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Reduction of Urea Fertilizer Uses through Application of Livestock Manures in An Integrated Farming of Maize and Cattle

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Abstract

Crops and livestock have historically been grown together in an integrated farming; this system facilitates sharing of nutrient and land resources, and benefiting both operations. The current study examined integrated farming of maize and cattle in Waleran Village, East Java, Indonesia. In maize cultivation, the farmers apply 10 tonnes of the manure, 300 kg Urea (46% N) and 300 kg NPK Phoska ($N:P_2O_5:K_2O$ = 15%:15%:15%) per hectare. However, more nitrogen had actually been applied when manure is added, increasing the amount of nitrogen by 180 kg $N.ha^{-1}$ which consequently a waste. Therefore, more efficient application of nitrogen in maize production needs to be studied. A field experiment was conducted from September 2017 to February 2018 using maize "Pioneer 32". The study was organised in a completely randomized block design consists of 10 m x 10 m plots and four replications. The crops were fertilized with nitrogen at 46, 91, 137 and 183 $kg.ha^{-1}$. Two seeds of maize were planted per hole with planting distance of 70 cm between rows and 40 cm within row. Plant growth were measured weekly at four to eight weeks after planting; yield variables were measured at harvest. The increasing nitrogen levels did not significantly influence the maize growth or yield. The manure contributed about 114 $kg.ha^{-1}$ nitrogen supply. The lowest total nitrogen fertilizer applied (159 kg.N ha^{-1}) resulted in the optimum leaf area index (4.65) and leaf nutrient content of N (2.70%) and P (0.26%) which is above to the critical leaf nutrient content with maize grain yield of 6.19 ton ha^{-1}. The manure in integrated farming could reduce the use of Urea due nitrogen contribution from the livestock manures.

Keywords: maize growth, nitrogen levels, leaf area index, leaf nutrient content

Introduction

Maize is the second important of food crop in Indonesia after rice; the main uses are for food and feed. The highest maize production area in Indonesia in 2015 was East Java (BPS, 2015), with the largest area of maize production is on dry land in the Tuban Regency of the East Java Province. Almost all farmers in Tuban Regency, especially in Grabagan Village integrated relay planting of maize/chilli/groundnut with cattle. Chilli was planted at 53 days after maize; one row chilli at every three rows of maize. At 73 days after planting, the maize leaves under cob was pruned to feed the cattle, then groundnut was planted among the maize and chilli. At 97 days afer planting the maize stems section above the cob was cut to feed the cattle, either fresh or dried. Maize planting season was six month duration started at November to April each year. Based on interviews with 23 farmers conducted by the author, every fam has two cattle animals, and at least 10 tonnes of farm manure can be produced from two cattle a year (unpublished report). Cattle manure is an important source of nitrogen (Sharifi et al., 2011). Manure from these two cattle is sufficient to supply one hectare of crops during the planting seasons throughout the year.

The amount of nitrogen applied to the crops is an important factor that affects maize yield (Okumura et al., 2011). The farmers in Grabagan, Tuban, use livestock manure as organic fertilizers for maize production, whereas the maize wastes are used for livestock feed. Manure differs from most commercial fertilizers in that it consists of a mix of organic nitrogen compounds that require conversion to inorganic nitrogen by microorganisms before they are available to crops. One of the challenges of manure management is to estimate the rate of nitrogen release from manure organic material and the fraction of organic nitrogen that is available to crops. The average dosage of the manure applied in the study location was 10 $ton.ha^{-1}$. Hartatik and

Widowati (2010) estimated that the nitrogen available for use by maize in manure varied by 0.4% - 2.04%. Based on these figures (Hartatik and Widowati, 2010) 10 ton.ha^{-1} manure is estimated to contain 40 to 204 kg nitrogen.

In order to reach the best maize growth and yield, farmers fertilized the maize with Urea and NPK Phonska. The farmers have a perception that 'more fertilizers will give more growth and yield of maize'. Due to this perception, the average dosage of Urea and NPK Phonska applied by the farmers is relatively high, i.e. 300 kg of Urea and 300 kg of NPK Phonska per hectare, which is equal to 183 kg N, 45 kg P_2O_5, and 45 kg K_2O per hectare.

Low soil nitrogen is often the limiting factor in increasing maize production in Indonesia. However, farmers in Tuban apply more Urea than a crop needs, resulting in inefficient use of nitrogen. Okumura et al (2011) stated that nitrogen fertilization is required for maize, but then stated that N is to be applied when there is a major requirement for N because nitrogen is readily available compared to other nutrients such as P and K. However, application of excessive amount of nitrogen is not economical, could have negative consequences to plant metabolism, and the excess nitrogen can potentially cause problems to the environment. Therefore, it is important to understand the optimum time of nitrogen application, and level at which to apply nitrogen for maximum availability to the crop. Nitrogen is highly volatile and inappropriate application to field crops not only contributes towards pollution but also increases the cost of production (Akmal et al., 2010).

The benefits of using manure as a fertilizer requires proper assessment of the available nutrients in manure, calculating the appropriate rate to provide the needed nutrients to the crop and applying the manure uniformly in the field. This study evaluated the practices of maize production in a central production of maize in Grabagan, East Java, and determined the efficient dosage of fertilizers, especially from Urea, for maize production. The contribution of manure as a source of nitrogen was examined to develop a production system with low external input for a sustainable agriculture, which is the main concept of an integrated farming system.

Material and Methods

An experiment was conducted on the maize production area of Village of Waleran, District of Grabagan, Tuban Regency, East Java, Indonesia, located at 112^{o}00' East Longitude and 7^{o}00 South Latitude during September 2017 to February 2018. The soil has a relatively neutral pH of 6.07. The experiment used a completely randomized block design with a single factor of nitrogen (N) fertilizer dosages. Four levels of N fertilizer dosages were tested, i.e. 45, 91, 137, and 183 kg N.ha^{-1}. Each treatment was repeated four times. The source of N fertilizers were a combination of Urea (45%N) and NPK Phonska (15%N - 15%P_2O_5 - 15% K_2O). Urea was applied at 0, 100, 200, and 300 kg.ha^{-1} , and NPK Phonska at 300 kg.ha^{-1}. The other source of N was the manure applied during land preparation at a rate of 10 ton.ha^{-1}. At the end chilli harvest, or when the dry seasons started, the land was prepared by cleaning from weeds followed by a minimum tillage, digging hole, and manuring for next maize planting seasons. Every planting hole was applied with an average of 280 g of manure, or 10 tonnes per hectare. One-third of NPK Phonska was applied at 15 days after planting, then at 25 and 40 days after planting, respectively 1/3 of NPK Phonska was mixed with ½ dosage of Urea were applied. The fertilizer was inserted into a hole at about 7 to10 cm distance from the maize plant and covered with soil. N, P_2O_5, K_2O levels in the manure and in the soil were analysed at Plant and Soil Analysis Laboratory of Department Agonomy and Horticulture, Bogor Agricultural University. The N, P_2O_5, K_2O of the soil in the study location was also analyzed before planting.

The size of the experimental plots was 10 m x 10 m. Seeds of the maize hybrid "Pioneer 32" were planted spaced at 70 cm between rows and 40 cm within rows; two seeds were planted in one planting hole. The NPK Phoska fertilizer was applied at 15, 25, and 40 days after planting, whereas urea was applied at 25 and 40 days after planting. Measured growth variables included plant height, stem diameter, and leaf number which were observed weekly at four to eight weeks after planting (WAP).

At the tasseling phase of maize (8 WAP) measurements of the ninth leaf length (l) and width (w) were taken to determine leaf area and leaf area index. The area of one maize leaf (cm^2) was calculated by the formula = l * w * 0.98 (Sitompul and Guritno, 1995), then multiplied with the number of leaves per plant to get a total leaf area per plant. Leaf area index was calculated as the projected area of leaves over a unit of land (m^2) (Waring and Runnin, 2007). The nutrient content of N, P, and K of the ninth leaf was also taken evaluate the nutrient status in the plant.

Yield variables measured at harvest time included weight of maize cob, weight of seeds per plant and weight of 100 seeds at 22% moisture content. The weight of seeds per plant was then converted to the moisture contents of 13% following the standard of moisture content in maize grain trading. The converted value was then used to estimate maize yield per hectare by multifliying with the plant population and correction factor of 0.7. The correction factor was applied because the effective land was estimated to be about 70% due to the rocky condition of the soil in the study site.

Data were analysed using ANOVA and significant differences between treatments were further analysed with Least Significant Differences (LSD) to determine the effect of the different N fertilizer dosages on the growth variables.

Results

Maize Growth

Plant height (Table 1), stem diameter (Table 2), and number of leaf (Table 3) of maize increased during 4 to 8 WAP. The dosage of nitrogen levels of 45, 91, 137, and 183 kg N.ha^{-1} did not significantly affected the growth variables. Leaf area index at 8 WAP was also not significantly influenced by the N fertilizer dosage (Table 4).

The weekly increment of plant height (Table 1) was normal for all levels of nitrogen applied; the plant height range at 8 WAP was 230 to 243 cm. Yulisma (2011) reported that at 4, 6 and 8 WAP plant height of "Pioneer 21" at Nangroe Aceh Darussalam was 88, 179 and 230 cm respectively. Surbakti et al. (2013) stated that the maize plant height of "Pioneer 12" at 6 WAP at Deli Serdang, North Sumatra was in the range between 188 to 190 cm.

Stem diameter of maize in all the nitrogen fertilizer dosages were in the range of 17.3 to 18.4 mm (Table 2) were also insignificant. Bora and Murdolelono (2006) reported that stem diameter of maize cultivated on dryland at Belu, Nusa Tenggara Timur, was in the range of 14.3 to 16.0 mm. The maize stem diameter was relatively stable starting at 6 WAP.

The number of leaf per plant is a genetic characteristic of the maize variety; this might be one of the reasons that the nitrogen fertilizers levels did not affect the number of leaf per plant. The number of leaf per plant in this study was 15.2 (Table 3). Depending on the maize variety, the number of leaves can range from 8 to 18; for example Efendi and Suwardi (2010) reported the number of leaves on maize cultivar "Bisi 2" and "Pioneer 21" were 13.5 and 12.8, respectively.

All dosages of N fertilizer resulted in a similar leaf area index (LAI) which was in the optimal range averaging 4.65 (Table 4). The LAI value was calculated from the average of leaf area per plant. The average leaf area within nitrogen dosage treatments of 45, 91, 137 and 183 kg.ha^{-1} were 6,970, 7,640, 7,242 and 8,174 cm^2, respectively. The leaf area values of the maize

Table 1. Maize plant height at different dosages of N fertilizers

N dosage (kg.ha^{-1})	Source of N		Plant height (cm)				
	Urea (kg.ha^{-1})	NPK Phonska (kg.ha^{-1})	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
45	0	300	85.0	129.9	161.2	199.1	230.2
91	100	300	86.9	133.7	164.7	204.9	240.7
137	200	300	87.2	131.7	162.1	200.7	234,1
183	300	300	87.5	135.6	167.3	208.7	243.2
Average			86.7	132.7	163.8	203.4	237.1

Table 2. Maize stem diameter at different dosages of of N fertilizers

N dosage (kg.ha^{-1})	Source of N		Stem diameter (mm)				
	Urea (kg.ha^{-1})	NPK Phonska (kg.ha^{-1})	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
45	0	300	15.8	18.0	18.7	18.3	18.4
91	100	300	15.9	18.0	18.7	18.1	18.0
137	200	300	15.7	17.9	19.0	18.2	18.4
183	300	300	15.5	17.1	18.1	17.8	17.3
Average			15.7	17.8	18.6	18.1	18.0

Table 3. Maize leaf number per plant at different dosages of N fertilizers

N dosage ($kg.ha^{-1}$)	Source of N		Number of leaf per plant				
	Urea ($kg.ha^{-1}$)	NPK Phonska ($kg.ha^{-1}$)	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
45	0	300	8.3	9.7	11.3	13.1	15.2
91	100	300	8.5	9.9	11.4	13.1	15.2
137	200	300	8.1	9.9	11.4	13.0	15.0
183	300	300	8.1	9.6	11.2	13.0	15.2
Average			8.3	9.8	11.3	13.1	15.2

crops in this study were higher than those reported by Yulisma (2011) in Reuleut Aceh Utara of 5,996 cm^2. In another study (Efendi and Suwardi, 2010) the maximum maize LAI was with the nitrogen dosage treatment of 150 $kg.ha^{-1}$ which was 4.2 for cultivar “Pioneer 22” and 4.0 for cultivar “Bisma 2”.

Maize Yield

Yield components of maize showed no significant responses to the nitrogen fertilizer treatments. The number of seeds per cob, seed weight per plant, and estimated grain yield slightly increased with the increase of nitrogen level of 137 $kg.ha^{-1}$ and then decreased (Table 5). The trend of maize yield with increasing dosages of nitrogen was similar to those of stem biomass under the cob (Table 4).

The maize grain yield in the range of 6.20 to 6.89 $ton.ha^{-1}$ were categorized as normal according to the Indonesian Ministry of Agriculture (2018). The maize yield in this study was higher than those reported by Yusalima (2011) at Nangroe Aceh Darussalam (5.25 $ton.ha^{-1}$). The potential yield of hybrid maize according to the Indonesian Ministry of Agriculture (2018) ranged 6 to 8 $ton.ha^{-1}$, which is higher than a traditional maize variety with the range of 3 to 4 $ton.ha^{-1}$. Therefore the maize grain yield of “Pioneer 32” at the all levels nirogen fertilizer in this study was normal.

Discussion

At the optimal LAI (4.32 – 5.07), photosyntesis should be maximal and result in sufficient energy for the plant to have normal growth of stems and leaves. In this study an optimal LAI has been achieved, therefore, all maize “Pioneer 32” growth variables including plant height, stem diameter, and number of leaf were in the normal range. This means that all N dosages of urea applied was sufficient to support to normal maize growth. The critical content of nitrogen and phosporus of the maize leaf at tasseling phase are 1.40% and 0.16%, respectively. The levels of nitrogen and phosphorus in the leaf of all N dosages (Table 6) were higher than the critical. However, the potassium content of leaf (1.45 to 1.58%) was still lower than the critical content (2.00%). It means that soil nitrogen and phosphorus were likely to be sufficient for corn growth, whereas the soil potassium was not.

Potassium is an essential nutrient and is also the most abundant cation in plants (Gul et al., 2015); it plays essential roles in enzyme activation, protein synthesis, photosynthesis, osmoregulation, stomatal movement, energy transfer, phloem transport, cation-anion balance, and stress resistance. The leaf potassium content lower than critical point in this study was probably related to water availability. Sometime, at the planting seasons maize leaves showed water stress symptoms. Wang et al. (2013) reported during drought stress, root growth and the rates of $K+$ diffusion in the soil towards the roots

Table 4. Maize leaf area index and total biomass at different dosages of N fertilizers

N dosage ($kg.ha^{-1}$)	Source of N		Leaf Area Index (8 WAP)	Stem biomass under cob at harvest (g per plant)
	Urea ($kg.ha^{-1}$)	NPK Phonska ($kg.ha^{-1}$)		
45	0	300	4.32	64.18
91	100	300	4.74	67.48
137	200	300	4.49	67.80
183	300	300	5.07	63.98
Average			4.66	65.86

Table 5. Yield components of maize at different dosages of N fertilizers

N dosage ($kg.ha^{-1}$)	Source of N		Number of seeds per cob	Seed weight at harvest at 22% moisture content (g per plant)	Seed weight at 13% moisture content (g per plant)	Estimated grain yield (ton per ha)
	Urea ($kg.ha^{-1}$)	NPK Phonska ($kg.ha^{-1}$)				
45	0	300	563	141.1	126.5	6.20
91	100	300	587	148.0	132.7	6.50
137	200	300	615	156.8	140.6	6.89
183	300	300	614	145.9	130.8	6.41
Average				147.9	132.6	6.50

Table 6. Nitrogen, phosphorus and potassium nutrient content of the nineth leaf at maize tasseling phase

N dosage ($kg.ha^{-1}$)	Source of N		Nitrogen (%)	Phosphorus (%)	Potassium (%)
	Urea ($kg.ha^{-1}$)	NPK Phonska ($kg.ha^{-1}$)			
45	0	300	2.70	0.26	1.45
91	100	300	2.82	0.29	1.50
137	200	300	2.92	0.30	1.58
183	300	300	2.95	0.31	1.45
Average			2.85	0.29	1.45

were both restricted, thus limiting K acquisition. The resulting lower K concentration can further reduce the plant resistance to drought stress, as well as K absorption.

The leaf nitrogen content was not significantly different with any of the N treatments. In this case, the manure applied at 10 $ton.ha^{-1}$ was important in contributing nutrient supply for the crops. Laboratory analysis demonstrated that the cattle manure contains 1.14% of nitrogen, 2.30% of phosphorus, and 1.18% of potassium. Based on this analysis results, the maize crop had been supplied with 114 kg nitrogen, 230 kg phosphorus, and 118 kg potassium per hectare from the 10 tonnes of manure applied.

Total amount of the nitrogen levels applied to the maize land that originated from the Urea and the manure were 159, 204, 249 and 294 $kg.ha^{-1}$. The total levels of phosphorus and potassium were 275 and 163 $kg.ha^{-1}$, respectively. Based on the leaf nutrient content (Table 5) and leaf area index (Table 4), the amount of nitrogen applied at the lowest level was already sufficient for supporting maize growth. This was indicated by all of the growth variables observed and the fact they were not significantly different among the treatments. The main stem under cob after cob harvested and the yield of maize at harvest slightly increased at the nitrogen fertilizer dosage of 135 $kg.ha^{-1}$. It is probably correlated with the potassium nutrient content of the leaf (Table 6). Potassium (K) is an essential nutrient that affects most of the biochemical and physiological processes that influence plant growth and metabolism (Wang et al., 2013). Out of all the mineral nutrients, potassium (K) plays a particularly critical role in plant growth and metabolism. Many studies suggest that K has no effect on stomatal control and photosynthetic rates under well-watered conditions, but K starvation could favor stomatal opening and promote transpiration (Benlloch-Gonzalez et al., 2008).

Okumura et al. (2011) stated that increase in nitrogen level applied normally promotes higher maize yield. IFIA (2002) reported that nitrogen amount used in maize production in China is 130 $kg.ha^{-1}$; in USA 150 kg ha^{-1}. In Brazil, increasing nitrogen level of 0, 40, 80, 120, 160, and 200 $kg.ha^{-1}$ presented quadratic response during vegetative and reproductive stages, and grain protein showed an increase until N level of 160 kg ha^{-1} (Okumura et al., 2011).

Nitrogen in excessive amounts can have negative consequences in plant metabolism and produce problems in agronomical, economical and environmental scales (Okumura *et al*, 2011). In a study by Donner and Kucharik (2003), when the application rate of nitrogen fertilizer was increased by 30%, the corn yield increased 4%, but the amount of nitrate lost through leaching increased by 53%. Furthermore, the yield decreased by 10% when the application rate of nitrogen fertilizer was reduced by 30%, the leaching loss was 37% less. Shariffi et al. (2011) reported that applying manure at at an equivalent to 150 kg N.ha^{-1}per year increased the yield of *Phleum pratense* L. Champ; however, the excess nitrogen that accumulates in the soil if a double the amount of manure was applied might result in a decrease in yield. Research by Akmal et al. (2010) demonstrated that maize grain yield increases in quadratic model with increased N application to a plateau level. Considering soil fertility status and cropping systems, the 150 kg.ha^{-1}. N application to maize cultivar "Jalal" in Peshawar was required for maximum grain production (Akmal et al., 2010).

Referring to the study of Okumura et al. (2011), Donner and Kucharik (2003), Shariffi et al. (2011) and Akmal et al. (2010), the nitrogen level of 159 kg.ha^{-1} would be optimum for maize production at Grabagan. Therefore, the combination of manure at 10 ton.ha^{-1} and NPK Phonska 300 kg.ha^{-1} without urea, which had already supplied nitrogen of 159 kg.ha^{-1} to the maize, could be recommended. The use of urea as external fertilizer input could be reduced by application of livestock waste in this integrated farming system.

Conclusion

The nitrogen fertilizer level of 45, 91, 137, and 183 kg N ha^{-1} combined with the manure at 10 ton.ha^{-1} are equivalent to supplying 159, 205, 251 and 297 kg.ha^{-1} of nitrogen to maize crops. The nitrogen levels did not significantly influence the maize growth and yield. Application of manure of livestock waste in an integrated farming of maize and cattle can reduce the use of urea fertilizers as an external input of nitrogen in Grabagan village. With regular application of the manure with nutrient content as analysed in this study at every planting season applying NPK Phonska at 300 kg.ha^{-1} should be sufficient to support maize growth to achieve maize grain yield of 6.20 ton per hectare.

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