PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.2916

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Growth and biomass of Porang (*Amorphophallus onchophyllus* Prain ex Hook. f.) at several ages of oil palm as a shading crop

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OPEN ACCESS

ARTICLE HISTORY

Received: 04 December 2023
Accepted: 17 May 2024

Available online
Version 1.0 : 29 June 2024

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

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Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
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Satriawan H, Fuady Z, Ernawita. Growth and biomass of Porang (*Amorphophallus onchophyllus* Prain ex Hook. f.) at several ages of oil palm as a shading crop. Plant Science Today (Early Access). https://doi.org/10.14719/pst.2916

Abstract

Oil palm, with its wide spacing and broad canopy, has the potential to be intercropped with crops that are adapted to shaded conditions. Porang (*Amorphophallus onchophyllus* Prain ex Hook. f.) is a type of plant that requires shade to grow well. Porang is known as an alternative food crop with a low glycemic index and is included in the healthy food group. This study aims to test the growth of porang in 3 groups of oil palm stands of different ages-3 years, 6 years and 9 years-and compared it with non-shaded conditions as a control. This research was designed as a field experiment using a Completely Randomised Design. The results showed that the growth of porang plants was influenced by shade, with the shade provided by 6-year-old oil palms (N2) and 9-year-old (N3) creating an ideal growing environment. This was indicated by parameters such as plant height, stem diameter, number of leaves and canopy width, which tended to be better. Similarly, nutrient uptake indicators, consisting of C, N, P and K elements, also indicated higher nutrient absorption compared to 3-year old shade (N1) and non-shaded conditions used as a control. The findings demonstrate that the presence of shade from 6 years (N2) and 9 years (N3) oil palm trees fosters an optimal growing environment for porang cultivation.

Keywords

intercropped; *Amorphophallus onchophyllus*; nutrient uptake; growth, biomass

Introduction

One of the characteristics of the oil palm is its wide canopy, which provides open space between its stands. The potential space between oil palms can be utilised for the cultivation of shade-tolerant food crops through intercropping systems. Porang (*Amorphophallus onchophyllus*) is a food crop that can be developed under wide canopy stands. One of the characteristics of the porang plant is its high tolerance to shaded environments, enabling it to thrive in plantation and forest areas (1). Porang's tolerance to low intensity (50-60 %) suggests that it can be planted under oil palm plantations, which are abundant in Indonesia. Intercropping techniques are also believed to increase the income of oil palm farmers in Indonesia, by improving the Land Equivalent Ratio (LER) (2). Previous studies have also reported the potential for porang growth under oil palm plantations (2, 3). However, there is still very limited information regarding the influence of diverse parameters found in oil palm plantations on porang's plant productivity. Porang's cultivation, due to its ability to grow well under shades, is often associated with intercropping. Previous reports have mentioned porang's intercropping with eggplant, chili and corn (4). In agroforestry system, teak and agarwood have been reported as shading plants for porang (5).

Porang can be used as an alternative food due to its relatively high nutritional content, including 20.1 % starch , 5-7 % protein, 2.7-3.8 % soluble sugar, 3.4-5.3 % ash and alkaloids, 2.6-2.8 % crude fiber, 0.105-0.141 % fat, 2.05-2.73 inorganic elements and the remainder as glucomannan (6). Furthermore, porang tubers contain a high glucomannan, constituting about 55 %-70.9 % of dry matter (7, 8). Glucomannan, a low-digestive carbohydrate, finds wide applications as a raw material for slimming drugs, low-calorie foods and beverages, medicinal tablet fillers, cosmetics, emulsifiers and natural coatings (6, 7, 9, 10). According to one report (11), glucomannan can improve digestion and prevent heart disease by lowering cholesterol and reducing the glycemic response Glucomannan can be commercially and industrially utilised as fat subsitutes (12).

Porang cultivation technology, from seedling to harvest, has been well mapped and is currently being developed under teak (*Tectona grandis*) and rosewood (*Sono spp.*) forest stands in East Java (13-16), sengon (17), rubber (18) as well as in mixed garden environments, such as in West Java (19). However, its development under plantation crop stands, such as oil palm, has never been attempted. Therefore, it is necessary to optimise the land under oil palm stands with commodities that have economic value and can grow under shade or tolerate low light intensity. Consequently, research on its growth under plantation crops, such as oil palm, is very important to be conducted.

Materials and Methods

The experiment was conducted from March to October 2023 in Bukit Sudan Village, Peusangan Siblah Krueng District, Bireuen Regency, Aceh, Indonesia. The materials used included porang tubers and plant stems ranging in size from 3 cm to 12 cm. The oil palm stands selected were 3, 6 and 9 years old, with crowns covering more than 80 % of the land. The oil palm stands had a density of 110 trees/ ha or with a spacing of 9 m x 9 m. The equipment used in this study included stationery, hoe, rope meter, machete, protractor, hygrometer, bucket, analytical balance, waste paper, plastic, lux meter and bamboo.

Planting holes were made with a depth of 10 cm to 15 cm and a width of 15 cm by 15 cm. The planting distance used for porang plants was 90 x 90 cm, with 40 tubers used for each plot. Manure and NPK were applied to the planting hole at a rate of 5 tonnes/ha and 350 kg/ha respectively. The manure in the planting hole was left for 7 days to decompose more completely. Porang plants were maintained by weeding once a week and no additional irrigation was provided during the experiment other than rainwater. Environmental factors observed included sunlight intensity, air temperature inside the stand and air humidity.

The experimental design employed was a randomised complete block design with shade treatment, namely: 1) non- shading (control treatment), 2) Shade of 3-year-old oil palm, 3) Shade of 6-year-old oil palm and 4) Shade of 9-year-old oil palm. There were 5 replicates for each treatment.

Maintenance of porang plants includes weed control and fertilisation. Weed control is performed manually by weeding around the plants. Herbicides are not used for weed control because they can interfere with the growth of porang plants.

Observations of the vegetative growth of porang plants are conducted monthly, focusing on measurements such as plant height, stem diameter, number of leaves and crown diameter. Yield parameter are assessed by observing plant biomass, including stem and leaf parts. The root part is not included in the observation due to porang's cyclic growth pattern, wherein after harvesting the upper biomass, it undergoes dormancy before regrowing. Additionally, macro nutrient uptake in plant tissue, namely the uptake of C, N, P and K is also mentioned.

Plant height was measured from the base of the stem to the end of the branched leaves after the leaves started to bloom. Measurements were taken monthly. Stem diameter was measured using a push rod. Measurements were taken at the base of the stem, in the middle and under the lowest petiole, and then averaged. The number of leaves was counted on plants with fully developed leaf organs.

In addition to plant parameters, climatic elements were also observed in this study. Rainfall was measured using a rain gauge (ombrometer), air temperature was recorded using a field thermometer, air humidity was monitored using a hygrometer, and sunlight intensity was measured using a lux meter with cal/cm^2 units.

The growth and development of porang plants are assessed by conducting the F test. If the results of the F test show significantly differences, then further testing with the Duncan Multiple Range Test (DMRT) is performed at a 5% confidence interval to determine the differences between treatments. Data processing is conducted using the Statistical Analysis System (SAS).

Results and Discussion

Table 1 shows that the lowest rainfall occurred in April, along with the average monthly air temperature and monthly air humidity. Conversely, April experiences the most intensive sunlight reception. In contrast, months categorized as wet or medium in terms of rainfall include May, June and August. In simpler terms, higher air humidity increases the probability of rain, leading to cloud formation and significant rainfall during these months. Regarding air temperature conditions, the meso-macro climatic environment encountered is categorized as suitable for optimal porang growth. This aligns with the findings of (20), which states that adequate climatic conditions for porang growth consists of 5-6 wet months

Table 1. Climatic conditions of the research site during the study

Month	Rainfall (mm)	Temperature (°C)	Humidty (%)	Day light (kal/cm²)
April	26.60	27.33	81.18	768
May	165.70	27.92	83.55	634
June	161.90	27.68	82.59	745
July	41.90	27.64	82.13	711
August	138.99	27.27	83.91	701

and relatively cool temperatures ranging from 24-30 °C, or as reported (18) with an air temperature range of 22-30 °C with 50 % shade.

Porang Growth

The results of field experiments revealed that porang seeds/seedlings planted in April 2023 exhibited slow growth of porang tuber. This was attributed to the dry-rainy season fluctuation present at the time of planting. Rainfall in the research location, as indicated in Table 1, occurred in April, categorizing it as a dry month. Porang tuber typically require one month from planting to grow. It was stated that the growth cycle of porang plants consists of four phases: the dormant phase, stem and root growth phase, tuber initiation and filling phase and old phase (21, 22).

Based on the results of analysis of variance on porang growth parameters (Table 2 and 3), shade treatment of porang growth under oil palm stands significantly affects the parameters of plant height and stem diameter at 1 - 4 months after planting (MAP) as well as the number of leaves at 3 and 4 MAP and canopy diameter (Fig. 1-3).

Plant height was measured after the leaves began to bloom from the base of the stem to the end of the leaf branching. According to the DMRT test (P 0.05 = 0.208), porang under the shade of 6-year-old oil palm (N2)

Table 2. Analysis of Variance (F-test) for the parameters plant height, stem diameter and plant nutrient uptake

	Plant Height (cm)															
Treatment	**1 MAP**				**2 MAP**				**3 MAP**				**4 MAP**			
	Mean	**±**	**SD**	**CV (%)**	**Mean**		**SD**	**CV (%)**	**Mean**		**SD**	**CV (%)**	**Mean**		**SD**	**CV (%)**
N0	10.71	±	0.87^{a}	8.12	21.68	±	1.07^{a}	4.92	35.51	±	1.58^{a}	4.45	39.09	±	0.45^{a}	1.15
N1	11.99	±	0.84^{ab}	7.01	22.95	±	6.19^{ab}	26.97	42.88	±	2.48^{b}	5.77	51.94	±	1.23^{b}	2.36
N2	13.53	±	1.35^{b}	9.94	26.70	±	3.04^{b}	11.37	43.50	±	0.12^{bc}	0.28	53.25	±	2.27^{bc}	4.25
N3	12.65	±	3.02^{ab}	23.87	26.96	±	2.74^{b}	10.15	46.38	±	4.46^{c}	9.62	55.03	±	1.33^{c}	2.42
CD	**1.76**				**3.48**				**2.67**				**1.47**			
Anova F α = 0.05	**0.119**				**0.095**				**0.000**				**0.000**			
	Stem Diameter (cm)															
Treatment	**1 MAP**				**2 MAP**				**3 MAP**				**4 MAP**			
	Mean		**SD**	**CV (%)**	**Mean**		**SD**	**CV (%)**	**Mean**		**SD**	**CV (%)**	**Mean**		**SD**	**CV (%)**
N0	0.17	±	0.06^{a}	38.95	0.22	±	0.09^{a}	41.49	0.31	±	0.06^{a}	20.84	0.40	±	0.06^{a}	14.91
N1	0.20	±	0.06^{a}	30.41	0.25	±	0.07^{a}	27.41	0.37	±	0.08^{ab}	20.06	0.49	±	0.03^{b}	6.95
N2	0.24	±	0.04^{a}	18.17	0.29	±	0.07^{a}	23.51	0.41	±	0.08^{b}	19.44	0.53	±	0.07^{b}	13.00
N3	0.23	±	0.05^{a}	23.33	0.29	±	0.10^{a}	33.33	0.44	±	0.11^{c}	25.34	0.54	±	0.03^{b}	6.08
CD	**0.05**				**0.08**				**0.08**				**0.05**			
Anova F α = 0.05	**0.192**				**0.483**				**0.125**				**0.003**			
	Nutrient Uptake (%)															
Treatment	**C-organic**				**Nitrogen**				**Phosphat**				**Kalium**			
	Mean		**SD**	**CV (%)**	**Mean**		**SD**	**CV (%)**	**Mean**		**SD**	**CV (%)**	**Mean**		**SD**	**CV (%)**
N0	34.03	±	4.93^{a}	14.49	1.32	±	0.18^{a}	13.33	0.53	±	0.16^{a}	29.47	0.89	±	0.114^{a}	12.825
N1	38.74	±	1.65^{b}	4.25	1.40	±	0.17^{a}	11.90	0.55	±	0.12^{a}	22.23	1.25	±	0.162^{b}	12.946
N2	32.16	±	6.55^{a}	20.37	1.34	±	0.09^{a}	7.00	0.55	±	0.07^{a}	12.20	1.30	±	0.125^{b}	9.5923
N3	38.32	±	4.21^{ab}	10.99	1.44	±	0.20^{a}	13.96	0.51	±	0.12^{a}	22.57	1.35	±	0.063^{b}	4.6885
CD	**4.68**				**0.16**				**0.12**				**0.12**			
Anova F α = 0.05	**0.107**				**0.643**				**0.950**				**0.000**			

Note: Numbers in the same column followed by different letters is significantly different according to DMRT test (P = 0.05).

Table 3. Analysis of Variance (F-test) for the parameters of leaves number and canopy diameter

Treatment	Leaves Number						Canopy Diameter (cm)		
	3 MAP			4 MAP			4 MAP		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
N0	7.81	± 0.77^{a}	9.90	11.30	± 1.67^{a}	14.76	25.81	± 2.20^{a}	8.53
N1	11.34	± 2.89^{b}	25.52	13.55	± 2.92^{ab}	21.52	34.65	± 3.83^{b}	11.04
N2	14.18	± 2.16^{b}	15.21	16.17	± 0.88^{b}	5.43	39.52	± 0.69^{c}	1.76
N3	12.62	± 2.52^{b}	19.99	15.66	± 2.77^{b}	17.71	35.97	± 1.82^{b}	5.05
CD		**2.23**			**2.22**			**2.41**	
Anova F α = 0.05		0.003			0.012			0.000	

Note: Numbers in the same column followed by different letters is significantly different according to DMRT test (P = 0.05).

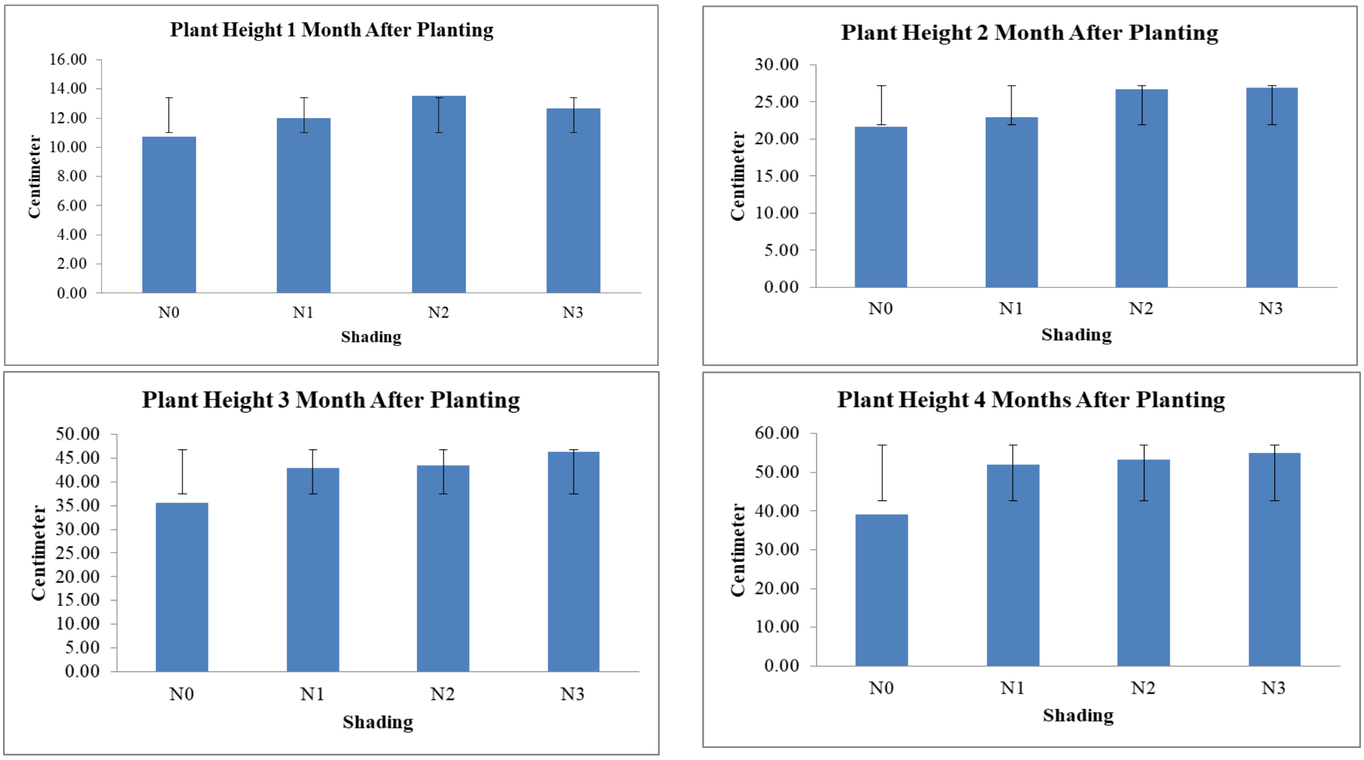

Fig. 1. Height growth of porang plants aged 1-4 months after planting.

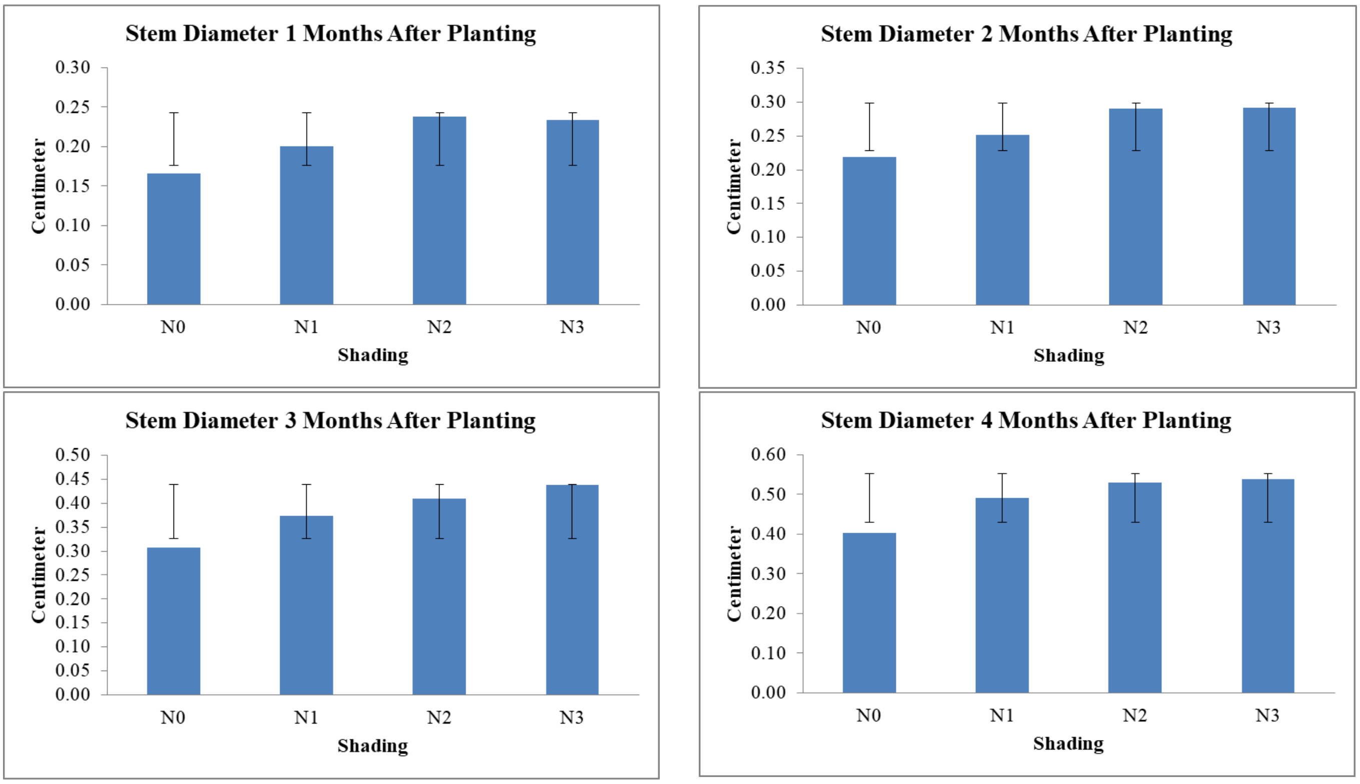

Fig. 2. Stem diameter of porang plants aged 1 month after planting (MAP) (top left), 2 MAP (top right), 3 MAP (bottom left) and 4 MAP (bottom right).

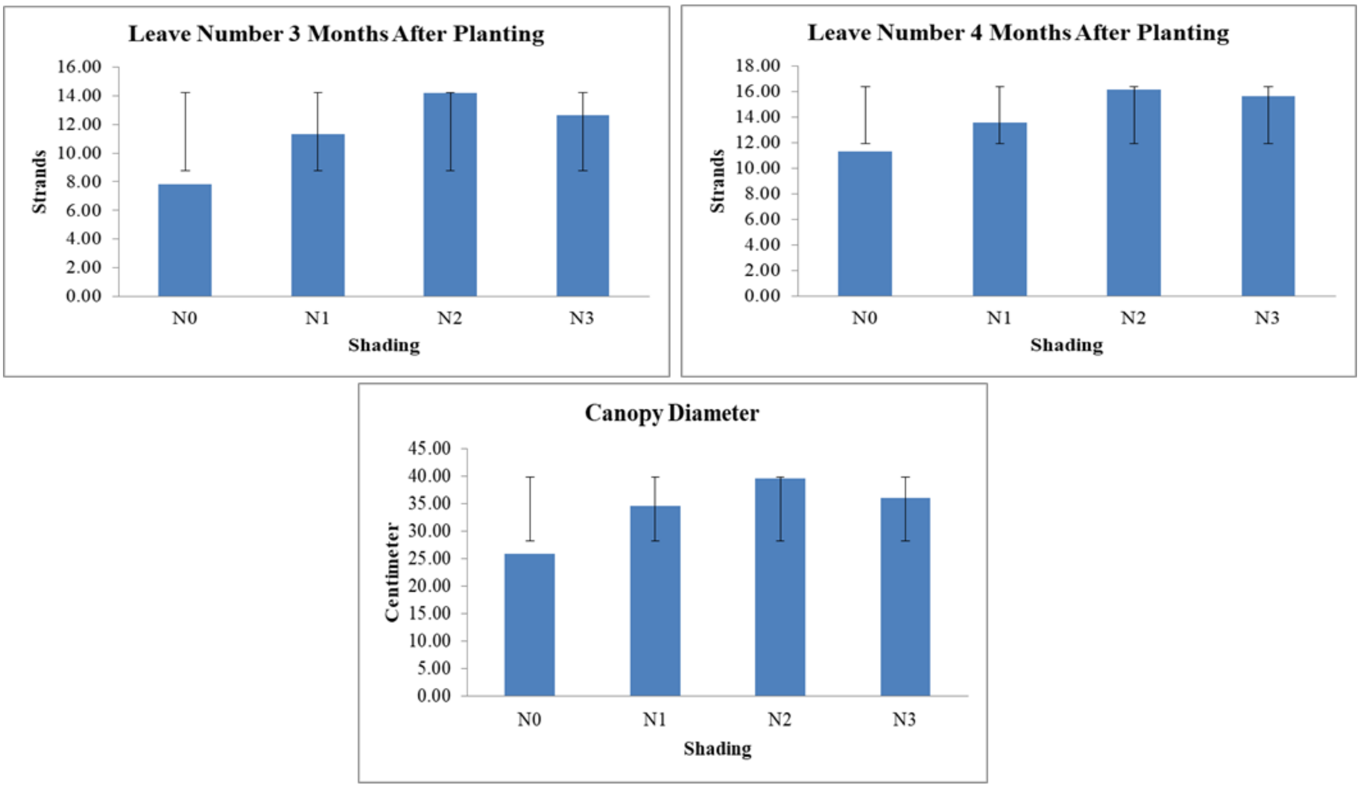

Fig. 3. Number of leaves at 3 and 4 MAP (left-right) and canopy diameter at 4 MAP.

exhibited the highest average plant height at the age of 1 MAP, significantly different from the growth of porang height under other shading conditions (Table 1 & Fig. 1). This was followed by plant height in the shade of 3 and 9 years (N1 and N3), where these three treatments were not significantly different, but significantly different from the growth of porang plant height in the control treatment (N0).

Furthermore, Fig. 1 also illustrates that the growth pattern of porang plant height at the age of 2 MAP is similar to that at the age 1 MAP. The shade treatments of 6-year-old (N2) and 9-year-old (N3) oil palms resulted in the best porang height compared to N1. Conversely, the control treatment produced the lowest porang plant height growth, significantly different from the shade treatments.

At the observation of plant height at the age of 3 and 4 MAP, a different growth pattern was observed compared to the age of 1 and 2 MAP (P 0.05 = 0.066 and P 0.05 = 0.073). During this period, the highest plant height growth was achieved in the 9-year-old oil palm shade treatment (N3), which was significantly different from the N2, N1 and control (N0) treatments. Conversely, treatments N2 and N1 did not show significant differences from each other but exhibited significantly better plant height growth compared to the control treatment.

The phenology and rate of development of a plant depend on climatic factors such as temperature, day length and water supply. Sunlight intensity is measured using a lux meter with units of cal/cm^2. In the oil palm stand, the average monthly light intensity ranges between 634 - 768 cal/cm^2. Additionally, the average daily temperature over 4 months in the oil palm stands ranged from 27.27 °C - 27.92 °C during a full day of sunlight.

It was stated that temperatures above 30 °C are critical factors for various types of plants, as protein compounds tend to denature and enzymes may become inactive (17). However, regarding photosynthesis, as measured by the amount of biomass collected, most plants exhibit a wide tolerance range. Temperatures between 25 °C - 35 °C have little effect on growth magnitude. Humidity in oil palm stands is generally high, with an average daily humidity ranging from 81.18 % - 84 % during the study period. Air humidity describes the water vapour content in the air, which is crucial factor for plant production. Water plays a vital role in transporting nutrients from the soil to the roots and other parts of the plant. The photosynthesis process can be impaired if leaf water loss reaches 30 %, and it will cease altogether if the loss exceeds 60 %.

The parameters of stem diameter and number of leaves are strongly correlated with the growth of porang plant height. Analysis of variance consistently showed that at the age of 1 MAP, there were no significant differences in the growth of stem diameter among shade treatments, as indicated by the DMRT test (P 0.05 = 0.08). However, Table 1 and Fig. 2 demonstrate that at the age of 1 MAP, shade treatments under 6 and 9 years of oil palm shade tended to produce greater stem diameter enlargement compared to the 3-year-old oil palm shade treatment and no shade, with trend values of 0.24 and 0.23 cm, versus 0.20 and 0.17 cm. Similarly, at the age of 2 MAP, the trend of stem diameter growth was consistent with the first month of observation. The growth of stem diameter at the age of 1 month after planting showed that treatments N2 and N3 still produced larger stem diameters than shade treatments N1 and N0, with values of 0.29 cm versus 0.25 and 0.22 cm (DMRT P0.05 = 0.224).

At the age of 3 and 4 MAP, the growth of stem diameter exhibited different results among all treatments (DMRT P0.05 = 0.08 and P0.05 = 0.199), with the largest stem diameter obtained in the 9-year shade treatment (N3), followed by the 6-year shade (N2). These 2 treatments were not significantly different from each other but were significantly different from the N1 and N0 treatments. Additionally, at the age of 4 MAP, significant differences were observed between the N3 and N2 treatments compared to N1 and N0 (Fig. 2).The number of leaves parameter fluctuated and was influenced by shading. The analysis revealed that the highest number of leaves in porang plants at the age of 3 and 4 MAP was obtained in plants subjected to the 6-year-old oil palm shade treatment (N2), followed by the 9-year-old shade (N3), 3 years (N1), and no shading (N0) treatments (Fig. 3). Similarly, the diameter of the porang plant canopy followed the same trend as the number of leaves parameter, with the 6-year-old shade treatment (N2) producing the largest canopy diameter, followed by N3, N1 and N0.

Previous studies have shown that porang plants are adaptable enough for intercropping under oil palm stands. Oil palm stands age 6 and 9 years provided sufficient shades for optimal porang growth. It was stated that optimum productivity in limited field tests was achieved with 75 % shades, while profitability was still attained with 25 % shade (23, 24). It was also mentioned that porang plants require only 40 % of maximum light and higher canopy density is better for porang growth (25). Optimal porang growth under sengon stands (*Parasarianthes falcataria*) was achieved at 30 % light intensity, resulting in better productivity compared to 80 % light intensity (25).

Porang adapts to shades by increasing leaf surface area, while its tolerance mechanisms involve reducing its respiration rate. Increase in shade % is associated with improved photosynthesis photochemistry efficiency, particularly at photosystem II (26). This finding aligns with the principle of utilizing land under oil palm stands with limited light intensity for cultivating shade-tolerant plants with high economic value, such as porang. It is estimated that 60 % of the area under oil palm stands can be utilized for porang cultivation (27). Plant spacing method can be implemented using a lane system between oil palm plants row, along with planting distance techniques to provide sufficient growing area and reduce competition.

Nutrient Uptake

The nutrient uptake parameters observed were the plant uptake of the elements C and K. The results of further test analysis (DMRT P 0.05 = 0.056 and 0.255) showed that the shade treatment produced no significant differences. Specifically, the shade of oil palm aged 3 years (N1) and 9 years (N3) exhibited the highest C uptake at 39.74 % and 38.32 % respectively, followed by the control treatment (N0) and N2 with 34.05 % and 32.16 %. Similarly, in the K uptake parameter, the highest uptake was found in the N3 treatment (1.35 %), followed sequentially by N2, N1 and N0. The N3, N2 and N1 treatments were not significantly different from each other but were significantly different from the control treatment (Fig. 4).

Unlike the uptake of C and K, the shade treatment did not have a significant effect on the uptake of N and P nutrients in porang plant tissue. However, based on the average values of the treatment, porang plants grown in the shade of 9-year-old oil palm (N3) exhibited the highest N nutrient uptake (1.44 %), followed by treatments N1, N0

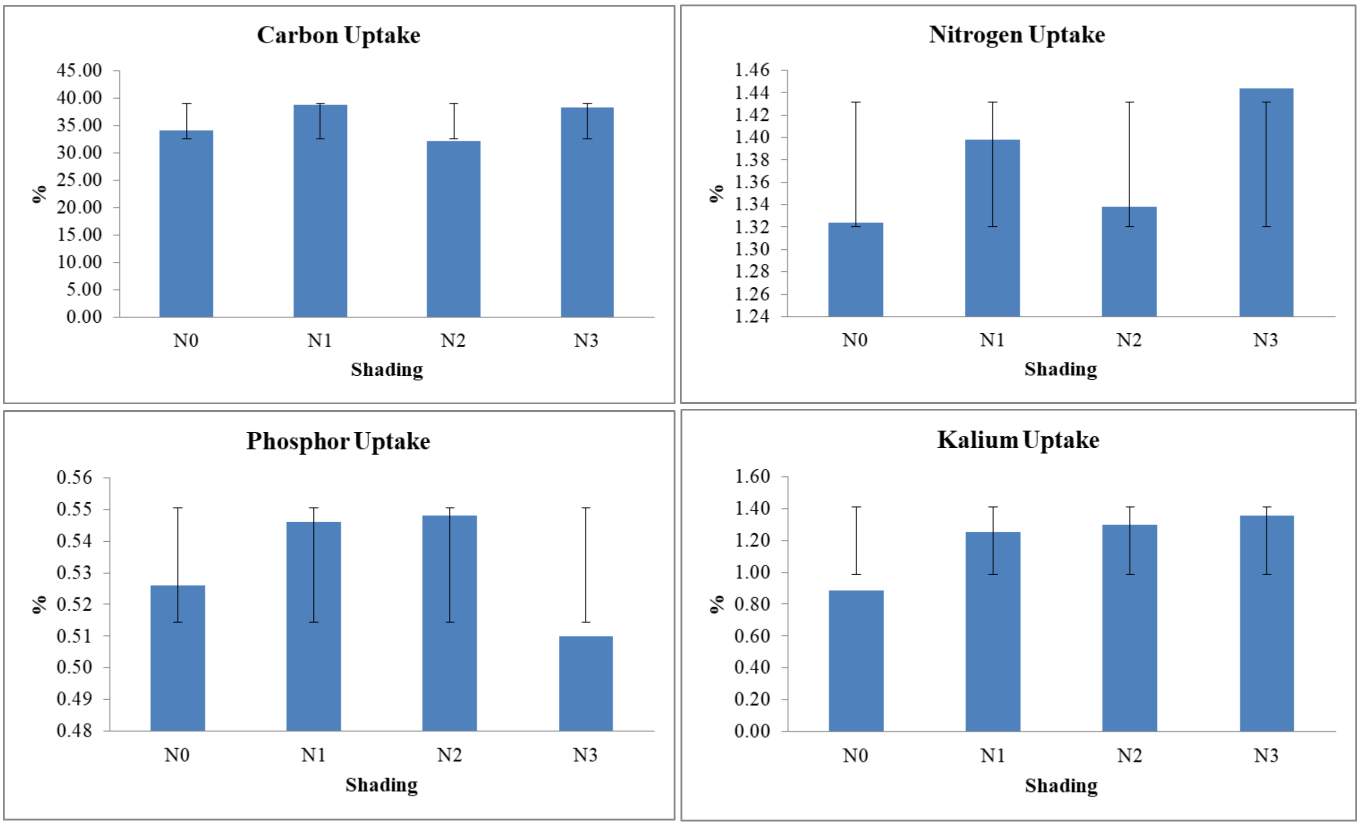

Fig. 4. Nutrient uptake levels of C, N, P and K in porang plant tissues.

and N2, with values of 1.40 %, 1.34 % and 1.32 % respectively. Regarding the P uptake parameter, the N1 and N2 treatments together exhibited a uptake of 0.55 %, followed by the N0 and N3 treatments,with values of 0.53 % and 0.51 % respectively. It is important to note that the intercropping system does not affect the overall land fertility; in fact, intercropping land areas showed higher nutrient content compared to monocultured land. However, the duration of intercropping periods is need to be observed, as a prolonged cultivation period may result in nutrient depletion due to intercropping practices.

Biomass Weight

Another important growth parameter observed in this study was the plant biomass weight. Biomass weight indicates the accumulation of growth responses to all growth factors, including shading in this case. The results showed that the shade treatment significantly affected the wet biomass of plants (Table 4 and Fig. 5). The N3 and N2 treatments produced heavier wet biomass weights than the N1 and N0 treatments. Statistically, these 2 treatments (N3 and N2) were significantly different from the control treatment (N0), but not significantly different from N1 (DMRT P 0.05 = 0.145). This implies that the non-shading treatment (N0) had the smallest biomass weight. Similarly, regarding the dry biomass weight, the N3 treatment was significantly different from the N1 and N0 treatments, but not significantly different from N2. On the other hand, the N2, N1 and N0 treatments were not significantly different from each other (DMRT P 0.05 = 0.055). Based on Table 4 and Fig. 5, the heaviest dry biomass was found in N3 at 36.96 g, while the lowest was in the control treatment, weighing 28.36 g. The highest wet biomass was also found in the N3 treatment.

Conclusion

This research elucidates the significant influence of shading, particularly under oil palm shade conditions, on the growth of porang plants. Specifically, the findings demonstrate that the presence of oil palm shade at 6 years (N2) and 9 years (N3) of age fosters an optimal growing environment for porang cultivation. This assertion is supported by observed improvements in crucial growth parameters such as plant height, stem diameter, leaf count and canopy width under these shaded conditions. Moreover, nutrient uptake indicators, encompassing essential elements such as C, N, P and K exhibit enhanced absorption levels in porang plants subjected to 6 and 9-year-old oil palm shade compared to both 3-year-old shade (N1) and unshaded control (N0). These findings underscore the potential for leveraging oil palm shading techniques to optimize porang cultivation practices, thereby contributing to the sustainable development of agricultural systems.

Acknowledgements

This research was supported by the Ministry of Research and Technology/Research and Innovation Agency of the Republic of Indonesia through Higher Education Excellence Basic Research Grants.

Authors' contributions

HS, ZF and ER conducted the research design, participated in data collection and drafted the manuscript. HS and ER Also perform statistical analysis of data, participated in the preparation and alignment of the manuscript, as well as general coordination. All authors read and approved the final manuscript.

Table 4. Analysis of Variance (F-test) for the parameters of plant biomass

Treatment	Biomass (gr)							
	Wet Weight				Dry Weight			
	Mean		SD	CV	Mean		SD	CV
N0	124.48	±	29.34[a]	23.57	28.36	±	2.21[a]	7.80
N1	137.08	±	38.98[ab]	28.43	29.26	±	3.89[a]	13.31
N2	160.06	±	30.95[b]	19.33	33.50	±	4.10[ab]	12.25
N3	163.48	±	46.61[b]	28.51	36.96	±	10.56[b]	28.58
CD	**37.09**				**6.09**			
Anova F α = 0.05	**0.320**				**0.136**			

Note: Numbers in the same column followed by different letters is significantly different according to DMRT test (P = 0.05).

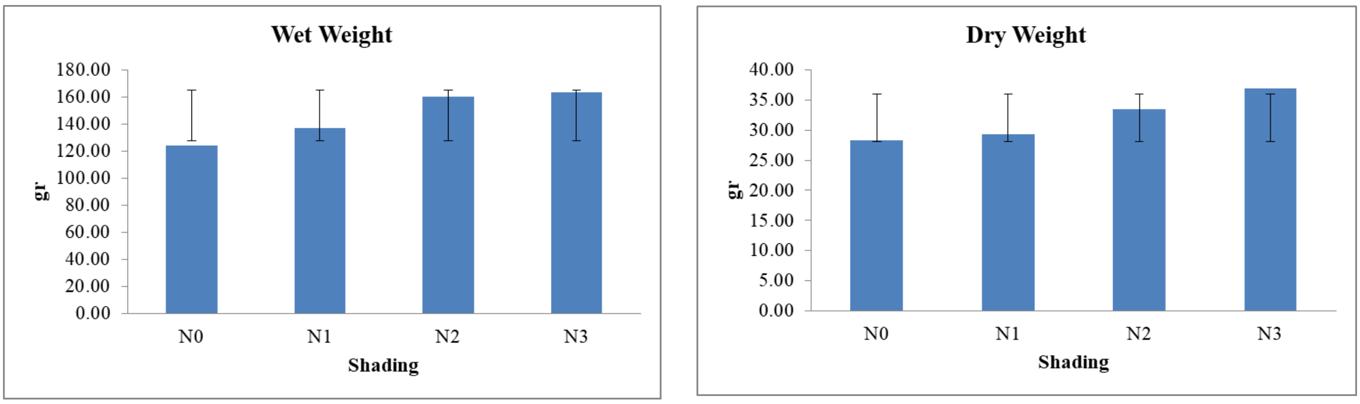

Fig. 5. Wet and dry biomass weight of porang plants.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None.

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