

The effect of nitrogen fertilizer on hybrid maize yields under the shade of coconut trees

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Abstract. The need for maize in West Kalimantan is around 320,000 tonnes per year, most of which is still imported from outside the region. Cultivating the maize under the shade of coconut trees is an alternative to meet the needs of maize in West Kalimantan and hence improvement on the cultivation of maize under the shade of coconut trees should be taken seriously. This study aims to determine the effect of nitrogen (N) fertilizer on the growth and yield of hybrid maize under the shade of coconut trees. The research method used a factorial randomized block design consisting of 2 factors. The first factor is maize variety (Nasa 29, Bima 19, Bima 20, JH 21 and Pioneer 35) and the second factor is nitrogen fertilization (64 kg ha⁻¹, 86.5 kg ha⁻¹, 109 kg ha⁻¹, and 131.5 kg ha⁻¹) of N, hence 20 treatment combinations are obtained and repeated 3 times. The results showed that the Nasa 29 variety with N fertilizer of 131.5 kg ha⁻¹ produced the highest maize grains yield of 4.8 t ha⁻¹. Therefore the using of Nasa 29 variety with the 131.5 kg ha⁻¹ of N fertilizer is recommended for intercropping system under the shade of coconut trees.

1 Introduction

The demand for corn in Indonesia continues to increase every year, especially for food, animal feed and industrial raw materials. In 2018, the Indonesian corn production projected to 26.5 million tons was increased in 2019 to 27.8 million tons of dry grains. The efforts to meet the corn production objective can be done by optimizing plantation land, such as coconut, oil palm and rubber plantations. This three types of plantation crops covered an area of 19.5 million hectares, and 3.2 million hectares that have the potential to be planted with corn in the immature plantations (TBM), non-productive plants (TTM) and damaged or less productive plants [1].

In West Kalimantan, there is open space between coconut plants that can be planted with food crops such as corn. About 80% of the land between coconut plants has the potential for intercrop with corn [2]. Corn production in West Kalimantan in 2020 is 103,742 tons and the productivity is 3.7 t/ha. The need for corn in West Kalimantan is around 320,000 tons per year, most of them is still imported from outside the region [3]. In an effort to meet the demand for corn that can be realized by utilizing of coconut plantation land as an intercrop plant. The results from some research showed that corn grown as intercrops among rubber plants can increase corn production and profitable with an R/C of 1.62 [4].

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The growth and production of maize is largely determined by the climate, especially temperature, rainfall, the sunlight intensity and the nutrients absorption from the soil [5]. Nitrogen elements will be absorbed by plants during the growth period until seed maturation, therefore this plant requires continuous availability of nitrogen at all stages of growth until seed formation [6]. One of the macro nutrients required by corn plants during their life cycle is nitrogen element [7,8].

The functions of nitrogen in plants are as a synthetic material for chlorophyll, protein, and amino acids [9]. Appropriate fertilizer application during maize plant growth can increase the maize yield. The nature of nitrogen fertilizers is generally mobile, so to reduce nitrogen loss due to leaching and evaporation, the nitrogen is given gradually. Lack or inappropriate application of nitrogen fertilizer provides a very detrimental effect to corn plants. In general, nitrogen fertilizers can increase corn production, which is nitrogen required by corn plants throughout their growth. Therefore, there is a requirement for an in-depth study about the effect of shading and level of nitrogen fertilization on the growth and yield of maize as an intercrop among coconut plants. The purpose of this study is to determine the effect of nitrogen fertilizer application on the growth and yield of several hybrid maize varieties under coconut trees.

2 Materials and methods

This research was carried out in the field experimental station of the Agricultural Technology Research and Assessment Installation (ATRAI) in Sungai Kakap, West Kalimantan, from February to June 2019. The materials used include several varieties of corn seeds, agricultural production input like fertilizers and other auxiliary materials, as well as stationery and recording sheet for the field work.

This study used a factorial randomized block design (RCBD) that consisted of 2 factors, the first factor is variety and the second factor is the level of nitrogen fertilizer. The treatments of this experiment were following these arrangements:

Factor I. Varieties consisting of 5 varieties :

V1 = Nasa 29

V2 = Bima 19

V3 = Bima 20

V4 = JH 21

V5 = Pioneer 35

Factor II. Level of Nitrogen (N) fertilizer which consists of 4 levels, include :

N1 = 64 kg ha⁻¹ of N fertilizer

N2 = 86.5 kg ha⁻¹ of N fertilizer

N3 = 109 kg ha⁻¹ of N fertilizer

N4 = 131.5 kg ha⁻¹ of N fertilizer

From those two factors, there were 20 treatment combinations with 3 replications to produce 60 treatment plots. The treatment combinations are presented in Table 1.

The data from the experimental results of the 2 treatment factors were analyzed using the F test and continued with the LSD at the level of 5% [10]. The variables observed were (1) plant height (cm), (2) cob height (cm), (3) plant height ratio with cob height, (4) male flower age (days), (5) female flower age (days), (6) delay day (days), (7) ear length (cm), (8) ear circumference (cm), (9) number of seeds per row (seeds), (10) number of seeds per ear circumference (seeds), (11) number of seeds per cob (seeds), (12) weight of 1000 grains (g) and corn productivity per hectare (t ha⁻¹).

The dose of fertilizing corn using agricultural lime 500 kg ha⁻¹, manure 2 t ha⁻¹, NPK 16-16-16 400 kg ha⁻¹ then urea fertilizer as treatment dose N 64 kg ha⁻¹ without urea fertilizer, dose N 86,5 kg ha⁻¹ added urea 50 kg ha⁻¹, dose of N 109 kg ha⁻¹ added urea 100 kg ha⁻¹ and dose of N 131.5 kg ha⁻¹ added urea 150 kg ha⁻¹. Corn that planting between coconut plants was carried out at a distance of 1.5 meters from the coconut tree, while the spacing of corn of 70 cm x 20 cm and coconut planting distance of 8 m x 8 m. In addition to N fertilizer as a treatment, maize plants were also fertilized with P2O5 and K2O fertilizers at 87 kg ha⁻¹ and 64 kg ha⁻¹, respectively, and fertilized with 2 t ha⁻¹ of chicken manure.

Table 1. Combination of varieties and level of N treatment

Factor Treatment I (Varieteis)	Factor Treatment II (Fertilizer Nitrogen)			
	64 kg ha ⁻¹ N fertilizer (N1)	86,5 kg ha ⁻¹ N fertilizer (N2)	109 kg ha ⁻¹ N fertilizer (N3)	131,5 kg ha ⁻¹ N fertilizer (N4)
Nasa 29 (V1)	V1 P1	V1 N2	V1 N3	V1 N4
Bima 19 (V2)	V2 N1	V2 N2	V2 N3	V2 N4
Bima 20 (V3)	V3 N1	V3 N2	V3 N3	V3 N4
JH 21 (V4)	V4 N1	V4 N2	V4 N3	V4 N4
Pionner 35 (V5)	V5 N1	V5 N2	V5 N3	V5 N4

3 Result and discussions

The results of statistical analysis in Table 2 shows there was no interaction of corn plant height between the hybrid corn varieties and nitrogen fertilizer level treatment during the plant growth phase. There was no difference on the maize plant height at the age of 30 days after planting (dap). At the age of 60 days after planting (dap), it showed that the Pionner 35 hybrid maize variety had a plant height of 216.56 cm, which is significantly different with other varieties. While the nitrogen fertilizer level treatment had the same plant height. At the age of 90 dap showed the same growth pattern as the age of 60 dap, the Pionner 35 corn variety at 193.54 cm was the highest plant height compared to other varieties. While the nitrogen fertilizer level treatment provides no difference between treatments.

Table 2. Effect of treatment of several hybrid maize varieties with nitrogen fertilizer level on maize under coconut stands on plant height observations at various plant ages.

Treatment	Plant Height (cm), at the age of-(dap)		
	30 dap	60 dap	90 dap
Varieties			
Nasa 29	71.25 a	198.40 b	180.42 b
Bima 19	76.04 a	194.58 bc	173.23 c
Bima 20	74.17 a	195.52 b	166.67 d
JH 21	75.94 a	189.58 c	174.17 c
Pionner 35	76.46 a	216.56 a	193.54 a
LSD 5%	ns	6.89	4.73
N fertilizer level			
64 kg ha ⁻¹	76.08 a	202.22 a	178.17 a
86,5 kg ha ⁻¹	73.00 a	194.25 a	175.00 a
109 kg ha ⁻¹	75.67 a	197.50 a	179.42 a
131,5 kg ha ⁻¹	74.33 a	201.75 a	177.83 a
LSD 5%	ns	ns	ns

Note: Numbers accompanied by the same letter in the same column mean that they are not significantly different according to LSD 5%, dap (days after planting) *ns* (not significant).

The results of the research on the height of maize varieties of Bima 10, Bima 19, Bisi 18, Pioneer 21 and Sukmaraga which between immature rubber plants there were no difference [11]. Corn planted in shade during growth and reproduction stage significantly affected corn plant height and cob height [12]. Corn varieties grown under coconut stands have the same height, include Sukmaraga, Srikandi Kuning, Lamuru, Lagaligo and Gumarang variety [13].

The data in Table 3 shows that the highest cob height in the hybrid maize varieties of Nasa 29 and Pioneer 35, at 78.17 cm and 76.98, respectively, had a significant difference to the varieties of Bima 19, Bima 20 and JH 21. While the level of nitrogen fertilizer on corn plant height has no difference in the cob height between treatments. The statistical analysis results on the ratio of plant height to cob height show that there is no difference in the treatment of hybrid corn varieties and the level of nitrogen fertilizer treatment.

The male flowers emergence on maize were the fastest in the Pioneer 35 variety, at 53 days after planting, while the Bima 20 variety had the slowest flower emergence, at 57.33 days. While the treatment of level of nitrogen fertilizer provide no difference in male flower emergence (Table 3). Further, the age of female flowers shows the same pattern as the age of male flowers, the Pioneer 35 variety has female flowers that come out faster significantly different from other varieties, while the age of female flowers the longest on the Bima 20 variety. The level of nitrogen fertilizer provide no difference to the age of female flowers.

Table 3. The effect of the hybrid corn varieties treatment with level of nitrogen fertilizer on corn plants under coconut stands on observations of cob height, plant height ratio with cob height, male flower age, female flower age and delay day.

Treatment	Cob height (cm)	Ratio of plant height to cob height	Male flower age (day)	Age of female flower (day)	Delay Day (day)
Varieties					
Nasa 29	78.17 a	43.68 a	56.00 bc	58.67 c	2.67 a
Bima 19	64.90 b	37.64 a	56.67 ab	59.58 b	2.92 a
Bima 20	64.69 b	39.13 a	57.33 a	60.58 a	3.25 a
JH 21	67.50 b	38.99 a	55.33 c	58.75 bc	3.42 a
Pioneer 35	76.98 a	39.98 a	53.00 d	57.00 d	4.00 a
LSD 5%	4.69	ns	1.03	0.88	ns
level of N fertilizer					
64 kg ha ⁻¹	67.87 a	38.29 a	55.80 a	58.60 a	2.80 a
86,5 kg ha ⁻¹	68.58 a	39.42 a	55.87 a	59.60 a	3.73 a
109 kg ha ⁻¹	72.25 a	40.51 a	55.60 a	58.73 a	3.13 a
131,5 kg ha ⁻¹	73.08 a	41.30 a	55.40 a	58.73 a	3.3 a
LSD 5%	ns	ns	ns	ns	ns

Note: Numbers accompanied by the same letter in the same column mean that they are not significantly different according to LSD 5%.

The delay day data in Table 3 shows that there is no difference in the corn hybrid varieties treatment and also in the level of urea fertilizer treatment. Early-aged maize plants flowering faster than deep-aged maize [14]. Corn grown under shade will slow down the flowering age of females, male flowering age and increase the anthesis-silking interval [12]. The difference between the release of male and female flowers is in the optimal range, which is between 1.3-2 days [15]. Several maize varieties grown under the shade of coconuts have a male flower age of 95%, which is between 60 days - 70 days [13].

The results of statistical analysis in Table 4 shows that the highest cob length on varieties Pioneer 35, Nasa 29, Bima 20 and JH 21 respectively 16.91 cm, 16.66 cm, 16.42 cm and 15.97 cm significantly different to the Bima 19 (15.19 cm) variety. Nitrogen fertilization with 109 kg ha⁻¹ N and 131.5 kg ha⁻¹ N had the highest cob length of 17.20 cm and 17.59 cm

respectively, that significantly different to the level of nitrogen fertilizer with 64 kg ha⁻¹ N and 86.5 kg ha⁻¹ N . The length of cobs planted between immature rubber plants was highest in Bisi 18 and Bima 10 varieties, at 18.39 cm and 18.14 cm respectively [11], and the range of cobs length between 15.2 cm – 20.8 cm [13].

The statistical analysis results on the length of the cob circumference in Table 4 shows no difference in the hybrid corn varieties treatment and the level of nitrogen fertilizer treatment. The data in Table 4 shows that there is no difference in the number of seeds per cob in the hybrid corn varieties treatment. Meanwhile, the addition of nitrogen fertilizer at level of 86.5 kg ha⁻¹ N (P2) up to 131.5 kg N ha⁻¹, significantly produce more seeds per row, that ranged between 27.17 seeds to 29.17 seeds respectively compared to corn that fertilized with 64 kg ha⁻¹ N that produced 25.87 seeds. The results from the similar study showed no difference in the number of seeds per row in the treatments of Srikandi Kuning, Sukmaraga, Lamuru, Lagaligo, Gumarang and Manado Kuning varieties [13].

Table 4. The effect of the hybrid corn varieties treatment with level of nitrogen fertilizer on corn plant under coconut stands on the observations of cob length, cob circumference, number of seeds per row, number of seeds per circle and number of seeds per cob.

Treatment	Cob length (cm)	Cob circumference (cm)	Number of seeds per row (seed)	Number of seeds per circle (seed)	Number of seeds per cob (seed)
Varieties					
Nasa 29	16.66 a	14.42 a	27.08 a	12.08 a	326.92 a
Bima 19	15.19 b	14.42 a	28.42 a	11.92 a	340.67 a
Bima 20	16.42 a	14.89 a	28.58 a	12.92 a	368.08 a
JH 21	15.97 ab	13.48 a	26.46 a	12.50 a	329.75 a
Pionner 35	16.91 a	14.68 a	27.58 a	13.00 a	343.42 a
LSD 5%	1.01	ns	ns	ns	ns
Level of N fertilizer					
64 kg ha ⁻¹	13.87 c	14.18 a	25.87 b	11.67 bc	297.40 c
86,5 kg ha ⁻¹	16.24 b	14.05 a	27.13 ab	12.33 ab	333.20 b
109 kg ha ⁻¹	17.59 a	14.45 a	28.33 a	13.13 a	368.87 a
131,5 kg ha ⁻¹	17.20 ab	14.83 a	29.17 a	12.80 a	367.60 a
LSD 5%	1.13	ns	2.20	0.86	30.88

Note: Numbers accompanied by the same letter in the same column mean that they are not significantly different according to LSD 5%.

The number of seeds per cob circumference in Table 4 provides consistent pattern as the number of seeds per row there is no difference in the hybrid corn varieties treatment. Meanwhile, the addition of nitrogen fertilizer at level of 86.5 kg ha⁻¹ N up to 131.5 kg ha⁻¹ of N, result the number of seeds per cob circumference from 12.33 seeds to 13.13 seeds that significantly different to the 64 kg ha⁻¹ N application with 11.67 seeds.

The statistical analysis results of hybrid corn varieties in Table 4 have the same number of seeds per cob. Meanwhile, the addition of nitrogen fertilizer at 109 kg ha⁻¹ N and 131.5 kg ha⁻¹ N had 368.87 seeds and 367.60 seeds per cob respectively, that significantly different to the result of seeds per cob on 64 kg ha⁻¹ and 86.5 kg ha⁻¹ of N fertilizer.

The statistical analysis results on the weight of 1000 grains in Table 5 shows the interaction between the several hybrid maize varieties treatment with the addition level of nitrogen fertilizer. The Bima 19 variety with 131.5 kg ha⁻¹ of N fertilizer provide the highest weight of 1000 grains with 314.33 g. This result is not different with the Bima 20 corn variety with 109 kg ha⁻¹ and 131.5 kg ha⁻¹ of N fertilizer and similar to JH 21 corn variety with 86.5 kg ha⁻¹ and 131.5 kg ha⁻¹ of N fertilizer. These results consistent with another study of Bima 19 maize variety that planted among young rubber plants on the weight of 1000 grains of 280

g [11]. Nitrogen fertilization with a dose of 112.5 kg ha⁻¹ has the same seed weight different from a nitrogen dose of 22.5 kg ha⁻¹ [16].

Table 5. Average weight of 1000 grains and maize productivity due to the interaction between hybrid maize varieties and levels of nitrogen fertilizer

Treatment	1000 grain weight (g)	Productivity (kg ha ⁻¹)
Varieties Nasa 29 + 64 kg ha ⁻¹ N fertilizer	265.77 fgh	3,875 b
Varieties Nasa 29 + 86,5 kg ha ⁻¹ N fertilizer	279.25 de	4,112 bcd
Varieties Nasa 29 + 109 kg ha ⁻¹ N fertilizer	280.53 cde	4,870 a
Varieties Nasa 29 + 131,5 kg ha ⁻¹ N fertilizer	278.99 de	4,415 ab
Varieties Bima 19 + 64 kg ha ⁻¹ N fertilizer	274.08 ef	2,345 h
Varieties Bima 19 + 86,5 kg ha ⁻¹ N fertilizer	281.73 cde	2,646 gh
Varieties Bima 19 + 109 kg ha ⁻¹ N fertilizer	287.33 cd	3,674 bcde
Varieties Bima 19 + 131,5 kg ha ⁻¹ N fertilizer	314.33 a	4,560 ab
Varieties Bima 20 + 64 kg ha ⁻¹ N fertilizer	261.58 fgh	2,788 fgh
Varieties Bima 20 + 86,5 kg ha ⁻¹ N fertilizer	285.02 cde	3,550 de
Varieties Bima 20 + 109 kg ha ⁻¹ N fertilizer	303.83 ab	3,161 efg
Varieties Bima 20 + 131,5 kg ha ⁻¹ N fertilizer	310.58 a	3,895 bcd
Varieties JH 21 + 64 kg ha ⁻¹ N fertilizer	293.02 bc	2,651 gh
Varieties JH 21 + 86,5 kg ha ⁻¹ N fertilizer	309.06 a	3,470 def
Varieties JH 21 + 109 kg ha ⁻¹ N fertilizer	301.73 ab	3,503 de
Varieties JH 21 + 131,5 kg ha ⁻¹ N fertilizer	301.62 ab	3,419 def
Varieties Pionner 35 + 64 kg ha ⁻¹ N fertilizer	257.62 gh	2,637 gh
Varieties Pionner 35 + 86,5 kg ha ⁻¹ N fertilizer	264.64 fgh	4,095 bcd
Varieties Pionner 35 + 109 kg ha ⁻¹ N fertilizer	263.69 fgh	4,275 abc
Varieties Pionner 35 + 131,5 kg ha ⁻¹ N fertilizer	255.39 h	3,571 cde
LSD 5%	13.23	706

Note: Numbers accompanied by the same letter in the same column mean that they are not significantly different according to LSD 5%.

The data in Table 5 shows the interaction between the hybrid maize varieties treatments with the level of nitrogen fertilizer. The Nasa 29 hybrid corn variety and 109 kg ha⁻¹ of nitrogen fertilizer level provide the highest productivity of 4.870 kg ha⁻¹, that significantly different to the other treatments. Several maize varieties include Bima 19, Bima 10, Bisi 18, Pionner 21 and Sukmaraga that planted among young rubber plants provide the productivity between 2.2 t ha⁻¹ to 4.1 t ha⁻¹[13]. The maize productivity intercrops among rubber trees is lower than the monoculture cropping by 68% [4]. The productivity of maize grown among coconuts is highest for the Srikandi Kuning and Sukmaraga varieties at 6.5 t ha⁻¹ and 6.8 t ha⁻¹ respectively [13]. The productivity of free pollinated corn and hybrids is strongly influenced by the adaptability of each variety [5]. Nitrogen fertilization of 112.5 kg ha⁻¹ can increase the total wet weight of plants by 23.53% compared to the use of nitrogen fertilizers at 22.5 kg ha⁻¹ [16]. The linear administration level of urea for corn plant up to 300 kg ha⁻¹ can increase the yields, urea is a nitrogen source synthesis. [17]. Nitrogen is one of the important nutrients for plants, to produce protein and chlorophyll, maintain photosynthetic efficiency and increase plant dry weight [17].

4 Conclusions

1. Hybrid maize varieties Nasa 29, Bima 19 and Pionner 35 have a high potential to be developed on shaded land, because their productivity is higher than other varieties.

2. Hybrid corn planted under the shade of coconut with a dose of Nitrogen fertilizer 109 kg ha⁻¹ and N: 131.5 kg ha⁻¹ can increase productivity yields 26 – 28%.

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