International Journal of Agricultural Technology 2022Vol. 18(6):2607-2616
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Mexican sunflower (*Tithonia diversifolia*) compost as substitution of synthetic fertilizers for sweet corn in Ultisols

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Setyowati, N., Hutapea, J. V. and Muktamar, Z. (2022). Mexican sunflower (*Tithonia diversifolia*) compost as substitution of synthetic fertilizers for sweet corn in Ultisols. International Journal of Agricultural Technology 18(6):2607-2616.

Abstract The combination of Mexican sunflower (MS) compost with NPK fertilizer significantly affected the yield component of sweet corn. Three hundred kg of NPK + 7.5 tons/ha of MS compost produced the highest yield, indicated by husked cob weight (256.56 g), unhusked cob weight (183.31 g), husked cob length (26.93 cm), husked cob diameter (43. 10 mm), and unhusked cob diameter (38.37 mm). Nonetheless, there was no significant effect of the combination on the growth of sweet corn; however, the combination tended to provide better fresh root weight (39.14 g), shoot dry weight (121.76 g), root dry weight (14.32 g) and plant dry weight (136,08 g). Accordingly, an MS compost application rate of 7.5 tons/ha may replace 50% of the recommended NPK fertilizer. This finding aids in the development of sustainable agricultural practices that minimize the usage of synthetic fertilizer.

Keywords: Natural resources, Organic fertilizer, Sustainable agriculture, Weed compost

Introduction

Sweet corn demand continues to rise yearly, requiring the growth of sweet corn production acreage. In addition to agricultural intensification, the strategy is to expand the planting area by utilizing marginal lands. Ultisols are dry land with the potential to be turned into a productive sweet corn farming area. However, the use of Ultisols for plant cultivation is hampered by several soil properties, including high soil acidity, an average pH of 4.50, high Al saturation, and low macronutrient content, particularly P, K, Ca, and Mg, and low organic matter content (Sianturi *et al*., 2019; Muktamar *et al*., 2016). Fertilization, using either synthetic or organic fertilizers, enhances land productivity. Synthetic fertilizers can meet plant nutrient requirement; however, in the long term, excessive and unwise use of synthetic fertilizers harms the environment, especially the soil. The use of synthetic fertilizers diminishes land productivity. Providing organic matter is an effort to sustain soil fertility (Leroy

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et al., 2008; Muktamar *et al*., 2022). Organic fertilizers can improve the soil's physical, chemical, and biological properties. According to Siregar *et al*. (2017) and Muktamar *et al*. (2020), organic fertilizers can increase pH, available P, and Cation Exchange Capacity and decrease exchangeable Al in Ultisols. However, a higher quantity of solid organic fertilizers is necessary than synthetic fertilizers. Therefore, transportation costs are more expensive. Furthermore, the rate of nutrient absorption by plants from solid organic fertilizers is slower than that of synthetic fertilizers. As a result, organic fertilizers must be combined with lower doses of synthetic fertilizers to meet plant nutrient requirements. Weeds are potential sources of organic matter, including Mexican sunflower. This annual weed contains 3.50-4.00% N, 0.35-0.38% P, 3.50-4.10% K, 0.59% Ca, and 0.27% Mg and the biomass can reach 9-11 ton ha^{-1} fresh weight in the dry season and 1418 ton ha^{-1} in the rainy season. Mexican sunflower biomass is commonly used as green manure, mulch, or compost to improve soil fertility and biology. Applying Mexican sunflower compost to the soil can increase the soil's P and K content (Lestari, 2016). The NPK fertilizer efficiently increased plant growth. NPK fertilizers with dosages ranging from 300 to 600 kg ha^{-1} yielded comparable results of corn to single N, P, and K fertilizers. However, sweet corn requires more minerals, particularly nitrogen, than regular corn. The study aimed to determine the best dose combination of Mexican sunflower compost with NPK fertilizer for the growth and yield of sweet corn on Ultisols.

Materials and methods

Experimental design

The research was carried out in December 2020 – February 2021 in Beringin Raya Village, Muara Bangkahulu, Bengkulu City, at an altitude of ± 10 meters above sea level. The study employed a completely randomized block design (RCBD), with treatment of the combination of Mexican sunflower compost and NPK fertilizer, including P_0 = No fertilization, P_1= 100% recommended dose of NPK (600 kg ha^{-1}), P_2 = 75% kg ha^{-1} NPK dose + 25% ton/ha Mexican sunflower compost, P_3 = 50% kg ha^{-1} NPK dose + 50% ton ha^{-1} Mexican sunflower compost, P_4 = 25% kg ha^{-1} NPK dose + 75% ton ha^{-1} Mexican sunflower compost and P_5 = 100% dose of Mexican sunflower compost (15 ton ha^{-1}). In this study, NPK compound fertilizer (16%:16%:16%) was utilized at the recommended dose for sweet corn of 600 kg/ha. Each treatment was repeated three times.

Field experiment

The experimental site was cleared and hoed approximately to the depth of 20 cm and divided into 18 experimental plots, each size of 3 m x 2 m (l x w). The block was separated by 50 cm, while among experimental unit was 30 cm apart. According to the treatment, Mexican sunflower compost was uniformly incorporated on the soil surface a week before planting. Sweet corn seeds were planted at a depth of 2 cm from the soil surface at a spacing of 60 cm x 40 cm. Furadan 3G was applied per planting hole to control insect infestation. Thinning was performed seven days after planting (DAP) by selecting a healthier plant. The land was watered frequently when necessary. Weeding was conducted three and five weeks after planting. Fertilization of synthetic fertilizer was conducted twice, a half dose at planting and the rest at the early generative phase. Pest and disease control was accomplished chemically by using pesticides such as insecticide Profenofos 500g/l, fungicide Dithane M45, and Dimethomorph 60%. Sweet corn was harvested when 75% of the plant population had reached the ripe stage, indicated by cob hair turning brown and white paste liquid release when the seed was squeezed.

Data analysis

The data were analyzed using the analysis of variance (ANOVA) or F test at the 5% level. The treatment means were compared using Duncan Multiple Range Test (DMRT) at 95% confidence level.

Results

Analysis of variance

The data were analyzed on all variables using analysis of variance (ANOVA) at a 5% F test. The analysis of variance is shown in Table 1. To evaluate the average combination treatment of Mexican sunflower compost with NPK fertilizer in Ultisols, growth variables and yields that indicated a significant effect were further tested using Least Significance Different (LSD 5%).

Sweet Corn Vegetative Growth

Sweet corn requires nutrients ready for absorption throughout the vegetative phase. The findings of this study revealed that throughout the vegetative stage, sweet corn responded differently to a treatment. There were no significant differences among treatments on plant height, stem diameter, and the number of leaves at 5 WAPs (Table 2). However, the application of 50% synthetic NPK + Mexican sunflower compost (P_3) resulted in superior development of sweet corn compared to the treatment of 100% synthetic NPK (without the addition of compost/P_1), as indicated by higher root dry weight, shoot dry weight, and plant dry weight (Table 3).

Table 1. Summary of calculated values of sweet corn growth response and yield in Ultisol applying various combinations of Mexican sunflower weed compost and NPK fertilizer

Variables	F-calculated
Plant height 5 WAP	1.74ns
Stem diameter 5 WAP	2.86ns
Number of leaf 5 WAP	1.37ns
Root fresh weight	4.79*
Shoot fresh weight	2.43ns
Plant fresh weight	3.22ns
Shoot dry weight	3.45*
Root dry weight	4.91*
Plant dry weight	3.64*
Husked cob weight	10.37**
Unhusked cob weight	10.88**
Husked cob length	9.03**
Unhusked cob length	3.22ns
Husked cob diameter	9.76**
Unhusked cob diameter	10.59**

Note: * = Significantly different, ** = highly significant difference, ns = not significantly different.
F-table = 3.33, WAP= week after planting

Table 2. Plant height, number of leaves, and stem diameter of sweet corn on various combinations of Mexican sunflower compost and NPK fertilizer in Ultisols at 5 WAP

Treatment	Plant height (cm)	Stem diameter (mm)	Number of leaves
P_0 = No fertilization	97.58	15.08	5.66
P_1= 100% NPK (600 kg/ha)	114.52	17.30	6.33
P_2 = 75% P_1 + 25% P_5	107.85	17.27	6.00
P_3 = 50% P_1+ 50% P_5	121.36	18.24	6.66
P_4 = 25% P_1 + 75% P_5	109.10	16.80	6.00
P_5 = 100% dose of Mexican sunflower compost (15 tons/ha)	121.62	18.67	6.66

Sweet corn plant height ranged from 97.58-114.52 cm, with stem diameter between 15.08-18.24 mm and leaf number 5.66-6.66. Although there were no significantly different, treatments P_3 and P_5 tended to produce higher plant height, stem diameter, and number of leaves than other treatments. The effect of treatment on plants' fresh and dry weight is shown in Table 3. The combination of Mexican sunflower compost + synthetic NPK fertilizer resulted in significantly different root and shoot fresh weight, root and shoot fresh weight, and plant dry weight. Treatment (P_3), a combination of 300 kg ha^{-1} NPK and 7.5 ton ha^{-1} of Mexican sunflower compost, resulted in better growth than treatments P_0 and P_1 (Table 3).

Table 3. Effect of treatment on fresh root weight (RF), shoot fresh weight (SF), root dry weight (RD), shoot dry weight (SD), and plant dry weight (PD)

Treatment	RF (g)	SF (g)	RD (g)	SD (g)	PD (g)
P_0	14.38 b	143.12	4.50 c	56.14 bc	60.64 c
P_1	21.66 b	184.08	7.56 bc	68.93 bc	76.49 bc
P_2	22.89 b	196.32	9.18 b	104.96 ab	114.15 bc
P_3	39.14 a	222.63	14.32 a	121.76 a	136.08 a
P_4	17.84 b	160.25	7.75 bc	91.60 abc	99.35 abc
P_5	19.34 b	181.96	7.10 bc	92.58 abc	99.68 abc

Note: The mean followed by the same letter in the same column is not significantly different in the 5% LSD test. P_0 = No fertilization, P_1= 100% NPK (600 kg/ha), P_2 = 75% P_1 + 25% P_5, P_3 = 50% P_1+ 50% P_5, P_4 = 25% P_1 + 75% P_5, P_5 = 100% dose of Mexican sunflower compost (15 tons/ha)

Sweet corn yield

The results showed a significant effect among treatments on husked cob length, husk cob diameter, unhusked cob diameter, husked cob weight, and unhusked cob weight. Treatment P_3 resulted in longer husked and unhusked cobs, 26.93 cm and 19.70 cm, respectively; the husked and unhusked diameter of the cob was greater, 43.10 mm and 38.37 mm, respectively; and the husked and unhusked cob weight was greater, 256.56 g and 183.31 g respectively, compared to treatments P_0 and P_1 (Table 4). P3 treatment increased HCW and UCW levels by 21.3% and 17.7%, respectively, compared to 100% NPK treatment (P_1).

Table 4. Effect of treatment on husked cob length (HCL), unhusked cob length (UCL), husked cob diameter (HCD) and unhusked cob diameter (UCD), husked cob weight (HCW), and unhusked cob weight (UCW)

Treatment	HCL (cm)	UCL (cm)	HCD (mm)	UCD (mm)	HCW (g)	UCW (g)
P_0	21.80 c	15.93	33.44 d	27.33 c	126.70 d	88.7 d
P_1	24.53 b	18.66	39.46 bc	34.32 b	201.72 bc	137.86 bc
P_2	25.00 b	18.76	40.85 ab	36.69 ab	216.51 ab	169.66 ab
P_3	26.93 a	19.70	43.10 a	38.37 a	256.56 a	183.31 a
P_4	23.33 bc	16.36	36.32 db	34.95 ab	163.77 cd	120.65 bc
P_5	23.20 bc	16.96	39.10 bc	33.21 b	167.12 cd	120.56 cd

Note: The mean followed by the same letter in the same column is not significantly different in the 5% BNT test. P_0 = No fertilization, P_1= 100% NPK (600 kg/ha), P_2 = 75% P_1 + 25% P_5, P_3 = 50% P_1+ 50% P_5, P_4 = 25% P_1 + 75% P_5, P_5 = 100% dose of Mexican sunflower compost (15 tons/ha)

Discussion

Sweet corn vegetative growth

The application of Mexican sunflower compost combined with NPK fertilizer resulted in plant growth that was not significantly different in terms of plant height, stem diameter, and number of leaves. The slow decomposition of the compost implied that the nutrients had not been available during the plant's vegetative growth period, so the results were not significantly different among the treatments. One of the characteristics of compost is its capacity to release nutrients slowly (Simanungkalit *et al*., 2006). According to Hartatik *et al*. (2015), organic fertilizers can increase soil's physical, chemical, and biological properties without being readily apparent. In addition, plants' response to applying organic fertilizers is relatively slow.

Although plant height, stem diameter, and the number of leaves were not significantly different among treatments, the treatment influenced the plant's fresh weight and dry weight at the end of the experiment. The P_3 treatment had better growth than the P_1 treatment. Combining compost and NPK fertilizer can provide sufficient nutrients for plants during the generative stage. During vegetative growth, the addition of NPK synthetic fertilizer is readily supplied to the plant. In addition, organic fertilizer can provide nutrients and increase soil pH (Zuraida and Nuraini, 2021), leading to more available NPK for plants at higher pH. Phosphate becomes accessible and available by plants as soil pH rises (Habi *et al*., 2018). An increase in pH influences the decrease in Al content, allowing P to be available. Plants utilize P for root growth, mainly the development of lateral roots and fibrous roots (Fauzi, 2020). The root may absorb more nutrients, increasing the fresh weight of sweet corn. In addition to adding nutrients and raising the soil's pH, compost provides better soil structure, leading to easier nutrient absorption by roots (Hutomo *et al*., 2015).

In general, adding compost along with NPK fertilizer increases root dry weight. The Mexican sunflower is a source of organic matter and has a relatively high content of N, P, and K. (Lestari, 2016). A previous study also confirmed that the combination of organic matter of Mexican sunflowers and NPK improves soil chemical characteristics (Khairunnisa *et al.*, 2019). Mexican sunflower, as an organic material, has the potential to improve the soil's physical, biological, and chemical qualities (Hartatik *et al.*, 2015). Mexican sunflower compost can thus loosen the soil and increase soil pores, allowing plant roots to develop and absorb nutrients from the synthetic NPK. In addition to increasing root dry weight, combining compost and synthetic fertilizer treatment rose plant dry weight.

Plant dry weight was higher in the P_3 treatment than in the P_1 treatment or plants with only synthetic NPK or without the addition of compost. These findings indicate that plants can utilize the available N from the compost treatment and synthetic NPK to run photosynthesis. Nitrogen affects the photosynthesis rate. An increase in photosynthesis rate contributes to total dry matter production (Sonbai, 2013). Photosynthesis results are distributed to all parts of the plant, forming greater plant biomass. This distribution process is related to the carbohydrates produced. A higher rate of photosynthesis leads to greater plant biomass production in the form of plant dry weight (Kresnatita *et al*., 2013). The shoot dry weight and total plant dry weight of the P_3 treatment were 43.3% and 43.7% greater, respectively, than the P_1 treatment. These findings indicate that compost can improve soil structure, allowing roots to grow and develop. Developed plant roots will eventually increase nutrient absorption; the added synthetic NPK can supply the nutrients plants need.

Sweet corn generative growth

It is demonstrated that sweet corn fertilized with 50% compost + 50% NPK (P_3) produced a longer cob, a larger cob diameter, and a greater cob weight than sweet corn treated with recommended NPK (P_1). When sweet corn reaches the generative phase, the nutrients in Mexican sunflower compost become readily available to plants, along with the increase in soil pH and enhancement of soil physical qualities (Syofiani, 2019). Plant roots can grow effectively in good soil structure, and their ability to absorb nutrients improves (Siregar and Nuraini, 2021). Mexican sunflower compost contains N released into the soil, increasing N availability. Nitrogen is an essential component in protein synthesis. The protein synthesis process was positively correlated to the length and diameter of the sweet corn cobs (Hidayat *et al.*, 2018).

The P3 treatment produced more leaves and longer cobs than the other treatments. Thus, sweet corn cobs' development is tightly related to sweet corn's vegetative growth, particularly leaves where the photosynthetic process takes place. The process of photosynthesis will improve as the number of leaves increases (Mahdiannoor, 2014). Photosynthetic products are stored in seeds, directly affecting sweet corn cobs' length. Another factor influencing cob length is P, which is associated with cob production, and K, which is involved in cob filling (Sintia, 2011). According to Arinofa and Sudiarso (2018), Mexican sunflower compost can supply additional nutrients to corn plants, particularly P, for cob development.

Organic Mexican sunflower fertilizer has the potential to supply nutrients to plants by enhancing the soil's physical and chemical qualities (Hutomo *et al.*, 2015). Improvement of soil quality makes plant nutrient absorption faster. Arinofa and Sudiarso (2018) stated that Mexican sunflower compost increases the diameter of the cob by providing an additional supply of N, P, and K nutrients to sweet corn. The N absorbed by the plant during the growth phase through seed maturation affects the diameter of the cob. Sweet corn requires nitrogen availability at all stages of development up to seed formation. The seeds' appearance will affect the cob's diameter (Shaila *et al.* 2019). The size of this cob is related to the higher photosynthate produced. Most photosynthetic products are used for seed development and cob enlargement (Kresnatita *et al.*, 2013).

Overall, the findings suggest that organic matter from Mexican sunflower compost can improve soil physical qualities, allowing plant roots to absorb synthetic NPK more effectively. The high nitrogen content of Mexican sunflower can enhance protein synthesis, which has a positive relationship with cob length, diameter, and weight (Hidayat *et al.*, 2018). This study found that the size and diameter of the cob were positively correlated with the weight of sweet corn cobs. Sweet corn cob weight increased in conjunction with corn cob length and diameter increases. The findings of this study are also similar to the results of Napitupulu *et al.* (2018), which reported that adding compost and NPK fertilizer enhanced the weight of cobs, 1000 corn kernels, soil pH, and K-dd Ultisols.

According to Noviarini *et al.* (2018), the weight of the cob was positively correlated with plant height, length, diameter, and weight. The results of this study indicate that the combination of Mexican sunflower compost 7.5ton/ha with 300kg/ha NPK for growth and yield of sweet corn in Ultisols. The combination of Mexican sunflower compost 7.5ton/ha with 300kg/ha NPK resulted in plant height, the number of leaves, husked cob, unhusked cob, husked cob length, husked cob diameter, and unhusked cob diameter higher than other treatments.

In summary, this study confirmed that the application of 300 kg ha^{-1} NPK synthetic combined with 7.5 ton ha^{-1} of Mexican sunflower compost resulted in the best growth and yield of sweet corn grown in Ultisols. This study implies that Mexican sunflower compost at a rate of 7.5 ton ha^{-1} can substitute a half dose of NPK synthetic fertilizer. This finding benefits the development of sustainable agriculture practices to reduce the use of synthetic fertilizer.

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(Received: 15 August 2022, accepted: 20 October 2022)