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The Effect of Fertilizer Treatment on the Morphology of Maize (*Zea mays*) Planted in An Intercropping System in the Immature Oil Palm Plantation

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Abstract

Applying and optimizing an intercropping system between oil palm and seasonal crops such as maize in the immature palm oil plantation is one way of obtaining additional income for farmers until the main crop (oil palm) mature and ready to harvest. The aim of the research was to determine the effects of fertilizers, particularly nitrogen (N) and potassium (K) on the growth and production of maize in an intercropping system with oil palm. The experiment, using one-factor randomized complete block design, was conducted at the Cikabayan Experimental Station, IPB University, Indonesia from August to December 2020. Four set-ups were prepared corresponding to four different fertilizer applications as follows: A0 (without treatment), A1 (240 g Urea + 80 g KCl + 320 g SP-36 per plot), A2 (480 g Urea + 160 g KCl + 320 g SP-36 per plot), A3 (720 g Urea + 240 g KCl + 320 g SP-36 per plot). Applying the highest dosages of N and K (A3), significantly increased plant height, fresh weight, number of leaves, leaf area, stem diameter, cob length, cob weight, and husk-free cob weight. Intercropping maize with immature oil palm did not affect the oil palm growth.

Keywords: intercropping, maize, nutrient content, oil palm

Introduction

Indonesia is one of the largest producers of palm oil in the world (Ditjenbun, 2018). According to Herman et al. (2009), an increase in the area of oil palm plantations in Indonesia started from 1980 to 2007 with an average rate of 12.30%. The increase in the area of oil palm plantations from 2016 to 2018 amounted to 11.2 million ha to 14.3 million ha (Ditjenbun, 2018). According to Nawiruddin (2017), the existence of oil palm plantations becomes a source of community livelihood and a great employment opportunity.

In Indonesia, the increase in the area of oil palm cultivation is inversely proportional to the area of land for food crops. The decrease in the area of rice fields in 2015 was 7.87 million ha but decreased to 7.73 million ha in 2018. The rice production area had increased again in 2019 to 7.88 million ha (BPS, 2020). Production area greatly affects the amount of production of each crop, including rice and maize (Sukarman et al., 2021; Erviyana, 2015), therefore it is necessary to plan for the use of land resources to be more productive and sustainable.

The decrease in the area of food crop cultivation is important to provide sufficient food production for the people of Indonesia and worldwide. Optimization of the uses land in the immature oil palm plantations is one of the steps that can be taken, by implementing an intercropping system between oil palm and seasonal crops, such as maize. The application of this system can be one way to increase the area of cultivation of food crops while providing additional production and income until the main crop (oil palm) becomes mature and ready to harvest. Oil palm land has several problems including acidic soil (low pH) and low nutrient content because oil palm land is generally planted on marginal land. According to Suharta (2010), margin al lands usually have acidic soil, low mineral and nutrient reserves, low organic matter, low P and K content, and low cation exchange capacity, but has a high aluminum (Al) saturation.

Soil acidity greatly limits plant growth. Efforts are needed to improve and manage soil fertility, especially on acid soils by adding nutrients and suppressing Al saturation levels. Acid soil fertility can be increased through balanced application of fertilizer, maintaining the nutrient content in the soil so that it remains available to plants, and liming or administering organic matter (Sopandie, 2013). This study aims to determine the effects of N and K fertilizers on the growth and production of maize. We also looked at the effect of maize intercropping on the growth of oil palm.

Material and Methods

The research was carried out at the Cikabayan Experimental Station, IPB, Indonesia for five months from August to December 2020. Observation of leaf tissue nutrients was carried out at the Testing Laboratory of Department of Agronomy. Soil analysis was carried out at the Laboratory of Department of Soil Science and Land Resources. Postharvest observations were carried out at the Postharvest Laboratory of the Department of Agronomy and Horticulture, Faculty of Agriculture, IPB.

Experimental Design and Collection of Data

Soil analysis was carried out before maize was planted. Soil sampling, which was done before planting the maize samples, was carried out in a composite manner at several points in the experimental field. Soil samples were taken at a depth of 0-10 cm, 10-20 cm, and 20-30 cm. Soil samples were analyzed for the following: pH H_2O, N-total, P-Bray/Olsen, CEC (cation exchange capacity), and K-dd (Table 1).

Ninety six maize plants of the Bisi 2 variety and 15 oil palm plants were used in this study using a one-factor randomized complete block design set-up,. Four fertilizer treatments were prepared as follows: A0 (without fertilizer), A1 (240 g Urea + 80 g KCl + 320 g SP-36 per plot), A2 (480 g Urea + 160 g KCl + 320 g SP-36 per plot), A3 (720 g Urea + 240 g KCl + 320 g SP-36 per plot). Each of the fertilizer treatments was administered on three replicates, so 12 experimental with units measuring 4 m x 4 m each. The experimental unit contained 96 maize plants, and 10 plants were sampled. The number of oil palm plants observed was one plant in each experimental unit, and three oil palm plants were observed as a comparison (area without maize), so there were 15 oil palm plants observed. Observation of plant height and number of maize leaves was carried out when the maize was 2 WAP to 8 WAP. Maize production was measured based on the growth (weight, length, diameter) of cobs and grain on cobs. Morphological observation of oil palm was carried out once a month, starting when the maize has not been planted until the maize is harvested. Plant growth measurements include plant height, number of fronds, stem diameter, canopy width, and frond length.

Data Analysis

The maize and oil palm morphological data were analyzed using analysis of variance (ANOVA) ran in *Microsoft excel.* When significant values were obtained at α = 5% level, the Duncan Multiple Range Test (DMRT) was performed.

Tabel 1. Soil chemical properties of Cikabayan determined before maize planting

Depth	Soil parameter	Extraction method	Value	Status
0-10 cm	pH	H_2O	3.87	Very acidic
	Total N (%)	Kjeldahl	0.43	Medium
	Available P (P_2O_5, ppm)	Bray I	2.94	Very low
	K (cmol (+)/kg)	NH_4OAc 1M pH 7.00	0.27	Medium
	CEC (cmol (+)/kg)	NH_4OAc 1M pH 7.00	25.91	High
10-20 cm	pH	H_2O	3.85	Very acidic
	Total N (%)	Kjeldahl	0.28	Medium
	Available P (P_2O_5, ppm)	Bray I	2.67	Very low
	K (cmol (+)/kg)	NH_4OAc 1M pH 7.00	0.09	Low
	CEC (cmol (+)/kg)	NH_4OAc 1M pH 7.00	22.00	Medium
20-30 cm	pH	H_2O	4.06	Very acidic
	Total N (%)	Kjeldahl	0.24	Medium
	Available P (P_2O_5, ppm)	Bray I	2.23	Very low
	K (cmol (+)/kg)	NH_4OAc 1M pH 7.00	0.06	Low
	CEC (cmol (+)/kg)	NH_4OAc 1M pH 7.00	19.88	Medium

Note: *Soil chemical properties criteria according to PPT (1983)

Results

Maize Morphology

The growth of maize plants treated with urea and KCl fertilizer in the immature oil palm fields was significantly better than those without or with low fertilizer treatment. The application of urea and KCl resulted in greater height and more number of leaves of maize plants (Table 2). It also increased greatly the stem diameter, plant weight, and leaf area (Table 3). Maize from the A3 treatment were observed to be the tallest plants (226.21 cm), with the most number of leaves (11.76), biggest stem diameter (2.49 cm), and highest maize weight (272.00 g). These results were significantly different from the maize plants without fertilizer (A0). The leaf area of maize was seen to be highest in A2 (133.63 cm) and this was significantly different from A0.

Maize Production

Compared to maize plants without fertilizer (A0), plant samples in A3 (720 g urea + 240 g KCl + 320 g SP-36 per plot) showed significantly better growth in terms of the weight of the cob (201.70 g), husk-free cob weight (158.33 g), and length of cobs (17.84 cm), The following factors, however, were not significantly different among maize plants from different fertilizer treatments: the diameter of cobs, grains weight per plot, grains weight per ha, and 100-grain weight (Table 4).

Oil Palm Morphology

Planting maize through intercropping system in immature oil palms did not affect theoverall plant morphology plant height, number of fronds, stem diameter, canopy width, and frond length) of the oil palm plants (Table 5). The oil palm plants continued to grow normally through to harvesting of maize.

Chlorophyll and Nutrient Levels in Maize Leaves

Treatment A3 (720 g urea + 240 g KCl + 320 g SP-36 per plot) maize plants had the highest total chlorophyll content (2.81 $mg.g^{-1}$) but this was not significantly different from maize without fertilizer or treatment

Table 2. Maize growth in height and number of leaves with the application of N and K fertilizer

		Weeks after planting (WAP)			
	Treatment	2	4	6	8
Plant height (cm)	A0	28.15	67.20	112.92b	138.90b
	A1	29.40	85.11	144.08ab	180.81ab
	A2	33.87	89.24	147.84ab	188.24ab
	A3	33.42	95.54	170.30a	226.21a
		ns	ns		
Number of leaves	A0	4.24	6.57b	6.24c	7.24c
	A1	4.80	7.81ab	7.67bc	8.96bc
	A2	4.60	8.30a	8.19ab	10.19ab
	A3	4.76	8.91a	9.60a	11.76a
			ns		

Note: A0 = without fertilizer; A1=240 g Urea + 80 g KCl + 320 g SP-36 per plot; A2= 480 g Urea + 160 g KCl + 320 g SP-36 per plot; A3= 720 g Urea + 240 g KCl + 320 g SP-36 per plot. Values followed by the same letter in the same column indicate that they are not significantly different based on Duncan Multiple Range Test at α = 5%; ns= non-significant.

Table 3. Maize stem diameter, plant weight, and leaf area treated with N and K fertilizer

Treatment	Stem diameter (cm)	Plant weight (g)	Leaf area (cm^2)
A0	1.70b	129.44b	92.15b
A1	1.98bc	195.11ab	119.93ab
A2	2.21ab	217.33ab	133.63a
A3	2.49a	272.00a	121.69ab

Note: A0 = without fertilizer; A1=240 g Urea + 80 g KCl + 320 g SP-36 per plot; A2= 480 g Urea + 160 g KCl + 320 g SP-36 per plot; A3= 720 g Urea + 240 g KCl + 320 g SP-36 per plot. Values followed by the same letter in the same column indicate that they are not significantly different based on Duncan Multiple Range Test at α = 5%.

Table 4. Cob weight, husk-free cob weight, cob length, cob diameter, weight of grains per plot, weight of grains per ha, and the weight of 100-grains of maize samples with varying treatments of N and K fertilizer

Treatment	Cob weight (g)	Husk-free cob weight (g)	Cob diameter (cm)	Cob length (cm)	Grain weight per plot (g)	Grain weight (kg.ha^{-1})	Weight of 100-grains (g)
A0	82.30b	64.43b	3.39	12.43c	421.80	263.63	23.35
A1	117.33ab	97.72ab	3.58	14.24bc	555.14	346.96	24.43
A2	149.05ab	119.30ab	3.52	15.90ba	521.80	326.13	24.09
A3	201.70a	158.33a	3.77	17.84a	788.47	492.79	26.89
			ns		ns	ns	ns

Note: A0 = without fertilizer; A1=240 g Urea + 80 g KCl + 320 g SP-36 per plot; A2= 480 g Urea + 160 g KCl + 320 g SP-36 per plot; A3= 720 g Urea + 240 g KCl + 320 g SP-36 per plot. Values followed by the same letter in the same column indicate that they are not significantly different based on Duncan Multiple Range Test at α = 5%, ns = non-significant.

A0. There was a high leaf N (2.44%) and K (1.99%) content had the highest value and but the values were not significantly different between treatments (Table 6).

Chlorophyll and Nutrient Levels in Oil Palm Leaves

Planting maize in the immature oil palm plantation did not affect the chlorophyll and leaf nutrients content of oil palm plants (Table 7). T application of fertilizer caused a non-significant increase in chlorophyll and N contents, and a decrease in K in oil palm leaves.

Discussion

Fulfilling nitrogen and potassium nutrient requirements during the vegetative growth period of maize can increase growth, especially plant height, and can increase the number of leaves (Rahmawati, 2017; Olowoboko et al., 2017; Assagaf, 2017). Suwarto (2018), reported that the application of 183 kg.ha^{-1} nitrogen could increase plant height at 8 WAP to 243.2 cm, and the number of leaves by 15.2 in maize.

Application of nitrogen and potassium was also able to increase the stem diameter and weight of maize (Fi'liyah et al., 2016; Rahmawati, 2017). Nitrogen is a key in plant biochemical systems, which acts as a constituent of enzymes, chlorophyll, nucleic acid, storage proteins, cell walls, and other cellular components (Harper, 1994). Potassium plays a role in growth and development, root system, enzyme activation, photosynthetic process, transport of photosynthate, protein synthesis, cell growth, opening and closing of stomata, and the main component of cell turgor in plants (Blevins, 1994).

The application of nitrogen and potassium increase the leaf area of maize plants; potassium plays a role in helping the availability of nitrogen during the growth process so that there is an increase in maize growth along with the increase in the dose of fertilization Prajapati and Modi (2012). In addition, Prajapati and Modi (2012) reported that potassium can increase the efficiency of nitrogen use for plants, help regulating the opening and closing of stomata and water balance in the plants.

Increasing the dose of urea and KCl can increase the assimilation yield so that it will affect maize production, according to research that has been carried out by Sinclair et al. (1990), reported that the number of grains per ear was determined at the time of pollination and assimilation results. According to Persad and Sink (1990), an increase in the application of nitrogen fertilizer will increase the number of cob seeds, and a significant reduction in the amount of nitrogen will cause a decrease in the number of cob seeds.

Suwarto (2018) reported the application of 183 kg.ha^{-1} N was able to increase the grains yield of maize in the range of 6.20 to 6.89 ton.ha^{-1}; these results are categorized normal. Pratikta et al. (2013) reported that the weight of the grain can affect the circumference of the cob, so it will affect the weight of the maize cobs. The increase in seed weight is also related to the allocated photosynthate yield; the greater the allocation of photosynthate, the greater the accumulation of food reserves that are translocated to seeds (Pratikta et al., 2013).

The increase in the morphological growth of oil palm is thought to be due to the absence of nutrient competition between oil palm and maize, but the presence of nutrient symbiosis. The nutrient symbiosis between the main crop and intercrops is thought to be caused by the fertilizer applied to maize, which can also be used by oil palm. This will lead to efficiency in the use of nutrients. According to Rifai et al. (2014), intercropping is a cultivation technique that

Table 5. Plant height, number of fronds, stem diameter, canopy width, and frond length of oil palm

Treatment	Time	Plant height cm)	Number of fronds	Stem diameter (cm)	Canopy width (cm)	Frond length (cm)
A0	S0	110.33	46.00	29.09	603.33	283.00
	S1	118.33	49.00	31.10	605.00	299.67
	S2	130.00	52.00	33.23	657.50	316.67
	S3	156.33	55.00	34.29	737.17	366.00
	Improvements over control	46.00	9.00	5.20	133.84	83.00
	S0	128.00	50.33	29.94	595.00	287.00
	S1	137.33	53.33	31.85	640.83	307.67
	S2	152.67	56.33	33.55	645.00	329.00
	S3	160.00	59.33	33.76	735.33	354.00
	Improvements over control	32.00	9.00	3.82	140.33	67.00
A1	S0	102.00	48.00	29.51	588.33	271.00
	S1	120.67	51.00	30.89	628.33	299.67
	S2	130.00	54.00	31.63	631.67	313.00
	S3	147.67	57.00	31.85	741.67	348.33
	Improvements over control	45.67	9.00	2.43	153.34	77.33
A2	S0	124.33	49,00	26,54	653,33	289.67
	S1	139.67	52,00	28,59	671,67	311.00
	S2	149.67	55,00	29,83	685,00	335.00
	S3	172.67	58,00	33,54	765,33	339.00
	Improvements over control	48.34	9,00	7,00	112,00	49.33
A3	S0	83.67	45.00	20.09	533.33	247.67
	S1	114.33	48.00	29.86	621.67	286.67
	S2	124.67	51.00	31.10	638.33	290.33
	S3	135.33	54.00	33.23	683.67	350.67
	Improvements over control	51.66	9.00	13.14	150.34	103.00

Note: A0 = without fertilizer; A1=240 g Urea + 80 g KCl + 320 g SP-36 per plot; A2= 480 g Urea + 160 g KCl + 320 g SP-36 per plot; A3= 720 g Urea + 240 g KCl + 320 g SP-36 per plot. WM = without maize, S0 (before maize planting), S1 (2 weeks after maize fertilization treatment), S2 (7 weeks after maize fertilization treatment), S3 (after maize harvesting).

Table 6. Chlorophyll and nutrients content in maize leaves with the application of N and K fertilizer

Treatment	Total chlorophyll ($mg.g^{-1}$)	N (%)/(Status)*	K (%)/(Status)*
A0	2.56ab	2.29 (Low)	1.60 (Low)
A1	2.31b	2.13 (Low)	1.80 (Low)
A2	2.41ab	2.36 (Low)	1.86 (Low)
A3	2.81a	2.44 (Low)	1.99 (Low)
		ns	ns

Note: A0 = without fertilizer; A1=240 g Urea + 80 g KCl + 320 g SP-36 per plot; A2= 480 g Urea + 160 g KCl + 320 g SP-36 per plot; A3= 720 g Urea + 240 g KCl + 320 g SP-36 per plot. Values followed by the same letter in the same column indicate that they are not significantly different based on Duncan Multiple Range Test at α = 5%, ns= non-significant, *Nutrient status of maize leaves according to Sofyan et al. (2019) and Novianty and Yunita (2020).

Table 7. Chlorophyll and nutrient contents of palm leaves after N and K fertilizer application

Time	Treatment	Total chlorophyll (mg.g^{-1})	N (%)/(Status)*	K (%) (Status)*
Before maize planting	A0	3.36	2.66ab (Medium)	0.78 (Low)
	A1	3.08	2.73a (Medium)	0.91 (Medium)
	A2	2.65	2.75a (Medium)	0.92 (Medium)
	A3	2.80	2.48c (Medium)	0.92 (Medium)
	WM	3.49	2.56bc (Medium)	1.27 (Medium)
		ns		
After maize planting	A0	3.68	2.66 (Medium)	0.73 (Low)
	A1	3.30	2.75 (Medium)	0.85 (Low)
	A2	3.61	2.74 (Medium)	0.85 (Low)
	A3	3.34	2.62 (Medium)	0.84 (Low)
	WM	3.81	2.64 (Medium)	0.70 (Low)
		ns	ns	ns

Note: A0 = without fertilizer; A1=240 g Urea + 80 g KCl + 320 g SP-36 per plot; A2= 480 g Urea + 160 g KCl + 320 g SP-36 per plot; A3= 720 g Urea + 240 g KCl + 320 g SP-36 per plot. Values followed by the same letter in the same column indicate that they are not significantly different based on the results of the Duncan Multiple Range Test (DMRT) α = 5%, ns= non-significant, *Nutrient status of palm leaves according to Nazari (2020).

is more efficient in land use. Intercropping is also a sustainable farming method, by maximizing land use, reducing fertilizer use (N), improving the economy, and minimizing weeding costs (Nchanji et al., 2016; Yang et al. 2018). Nasamsir and Usman (2019), stated that the monoculture system has a higher production value than the polyculture system, but the polyculture system has an LER (land equivalence ratio) value of 1.4. This value indicates that the polyculture system between oil palm and is 40% more profitable than the monoculture system.

High nitrogen application is directly proportional to the increase in total chlorophyll content. Nitrogen is needed by plants in large quantities, which plays a role in the production of chlorophyll and protein synthesis and is used for growth and production processes (Lazureanu et al. 2007). Marschner (2012) also reported that the high concentration of chlorophyll was caused by the high concentration of nitrogen.

According to Sofyan et al. (2019) and Novianty and Yunita (2020), the N uptake status of 2.47% - 2.49% in maize leaves was classified as low, 3.00 - 3.44% was classified as medium, and 3.52% - 3.56% is high. The K absorption of 1.25% - 1.33% is classified as low or the critical limit of the K element absorption status is 2%. Nitrogen and potassium are nutrients with high mobility in the phloem and can be remobilized from mature leaves to newly growing organs (Marschner, 2012). Nutrient remobilization is important during the formation of seeds, fruit, and storage organs.

At the generative phase the concentration of nutrients in oil palm leaves is usually low because nutrients and photosynthetic products are distributed to the strongest sinks, i.e., flowers, fruit, and seeds. The tips of shoots and roots are the main sinks during the vegetative phase, while seeds and fruits are the dominant sinks during the reproductive phase (Taiz and Zeiger, 2002).

According to Marschner (2012), nitrogen, phosphorus, and potassium are nutrients with high mobility in the phloem and can be remobilized from mature leaves to newly growing organs. Nutrient remobilization is important during reproductive growth when seeds, fruit, and storage organs occur. Root activity and nutrient absorption generally decrease in this phase, due to a decrease in the supply of carbohydrates to the roots due to competition between sinks so that the concentration of nutrients in vegetative organs decreases drastically during the reproductive phase. Nazari (2020), stated that nutrient uptake (N and K) in oil palm leaf tissue with an absorption capacity for N of 1.43% - 1.67% was classified as low (condition of deficiency < 2.4%). The absorption capacity for K nutrients of 0.47% - 0.58% is classified as low (deficiency below the value < 0.90%).

The increase in total chlorophyll in oil palm leaves is thought to be because nitrogen and potassium fertilizers applied to maize can also be absorbed by oil palms. Shintarika et al. (2015), reported that the application of N fertilizer at a dose of 382.00 g per plant was able to increase the chlorophyll content of oil palm leaves by 10.46%.

Conclusion

The application of nitrogen and potassium fertilizers as much as 720 g urea + 240 g KCl + 320 g SP-36 per plot increased the number of leaves, plant height, cob length, stem diameter, plant weight, cob weight, leaf area, and husk free cob weight; this treatment also increased the total leaf chlorophyll, had little effects on the nutrient content of maize leaves. Maize intercropping in the immature oil palm plantation 3 years after planting did not slow down the growth of oil palms and did not affect the final content of leaf chlorophyll and nutrients.

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