Research article

Reduction of Synthetic Nitrogen Fertilizer Using Tithonia-based Liquid Organic Fertilizer for Sweet Corn Production in Ultisols

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Abstract

Keywords

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Nitrogen (N) fertilization method is of great interest in nutrient management in sweet corn production. Sweet corn production areas in Indonesia have been increasingly extended to Ultisol land due to decline in the amount of arable land. Proper nitrogen management in Ultisols including the use of tithonia-based liquid organic fertilizer (LOF) as a way of reducing the use of synthetic N fertilizer need to be investigated. In this experiment, we aimed to determine the effects of various combinations of tithonia-based LOF and synthetic N on the growth and yields of sweet corn grown in Ultisols. This experiment was conducted from April to July 2018, in Bengkulu City, Indonesia at an elevation of 36 m above sea level and was arranged in complete randomized design with four replications. Treatments consisted of five combinations of LOF and synthetic N, i.e. 0 % LOF+100 % N, 25 % LOF+75 % of N, 50 % LOF+50 % N, 75 % LOF+25 % N, and 100 % LOF+0 % N. The results indicated that fertilizer combination composition significantly affected plant height, leaf greenness, husked ear weight, unhusked ear weight, and ear length of sweet corn, but did not affect leaf number and shoot dry weight. Overall, the use of 75% LOF in combination with 25% synthetic N produced similar results to 100% synthetic N. It was concluded that the use of tithonia-based LOF reduced the use of synthetic N fertilizer in sweet corn production grown in Ultisols. This conclusion should be further evaluated for sweet corn production under field conditions in Ultisols.

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1. Introduction

Sweet corn (*Zea mays* L. var. saccharata), also known as sugar corn and pole corn, is a maize variety with a high sugar content and is increasingly in demand by consumers for fresh consumption or medicinal purposes. Successful sweet corn production requires proper nutrient management in order to sustain soil fertility, and factors of importance include types of fertilizers, fertilizer dosage, application techniques and so on. Sweet corn requires sufficient nutrient supply for a reliable economic yield during its course of growth and development. Indeed, Polii and Tumbeleka [1] mentioned that the generally recommended dosages of macronutrient fertilizers for sweet corn in Indonesia were 200 kg N ha^{-1}, 150 kg P_2O_5 ha^{-1}, 150 kg K_2O ha^{-1} and 10-20 ton ha^{-1} of organic material. Nevertheless, such recommendations are subject to change and depend on sweet corn variety, soil type and other growing conditions.

Nitrogen (N) application is of great interest in nutrient management in sweet corn production. Plant requires a large amount of N since it comprises 1-5% of total plant dry matter, and is a fundamental component of proteins, nucleic acids, chlorophyll, co-enzymes, phytohormones and secondary metabolites [2]. In addition, this nutrient is also related to all of plant's metabolic processes, and its uptake and partition rates are mainly determined by supply and demand during the stages of plant growth and development [3]. Sweet corn is considered to be a heavy user of N and can use 168 kg or more of N per hectare [4]. However, the amount of application depends on days to maturity, plant density, soil type, irrigation and other cultural practices. Moreover, N fertilizer recommendations for sweet corn production should be based on yield goal and previously planted crop as well as soil types. Crop grown in various soils such as sandy soils, or sandy irrigated soils, sandy non irrigated soils, or heavy soils show different responses to N application in terms of rate of nutrient leaching and uptakes. This implies that excessive N application or all-at-once application to the soil can involve significant nutrient loss by leaching and/or volatilization, which can eventually bring about economic loss to the growers and damage to the water and land resources.

Sweet corn production in Indonesia generally takes place in highland areas. Land use and soil fertility at altitude have drastically changed over the past decades [5], and growers have found the substituted areas at lower altitudes to compensate for declining highland production areas. At lower altitude, Ultisols are one of the dominant soil types that can be used for sweet corn production. In Indonesia, Ultisols cover about 48,000,000 ha which accounted for almost 25% of agricultural land [6]. This type of soil is characterized by high soil acidity, high Al^{3+} and low nutrient availability, especially phosphorus [7]. In addition, this type of soil is generally characterized by low pH, high Al^{3+}, poor organic-C and phosphorus as well as low cation exchange capacity and base saturation [8, 9], conditions which eventually reduce crop growth and yield. Poor nutrient balance in Ultisols, especially N, can be compensated by proper N management that can lead to better sweet corn with excellent growth and yields. Pangaribuan *et al.* [10] evaluated the use of liquid organic fertilizer from plant extracts and concluded that liquid organic fertilizer improved growth, yield and quality of sweet corn grown in Ultisols. It was also suggested that the use of liquid organic fertilizer could serve as an additional supplement to synthetic fertilizer. Clearly, the addition of organic fertilizer in Ultisols has the potential to improve the chemical, physical and biological properties of soils, all of which eventually increase soil fertility and improve crop growth and yields.

Tithonia-based liquid organic fertilizer is one of the locally produced organic fertilizers made from the Mexican sunflower (*Tithonia diversifolia* (Hemsl.) A. Gray), a wild weed commonly found in the highlands of equatorial areas. This weed has been widely used in organic agricultural practices, both as mulching material and organic fertilizer, to maintain soil productivity and crop yields and it has high nutrient content. This weed contained about 3.5% N, 0.37% P and 4.1% K [11]. Another study concluded that the organic matter, total content of N, P, K, Ca, Mg and C in *T. diversifolia* were 24.04%, 1.76%, 0.82%, 3.92%, 3.07%, 0.005% and 14.00%, respectively [12].

The uses of tithonia-based liquid organic fertilizer in combination with solid organic fertilizer for sweet corn production in Andosols of highland areas have been previously reported [13-15]. However, there has been no specific report on the use of tithonia-based liquid organic fertilizer to minimize the use of synthetic N in sweet corn production in Ultisols.

The main aim of this experiment was to determine the effectiveness of using tithonia-based liquid organic fertilizer to minimize the use of synthetic N for the growth and yields of sweet corn grown in Ultisols.

2. Materials and Methods

The polybag experiment was conducted from April to July 2018, at Integrated Agricultural Zone of Faculty of Agriculture, University of Bengkulu, in Bengkulu City, Indonesia, at an elevation of 36 m above sea level (Latitude 3°, 45', 10" South, and Longitude 102°, 16', 59'' East). The experiment was arranged in complete randomized design with four replications. Treatments consisted of five combinations of liquid organic fertilizer (LOF) and synthetic N, namely (1) 0% LOF and 100% N (control), (2) 25% LOF and 75% of N, (3) 50% LOF and 50% N, (4) 75% LOF and 25% N, and 100% LOF and 0% N. Each treatment unit consisted of three plants grown in each black polyethylene polybags (28 cm in diameter).

Production of liquid organic fertilizer (LOF) was conducted according to Fahrurrozi *et al.* [16]. Leaves of tithonia were collected from unflowering branches and were immediately chopped into pieces for LOF production. All organic materials consisted of 5 kg of tithonia leaves, 5 kg of fresh cattle feces, 10 l of cattle urine, 2.5 kg of topsoil, 10 l solution of 24-h incubated 10 ml EM 4 + 0.125 kg white sugar, which were mixed together with water in a blue plastic container to reach a final volume of 100 l. The mixture was securely covered and aerobically incubated for five weeks. It was opened and stirred every four days. After incubation, the mixture was filtered to separate liquid and debris. The liquid portion was further used for LOF application. Lab analysis indicated that it contained N-total, P, and K as much as 1.3%, 0.7% and 1.3%, respectively.

Composited soil samples (from 0.2 m in depth) were taken and nutrient analysis of N-total, available P, exchangeable K and pH were performed with Khejdhal, Bray I, Flame-photometric, Walkey and Black, and electrometric methods, respectively. A week before planting, 10 kg of Ultisols soil (top soil of 0.2 m in depth) was filled into each planting, and limed with dolomite as much as 2 ton ha^{-1} (10 g $polybag^{-1}$). Two seeds of sweet corn (var. Bonanza) were sowed in each polybag, then at 7 days after sowing, the sweet corn crop with worse performance was removed. After thinning, each polybag was fertilized with 100 kg ha^{-1} SP-36 and 75 kg ha^{-1} KCl. Synthetic N fertilizer (urea) at recommended dosage (150 kg N ha^{-1}) was equally applied at 21 and 30 days after planting in accordance with treatment portion. Each plant in the polybag got fertilized with LOF at 14, 21, 28 and 35 days after planting according to the calculated dosages (400 ml $plant^{-1}$). Each application was proportionally applied according to treatment. For example, the application of 100% LOF was 50, 100, 100, and 150 ml at 14, 21, 28 and 35 days after planting, respectively. Manual irrigation was applied to the sweet corn when there was no precipitation, until the growing medium reached field capacity, indicated by water dripping from the bottom of polybag. Manual weeding and soil upraising were conducted at 21 and 49 days after planting. All pests were physically controlled by removing them from the polybags.

Sweet corns were harvested at 78 days after planting. Treatment effects were determined in terms of plant height (cm), leaf greenness by SPAD-meter, leaf number, shoot dry weight (g), husked ear weight (g), unhusked ear weight (g) and ear length (cm). Shoot dry weight was measured by drying the sample in open dry air for three days, then in an oven for 48 h at 70ºC until constant weight was attained. Data were subjected to homogeneity testing before analysis of variance using the Statistical Analysis System at $P<0.05$. Means of treatment effects were compared using the Least Significantly Different test at $P<0.05$.

3. Results and Discussion

3.1. Environmental growing conditions

Laboratory analysis of soil samples revealed that soil at the experimental site was characterized by pH of 5.4 (acid), N-total of 0.25 % (medium), organic-C of 2.97 % (low), available P of 6.83 mg kg^{-1} (low), exchangeable K of 0.18 cmol $kg\text{-}1^{-1}$ (low), and moisture content of 44.59% (medium). During the growing season, the experimental site received sufficient water supply from rainfall, however, when sweet corn started to flower, the amount of daily precipitation decreased drastically. Rainfall around the experimental site was recorded at the closest meteorological station, the Meteorology, Climatology, and Geophysical Agency, Bengkulu (ID WMO: 96255). Data indicated that monthly rainfall in April, May, June and July 2018 was 432.5 mm, 468.8 mm, 141 mm and 16 mm, respectively. Sweet corn production requires a continuous supply of moisture to ensure successful pollination and kernel growth [17]. For example, after the tasseling stage, sweet corn requires 25.4 to 38.1 mm of water each week (or 101.2 to 152.4 mm per month). Rainfall was not well distributed in July and very little precipitation took place in August. Although the sweet corn was manually watered during the absence of precipitation, low rainfall during August might have contributed to low kernel development. Meanwhile, relative air humidity around the experimental site in April, May, June and July 2018 was 83.6%, 82.5%, 82.8%, and 78.0%, respectively.

3.2. Growth and yield of sweet corn

The results indicated that fertilizer combinations of liquid organic fertilizer (LOF) and synthetic N significantly affected plant height ($P<0.01$), leaf greenness ($P<0.01$), but not leaf number ($P>0.05$) and shoot dry weight ($P>0.05$). Treatment comparisons of selected variables are presented in Figure 1. In addition, the application of fertilizer combinations of LOF with synthetic N significantly affected husked ear weight ($P<0.05$), unhusked ear weight ($P<0.01$), and ear length ($P<0.01$). Means of treatment comparisons of selected variables are presented in Figure 2.

The results presented in Figures 1 and 2 suggested that combinations of LOF with synthetic N fertilizer up to 75% of LOF and 25% of recommended synthetic N fertilizer had similar effects to those of 100% synthetic N, as indicated by plant height, leaf greenness, leaf number, shoot dry weight, husked ear weight, unhusked ear weight, and ear length of sweet corn. However, sweet corn grown with 100% LOF fertilizer had the lowest growth and yield indicators compared to other treatment combinations. The lower effectiveness of 100% LOF application might be related to loss of LOF after application. The application of LOF can be either through ground application or foliar application [18]. Both foliar and ground application are subject to short-lived availability of fertilizer throughout the growing season due to volatilization in foliar application and leaching in ground application. Combined applications of liquid and solid fertilizers might be a way of correcting mid-season deficiencies of fertilizers.

The ability of tithonia-based LOF to complement N supplies of reduced synthetic N application was related to the N contents of the LOF. According to Fahrurrozi *et al*. [18], tithonia-enriched LOF contained 3.36%, 146 ppm, and 0.0325% of N, P, and K, respectively. Higher N in this LOF might have resulted from the high N content of the tithonia leaves. On a dry weight basis, the biomass of tithonia leaves contained 6.65% of N, 0.87% of P, 3.94% of K, 7.5 me 100 g^{-1} of Ca-*ex*.

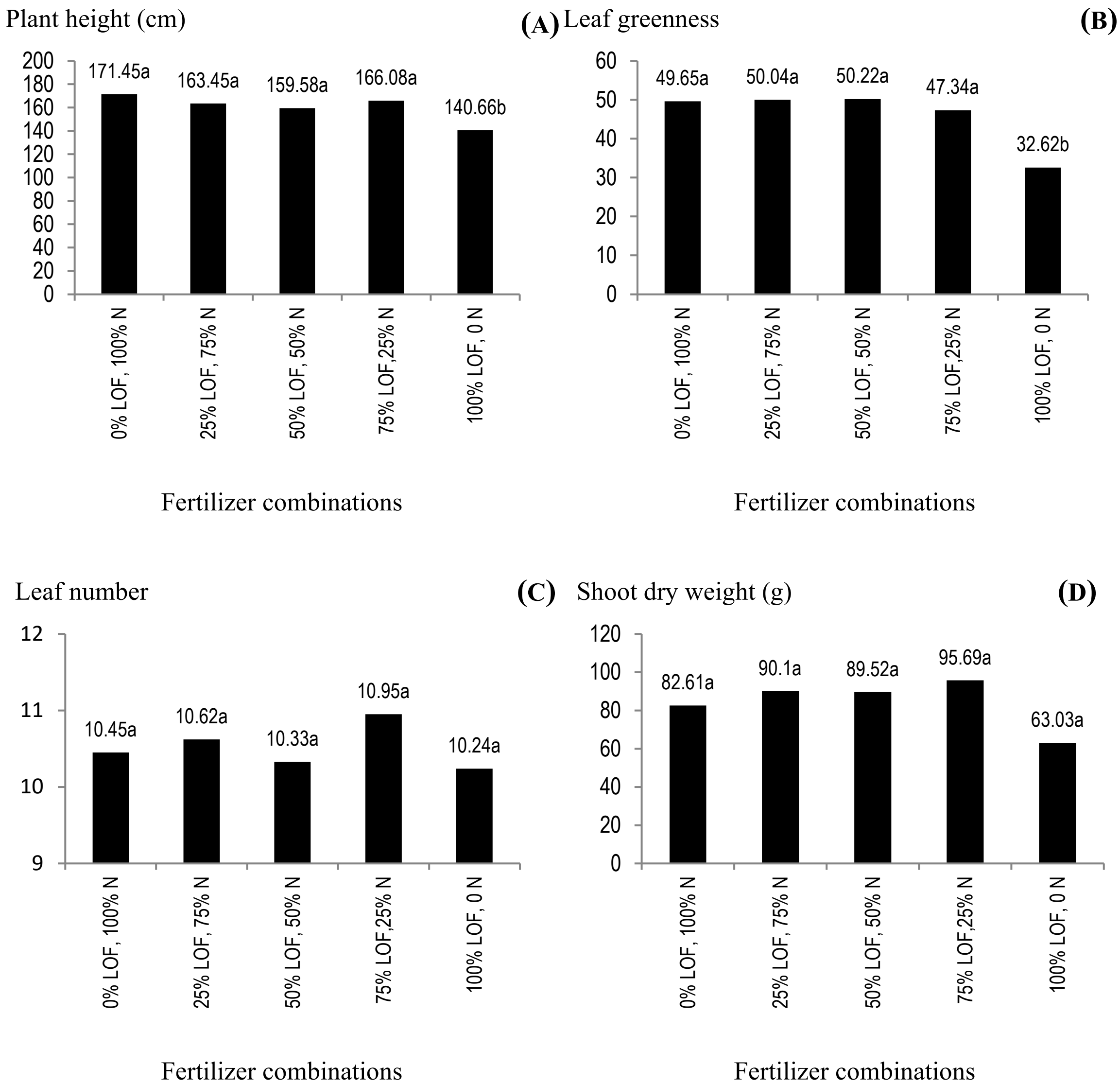

Figure 1. Effect of fertilizer combinations of liquid organic fertilizer (LOF) and synthetic nitrogen (N) on plant height (A), leaf greenness (B), leaf number (C) and shoot dry weight (D) of sweet corn *(Means in the same column followed with the same letter are not significantly different according to Least Significant Difference at 5%).*

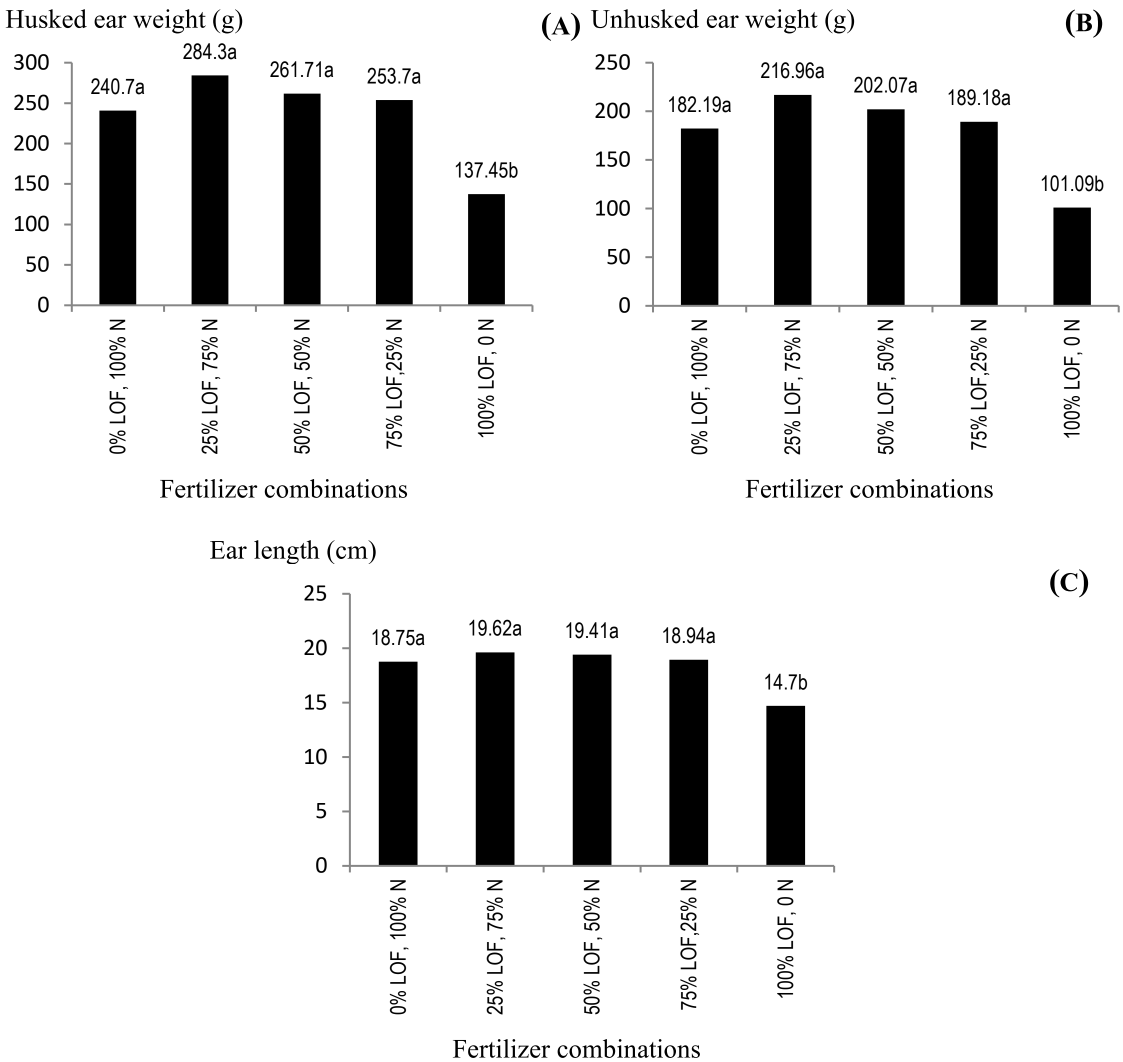

Figure 2. Effect of fertilizer combinations of liquid organic fertilizer (LOF) and synthetic nitrogen (N) on husked ear weight (A), unhusked ear weight (B), and ear length (C) of sweet corn *(Means in the same column followed with the same letter are not significantly different according to Least Significant Difference at 5%).*

and 5.67 me 100 g^{-1} of Mg-*ex*. [16]. The effectiveness of LOF in influencing sweet corn growth and yields might have been related to the ability of sweet corn to use available N in the rhizosphere. Research conducted by Muktamar *et al.* [14] concluded that higher rates of LOF application to sweet corn significantly increased nitrogen uptake by sweet corn. Furthermore, the application of tithonia-based LOF substantially increased total soil N, NO_3-N, exchangeable K, and soil pH [15]. Such increases eventually improve N uptake by sweet corn and benefit crop growth and development. In addition, the complementary effects of treatment combinations might also be related to the fact that liquid organic N has higher availability than synthetic N does to sweet corns. Research conducted by Raun *et al.* [19] suggested the application of liquid N fertilizer could have increased nitrogen use efficiency.

The results of this experiment also suggested that tithonia-based LOF could be applied in combination with synthetic N fertilizer in sweet corn production. Reduction of synthetic N application will reduce the negative effect of excessive N in the soil and groundwater environment. According to Olabode *et al*. [12], excess amounts of N fertilizer application are lost into the environment through leaching, volatilization and denitrification. The magnitude of N loss through leaching in an agricultural ecosystem can vary due to environmental conditions. Research conducted by Walsh and Belmont [20] concluded that 50-60 % of applied N can be lost through leaching.

This experiment, however, did not measure N uptake by sweet corn. The nature of how crop accumulates certain amounts of essential nutrients including N, due to treatment effects, is a very important aspect of N management in sweet corn production. According to Heckman [21], nutrient uptake measurement is an invaluable part of nutrient management in sweet corn production. Indeed, N uptake determines N use efficiency by a particular crop. Nitrogen use efficiency or nitrogen utility efficiency in crop production is not only a matter of environmental concern, but also a socioeconomic issue. Excessive nitrogen application will not only reduced crop yields and environmental supports, but also bring about increased production costs and eventually reduced economic returns to the farmers. Although sweet corn in this study was grown in polybags, the results of the study are very useful in establishing a sustainable sweet corn production program with high crop productivity, high efficiency and minimum nutrient loss.

4. Conclusions

Based on this experiment, it is concluded that the use of tithonia-based liquid organic fertilizer (LOF) reduced the use of synthetic nitrogen (N) fertilizer in sweet corn production grown in Ultisols. The reduction of synthetic N fertilizer for sweet corn production can reach as high as 75% due to the complementary effects of LOF. The use of 75% of LOF in combination with 25% of recommended synthetic N fertilizer had similar effects to fertilization with 100% synthetic N as indicated by plant height, leaf greenness, leaf number, shoot dry weight, husked ear weight, unhusked ear weight, and ear length of sweet corn. Future research in Ultisols should be scaled up to the field, and nutrient uptake by sweet corn at that scale should be evaluated.

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