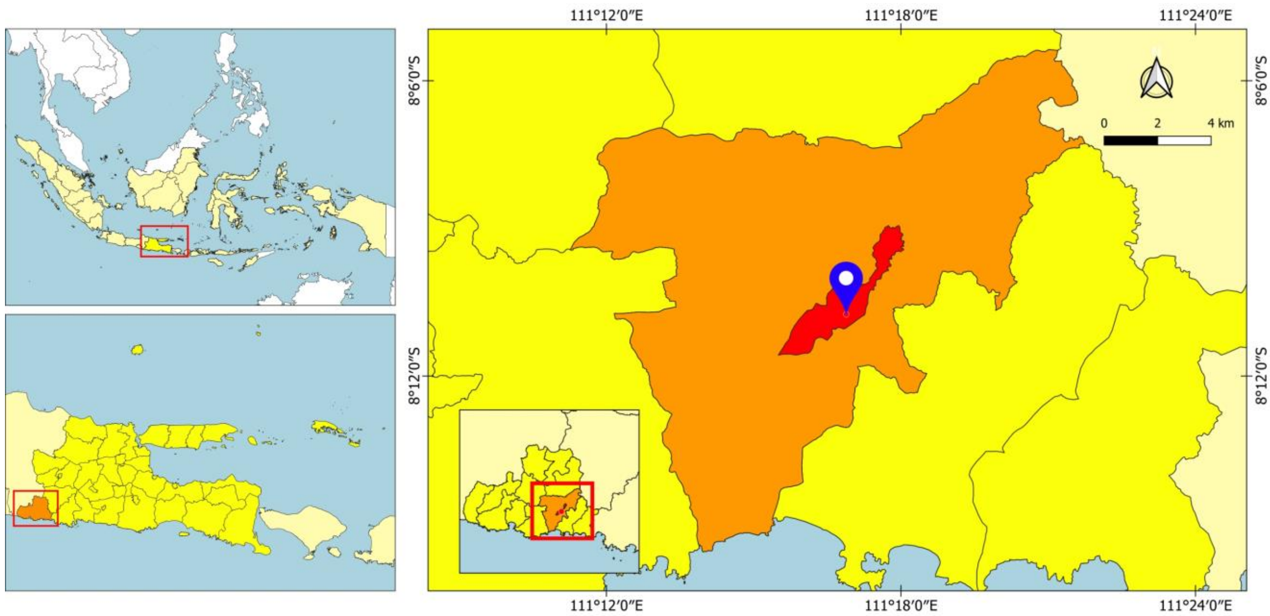

Figure 1. Location of Somopuro Cave Area, Bungur Village, Tulakan, Pacitan, East Java, Indonesia

Figure 2. The panoramic view of Somopuro Cave, Bungur Village, Tulakan, Pacitan, East Java, Indonesia

RESULTS AND DISCUSSION

Vascular plants in Somopuro Cave

Gunung Sewu Karst area is currently being used as land to produce a source of food for the surrounding community. This is influenced by the perspective of the surrounding community towards karst conservation. According to Sunkar (2008), karst areas known to be dry can benefit the soil because they are not polluted by chemicals that can be carried by water. Therefore, the vegetation found in the Gunung Sewu karst area is dominated by plants resistant to dry conditions; this is due to the dry area of Gunung Sewu with limited water sources. Seasonal uncertainty and global warming encourage farmers to plant different crops in each growing season. This is so that they can harvest a variety of food supplies during the harvest season. Not only that, but this planting model can also indirectly maintain soil fertility.

Vascular plants often referred to as Tracheophytes, have a vascular system. Vascular system plants perform two important functions: the delivery of resources (water, essential mineral nutrients, sugars, and amino acids) to various plant organs and the provision of mechanical support (Lucas et al., 2013). The diversity of different vascular plants on each slope at all growth rates and lower plants. This can be caused by the topographic shape of the slope, the intensity of light, and land clearing. In addition, the composition of vegetation species is still dominated by pioneer types at all growth rates, while lower-level plants are generally dominated by exotic and invasive types (Widiyanti and Kusmana 2014).

The collection of vascular plants in Somopuro Cave is 103 species from 51 families (Table 1). The most common family found in the area are Asteraceae, Araceae, Fabaceae, and Euphorbiaceae. Asteraceae, commonly called the daisy family, has the largest number of species, namely 24,000-30,000 species in 1,600-1,700 genera (Funk et al. 2005; Mandel et al. 2019). Members of the Asteraceae can be found in all ecosystems and have uniquely shaped flowers and attractive colors. There are 8 species from the Asteraceae family found in Somopuro Cave. All of the plants of this family were used as medicinal plants. The Araceae has a high species diversity, with 144 genera and 3645 species recorded worldwide (Nauheimer et al. 2012). Based on Table 1, found 7 species of Araceae in Somopuro Cave. Plants from this family have the potential to be used as medicinal plants, ornamental plants, and food ingredients. According to Acebey et al. (2010), Araceae are often found in moist lowland and montane forests, but they can also be found in seasonally dry forest habitats. Araceae has a wide diversity of habitats; therefore, the species diversity is high (Croat and Ortiz, 2020). The Fabaceae family has a wide distribution in almost all parts of the world; its good adaptability makes species of the Fabaceae family grow wild, especially on the tropical island of Java (Mountara et al., 2021). The Fabaceae family has the ability to live in all soil conditions, including dry soil such as in the karst area, due to its shallow root system. Most of these plants functioned as wood-producing plants and medicinal plants. In Somopuro Cave, various species of the Fabaceae family were found, such as *Acacia* sp., *Albizia chinensis, Dalbergia latifolia, Flemingia macrophylla, Leucaena leucocephala, Mimosa pudica,* and *Zapoteca tetragona.* Many species of the Euphorbiaceae family are found; apart from being cultivated, many plant species grow wild in the tropical area. Euphorbiaceae family are the longest inhabited flora in the karst area in general (Faida et al. 2011). In Somopuro Cave, various species of the Euphorbiaceae family were found, such as *Codiaeum* sp., *Euphorbia heterophylla*, *Euphorbia hirta*, *Macaranga* sp., and *Manihot carthaginensis.* Almost all species have the potential to be used as medicine.

The collection of plants in the karst area of the Somopuro Cave contains 103 types of plants. The division of plants is based on their habitus; there are five categories. Each of the plants that are found in the karst area has a habitus consisting of epiphytes (10 species), trees (20 species), shrubs (29 species), vines (7 species), and herbs (37 species), most of these were represented by herbaceous species. Based on research, the number of understory vascular plants is more than trees. This is considered good because the understory vegetation plays an important role in most forest ecosystems, one of which is in the karst area. According to Ou et al. (2020), understory vegetation plays an important role in conserving soil, water, and biodiversity in karst areas.

The potency of plant

Plants found in the Somopuro Cave area have potential that the surrounding community can utilize. The research results show that plants are classified into 6 potentials: medicinal plants, ornamental plants, foodstuffs, wood-producing plants, animal feed, and energy sources.

Medicinal plants

Plants in the study area showed that most have potential as medicinal plants. In identifying vascular plants in Somopuro Cave, we found 41 species from 23 families that have the potential to be used in medicine. Medicinal plants contain ingredients that can help in the healing process of a disease. Many people have taken advantage of the plants around them. Knowledge of this medicinal plant will be passed on to the next generation. There is a lot of information about the utilization of medicinal plants. So, a lot of research has been done to find out the content of plants. The plant parts commonly used for medicine are leaves, fruit, flowers, roots, rhizomes, and tubers. *Iresine herbstii, Ageratum conyzoides, Piper betle,* and *Colocasia esculenta* are medicinal plants that have the same use as wound medicine. The plant part used is the leaf (Dipankar et al. 2011; Dwivedi and Tripathi 2014; Asih and Kurniawan 2019; Herlina 2019). *Iresine herbstii*, *Solanum stramoniifolium* and *Swietenia mahagoni* contain antioxidants helpful in protecting cells in the body from the effects of free radicals (Dipankar et al., 2011; Svobodova et al., 2017; Herlina, 2019). Based on Widodo et al.'s 2019) research, the Fabaceae family, like *M. pudica* and *L. leucocephala*, can be used for liver disease treatment (Figure 3A&B). At the same time,e the research of Asih and Kurniawan (2019) shows that the plant Amorphophallus sp. (Figure 3C) from the Araceae family contains glucomannan and low glucose levels from its tubes. Hence it is good for people with diabetes.

Tabel 1. List of record species on Somopuro Cave Area, Pacitan, East Java, Indonesia

Family	Name	Local name	Habitus	Potency
Acanthaceae	*Hemigraphis reptans* (G.Forst.) T.Anderson ex Hemsl.	-	H	-
	Ruellia tuberosa L.	Pletekan	H	Medicine (1)
Adiantaceae	*Adiantum* sp.	Suplir	E	Ornamental plant (6)
Amaranthaceae	*Iresine herbstii* Hook.	-	H	Ornamental plant, Medicine (18)
Apiaceae	*Centella asiatica* (L.) Urb.	Pegagan	H	Medicine (10)
Apocynaceae	*Cerbera manghas* L.	Bintaro	T	Energy (11)
	Dischidia major (Vahl) Merr.	-	E	Ornamental plant
	Tabernaemontana sp.	-	S	-
Araceae	*Amorphophallus paeoniifolius* (Dennst.) Nicolson	Suweg	H	Medicine (9)
	Colocasia gigantea (Blume) Hook.f.	Talas (besar)	H	Foodstuffs (9)
	Colocasia sp.	Talas (kecil)	H	Foodstuffs
	Syngonium sp.	-	V	Ornamental plant
	Colocasia esculenta (L.) Schott	Talas (ungu)	H	Foodstuffs, Medicine (9)
	Caladium bicolor (Aiton) Vent.	Keladi	H	Ornamental plant (9)
	Philodendron sp.	-	H	Ornamental plant
Arecaceae	*Adonidia merrillii* (Becc.) Becc.	-	T	Ornamental plant
	Arenga pinnata (Wurmb) Merr.	Aren	T	Foodstuffs
	Cocos nucifera L.	Kelapa	T	Wood, Foodstuffs (6)
	Burretiokentia dumasii Pintaud & Hodel	Palem	T	Ornamental plant (4)
Asparagaceae	*Cordyline fruticosa* (L.) A.Chev.	Andong	S	Ornamental plant (4)
Asteraceae	*Ageratum conyzoides* L.	Bandotan	S	Medicine (2,6,10)
	Tridax procumbens L.	Gletang	H	Medicine (6)
	Wedelia chinensis (Osbeck) Merr.	-	H	Medicine (13)
	Crassocephalum crepidioides (Benth.) S.Moore	Sintrong	S	Medicine (12)
	Chromolaena odorata (L.) R.M.King & H.Rob.	Rumput Minjangan	S	Medicine (6)
	Ayapana sp.	Prasman	S	-
	Ageratina riparia (Regel) R.M.King & H.Rob.	-	S	Medicine (19)
Balsaminaceae	*Impatiens* sp.	Pacar air	H	Ornamental plant
Begoniaceae	*Begonia* sp.	Begonia	H	Ornamental plant (5)
	Begonia sp. 2	Begonia	H	Ornamental plant (5)
Bromeliaceae	*Ananas comosus* (L.) Merr.	Nanas	H	Foodstuffs
Campanulaceae	*Hippobroma longiflora* (L.) G.Don	Ki Tolod	H	Medicine (2)
Cucurbitaceae	*Momordica* sp.	-	V	-
Cystopteridaceae	*Gymnocarpium dryopteris* (L.) Newman	Pakis	H	Ornamental plant
	Gymnocarpium robertianum (Hoffm.) Newman	Pakis	H	Ornamental plant
Dioscoreaceae	*Tacca palmata* Blume	-	H	Ornamental plant
Euphorbiaceae	*Codiaeum variegatum* (L.) Rumph. ex A.Juss.	Puring	S	Medicine (12)
	Euphorbia heterophylla L.	Patikan emas	H	Medicine (21)
	Euphorbia hirta L.	Patikan kebo	H	Medicine (12)
	Macaranga sp.	-	T	-
	Manihot carthaginensis (Jacq.) Müll.Arg.	Singkong	S	Foodstuffs
Fabaceae	*Dalbergia latifolia* Roxb.	Sono	T	Wood
	Acacia sp.	Akasia	T	Wood (6)
	Albizia chinensis (Osbeck) Merr.	Sengon	T	Wood (6)
	Leucaena leucocephala (Lam.) de Wit	Lamtoro	T	Foodstuffs, Medicine (17)
	Mimosa pudica L.	Putri Malu	H	Medicine (2,10)
	Zapoteca tetragona (Willd.) H.M.Hern.	Kaliandra putih	S	Ornamental plant
	Flemingia macrophylla (Willd.) Kuntze ex Merr.	-	S	Medicine (22)
Gnetaceae	*Gnetum gnemon* L.	Melinjo	T	Foodstuffs
Lamiaceae	*Orthosiphon aristatus* (Blume) Miq.	Kumis kucing	S	Medicine (10)
	Plectranthus monostachyus (P.Beauv.) A.J.Paton	-	H	Medicine (3)
	Tectona grandis L.f.	Jati	T	Wood (6)
Linderniaceae	*Lindernia crustacea* (L.) F.Muell.	-	S	Ornamental plant
Lygodiaceae	*Lygodium circinatum* (Burm.) Sw.	Paku Hata	E	Ornamental plant (4)
Malvaceae	*Hibiscus tiliaceus* L.	Waru	T	Medicine (6)
	Hibiscus rosa-sinensis L.	Bunga Sepatu	S	Ornamental plant
	Urena lobata L.	Pulutan	S	Medicine (6)
Melastomataceae	*Clidemia hirta* (L.) D.Don	Senduduk Bulu	S	Medicine (2)
Meliaceae	*Swietenia mahagoni* (L.) Jacq.	Mahoni	T	Wood (6), Medicine (10)
Menispermaceae	*Tinospora* sp.	-	V	-
Moraceae	*Artocarpus heterophyllus* Lam.	Nangka	T	Medicine (10)
	Ficus septica Burm.f.	Awar-awar	T	Medicine (10)
	Ficus retusa L.	Ara	T	Medicine (10)

Muntingiaceae	*Muntingia calabura* L.	Talok	T	Foodstuffs
Musaceae	*Musa paradisiaca* L.	Pisang	H	Foodstuffs
Myrtaceae	*Psidium* sp.	Jambu	T	Foodstuffs
Orchidaceae	*Aerides* sp.	Anggrek	E	Ornamental plant (5)
	Dendrobium sp.	Anggrek	E	Ornamental plant (5)
	Geodorum densiflorum (Lam.) Schltr.	Anggrek tanah	H	Ornamental plant (5)
Oxalidaceae	*Oxalis barrelieri* L.	Belimbing tanah	H	Medicine (23)
Phyllanthaceae	*Phyllanthus buxifolius* (Blume) Müll.Arg.	Seligi	S	Medicine (16)
	Phyllanthus urinaria L.	Meniran	S	Medicine (2)
Piperaceae	*Peperomia pellucida* (L.) Kunth	Sirih Cina	H	Medicine (6)
	Piper betle L.	Sirih	V	Medicine (20)
Poaceae	*Bambusa* sp.	Bambu	T	Wood
	Brachiaria mutica (Forssk.) T.Q.Nguyen	Kolonjono	H	Animal feed
	Oplismenus hirtellus (L.) P.Beauv.	-	S	Animal feed
	Ancistrachne numaeensis (Balansa) S.T.Blake	-	H	Animal feed
Polygalaceae	*Polygala paniculata* L.	Akar tuju angin	S	Medicine (14)
Polygonaceae	*Polygonum aviculare* L.	-	V	Medicine (8)
Polypodiaceae	*Lepisorus excavatus* (Bory ex Willd.) Ching	Paku	E	Ornamental plant
	Pyrrosia sp.	Paku	E	-
Primulaceae	*Maesa* sp.	-	S	-
Pteridaceae	*Pityrogramma calomelanos* (L.) Link	Paku perak	E	Ornamental plant
	Pteris vittata L.	Pakis rem china	V	Ornamental plant
	Pteris ensiformis Burm.f.	Paku	H	Medicine (25)
Rosaceae	*Rubus* sp.	-	S	-
Rubiaceae	*Gardenia jasminoides* J.Ellis	Kacapiring	S	Ornamental plant
	Canthium sp.	-	S	-
Selaginellaceae	*Selaginella plana* (Desv.) Hieron.	Rane	E	Ornamental plant
	Selaginella repanda (Desv.) Spring	-	E	Ornamental plant
Solanaceae	*Solanum torvum* Sw.	Takokak	S	Foodstuffs
	Solanum stramoniifolium Benth.	-	S	Medicine (24)
Tectariaceae	*Tectaria* sp.	-	H	-
Thelypteridaceae	*Phegopteris connectilis* (Michx.) Watt	Pakis beech	S	-
	Christella dentata (Forssk.) Brownsey & Jermy	-	H	-
Thymelaeaceae	*Phaleria macrocarpa* (Scheff.) Boerl.	Mahkota Dewa	S	Medicine (7)
Urticaceae	*Pilea microphylla* (L.) Liebm.	-	H	Medicine (10)
Violaceae	*Viola rubella* Cav.	-	S	Ornamental plant
Vitaceae	*Cissus javana* DC.	Irah-Irahan	V	Ornamental plant
Zingiberaceae	*Curcuma longa* L.	Kunyit	H	Foodstuffs, Medicine (15)
	Globba sp.	-	H	Foodstuffs, Medicine (4)
	Zingiber officinale Roscoe	Jahe	H	Foodstuffs, Medicine (15)

Note: E: Epiphytes, T: Trees, S: Shrubs, V: Vines, and H: Herbs; 1. Xu et al. (2020), 2. Kartika (2017), 3. Astuti et al. (2021), 4. Ilhamullah et al. (2015), 5. Surya and Astuti (2017), 6. Priyanti et al. (2011), 7. Faried et al. (2007), 8. Park et al. (2018), 9. Asih and Kurniawan (2019), 10. Herlina (2019), 11. Handayani et al. (2015), 12. Karyati and Adhi (2017), 13. Hossen et al. (2020), 14. Pizzolatti et al. (2009), 15. Hadi et al. (2016), 16. Rahmahani (2017), 17. Zayed and Samling (2016), 18. Dipankar et al. (2011), 19. Hynniewta and Kumar (2010), (20. Dwivedi and Tripathi (2014), 21. Ughachukwu et al. (2014), 22. Ho et al. (2011), 23. Tagne et al. (2015), 24. Svobodova et al. (2017), 25. Shi et al. (2017).

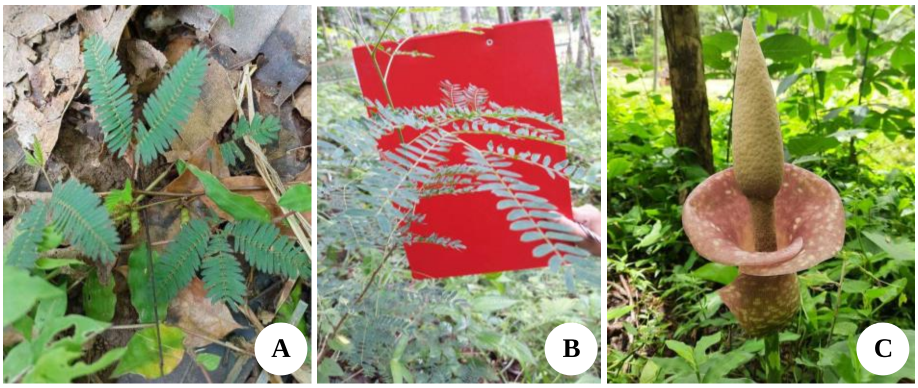

Figure 3. A. *Mimosa pudica*, B. *Leucaena leucocephala,* and C. *Amorphophallus* sp.

Figure 4. A. *Hibiscus rosa-sinensis,* B. *Syngonium* sp., and C. *Cordyline fruticosa*

Ornamental plants

Based on Table 1, 30 species from 21 families have potential as ornamental plants as an addition for view and visual therapy. Ornamental plants can include plants from vines, shrubs, and even trees. All plants that fall into the ornamental plant category are unique in color, shape, or smell. Plants that have beautiful flowers will be used as ornamental plants. According to Shibata (2008), plants are referred to as ornamental plants because of their ornamental purpose and value. These plants can be used for unique, floricultural crops, such as flowers with new and beautiful shapes or colors. These ornamental plants consist of *Adiantum* sp., *I. herbstii, Dischidia major, Syngonium* sp., *Caladium bicolor, Philodendron* sp., *Adonidia merrillii, Burretiokentia dumasii, Cordyline fruticosa, Impatiens* sp., *Begonia* sp., *Begonia* sp. 2, *Gymnocarpium dryopteris, Gymnocarpium robertianum, Tacca palmata, Z. tetragona, Lindernia crustacea, Lygodium circinatum, Hibiscus rosa-sinensis, Aerides* sp., *Dendrobium* sp., *Geodorum densiflorum, Lepisorus excavatus, Pityrogramma calomelanos, Pteris vittata, Gardenia jasminoides, Selaginella plana, Selaginella repanda, Viola rubella,* and *Cissus javana*. Besides that, some ornamental plants can be used to analyze biomass and carbon absorption, like *H. rosa-sinensis* (Figure 4A) (Haruna 2020). Ornamental plants like *Syngonium* sp. can be used as environmental indicators for vertical garden and green wall systems (Figure 4B) (Jozay et al. 2021). In addition, *C. fruticosa* ornamental plants have many leaf variations, making them very popular and used as ornamental plants (Figure 4C) (Tobondo et al. 2021). However, if there is an increase in the number of ornamental plant lovers, it will threaten these plants in the future. Therefore, cultivation efforts need to be carried out to preserve ornamental plants. So that the needs of this plant remain abundant and there is no need to take it from nature.

Foodstuffs

Plants that have the potential as foodstuffs are 16 species from 12 families. The plant parts used for food are leaves, flowers, fruit, rhizomes, and tubers. The utilization of plants can be processed first or eaten directly. This includes foodstuffs plants consisting of *Colocasia gigantea*, *Colocasia* sp., *C. esculenta, Arenga pinnata, Cocos nucifera, Ananas comosus, M. carthaginensis, L. leucocephala, Gnetum gnemon, Muntingia calabura, Musa paradisiaca, Psidium* sp., *Solanum torvum, Curcuma longa, Globba* sp., and *Zingiber officinale*. The tubers of *C. esculenta* can be made into various processed foods, such as fried, steamed, boiled, sweetened, or salted. Meanwhile, the young leaves of *C. esculenta* can be used as vegetables for cooking (Figure 5) (Mutaqin et al. 2018).

Wood-producing plants

Based on Table 1 found 7 species from 5 families that have the potential for wood production. Wood-producing plants have a strong stem texture to be used as building materials. This wood can be used for industrial products like buildings, handcraft, and furniture. Wood-producing plants have high economic value, depending on the type of plant and quality. But to get a good quality takes a long time to harvest. Wood production plants consist of *C. nucifera, D. latifolia, Acacia* sp., *A. chinensis, Tectona grandis, S. mahagoni,* and *Bambusa* sp. These plants are composed of chemicals that can make their stems strong, tough, and suitable for wood-producing materials. In general, wood consists of chemicals such as carbohydrates, cellulose, lignin, and extractives. One of the substances that determine the durability of wood is the extractive substance (Wibisono et al., 2018).

Figure 5. *Colocasia esculenta*

Figure 6. *Brachiaria mutica* (source: https://www.feedipedia.org/)

Figure 7. *Cerbera manghas*

Animal feed

There are 3 species of plants that have the potential as animal feed, and all of them are from the Poaceae family. The plants used were *Ancistrachne numaeensis*, *Brachiaria mutica*, and *Oplismenus hirtellus*. Kalanjana grass, or *B. mutica*, is an economically important plant (Figure 6). This plant is used as cut grass for animal feed, hay, or livestock grazing (Reksohadiprojo 1985; Dwari and Mondal 2011). The part of the plant used for animal feed is from the base to the tip of the leaf.

Energy source

Meanwhile, species that have the potential as an energy source, only one species was found is *Cerbera manghas* (Figure 7). *Cerbera manghas* are commonly grown as roadside urban plants. This plant has a lot of fruit but is not used because it is poisonous. Based on research from Handayani et al. (2015), *C. manghas* has a toxic fruit, so it doesn't have much potential besides seed oil extraction for biodiesel. Bintaro seeds or *C. manghas* have a fairly high oil content of around 40-65% but cannot be consumed because they contain toxins, so their use as an energy source will not compete with food needs (Herwanda 2011).

From the research that has been done, it can be concluded that there are 103 species from 51 families that grow in the Somopuro Cave area, Tulakan, Pacitan, East Java, Indonesia. Results revealed that the most common vascular plants are Asteraceae, Araceae, Fabaceae, and Euphorbiaceae family. Based on their habitus, they are divided into 5 categories, namely epiphytes (10 species), trees (20 species), shrubs (29 species), vines (7 species), and herbs (37 species). Six potentials can be utilized from vascular plants in the Somopuro Cave Area, namely medicinal plants (41 species), ornamental plants (30 species), foodstuffs (16 species), wood-producing plants (7 species), animal feed (3 species) and energy sources (1 species).

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INTL J TROP DRYLANDS
Volume 5, Number 2, December 2021
Pages: 84-93
E-ISSN: 2580-2828
DOI: 10.13057/tropdrylands/t050205

Ethnobotanical study of the medicinal plant used by local communities in karst area of Pacitan District, East Java, Indonesia

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[1]Department of Environmental Science, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret. Jl. Ir. Sutami 36A Surakarta 57126, Central Java, Indonesia. Tel./fax. +62-271-663375, ♥email: volatileoils@gmail.com
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Manuscript received: 4 December 2021. Revision accepted: 30 December 2021.

Abstract. *Ammar LA, Kurniawati B, Anggorowati D, Cahyaningsih AP, Setyawan AD. 2021. Ethnobotanical study of the medicinal plant used by local communities in karst area of Pacitan District, East Java, Indonesia. Intl J Trop Drylands 5: 84-93.* Local people's trust in traditional medicine methods is still high, especially in rural areas. Most of the villagers in Tulakan Sub-district, Pacitan District, East Java, Indonesia, grow their medicinal plants in their yards. However, local people's knowledge of various medicinal plant types is only conveyed orally from parents to children and community practice habits. Information about the using medicinal plants may begin to degrade from time to time. This study aimed to investigate the knowledge of local communities regarding the use of medicinal plants and the plant diversity, especially in the village of karst areas. The research was conducted in Bungur Village and Tulakan Village, Tulakan Sub-district, Pacitan District, East Java, Indonesia. Data collection was carried out using the snowball technique through open interviews and field surveys. A total of 40 respondents with 7 people of young age range 15-40 years and 33 people of old age range 41-75 years. Respondents with the most educational backgrounds are high school graduates. A total of 51 species were found, from 46 genera and 29 families, with 35 diseases being treated. Fever, cough, and external wounds are the most commonly treated diseases. The most widely used medicinal plant is *Zingiber officinale* Roscoe to warm the body, prevent fever, and increase immunity. During the COVID-19 pandemic, the villagers orally consumed ginger for post-COVID-19 positive recovery and maintained health. The most used plant parts are leaves and rhizomes by decoction and consumption orally. Based on the research results, it is known that the knowledge of the local communities and the use of medicinal plants is still quite good among the older and younger people with various types of plants.

Keywords: Diversity, karst area, local knowledge, medical plant, Pacitan

INTRODUCTION

Local communities, particularly those in rural regions, continue to use medicinal plants directly, specifically simplicia in the form of leaves, bark, roots, stems, flowers, or fruit (Latifah et al., 2020). People are accustomed to using natural remedies and continue to believe in their health benefits (Widianto et al., 2019). People generally determine their method of composing medicinal plants, such as chewing finely, chopping and then boiling, finely ground then soaking in cold water overnight, and so on, as well as using doses in less standard sizes, such as a handful of adults, a thumb size, a pinch, and so on (Muharni et al. 2017). Local people's knowledge of medicinal plants from various regions follows a consistent pattern, which is passed down from generation to generation from parents to children in their mother tongue, and it becomes a habit of the community that can spread in an area without written documentation (Ramadhani et al. 2021).

Most people in Bungur and Tulakan Villages have spacious yards where they can grow various plants, including medicinal herbs that can be used whenever needed. Bungur and Tulakan Villages are located in the Southern Mountains karst region of East Java, Indonesia, where residents can cultivate various medicinal plants that are often utilized for health requirements, both disease prevention, and healing. In addition to the house yard to grow the plants, the traditional market in the local village contributes to the availability of plant materials, making it possible for the community to obtain the medical plants they require.

The issue frequently raised concerning the village community's knowledge of medicinal plants is their sustainability, both in cultivation and consumption. Rural areas, including mountainous karst areas, will gradually create more sufficient health care facilities, raising concerns about the long-term viability of traditional remedies, which are only spread from generation to generation and by habit, are also feared to be increasingly degraded for future generations (Silalahi et al. 2015). A study on ethnobotany is required to investigate the level of knowledge and applications of rural communities regarding the use of plants, particularly medicinal plants. This study aims to investigate the knowledge of the people of Bungur and Tulakan Villages in the karst area about the use and diversity of medicinal plants in the two villages.

MATERIALS AND METHODS

Study area

The study was conducted in December 2021 in Bungur and Tulakan Villages, Tulakan District, Pacitan District, East Java, Indonesia (Figure 1). Tulakan District, Pacitan, is located at an altitude of 200 to 700 meters above sea level and is 25 km to the east of Pacitan. Tulakan District is located at the coordinates of latitude 8°10′13″ S and longitude 111°16′39″ E with the structure of highlands and karst mountain areas and limestone mountain areas. Rural communities in Bungur and Tulakan Villages primarily work as farmers, utilizing agroforestry land and house yards to meet their daily needs.

Data collection and analysis

A total of 40 respondents were obtained using the snowball technique, with the village head in each research area serving as the first resource person. The snowball technique was carried out by collecting a large amount of data through relationships from one person to another, then searching for further relationships through the same process, and so on (Nurdiani 2014). Data regarding the demographic structure of the respondents (Table 1) and the use of medicinal plants by each respondent were gathered through an open interview method using Indonesian and the local language (Javanese). Respondents are local residents of Bungur and Tulakan Villages aged 14 to 75 years. During the interview process, recording and taking notes were carried out. The data obtained in local names of medicinal plants, plant parts used, cured diseases, preparation methods, and consumption methods are presented descriptively in tables and graphs, analyzed in terms of frequency and percentage, and presented descriptively (Navia et al., 2021).

Table 1. The demographic structure of respondents

Parameter	Specification	Freq.	Percentage
Gender	Male	14	35.0
	Female	26	65.0
Age	15-25	1	2.5
	26-35	4	10.0
	36-45	7	17.5
	46-55	12	30.0
	56-65	8	20.0
	65-75	8	20.0
Education	Elementary School	9	22.5
	Junior High School	8	20.0
	Senior High School	15	37.5
	University	8	20.0

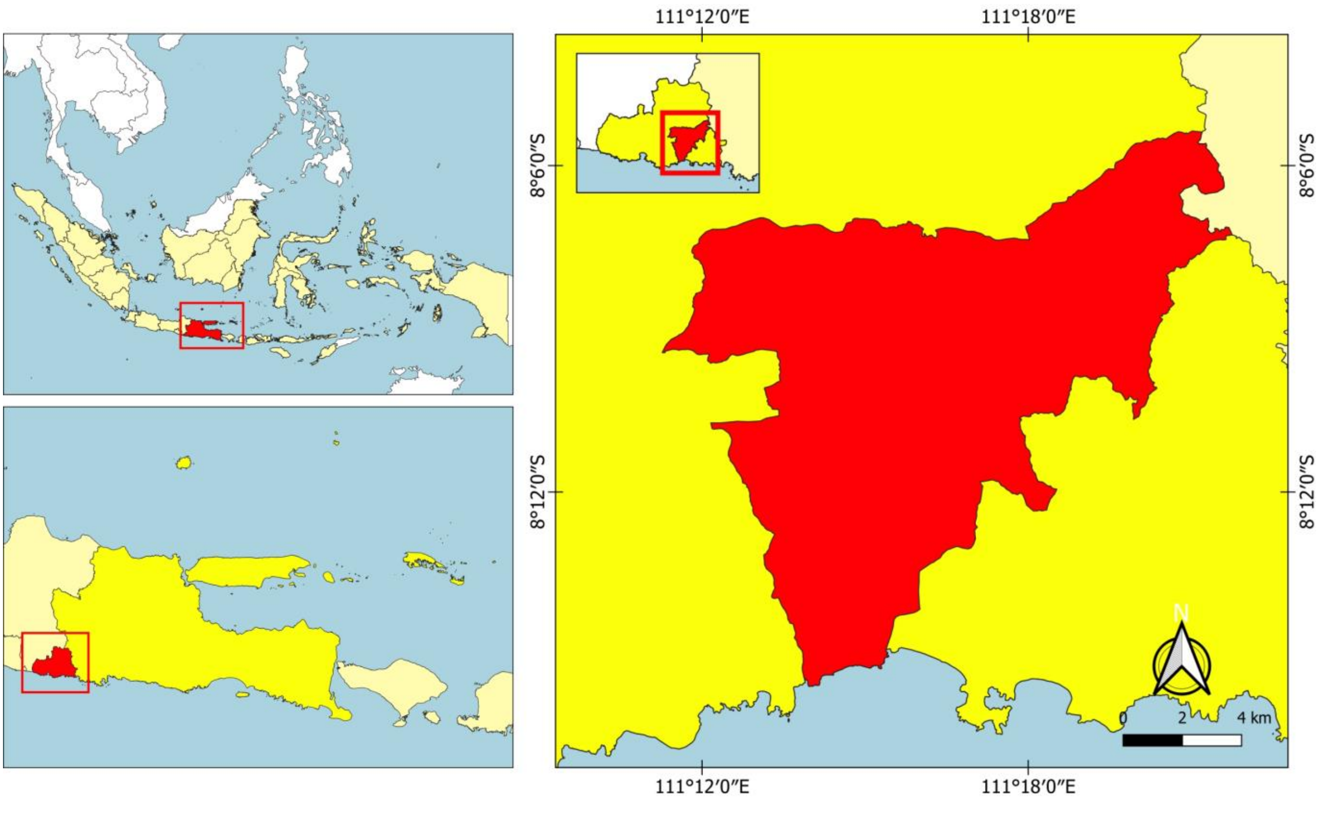


Figure 1. Map of the research location in Tulakan District, Pacitan, East Java, Indonesia

RESULTS AND DISCUSSION

Diversity of medicinal plants

Local populations in Bungur and Tulakan Villages utilize 51 species of medicinal plants belonging to 46 genera and 29 families (Table 2, Figure 2) to treat approximately 35 diseases. According to the findings of the interviews, the majority of people continue to utilize medicinal plants as an alternative treatment. Almost all medicinal plants utilized are cultivated in the community's yards, gardens, and rice fields or purchased at traditional markets. The village community employs bushes, shrubs, trees, and climbers with various parts such as leaves, rhizomes, tubers, flowers, and fruit.

According to the interview findings, many different species of plants are utilized as traditional medicines by the residents of Bungur and Tulakan Villages. *Zingiber officinale* Roscoe, widely known as ginger, is the most commonly utilized plant in Bungur and Tulakan Villages. According to Lestari et al. (2021), ginger is an easy plant to grow and care for since it has roots in rhizomes, which grow swiftly. Ginger plants are used to treat diseases such as fever, chills, coughs, and colds and boost the body's immunity. Besides ginger, another mother rhizome (*empon-empon* plants) often utilized by the community include *Kaempferia galanga* L., also known as aromatic ginger or *kencur* in the local language, which can be used for cough treatment. *Curcuma longa* L., also known as turmeric, treats ulcers and reduces menstruation pain. *Curcuma zanthorrhiza* Roxb. or *temulawak* can be used to stimulate appetite, especially in children. *Alpinia Galanga* (L.) Willd. or galangal reduces fever and cooking spices. People in Bungur and Tulakan Villages consumed a lot of boiled ginger oral throughout the pandemic to maintain and boost immunity after being found positive for COVID-19 during the health recovery period.

Medicinal plants of rhizomes or *empon-empon* such as ginger, turmeric, aromatic ginger, fingerroot, and galangal are most often needed by the community as a traditional medicine because they tend to be easy to grow and find both in yards and markets (Zufahmi and Zuraida 2018). Furthermore, in the local language, Physalis angulata L., also known as cutleaf groundcherry or ciplukan, can be utilized as medicine for heart and lung health and to lower high blood pressure (Rohman et al. 2019). *Gynura procumbens* (Lour.) Merr. or longevity spinach is used as an alternative treatment for hypertension. The leaves are believed to be capable of treating hypertension by inhibiting the angiotensin-converting enzyme (ACE) activity. This enzyme regulates blood pressure and dilates blood vessels (Simamora and Hasibuan, 2021).

Moringa oleifera Lam. *or* moringa treats various ailments, including visual abnormalities, fat accumulation in the liver, beriberi, dermatitis, hypertension, cholesterol, anemia, osteoporosis, and many more. *Moringa* leaves contain vitamins A, B, C, protein, and minerals and is believed to be able to cure up to 300 diseases (Saputra et al., 2021). *Erythrina subumbrans* (Hassk.) Merr. or *dadap serep* in the local language reduces fever. *Piper betle* L. or betel leaf is utilized by the community to treat coronary heart disease. Betel leaf contains flavonoid compounds which are natural phenolic compounds that can reduce cholesterol levels (Naufalza 2021). *Anredera cordifolia* (Ten.) Steenis, also known as Madeira-vine or *binahong* in the local language, is used to treat ulcer disease, diabetes, hypertension, and heart disease. *Sauropus androgynus* (L.) Merr. or *katuk* leaf in the local language is used to increase the quality of breast milk in nursing women. *Katuk* leaf is a plant that is believed to boost prolactin and oxytocin levels and contains nutrients that can be used as raw materials for the synthesis of breast milk (Zhuliyan et al., 2021).

According to the results of interviews with the people of Bungur and Tulakan Villages, there were 29 plant families consisting of 6 species of Zingiberaceae (12%), 6 species of Asteraceae (12%), 3 species of Myrtaceae (6%), 3 species of Acanthaceae (6 %), 3 species of Piperaceae (6%), 2 species of Phyllanthaceae (4%), 2 species of Annonaceae (4%), 2 species of Moraceae (4%). 2 species of Rubiaceae (4%), 2 species of Malvaceae (4%), 2 species of Fabaceae (4%), 2 species of Solanaceae (4%), and the remaining 1 species each from families Moringaceae, Rutaceae, Caricaceae, Basellaceae, Acoraceae, Araceae, Pandanaceae, Rubiaceae, Xanthorrhoeaceae, Lauraceae, Menispermaceae, Lamiaceae, Poaceae, Clusiaceae. Liliaceae, and Verbenaceae (Figure 2). This demonstrates that the Zingiberaceae and Arecaceae families have the greatest species diversity compared to other families. This could be attributed to topographic or soil structure characteristics in the highlands. Furthermore, changes in species diversity conditions might occur faster due to human activities and other natural occurrences that alter vegetation and the overall condition of the land (Tudjuka et al., 2014).

Most of the plant species belonging to the Zingiberaceae include *Z. officinale, C. longa, K. galanga, C. zanthorrhiza, A. galanga,* and *Boesenbergia rotunda* (L.) Mansf. are utilized as medicinal plants. The demand for medicinal plants of the Zingiberaceae family in the herbal and pharmaceutical sectors is quite significant, owing to the community's increasing demand for medicinal plants. In their research, Sari et al. (2012) stated that environmental factors such as topography greatly affect the distribution and growth of an organism. It was explained that the distribution of the Zingiberaceae plant family was affected by environmental factors and, most importantly, the community's interest and needs for Zingiberaceae plants for consumption or commerce. The interview results reveal that the Zingiberaceae family has long been used to cure various diseases. Some of the plants utilized will function effectively when combined into a mixture, specifically a mixture of plants in one herb (Hartanto et al. 2014).

The next highest species diversity in this study is the Asteraceae family. The Asteraceae family is the second-largest family in the kingdom Plantae system, dominating plant vegetation on Earth with over 24,000-30,000 species and 1,600-1,700 genera spread throughout the world and found in almost all environments. The Asteraceae family contains components of bioactive substances, including sesquiterpenes, lactones, pentacyclic triterpenes, alcohols, alkaloids, tannins, polyphenols, saponins, and sterols. Several plants from the Asteraceae family can be utilized as traditional medicines, including *Pluchea indica* (L.) Less., *Smallanthus sonchifolia* (Poepp. & Endl.) H.Rob., *Vernonia amygdalina* Delile, *Elephantopus scaber* L., *G. procumbens* (Simanjuntak 2017).

Table 2. Plants used as medicinal plants by the people of Bungur and Tulakan Villages, Pacitan, East Java, Indonesia

Family	**Genus**	**Scientific name**	**Local name**	**Growth form**
Acanthaceae	*Andrographi*	*Andrographis paniculata* (Burm.fil.) Nees	Sambiloto	Shrub
Acanthaceae	*Graptophyllum*	*Graptophyllum pictum* (L.) Griff.	Daun ungu	Scrub
Acanthaceae	*Strobilanthes*	*Strobilanthes crispa* (L.) Blume	Keji beling	Scrub
Acoraceae	*Acorus*	*Acorus calamus* L.	Delingo	Herbaceous
Annonaceae	*Annona*	*Annona muricata* L.	Sirsak	Tree
Annonaceae	*Annona*	*Annona squamosa* L.	Srikaya	Tree
Araceae	*Amorphophallus*	*Amorphophallus muelleri* Blume	Coblok/Compleng	Herbaceous
Asteraceae	*Elephantopus*	*Elephantopus scaber* L.	Tapak liman	Climber
Asteraceae	*Gynura*	*Gynura procumbens* (Lour.) Merr.	Sambung Nyowo	Shrub
Asteraceae	*Pluchea*	*Pluchea indica* (L.) Less.	Beluntas, Luntas	Scrub
Asteraceae	*Smallanthus*	*Smallanthus sonchifolia* (Poepp. & Endl.) H.Rob.	Daun insulin	Scrub
Asteraceae	*Vernonia*	*Vernonia amygdalina* Delile	Daun Afrika	Scrub
Basellaceae	*Anredera*	*Anredera cordifolia* (Ten.) Steenis	Binahong	Climber
Caricaceae	*Carica*	*Carica papaya* L.	Pepaya gantung	Tree
Clusiaceae	*Garcinia*	*Garcinia mangostana* L.	Kulit manggis	Tree
Fabaceae	*Clitoria*	*Clitoria ternatea* L.	Telang	Climber
Fabaceae	*Erythrina*	*Erythrina subumbrans* (Hassk.) Merr.	Dadap serep	Scrub
Lamiaceae	*Cuminum*	*Cuminum cyminum* L.	Jinten	Scrub
Lauraceae	*Persea*	*Persea americana* Mill.	Alpukat	Tree
Liliaceae	*Allium*	*Allium sativum* L.	Bawang lanang	Herbaceous
Malvaceae	*Sida*	*Sida rhombifolia* L.	Sidaguri	Herbaceous
Malvaceae	*Hibiscus*	*Hibiscus sabdariffa* L.	Rosella	Climber
Menispermaceae	*Cyclea*	*Cyclea barbata* Miers	Cincau	Climber
Moraceae	*Artocarpus*	*Artocarpus altilis* (Parkinson) Fosberg	Sukun	Tree
Moraceae	*Morus*	*Morus alba* L.	Murbei	Tree
Moringaceae	*Moringa*	*Moringa oleifera* Lam.	Kelor	Tree
Myrtaceae	*Melaleuca*	*Melaleuca leucadendra* (L.) L.	Kayu putih	Herbaceous
Myrtaceae	*Psidium*	*Psidium guajava* L.	Jambu biji	Tree
Myrtaceae	*Syzygium*	*Syzygium polyanthum* (Wight) Walp.	Salam	Scrub
Pandanaceae	*Pandanus*	*Pandanus tectorius* Parkinson ex Du Roi	Pandan	Climber
Phyllanthaceae	*Sauropus*	*Sauropus androgynus* (L.) Merr.	Katuk	Scrub
Phyllanthaceae	*Phyllanthus*	*Phyllanthus urinaria* L.	Meniran	Scrub
Piperaceae	*Peperomia*	*Peperomia pellucida* (L.) Kunth	Sirih Cina	Herbaceous
Piperaceae	*Piper*	*Piper betle* L.	Daun Sirih	Climber
Piperaceae	*Piper*	*Piper ornatum* N.E.Br.	Sirih merah	Climber
Poaceae	*Imperata*	*Imperata cylindrica* (L.) P.Beauv.	Alang-alang	Scrub
Rubiaceae	*Gardenia*	*Gardenia jasminoides* J.Ellis	Kacapiring	Scrub
Rubiaceae	*Morinda*	*Morinda citrifolia* L.	Pace	Tree
Rubiaceae	*Paederia*	*Paederia foetida* L.	Daun Kentut	Climber
Rutaceae	*Citrus*	*Citrus aurantifolia* (Cristm.) Swingle	Jeruk nipis	Tree
Solanaceae	*Solanum*	*Solanum torvum* Sw.	Pokak/takokak	Scrub
Solanaceae	*Physalis*	*Physalis angulata* L.	Ceplukan	Scrub
Verbenaceae	*Lantana*	*Lantana camara* L.	Tembelekan	Herbaceous
Xanthorrhoeaceae	*Aloe*	*Aloe vera* (L.) *Burm. f.*	Lidah buaya	Scrub
Zingiberaceae	*Alpinia*	*Alpinia galanga* (L.) Willd.	Lengkuas	Herbaceous
Zingiberaceae	*Boesenbergia*	*Boesenbergia rotunda* (L.) Mansf.	Temu kunci	Herbaceous
Zingiberaceae	*Curcuma*	*Curcuma longa* L.	Kunyit	Herbaceous
Zingiberaceae	*Curcuma*	*Curcuma zanthorrhiza* Roxb.	Temulawak	Herbaceous
Zingiberaceae	*Kaempferia*	*Kaempferia galanga* L.	Kencur	Herbaceous
Zingiberaceae	*Zingiber*	*Zingiber officinale* Roscoe	Jahe	Herbaceous

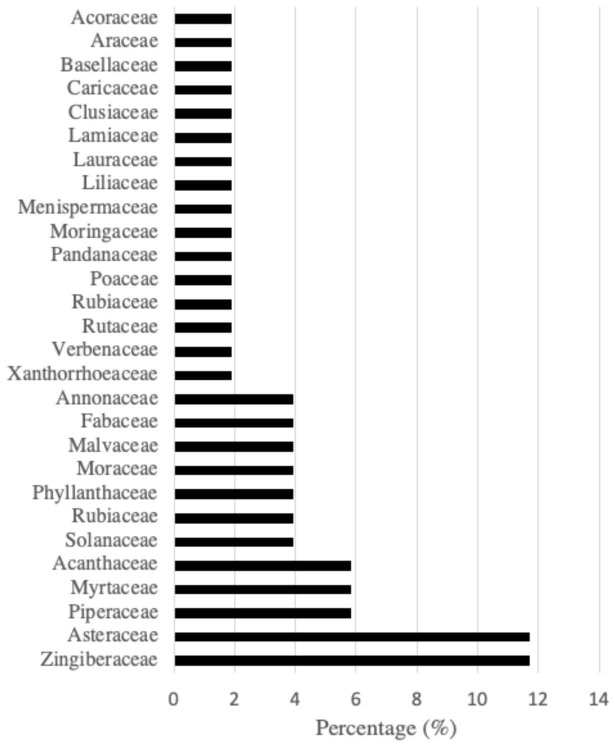


Figure 2. Family of plants used by the people of Bungur and Tulakan Villages, Pacitan, East Java, Indonesia, as medicinal plants

Growth form and plant part used

The growth form of the entire plant utilized as a medicinal plant is made up of several sorts of plants (Figure 3). Shrubs are the most common type of growth, accounting for up to 35% of all growth. The percentage of growth in the form of shrubs is in the second-highest order at 26%. Then it is followed by trees, which account for up to 21% of the total. Vine growth was the least common, accounting for only 18% of all observed growth.

Betel leaves are one of the most widely used herbal medicinal plants. Betel leaves have nutritional, organoleptic, therapeutic, prophylactic, functional, antimicrobial, and antioxidant characteristics (Madhumita et al., 2020). Besides betel leaves, bay leaves can be utilized as medicinal ingredients to treat various diseases such as diabetes, cancer, hypertension, and endometriosis (Abdulrahman et al., 2018). Ginger is one of the medicinal plants that grow as a shrub. Ginger is unique because it may create a wide range of natural compounds with great nutritional value (Deme et al., 2021).

Guava plants grow in the form of tree plants. Guava contains a lot of phenols and other antioxidants (Angulo-López et al. 2021). The *beluntas* plant, for example, has the least encountered growth form of medicinal plants, with the growth form of vines. Active phytochemicals in *beluntas* plants include flavonoids, triterpenoids, phenols, sterols, glycosides, and essential oils. Flavonoids are classified into numerous classes, one of which is a flavonol, which contains the most prevalent ingredient in *beluntas*, quercetin. Quercetin has previously been shown to have antioxidant and antifibrotic properties.

Medicinal plants used include several types of parts. The most widely used plant part is the leaf part, accounting for 67% of all plant parts. The rhizome part of the plant is the second most commonly used plant part, accounting for 13% of all plant parts. The fruit was the second most commonly used plant part, accounting for 10%, followed by the flower (6%), stem (2%), and tuber (2%).

The plant whose leaves are utilized as medicine is the leaves of *Acorus calamus* L. The *A. calamus* leaves exhibit antioxidant and anti-cytolytic properties (Andryushayev et al., 2021). A plant that is used as part of the rhizome as medicine, for example, is galangal. Galangal root can treat tuberculosis, skin problems, nausea, and stimulating properties (Eram et al. 2019).

The fruit part of the medicinal plant, for example, is found in the garcinia fruit. *Garcinia* fruit can treat wounds, ulcers, and dysentery (Santo et al., 2020). The medicinal plant's useable floral component is found in the *Lantana camara* L. plant. The *L. camara* is used for its anti-rheumatic, carminative, antibacterial, antispasmodic, vomiting, antifungal, and antitumor activities, bronchopulmonary disease, malaria, ulcers, cancer, high blood pressure, tetanus, tumors, eczema, wounds, catarrhal infections, stomach viscera atoxy, smallpox, measles, asthma, fever, sore throat, cough, conjunctivitis, toothache, skin rash and itching, headache and runny nose, diarrhea, stimulant, and treatment of jaundice (Cabrido and Demayo 2018). Meanwhile, the part of the tuber that may be used as a medicinal plant can be found in the garlic plant. Several studies state that garlic is an effective drug in preventing and treating several diseases, such as atherosclerosis, due to its lipid-lowering effect, mild arterial pressure reduction, and fibrinolytic and platelet anti-aggregation activity. Garlic also contains antioxidant, hypotensive, antimicrobial, antifungal, antitumorigenic, and immunomodulatory properties (Patiño-Morales et al., 2022).

Preparation and application methods

People in Bungur and Tulakan Villages, in general, continue to use traditional methods of preparation and application that have been passed down through generations and need little equipment. Preparation methods include decoction, crushed, raw, extracting, juicing, and drying (Table 3). Many people utilize the decoction method for plant material in leaves and rhizomes; however, the community prefers fruit's direct consumed/raw, juicing, and drying methods. The village community still uses this method because the traditional method is thought to have greater efficacy and be simple. After all, its naturalness is preserved.

The people of Bungur and Tulakan Villages boil some plant parts such as leaves, rhizomes, stalks, and flowers; parts of the plant are boiled to obtain boiled water consumed directly. This method is easy because it requires few tools and takes few steps. The boiled method is the most common and the most widely used method by local people in Indonesia, such as the local community of Subang, West Java (Putri et al. 2016), Cianjur, West Java (Malini et al. 2017), the Tengger (Jadid et al. 2020), and

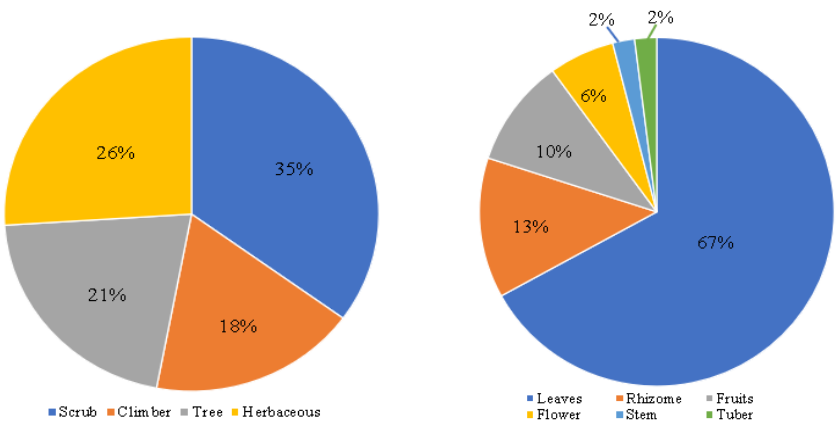
Labu Village, Aceh (Elfrida et al. 2021). In Iran, a decoction of flowers, roots, and sap of *Astragalus fasciculifolius* Boiss, known as "Gineh or Ginja," is widely used for body heating, easing joint pain, toothache, and diabetes (Mosaddegh et al. 2012). In some areas, the leaves of the Zygophyllaceae are boiled and used to treat diabetes (Bouyahya et al., 2021). Some decoctions of the leaves, roots, and bark are also used in steam baths (Nguyen et al., 2019).

The direct way of using medicinal plants is a method that does not include the processing of the parts consumed. This is typically the fruit or stalk of the vines. The extraction method is done on the *Aloe vera* (L.) Burm. f. plant. This plant can be ingested directly by crushing or extracting and processing it as desired. Regardless of the varied processing methods used, the benefits will be useful to consumers. Another example is indigo leaf extract, which has anabolic, astringent, and detergent-like properties (Speranza et al., 2020). The people of Bungur Village frequently process medicinal plants that produce fruit into juice.

Furthermore, the fruit of medicinal plants can be dried, brewed, and the water can be directly consumed. The dried powdered petals, like *biduri* leaves, can be cooked in sugar and used to cure asthma (Timilsina et al., 2020). The local residents of Karliova used to dry wild plants so that medicinal plants may be preserved for a year throughout the season (Nadiroğlu et al., 2019).

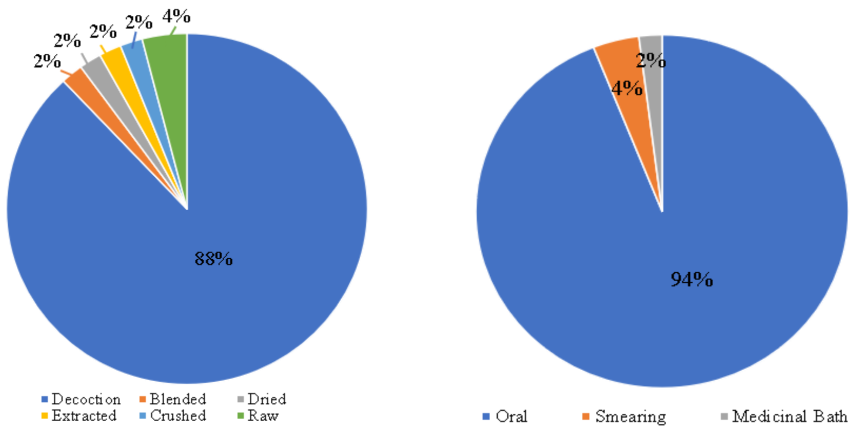
The boiling process has the highest percentage, followed by other methods, including ingested directly, powdered, dried, mashed, and extracted. The residents of Bungur and Tulakan Villages continue to use simple and inexpensive traditional preparation methods and applications. Meanwhile, the most common application method is consumed directly.

As depicted in Figure 4, the study results show that the preparation by decoction is the most widely utilized method for processing medicinal plants, accounting for 88 percent of the total. It is followed by the method of being consumed directly or raw, accounting for 4%. Then, the remaining is 2% for each method, including crushed/ground, dried, mashed, blended, and extracted. These results align with a study conducted in Ngadisari, showing that rural communities use various methods to process medicinal plants, with the most common being boiling (Jadid et al. 2020). Another study stated that decoction is most often utilized (Malik et al. 2018). The boiled method is fairly easy for the community to implement (El Amri et al., 2015).



A B

Figure 3. Percentage of growth form and plant part used by the people of Bungur and Tulakan Villages, Pacitan, East Java, Indonesia as medicinal plants. A. Growth form, B. Plant part used



A B

Figure 4. Percentage of preparation and application methods by the people of Bungur and Tulakan Villages, Pacitan, East Java, Indonesia, as medicinal plants. A. Preparation, B. Application methods

Table 3. Preparations, applications, and diseases cured by medicinal plants used by the people of Bungur and Tulakan Villages, Pacitan, Indonesia

Scientific name	Part used	Preparation	Application methods	Disease
Acorus calamus	Leaves	Decoction	Oral	Inflammation and fever
Allium sativum	Tuber	Raw	Oral	Coronary, diabetes, cholesterol
Aloe vera	Leaves	Extracted, crushed	Smearing	Hair growth shampoo, wound
Alpinia galanga	Rhizome	Decoction	Oral	Fever, warm the body
Amorphophallus muelleri	Leaves	Decoction	Oral	Cholesterol
Andrographis paniculata	Leaves	Decoction	Oral	Flu
Annona muricata	Leaves	Decoction	Oral	Heart attack, gout, hypertension, cholesterol, anemic, insomnia
Annona squamosa	Leaves	Decoction	Oral	Diabetes, body endurance
Anredera cordifolia	Leaves	Decoction	Oral	Diabetes, cholesterol, lung detoxing
Artocarpus altilis	Leaves	Decoction	Oral	Diabetes, coronary, digestion, cholesterol
Boesenbergia rotunda	Rhizome	Decoction	Oral	Cough, digestion
Carica papaya	Leaves	Decoction	Oral	Diabetes
Citrus aurantifolia	Leaves	Decoction	Oral	Cough
Clitoria ternatea	Flower	Decoction	Oral	Cholesterol
Cuminum cyminum	Leaves	Decoction	Oral	Digestion, inflammation
Curcuma longa	Rhizome	Decoction	Oral	Coronary, diabetes
Curcuma zanthorrhiza	Rhizome	Decoction	Oral	Supplement, weight gain, stomach ache
Cyclea barbata	Leaves	Decoction	Oral	Maag, stomach ache, stroke
Elephantopus scaber	Leaves	Decoction	Oral	Fever, coronary, hepatitis
Erythrina subumbrans	Stem	Decoction	Oral	Digestion
Garcinia mangostana	Fruits	Dried, decoction	Oral	Cancer, diabetes, cholesterol, stroke
Gardenia jasminoides	Leaves	Decoction	Oral	Diabetes, disgetion, stroke, maag
Graptophyllum pictum	Leaves	Decoction	Oral	Painful, wound
Gynura procumbens	Leaves	Decoction	Oral	Inflammation
Hibiscus sabdariffa	Flower	Decoction	Oral	Lose triglycerides, cholesterol
Imperata cylindrica	Rhizome	Decoction	Oral	Kidney failure
Kaempferia galanga	Rhizome	Decoction	Oral	Cough, inflammation, fever
Lantana camara	Flower	Decoction	Oral	Poison detoxification
Melaleuca leucadendra	Leaves	Distilled	Smearing	Headache, flu/cold
Morinda citrifolia	Leaves	Decoction	Oral	Diabetes, cholesterol, hypertension
Morinda citrifolia	Fruits	Blended	Oral	Diabetes, cholesterol, hypertension
Moringa oleifera	Leaves	Decoction	Oral	Cholesterol
Morus alba	Leaves	Decoction	Oral	Diabetes, coronary,
Paederia foetida	Leaves	Decoction	Oral	Cough, digestion
Pandanus tectorius	Leaves	Decoction	Oral	Hypertension, painful
Peperomia pellucida	Leaves	Decoction	Oral	Cholesterol
Persea americana	Leaves	Decoction	Oral	Kidney, hypertension, diabetes, coronary
Phyllanthus urinaria	Leaves	Decoction	Oral	Fever
Physalis angulata	Fruits	Raw	Oral	Diabetes, eye health, kidney, cholesterol
Piper betle	Leaves	Decoction	Medicinal bath	Wound
Piper ornatum	Leaves	Decoction	Oral	Vaginal discharge, smallpox, eye health
Pluchea indica	Leaves	Decoction	Oral	Diabetes, cholesterol
Psidium guajava	Leaves	Decoction	Oral	Diabetes, cholesterol
Sauropus androgynus	Leaves	Decoction	Oral	Inflammation, wound, diabetes, bone health
Sida rhombifolia	Leaves	Decoction	Oral	Gout
Smallanthus sonchifolia	Leaves	Decoction	Oral	Hypertension
Solanum torvum	Fruit	Decoction	Oral	Stomach ache, diabetes
Strobilanthes crispa	Leaves	Decoction	Oral	Diabetes, kidney stones, wound
Syzygium polyanthum	Leaves	Decoction	Oral	Cholesterol, gout, inflammation, coronary, digestion
Vernonia amygdalina	Leaves	Decoction	Oral	Thypus
Zingiber officinale	Rhizome	Decoction	Oral	Body endurance

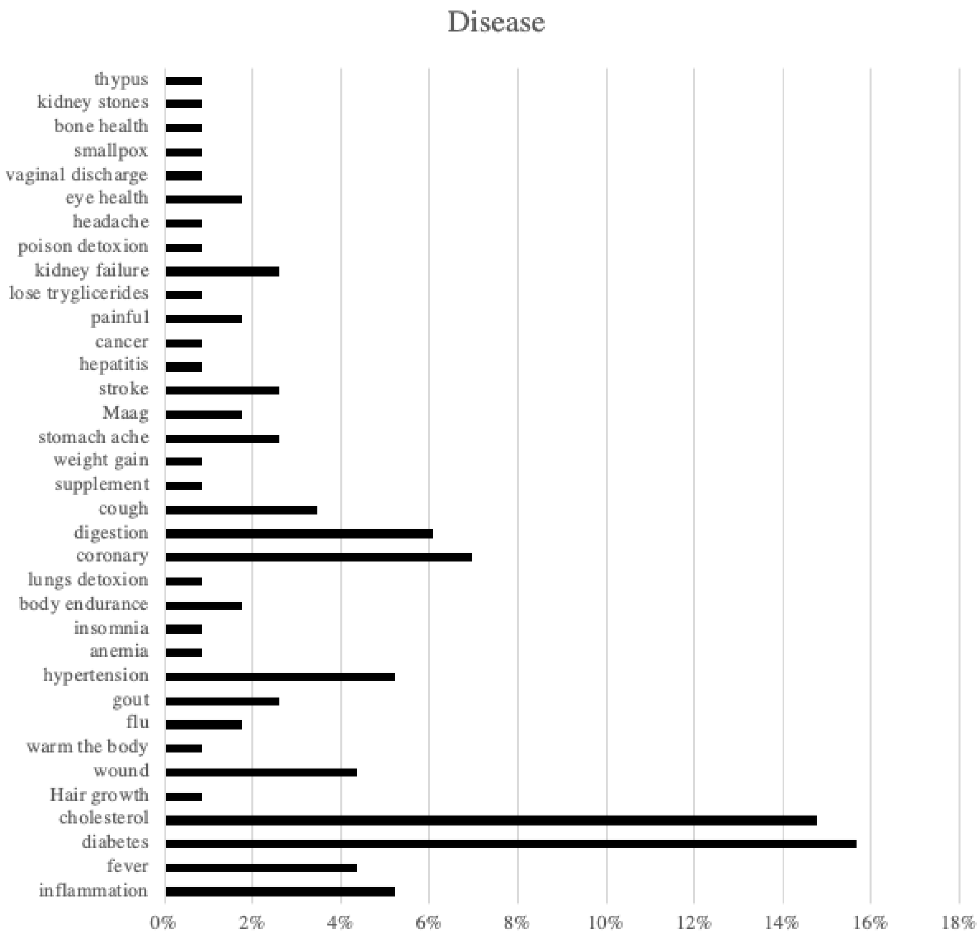


Figure 5. Percentage of diseases treated

The most common preparation method, decoction, affects the application method of these medicinal plants. The method of application with the highest percentage is consumed directly by mouth with 94%. It is followed by the smear method (smearing), accounting for 4%. Another study states that the Sasak people in Lombok are also more likely to drink medicinal plants directly in their area (Damayanti and Suhirman, 2021). Other studies show direct consumption is the most popular traditional method, followed by dermal, nasal, and anal orifice treatment (Gebremedhin and Beyene 2018).

Disease treated

From 51 plant species in total, there are 35 diseases ranging from mild to severe diseases (Figure 5). In Figure 5, it is illustrated that the people of Bungur and Tulakan mostly use medicinal plants around their homes to relieve the symptoms of diabetes, with a percentage of 15.65% of the total curable diseases. As research has been done in Morocco, some plants with less use value (UV) are believed to be used to treat diabetes (Mechchate et al., 2020). Of the various parts of the plant, leaves are the most common part for curing diabetes, supported by research that has been conducted in Congo (Masunda et al. 2019). Then the disease that may be cured by plants from Bungur and Tulakan villages is cholesterol, with a percentage of 14.78%. Previous research has also stated that some plants, such as betel leaf, garlic, and star fruit, can cure cholesterol (Jaya et al., 2019).

A percentage of 6.96% may also alleviate heart disease. As is the case with research conducted in Guizhou, China, people believe that consuming herbal tea will improve body care (Geng et al., 2022). Medicinal plants in Bungur and Tulakan also have an efficacy, such as maintaining fitness while reducing symptoms of heart disease. The next curable disease is digestive problems, with 6.09%. There are 54 species that could cure and relieve digestive problems (Bhattarai 2020). This further strengthens that digestive problems are a common problem in society, and many medicinal plants can be used to cure them. The next is to relieve the inflammation problem and high blood pressure with 5.22%. In the survey conducted in Togo, it was stated that at least one species was found in each study related to medicinal plants. This shows that hypertension can potentially be cured through various plants and processing methods (Gbekley et al., 2018).

The next efficacy that is felt by the community is to relieve and heal wounds with a percentage of 4.35%.

Besides, some plants can also relieve cough, which is calculated by the percentage of 3.48%. Medicinal plants in Bungur and Tulakan produce many efficacies such as easing gout, stomach acid, stroke symptoms, and kidney failure with a percentage of 2.61% of the total disease. In addition, it can also cure flu, increase endurance, relieve ulcer disease, relieve pain, and improve the eyes health condition by 1.74%. Other efficacy that the community can feel is growing the hair, warming the body, relieving anemia, reducing insomnia, detoxifying the lungs, increasing appetite, gaining weight, relieving symptoms of hepatitis and cancer, lowering triglyceride levels, detoxifying toxins, relieving headaches, eliminate chickenpox, improve bone health, reduce kidney stones, and relieve typhus symptoms with a percentage of 0.87% of the total.

In conclusion, the people of Bungur and Tulakan Villages utilize plants as medicine with relatively diverse species. Fifty-one (51) species of plants were identified. These medicinal plants offer properties that may treat 35 symptoms of diseases in humans. The Zingiberaceae family is the most widespread in this region, and the species is the most widely used by the community. The leaf is the most commonly used part of the plant, and it is prepared in the most typical method, which is decoction. In this area, it is also described that there is no difference in information knowledge between men and women regarding medicinal plants and traditional medical procedures. In addition, education levels do not significantly affect people's knowledge regarding medicinal plants. Meanwhile, the age of the people significantly affects their knowledge regarding the medicinal plants, with older residents tend to have better knowledge regarding the medicinal plants than younger ones. Furthermore, no special medicinal plants were found growing in the karst areas of Bungur and Tulakan Villages.

ACKNOWLEDGEMENTS

We thank the residents of Bungur and Tulakan Villages, Pacitan, East Java, Indonesia, who participated as respondents in this research.

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