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Agronomic assessment of corn utilization as cocoa intercrop under coconut stands

I Butolo[1], F Hasan[2] and Z Sirajuddin[3]
[1] Development Planning Agency at Sub-National, Gorontalo Province, Jl. bypass Kelurahan Tamalate Kecamatan Kota Timur, Kota Gorontalo, Indonesia
[2] Department of Agrotechnology, Faculty of Agriculture, Universitas Ichsan Gorontalo, Jl. Ahmad Najamuddin, Kota Gorontalo, Indonesia
[3] Department of Agribusiness, Faculty of Agriculture, Universitas Negeri Gorontalo, Jl. Jend. Sudirman No.6, Kota Gorontalo, Indonesia 96128

Email: fardiansyahhasan@gmail.com

Abstract. Cocoa is known as shade-loving plants, i.e. plants that suitably grow with shaded conditions. Therefore, particular cultivation techniques are needed, such as planting shade trees to cover cocoa trees from direct sunlight exposure. The utilization of shade-loving plants from annual and seasonal crops, such as coconut and corn, can provide several benefits for farmers, including optimal early growth of cocoa seedlings, and the byproduct of shade-loving plants can provide short-term economic benefits for farmers. Corn plants in sustainable cocoa farm management are grouped as pioneer plants that can provide temporary shade so that cocoa plants can be protected from direct sunlight because cocoa is known as a shade-loving plant. One of the efforts to get short-term income for farmers is to utilize corn as an intercrop while allowing for the generative phase of cocoa plants. This research aimed to find the growth and production of several corn varieties and their effect on cocoa growth under shade. It was conducted in a farmer's field in Bualo Village, Paguyaman subdistrict, Boalemo District, Gorontalo Province from June to November 2022. This research employed a Randomized Group Design consisting of four treatments of corn varieties, namely: BISI 18 (V1), BISI 99 (V2), NASA 29 (V3); and NK 6172, repeated 4 times with 16 experimental units. The results explained that all varieties of corn were able to adapt and tolerate conditions under coconut trees as shades, while the BISI 18 variety showed the highest production yield. Furthermore, there is a positive correlation between the use of corn as an intercrop with the vegetative growth of cocoa plants.

1. Introduction

Cocoa (*Theobroma cacao* L.) is one of the tropical plantation commodities that play an important role in Indonesian economy, especially in providing raw materials in the industrial sector, employment rate, and earning foreign exchange. Indonesia is the third largest producer and exporter of cocoa in the world after Ghana and Ivory Coast. However, based on data from the Central Bureau of Statistics of the Republic of Indonesia, there has been a decrease in the area of cocoa plantations between 2015-2019 [1]. Problems faced by cocoa farmers include pest attacks, lack of farmer's knowledge, the uncertainty of farmer's income, and changes in environmental conditions [2]. Cocoa development, especially in Gorontalo Province, highly rely on farmer's motivation and the Government's commitment to encourage cocoa a regional superior commodity [3].

Planting cocoa trees in coconut plantations with an intercropping model can increase the area of cocoa cultivation. Cocoa is known as a shade-loving plant, making it suitable to be planted under coconut stands to utilize and obtain optimal environmental conditions for cocoa growth, protected from direct sunlight and increase efficient land use [4].

Using shade through intercropping techniques can be undertaken from the beginning phase of planting cocoa seedlings to the cultivation field. One of the critical phases of successful cocoa cultivation is during the early growth period of seedlings after transplanting the seedlings to the cultivation field. Intercropping can guarantee the success of cocoa cultivation in experiencing uncertain climate change. Research indicates that cocoa seedlings shaded by other plants grow optimal compared to seedlings in open areas exposed to direct sunlight [5]. Recommendations for plant species that can be used for shades include corn, sorghum, pumpkin, sweet potato, and ginger. Among these crops, corn is the most suitable crop as cocoa intercrop in terms of market opportunities and ease of maintenance and harvesting.

Corn in sustainable cocoa farm management is classified as a pioneer crop that can provide temporary shade to protect cocoa seedlings from direct sunlight. In terms of ecology, planting corn as an intercrop can reduce the rate of surface runoff, leaching of soil nutrients and erosion, suppress the growth of weeds. Corn debris can be used as a source of organic matter that can improve the soil structure and increase soil fertility [6]. Furthermore, from an economic point of view, farmers generate income from the corn production.

The problem faced by cocoa farmers is the poor results generated from intercrop model between cocoa, corn, and coconut due to the type of corn varieties intolerant of shaded conditions and the lack of cultivation techniques, and the lack of farmer's knowledge in growing cocoa plants both on open and shaded land. Therefore, in this research, several types of shade-tolerant corn varieties were tested. This research also compared the different growth of cocoa plants that were only planted on land under coconut stands with cocoa planted with corn as an intercrop.

2. Methods

2.1. Time and place

Field experiments were conducted in a farmer-owned coconut plantation in Bualo Village, Paguyaman Subdistrict, Boalemo District, Gorontalo Province. Soil sample analysis was conducted at the soil and fertilizer testing laboratory of the Center for Agricultural Technology Assessment of South Sulawesi. The research was conducted from June through November 2022.

2.2. Research design

The research design employed a Randomized Group Design with four replications. The treatment was the type of hybrid corn varieties consisting of 4 levels, namely V1 = BISI 18 variety; V2 = BISI 99 variety; V3 = NASA 29 variety; V4 = NK 6172 variety. Each experimental unit measured 8 m x 8 m and was placed on each coconut tree with a coconut spacing of 10 m x 10 m. Cocoa seedlings were planted in between corn plants at the age of 2 weeks after planting. Each experimental unit contained 4 cocoa seedlings with a spacing of 4 m x 4 m.

2.3. Research implementation

The research site was a 15-year-old coconut plantation with an altitude of 15 meters. Tilling was conducted once to create planting lanes. Aglime application was carried out at a dose of 500 kg/Ha. Planting holes were made for the cocoa planting with the size of 40 cm x 40 cm. Corn seeds was planted with a spacing of 70 cm x 20 cm with one seed per planting hole. The planting of cocoa seedlings was conducted when the corn age reached two weeks after planting. Weeding was carried out at four weeks after planting. Furthermore, corn fertilization was conducted twice at the age of three weeks after planting and six weeks after planting with the total doses of Urea 200 kg per hectare and NPK 400 kg per hectare. Cocoa fertilization was done simultaneously after planting with a dose of 50 grams of NPK per plant. Corn was harvested at the age of 105 days after planting.

2.4. Observation variables

Observation of corn growth was conducted by observing plant height, number of leaves, and stem diameter. Furthermore, the measurement of production yield includes cob length, cob weight, and dry kernel production per hectare. Cocoa growth variables observed include height increase, number of leaves, and stem diameter. Soil samples were also tested before and after the research to determine soil nutrient status. Furthermore, sunlight intensity was measured to see the level of shading under coconut stands. Calculation of projected corn farming analysis was conducted to see the comparison between the four tested corn varieties.

2.5. Data analysis

Data from the study were tested with Analysis of Variance (ANOVA) at a 95% confidence level. If there was a significant effect, it was followed by LSD 0.05 test. Furthermore, a correlation test was conducted to see the correlation between corn and cocoa growth as well as a farming analysis of the four corn varieties.

3. Results and discussion

3.1. Soil characteristics

The test results of the physical and chemical properties of soil at the research site showed that most of the soil constituent material was sand (table 1). The test results before and after planting indicated that the sand content was in the range of 69-74%. The high sand composition caused the infiltration rate (water absorption) to be faster than soil types with higher amounts of dust and clay. This results in the water around the soil surface were to be quickly lost either absorbed or evaporated (evaporation). Yuliprianto [7] explained that sandy soil types have a low ability to hold water, so dissolved nutrients are lost through leaching.

Table 1. Soil physics and chemical characteristics before and after planting of corn

Parameter	Unit	Before planting		After planting	
		Value	Category	Value	Category
Soil texture					
Sand	%	69		74	
Dust	%	27	Loamy sand	23	Loamy sand
Clay	%	4		3	
Soil nutrients					
Ph		7.50	Neutral	6.26	Slightly Sour
C-organic	%	2.52	Medium	1.09	Low
Nitrogen	%	0.17	Low	0.13	Low
P_2O_5	ppm	21	Low	23	Low
K_2O	ppm	165	Low	18	Low
KTK		5.26	Low	3.33	Very Low
C/N ratio		15		8	

There were differences in soil nutrient levels before and after corn planting. In general, the soil in the location under the coconut shade had a low status, indicated by the low levels of Nitrogen, Phosphorus, Potassium, and Cation Exchange Capacity. Furthermore, the application of dolomite lime before planting had a direct effect on pH conditions. The results of the soil pH test at the time of the initial observation of the research site showed a pH of 5 which was in an acidic condition. Lime application is known to be able to increase soil pH to 7.5 or in neutral conditions. Increasing soil pH to neutral directly affects nutrients in the soil. The lime application can increase soil pH so that it can

increase the availability of nutrients that can be absorbed by plants [8,9]. Measurement of soil nutrient status after the research indicated a decrease in soil nutrient levels (table 1). It was due to plant absorption and the leaching of nutrients by rain during corn plant growth.

3.2. Sunlight intensity

Measurements of sunlight intensity were made 3 times, namely when the corn plants were 3, 5, and 7 weeks after planting (WAP) with four intervals of observation time. Measurements were made by placing the tool at 2 points, namely open points and shaded points. The measurement results were then calculated as a percentage of the level of closure of solar radiation due to shading. The measurement results are presented in figure 1.

The observation results showed that the level of closure of sunlight intensity under coconut stands ranged from 48% to 65%. The greatest level of shading was at 08.00 am with a closure level of up to 60%. The lower the sunlight received by plants can affect plant growth. It is related to the photosynthetic capacity of plants which decreases due to a lack of energy from sunlight.

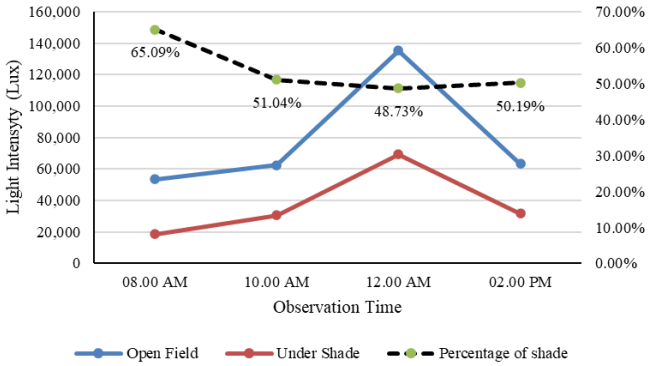

Figure 1. The average intensity of sunlight in open and shaded conditions

3.3. Corn growth

Observations of plant height, the number of leaves, and stem diameter of corn plants showed a significant effect on the four varieties tested. The highest average corn plant height was produced by BISI 18 variety which amounted to 226.60 cm. Plant height growth can be influenced by genetic factors of varieties and environmental factors [10]. The increase in shading intensity, the lower the level of sunlight received by corn plants. It is related to the occurrence of etiolation caused by the activity of the hormone gibberellin [11]. The difference in plant height that occurred was more dominantly influenced by the genetic characteristics of corn varieties because in general, the level of light acceptance of the four varieties was the same [12].

The results of measuring the number of leaves and stem diameter at 7 weeks after planting also showed a significant effect. The BISI 18 variety produced an average number of leaves of 12.10 and a stem diameter of 1.71 cm which was higher than the other corn varieties tested. However, the growth of the number of leaves and diameter was still lower when compared to the potential growth of corn in the open field. Corn in the open field can reach 16 leaves with a stem diameter of 2 cm. Sahuri [13] reported in his research that corn plants experience inhibition of corn plant growth in shade conditions of more than 50%. The BISI 18 variety is known to adapt well to conditions under the shade of rubber plants.

Table 2. The average plant height, number of leaves, and diameter of stem with different corn varieties at 7 weeks after plant (WAP)

Corn varieties	Growth variables		
	Plant height (cm)	Number of leaves	Stem diameter (cm)
V1 (BISI 18)	224.60 a	12.10 a	1.71 a
V2 (BISI 99)	202.21 ab	11.23 ab	1.56 b
V3 (NASA 29)	193.30 b	11.00 b	1.53 b
V4 (NK 6172)	183.70 b	10.65 b	1.59 ab
LSD (0.05)	22.92	0.92	0.17

Note: The numbers followed by the same letters in the columns (a, b) mean that they were not significantly different in the LSD 0.05 test.

3.4. Corn production

Analysis of Variance showed no significant effect of production variables on the four corn varieties tested. The average length of corn cobs of the four varieties was in the range of 10-12 cm and the weight was in the range of 98-120 grams per cob. There was a difference between the length and weight of the cob where the largest average cob length was produced by the NASA 29 variety, while the highest cob weight was produced by the BISI 18 variety. Referring to the variety description information, BISI 18 has a high yield level, meaning that the seed weight was heavier than other types of corn varieties. The calculation of dry weight of kernel production per hectare indicated the highest yield in the BISI 18 variety. The results of this research agree with the research of Suparwoto et al. [14]. The research reported that the BISI 18 corn variety can adapt well as an intercrop in rubber plantations. Furthermore, it was reported that the production level of BISI 18 corn under rubber shade was 4.1 tons per hectare of dry shells. Shade conditions cause a decrease in photosynthetic activity as a result of a decrease in the net assimilation of plants [15]. The response and level of plant adaptation depend on the effectiveness of light capture and its use as well as the response of genetic traits and environmental conditions [16]. In the line with the research of Dewi et al [12] that increase the levels of shade up to 50% can reduces the production of corn.

Table 3. The average plant height, number of leaves, and diameter of stem with different corn varieties at 7 weeks after plant (WAP)

Corn varieties	Production variables		
	Length of corn cob (cm)	Weight of corn cob (g)	Dry weight of kernel (Kg. ha^{-1})
V1 (BISI 18)	11.52	120.41	4453.13
V2 (BISI 99)	10.92	98.47	4179.69
V3 (NASA 29)	12.70	115.88	4218.75
V4 (NK 6172)	10.74	108.17	3984.38
LSD (0.05)	ns	ns	ns

Note: ns= not significant at 95% confidence level

3.5. Cocoa growth

Cocoa is an annual crop that grows and produces in the tropics. Observations and measurements of growth variables were carried out to see the growth rate of cocoa under coconut and corn shades and then compared with cocoa grown under coconut shades without corn. The measurement results presented were incremental values obtained from the difference in height growth, the number of leaves, and stem diameter measured at the beginning of planting and 3 months after corn planting (table 4).

Observations of cocoa growth in each plot of corn varieties showed different results although not significant. Measurements of the increase in plant height, number of leaves, and stem diameter of cocoa indicated that planting corn as an intercrop was able to increase the vegetative growth of cocoa plants (table 4). The four varieties tested as intercrops were able to increase cocoa height growth up to 23 cm, obtained by the BISI 18 variety.

Table 4. The average cocoa enhancement of plant height, number of leaves, and diameter of stem under different corn varieties at 12 weeks after planting (WAP)

Cocoa position	Vegetative growth enhancement of cocoa		
	Plant height (cm)	Number of leaves	Stem diameter (cm)
V1 (BISI 18)	23.00	6.00	0.92
V2 (BISI 99)	18.25	7.00	0.78
V3 (NASA 29)	17.00	5.75	0.80
V4 (NK 6172)	15.25	4.00	0.79
Without corn	7.75	2.38	0.36

There was a difference in the growth of cocoa grown only under coconut shade compared to cocoa grown under coconut + corn shade. The average growth of cocoa grown only under coconut shade showed an increase in plant height of 7.75 cm during the 3 months of growth, while cocoa grown with corn as an intercrop indicated a higher value of height increase which was in the range of 15 cm - 23 cm.

These results agreed with the research conducted by Saleh and Jayanti [17] stating that there were differences in the growth of cocoa seedlings grown under shade and in open spaces. In addition to shade, other influencing environmental factors were cloud cover and rainfall. The slow growth of cocoa at high lighting levels was caused by limited leaf growth due to high transpiration rates [18].

3.6. Correlation analysis of corn growth with cocoa growth

The analysis showed that there was a positive correlation between corn growth and cocoa growth in all observed variables (> 0). Significant correlations were found between corn plant height, cocoa height, and cocoa stem diameter. It implied that an increase in corn plant height was able to spur the growth of cocoa height and stem diameter. Based on the report of Galyuon et al. [19], there were differences in the morphological characteristics of cocoa growth in full sunlight conditions with conditions shaded up to 50%. Cocoa plants shaded up to 55% were able to grow optimally in terms of leaf size and area as well as stem growth. Under shaded conditions, cocoa leaves were able to produce more chlorophyll which serves to increase the effectiveness of light energy capture for photosynthesis [20].

Table 5. Correlation analysis between vegetative growth of corn and vegetative growth of cocoa

Variables	*Plant height of corn*	*Number of leaves of corn*	*Stem diameter of corn*
Height of cocoa	0.53*	0.32	0.08
Number of leaves of cocoa	0.22	0.26	0.07
Stem diameter of cocoa	0.63**	0.39	0.54*

Notes: * = Correlation is Significant at 0.05 level; ** = Correlation is Significant at 0.01 level

3.7. Farming analysis

Based on the results of the analysis, it is known that the four corn varieties tested provide short-term added value to farmers. In terms of income, corn with BISI 18 produced an income level of IDR 7,170,800 per hectare and followed by NASA29 at IDR 6,999,800. The BISI 99 and NK 6172 varieties respectively had income values of IDR 6,334,400 and IDR 5,557,400. Furthermore, when viewed from the ratio of revenue to costs, the highest value was obtained in corn farming of NASA 29 varieties with a value of 1.86, followed by corn farming of BISI 18 varieties with a value of 1.81. Meanwhile, the BISI 99 and NK6172 varieties produced R/C ratio values of 1.73 and 1.63 respectively. In general, the four varieties were feasible to be cultivated by farmers as intercrops. The consideration was on seed stocks not always being available all the time. Production inputs not used by farmers include dolomite lime which in this farming projection cost up to IDR 1,250,000 per hectare. In addition, the application of soil conditioners before planting using liquid fertilizer and bio decomposer was also a new technology adoption for farmers.

Table 6. Farming analysis of various hybrid corn varieties under coconut stand

Description	Farming cost (IDR)			
	BISI 18	BISI 99	NASA 29	NK 6172
A. Production input				
Corn seeds	1,425,000	1,275,000	750,000	1,350,000
Seed treatment	175,000	175,000	175,000	175,000
Soil Liquid organic fertilizer	30,000	30,000	30,000	30,000
EM4	30,000	30,000	30,000	30,000
Dolomite	1,250,000	1,250,000	1,250,000	1,250,000
Urea N	450,000	450,000	450,000	450,000
NPK Phonska	920,000	920,000	920,000	920,000
Systemic herbicide	160,000	160,000	160,000	160,000
Selective herbicide	300,000	300,000	300,000	300,000
Insecticide	220,000	220,000	220,000	220,000
Foliar fertilizer	100,000	100,000	100,000	100,000
B. Labor (IDR)				
Land preparation	500,000	500,000	500,000	500,000
Planting	800,000	800,000	800,000	800,000
Fertilization	600,000	600,000	600,000	600,000
Pest control	400,000	400,000	400,000	400,000
Harvest	1,000,000	1,000,000	1,000,000	1,000,000
Processing	500,000	500,000	500,000	500,000
Total A+B	8,860,000	8,710,000	8,185,000	8,785,000
C. Yield				
Crop yield (kg/Ha)	4,453	4,179	4,218	3,984
Selling price (IDR/Kg)	3,600	3,600	3,600	3,600
Return	16,030,800	15,044,400	15,184,800	14,342,400
Net income	7,170,800	6,334,400	6,999,800	5,557,400
R/C ratio	1.81	1.73	1.86	1.63

4. Conclusion

Based on the research results, the conclusions are as follows:

1. The four tested varieties of corn were able to adapt and tolerate conditions under shade (coconut stands) by maintaining their cultivation techniques.

2. There was a positive correlation indicated by the presence of corn as an intercrop to spur the vegetative growth of cocoa plants. Cocoa plants under corn + coconut shade can grow more optimally compared to cocoa plants that only grow under coconut stands.
3. The BISI 18 and NASA 29 varieties are more recommended for cocoa intercropping based on the R/C ratio value of farming analysis.

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