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The Effect of Organic and Inorganic Fertilizer Applications on N, P and K Uptake and Yield of Sweet Corn (*Zea mays* saccharata Sturt)

Emma Trinurani Sofyan and Dirga Sapta Sara

Department of Soil Science, Faculty of Agriculture, Universitas Padjadjaran
Jl. Raya Bandung-Sumedang km 21, Bandung 45363 – West Java Indonesia
e-mail: emma.trinurani@unpad.ac.id

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ABSTRACT

To overcome insufficient sweet corn production in Indonesia, various strategies have been developed to improve its production. This study was conducted to evaluate the effect of organic fertilizer (*i.e.* cow manure) and inorganic fertilizer application on nutrient uptake and yield of sweet corn (*Zea mays* saccharata Sturt). Inceptisol possess low soil fertility and relatively low to moderate level of organic matter content. Application of organic fertilizer in combination with inorganic fertilizers is expected to increase N, P and K uptake and yield of sweet corn. This study was conducted from October 2016 to February 2017 at the Field Experimental Station of Agriculture Faculty, Universitas Padjadjaran in Jatinangor, West Java. The study was performed in a Randomized Block Design consisting of 10 treatments and 3 replications. The treatments were as follow: A = Control, B = Standard NPK, C = 0 NPK + 1 organic fertilizer, D = ¼ NPK + 1 organic fertilizer, E = ½ NPK + 1 organic fertilizer, F = ¾ NPK + 1 organic fertilizer, G = 1 NPK + 1 organic fertilizer, H = ¾ NPK + ¼ organic fertilizer, I = ¾ NPK + ½ organic fertilizer and J = ¾ NPK + ¾ organic fertilizer. The results showed that the treatment I (¾ NPK + ½ organic fertilizer) resulted in the highest N, P and K uptake, *i.e.* 54.31 mg plant^{-1}; 82.85 mg plant^{-1} and 56.40 mg plant^{-1}, respectively and the heaviest weight of sweet corn, *i.e.* 407.33 g.

Keywords: Cow manure, fertilizer, sweet corn

ABSTRAK

Hingga saat ini produksi jagung manis di Indonesia belum mencukupi kebutuhan nasional. Berbagai strategi telah dikembangkan untuk meningkatkan produksi jagung manis. Penelitian ini dilakukan untuk mengevaluasi pengaruh aplikasi pupuk organik dari kotoran sapi dan pupuk anorganik terhadap serapan hara dan hasil tanaman jagung manis. Tanah Inceptisol memiliki kesuburan yang rendah dan kadar bahan organik yang relatif rendah hingga sedang. Aplikasi pupuk organik pada tanah Inceptisol bersamaan dengan pupuk anorganik diharapkan mampu meningkatkan serapan N, P dan K serta hasil jagung manis. Penelitian ini dilakukan dari Oktober 2016 hingga Februari 2017 di Kebun Percobaan di Jatinangor, Jawa Barat. Metode yang digunakan dalam penelitian ini adalah Rancangan Acak Kelompok yang terdiri dari 10 perlakuan dan 3 ulangan. Perlakuan tersebut yaitu sebagai berikut: A = Kontrol, B = NPK Standar, C = 0 NPK + 1 pupuk organik, D = ¼ NPK + 1 pupuk organik, E = ½ NPK + 1 pupuk organik, F = ¾ NPK + 1 pupuk organik, G = 1 NPK + 1 pupuk organik, H = ¾ NPK + ¼ pupuk organik, I = ¾ NPK + ½ pupuk organik dan J = ¾ NPK + ¾ pupuk organik. Hasil penelitian menunjukkan bahwa perlakuan I (¾ NPK + ½ pupuk organik) menghasilkan serapan hara N, P dan K tertinggi pada tanaman jagung manis, masing-masing sebesar 54,31 mg tanaman^{-1}; 82,85 mg tanaman^{-1} dan 56,40 mg tanaman^{-1}, dan bobot tongkol jagung manis tertinggi yaitu 407,33 g.

Kata kunci: Jagung manis, kotoran sapi, pupuk

INTRODUCTION

In Indonesia, sweet corn (*Zea mays* saccharata Sturt) is a very popular vegetable. The annual production of sweet corn in Indonesia until 2015 increased by 3.17% per year with the production rate of 5.18 Mg ha^{-1}, and the production in 2017 was about 27.9 x 10^6 Mg (BPS 2018). To supply the national needs, Indonesia is still importing the sweet corn. Until 2013, the import rate of sweet corn increased 1.43% annually, while the export rate decreased up to 17.25% (BPS 2014).

The marginal lands in Indonesia dominated by Inceptisols are abundant. Inceptisol is widely distributed in Indonesia, *i.e.* about 20.75 millions ha or about 37.5% of the Indonesian mainland (Muyassir *et al.* 2012). Inceptisol is potential for future agricultural development (Hairiah *et al.* 2000). The Inceptisols in Indonesia have some characteristics, namely 1) nutrient status varies from low to high; 2) soil pH is from acid to neutral; 3) levels of organic matter content are low to moderate; 4) N and P contents are low to high; 5) K is very low to moderate, and 6) Cation Exchange Capacity (CEC) is low to high (Syafruddin *et al.* 2009). The application of organic fertilizer can be an alternative solution to improve soil physical and chemical characteristics so that the acid soils and marginal soils can become productive soils.

Fertilization is able to provide and supply nutrients to plants. Inorganic fertilizers commonly used by farmers are NPK fertilizers in the forms of Urea, SP-36, and KCl, respectively. N, P, and K are essential nutrients for plants, they should always be available in soil. Often farmers provide excessive amounts of inorganic fertilizers that can cause physical, chemical, and biological soil damages , thus decreasing the soil fertility. An effort that can be made to reduce the impact of inorganic fertilizer use is the application of organic fertilizer that can improves soil properties and increases the nutrient content of the soil.

The use of organic inputs such as crop residues, manures and compost has great potential effects to improve soil productivity and crop yields through improvement of physical, chemical and biological properties of the soil as well as nutrient supply (Stone and Elioff 1998). It follows that if a sustainable productive agriculture will be achieved, practices that maintain or increase soil organic matter reserves must be adopted. Effects of the combined application of organic and inorganic fertilizers in improving soil fertility and crop yields have been demonstrated. Recently Moe *et al.* (2017) reported that the combined application of inorganic fertilizers and organic manures had the benefits not only reducing the use of chemical fertilizers but also improving N uptake by hybrid rice, leading to a better environmental quality. Wang *et al.* (2001) reported that the application of organic and inorganic fertilizers showed great benefits not only for the increase of N uptake by plants and available N in soil, but also for the improvement of maize yield. The extent to which organic fertilizers could increase the efficiency of applied inorganic fertilizers in soil and crop productivity has not received much attention for research. However, the combined use of organic and inorganic fertilizers increases crop yields more than the use of single fertilizer (Engel *et al.* 2010). The application of 75% of inorganic fertilizer + 5 Mg ha^{-1} organic fertilizer has resulted in N, P and K uptake by sweet corn with the magnitude of 1.850, 0.418 and 2.374 g $plant^{-1}$, respectively, and good growth and yield of sweet corn with the magnitude of 356.36 g $plant^{-1}$ or 15.21 Mg ha^{-1} (Marlina *et al.* 2017).

Organic material is needed for the growth of plants. The addition of organic materials from several sources such as manure, green manure, compost of crop residues, domestic compost, and compost of industrial residues could reduce soil acidity by increasing the soil organic matter content, promoting the soil maturation, improving the soil structure, enriching soil bacteria and enhancing the soil base saturation (Zhang 2005; Li *et al.* 2010). A thorough understanding of how these fertilizers and various management practices affect the long-term soil fertility of conventional cropping systems is still lacking. The objective of the research was to investigate the effect of the application of organic fertilizer combined with inorganic fertilizer on N, P and K uptake and yield of sweet corn grown on Inceptisol from Jatinangor, West Java.

MATERIALS AND METHODS

Site Description

A field experiment was conducted in October 2015 until February 2016 at the field experimental station of Agriculture Faculty, Universitas Padjadjaran (6°54'56.4"S and 107°46'16.9"E). The elevation of the area is approximately 625 m above sea level. The results of a pervious study showed that the Inceptisol characteristics in the experimental station include pH of 5.83, Organic-C content of 1.63%, total-N content of 0.16%, C/N ratio of 10.18, available P content of 2.4 mg kg^{-1} available K content of 1.53 mg kg^{-1}, soil texture of silty clay, CEC of 19.8 me 100 g^{-1}, and base saturation of 52.2% (Sudirja *et al.* 2017).

Experimental Design

The study was arranged in a Randomized Block Design consisting of 10 treatments and 3 replicates, in total there were 30 plots. The size of each plot was 10 m^2 (2m × 5 m). The treatments were as follow: A = Control, B = Standard NPK, C = 0 NPK + 1 organic fertilizer, D = ¼ NPK + 1 organic fertilizer, E = ½ NPK + 1 organic fertilizer, F = ¾ NPK + 1 organic fertilizer, G = 1 NPK + 1 organic fertilizer, H = ¾ NPK + ¼ organic fertilizer, I = ¾ NPK + ½ organic fertilizer and J = ¾ NPK + ¾ organic fertilizer. The recommended doses of inorganic fertilizers used in this study were 300 kg ha^{-1} urea, 100 kg ha^{-1} SP-36 and 50 kg ha^{-1} KCl. The organic fertilizer used was cow manure with a dose 2 Mg ha^{-1} .

Plant Sampling and Analysis

Nutrient uptake by sweet corn were measured on five randomly selected plant samples from each plot at 49 days after planting. Sweet corn leaves were sampled at tasselling stage (maximum growth). Leaf samples were oven-dried at 65ºC for 120 hours to reach a constant weight, and ground for further analyses. Nitrogen content in the plant materials was determined using the Kjeldahl method. Phosphorus content was determined in the plant samples after the samples were dried-ashing at 550ºC for 6 hours. Next, the ash obtained was mixed with diluted HNO_3 (ratio of concentrated HNO_3 and distilled water was 1:1). Phosphorus was determined calorimetrically using vanadium ammonium molybdate solution. Potassium concentration was assessed by the Flame Atomic Absorption Spectrophotometry (FAAS) method. The nutrient uptake by sweet corn was calculated based on dry weight values multiplied with the nutrient concentrations in the plant organs. The sweet corns were harvested at 70 days after planting, and the corn husks were removed.

Data Analysis

Data analysis using One-way Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT) were performed to determine the differences among the fertilizer treatments. A difference at 5% significance level was used. All statistical analyses were performed using the SPSS software package (version 15.0) (Statistical Graphics Crop, Princeton, USA).

RESULTS AND DISCUSSION

Nitrogen Uptake

The results of the analysis of variance indicated the the application of inorganic NPK and organic fertilizers affected N, P and K uptake by sweet corn plants. The effects of each treatment on the nutrient uptake are presented in Table 1.

The N uptake by sweet corn plants was significantly affected by fertilization (Table 1). This finding indicates that along with inorganic fertilization, the addition of organic fertilizer during the growth period provides the substantial improvement on sweet corn growth since the nutrients are available when they are required by the plants. The results also suggested the high demand of nutrients during the plant growth period. The results showed that the application of ¾ NPK + ½ organic fertilizer can increase the uptake of N by corn plants from 41.80 mg $plant^{-1}$ (Standard NPK application) to 54.31 mg $plant^{-1}$.

Table 1. Nutrient uptake by sweet corn applied with organic and inorganic fertilizers.

Treatment	N-Uptake (mg kg^{-1})	P-Uptake (mg kg^{-1})	K-Uptake (mg kg^{-1})
A = Control	18.26 a	46.03 a	18.95 a
B = Standard NPK	41.80 e	64.34 d	37.25 e
C = 0 NPK + 1 organic fertilizer	20.39 a	54.97 b	24.74 b
D = ¼ NPK + 1 organic fertilizer	20.88 a	56.15 b	25.90 b
E = ½ NPK + 1 organic fertilizer	24.06 b	59.08 c	30.45 c
F = ¾ NPK + 1 organic fertilizer	26.34 bc	65.84 d	33.11 c
G = 1 NPK + 1 organic fertilizer	28.61 c	69.84 e	36.07 d
H = ¾ NPK + ¼ organic fertilizer	36.07 d	71.21 ef	36.61 d
I = ¾ NPK + ½ organic fertilizer	54.31 g	82.85 h	56.40 g
J = ¾ NPK + ¾ organic fertilizer	48.49 f	77.03 g	48.32 f

Note: The numbers followed by the same letters in each column are not significantly different according to the Duncan's Multiple Range Test at 5% level.

The application of organic fertilizer (cow manure) and inorganic fertilizers can increase the N uptake by sweet corn plants. The balance of organic fertilizer from cow manure and inorganic fertilizers causes fast nutrient availability to plants. This condition allows nutrients such as nitrogen to be taken up more easily by plants. This will lead to an increase in the ability of plant roots to absorb air and N in the soil that will further support the improvement of plant development (Mengel *et al.* 2001). Combination of balanced organic fertilizer and inorganic fertilizer will be able to increase the efficiency of N uptake by plants, so that an optimum crop yield can be obtained.

Previous studies have shown the superior effect of application of combined organic and inorganic fertilizers over the sole use of inorganic or organic source in terms of balanced nutrient supply, improved soil fertility and crop yield. The results of current study have shown that the combination of organic and inorganic fertilizer increased the N uptake by plants. The results of current study is in line with the synergistic effect of N from organic fertilizers (farmyard manure) that accumulates more N uptake of maize (Huang *et al*. 2007, Zada *et al*. 2000).

Phosphorus Uptake

Phosphorus uptake by sweet corn plants ranged between 46.03 mg plant^{-1} and 82.85 mg plant^{-1} (Table 1). The highest P uptake of 82.55 mg plant^{-1} was measured in the plot applied with ¾ NPK + ½ organic fertilizer. Statistically, the P uptake in the treatment of ¾ NPK + ½ organic fertilizer is significantly different from that in all other treatments. The combined organic fertilizer and inorganic fertilizer application significantly affected P uptake. Manzar *et al.* (2005) reported that the combination of Poultry Waste (PW) and di-calcium phosphates (DCP) with the ratio of 2:1 resulted in the maximum dry matter yield and the highest P-uptake of 74.63 mg pot^{-1}. The increase in yield is due to the combined use of organic and inorganic fertilizers that is related to the improvement of some yield contributing factors. Akhtar *et al.* (2000) reported that the combined application of farmyard manure and chemical fertilizers improved yield contributing factor of crop significantly more than the use of chemical fertilizers alone.

The results of current study have shown that the combination of organic and inorganic fertilizers increased the P uptake by plants. The results of current study is in line with the study of Mukuralinda *et al.* (2010), which showed that the combination of green manure and inorganic TSP fertilizer at a rate of 50 kg P ha^{-1} significantly increased P uptake of maize (15.6–18. 6 kg P ha^{-1}) compared to the control treatment (5 kg P ha^{-1}), and 65% of maize yield variation was explained by the total P uptake.

Potassium Uptake

As shown in Table 1, it can be noticed that the high amount of K uptake by plant tissues was measured in the plots applied with NPK fertilizers + organic fertilizer compared to that in the control plot. Furthermore, the higher the rate of NPK fertilizers applied to the soil, the higher amount of K uptake by plant tissues is. Table 1 showed that the highest K uptake by sweet corn plants was 56.40 mg kg^{-1}, which was obtained in the plot applied with

Table 2. Weight, diamater and length of corn ears applied with organic and inorganic fertilizers.

Treatments	Weight of Corn Ear (g)	Diameter of Corn Ear (cm)	Length of Corn Ear (cm)
A = Control	147.33 a	3.69 a	22.60 a
B = Standard NPK	339.00 d	5.03 bc	23.13 a
C = 0 NPK + 1 organic fertilizer	159.00 a	4.24 ab	22.67 a
D = ¼ NPK + 1 organic fertilizer	216.00 b	4.47 abc	23.80 a
E = ½ NPK + 1 organic fertilizer	268.00 c	4.64 bc	24.40 b
F = ¾ NPK + 1 organic fertilizer	274.67 c	4.71 bc	24.63 b
G = 1 NPK + 1 organic fertilizer	319.00 d	4.83 bc	24.53 b
H = ¾ NPK + ¼ organic fertilizer	330.00 d	4.93 bc	24.07 b
I = ¾ NPK + ½ organic fertilizer	407.33 e	5.43 c	24.60 b
J = ¾ NPK + ¾ organic fertilizer	393.00 e	5.13 bc	24.67 b

Note: The numbers followed by the same letters in each column are not significantly different according to the Duncan's Multiple Range Test at 5% level.

¾ NPK + ½ organic fertilizer. Meanwhile, the lowest K uptake was 18.95 mg kg^{-1}, which was occurred in the control treatment. The results of the current study showed that the combination of organic and inorganic fertilizers increased K uptake by plants. The results of current study is in line with the study of Rasool *et al.* (2008) in which the grain yield and K uptake by both maize and wheat are higher with the application of farmyard manure and inorganic fertilizers than in the control plots. Makinde and Ayoola (2010) also reported that the complementary application of organic and inorganic fertilizers increased K content in maize about 1.70% in comparison to that of inorganic fertilizer alone.

Yield of Sweet Corn

The components of yield measured in this study include weight, diameter and length of corn ears. The results showed that there were differences on the effects of the treatments on the yield components of sweet corn (Table 2)

The effects of the treatments on the weight, diameter and length of corn ears are related to each other. The weight of corn ear is closely related to the diameter and length of corn ear. Long ear of corn with a large diameter and many kernel rows will produce a heavy corn ear. The yield of sweet corn crops will increase in line with the nature of the sweet corn. Based on the weight, diameter and lenght of corn ears measured in this study, the application of organic fertilizer in combination with NPK fertilizers showed better results compared to the application of organic fertilizer alone.

The results of the statistical analysis on the weight of corn ear showed that the highest yield was obtained in the treatment I (¾ NPK + ½ organic fertilizer). The results indicate that the treatment I can be a recommended dosage of fertilizers that can increase the yield of sweet corn plants. Mukuralinda *et al*. (2010) also showed that the combination of organic and inorganic fertilizer significantly increased maize yield about 508% compared to the control treatment. This result indicated that the mixture organic and inorganic fertilizers is a good treatment to increase yield. This may be due to the fact that inorganic fertilizer of the mixture provided nutrients earlier to the growing crops during the early vegetative growth stage, while the organic fertilizer provided nutrients at the later stage of the crop development.

CONCLUSIONS

The study showed that the productivity of sweet corn plants is considerably higher when using the combined organic and inorganic fertilizer applications. The study has shown that the nutrient uptake and yields of sweet corns from plots applied with organic fertilizer are significantly lower than those from the combined organic and inorganic fertilizer plots. In addition, the yields of sweet corn plants from plots applied with organic and inorganic fertilizers are significantly higher than the yields from sole inorganic fertilizer application. The plant nutrient contents are also significantly different. Farmers can use less amount of inorganic fertilizers, complemented with organic manures to cultivate sweet corn, however, higher yields will still be obtained than only sole inorganic fertilizer application.

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