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Original Research Article

The effect of organic fertilizer and urea fertilizer on growth, yield and quality of sweet corn and soil health

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Abstract

This study aims to determine the effect of organic fertilizer and urea fertilizer on growth, yield, and quality of sweet corn (*Zea mays* L. *saccharata)* and soil health. The research was conducted in Bandar Lampung, Indonesia in December 2016 until March 2017. This research was designed using a randomized factorial block design 2 x 4 with three replications. The arrangement of treatments are as follows: The first treatment was organic fertilizer (poultry manure that has been composted and combined with *Biomax-Grow* biofertilizer) consisting of 2 levels that are, 0 and 15 ton ha^{-1}. The second treatment was the dosage of urea fertilizer consisted of 0, 150, 300 and 450 kg ha^{-1}. The results showed that application of integrated use of organic fertilizer and urea fertilizer would decrease the use of urea and be recommended for sweet corn cultivation. Organic fertilizer gives a better postharvest quality of sweet corn and a better soil health with respect to soil respiration as well as fungi and bacterial population.

Keywords : Poultry manure, Soil respiration, Fungi, Microbial, Sucrose content

Introduction

Sweet corn is an increasingly popular horticultural product and it is much in demand because it has a sweet taste when consumed. Sweet corn also has a short production life and a relatively high price; it is considered very profitable to be cultivated by farmers. Production of sweet corn in Lampung in 2015 reached 5.11 ton ha^{-1} (Badan Pusat Statistik, 2015), whereas according to the description sweet corn yield potential can reach 14-18 ton ha^{-1}. One of the problems encountered by farmers, especially in Lampung is the low soil fertility. Soil type in Lampung, Indonesia is Ultisol, according to Hardjowigeno (2003) and Prasetyo and Suriadikarta (2006). Ultisol soil is a poor soil due to low nutrients, low soil pH, saturated by Al, Fe, and Mn poisoning, high adsorption of P, and low CEC.

The low production of sweet corn is influenced mainly by low soil fertility. Efforts to improve soil fertility is by giving fertilizer both organic fertilizer and inorganic fertilizer. Organic fertilizer is a fertilizer that is beneficial to increase agricultural production both quality and quantity, reduce environmental pollution and improve the quality of land in a sustainable manner. Organic fertilizer can be made by composting manure by using microbes contained in biofertilizer as a decomposer. *Biomax-Grow* is a biofertilizer containing the bacteria *Azotobacter* sp. and *Azospirillum* sp. which is an N binding bacteria and contains phosphorous solubilizing bacteria (Gunarto, 2015).

Nitrogen is the most nutrient needed plant. Nitrogen is a major element required for successful plant growth and development. Farmers often cultivate sweet corn with excessive nitrogen, which will damage soil fertility. Urea should be given sufficiently without damaging soil fertility. Sweet corn production is more often limited by nitrogen deficiency than other elements. The addition of urea fertilizer containing

46% N nutrient is assumed to decrease the level of deficiency of sweet corn plant to N nutrients. According to Hayati (2006) inorganic fertilizers, such as urea, improved sweet corn growth. Ramadhani et al. (2016) explains that the application of urea fertilizer and manure can produce the highest cob corn. Moreover, the previous experiment by the same author (Pangaribuan et al., 2017) showed that the use of enriched rice straw compost and recommended nitrogen fertilizer was recommended for sweet corn cultivation in Ultisol soil.

Fertilization using organic fertilizer is expected to reduce the need for urea fertilizer as well as to improve soil fertility and soil health to support growth and increase production of sweet corn. The purpose of this research is to investigate the effect of organic fertilizer and dosage of urea fertilizer on growth, yield and quality of sweet corn, microbial populations and soil respiration.

Material and Methods

The research was conducted in the experimental site Kotasepang, Bandar Lampung, Indonesia, with the coordinates between 105 ° 15 '23' 'and 105 ° 15' 82 " E and between 5 ° 21' 86 " S. The study was conducted during the wet season which began in December 2016 until March 2017. The land used in this study belongs to the Ultisol soil type. Soil analysis was conducted at Soil Science Laboratory, Faculty of Agriculture, Lampung University. Postharvest quality and carotenoid pigment analysis conducted at Integrated Laboratory and Technology Innovation Center of Lampung University.

The materials used in this research are sweet corn cultivar Jambore, composted poultry manure, *Biomax-Grow* biofertilizer, Urea, SP36, and KCl. This research was conducted by Factorial Random Block Design 2 x 4 with three replications. The first factor was without organic fertilizer and with organic fertilizer 15 ton ha^{-1} (compost package of poultry manure plus *Biomax-Grow* biofertilizer 20 ml l^{-1}); while the second factor was the dosage of urea fertilizer consisted of 0, 150, 300, and 450 kg ha^{-1}. The homogeneity between treatments was tested by Bartlet test, and the data additivity was tested by Tukey test, and then variance was analyzed and tested continued using orthogonal polynomial. Research began with composting. Package organic fertilizers consist of 15 ton ha^{-1} of poultry manure mixed with straw and dolomite lime with a ratio of 6: 3: 1 then composted with 1 l *Biomax-Grow* biofertilizer. Package organic fertilizer was applied on one week before planting. The size of the experimental plot is 3 x 3 m. Seed planting was done with the spacing of 70 x 20 cm. The urea fertilizer was applied at 7 and 30 day after planting (DAP) according to the treatment while SP36 and KCl were applied once at 7 DAP. Additional *Biomax-Grow* biofertilizer 20 ml l^{-1} was applied at 9 and 28 DAP by way of draining near the root to the organic fertilizer treatment plot. Weeding was removed manually. Plants were harvested at 70 days after planting.

The soil was analyzed before sweet corn planting. The analysis included soil pH data, N-total, P-available, K-total, K-add, and C-organic. Measurement of soil pH using pH meter, N-total using Kjeldahl, P-available and K-dd method using Olsen, and C-organic using Spectrofotometer. Plant variables observed in this study included plant height, leaf area index, chlorophyll content (SPAD value), analysis of leaf carotenoid pigment content using procedure performed by Sumanta et al. (2014), cob length, cob diameter, yield and sucrose content. Analysis of soil health consisted of initial and final microbial populations by plate count method (Ptiwari et al., 2009) as well as initial and final soil respiration (Verma et al. 2010).

Results

Soil analysis before planting showed a slightly acidic pH value of 6.16. The low C-organic content is low 1.04%. Other chemical properties of N-total, P-available, and K-dd respectively are 0.10%, 2.38 ppm, and 0.20 ppm. Based on the results of initial soil analysis showed that fertilization needs to be done to improve soil fertility. Fertilization using organic compost can improve soil fertility. According to Clark and Cavigelli (2005), C/N ratio of chicken compost ideal is < 20. The organic fertilizer compost of this study contains pH of 7.37 and organic C, N-total, P-total, K total, and C/N ratios of 22.63%, 1.04%, 0.98%, 0.27%, and 18.81 respectively.

The results showed that the response of plants to the application of organic package fertilizer and urea fertilizer gave a significant effect on plant height variables, leaf area index, SPAD value and carotenoid pigment. Application of organic fertilizer was able to increase plant height by 15.97%, leaf area index was 23.41%, SPAD value 3.19% and the carotenoid pigment was 20.39% higher than without organic fertilizer (Table 1).

Figure 1A shows the height of the plant increases quadratically. With the application of organic package fertilizer, the optimum dose of urea fertilizer is 231.23 kg ha^{-1} to reach the maximum height of 111.06 cm. Without organic fertilizer treatment, the optimum dose of urea fertilizer was 337.75 kg ha^{-1} to reach the maximum height of 95.75 cm.

The results showed that the leaf area index response increased linearly (Fig. 1B). Application of organic package fertilizer can increase the index of leaf area higher than without the application of organic fertilizer. With the addition of organic package fertilizer can increase the leaf area index by 1.725 each for each additional 150 kg ha^{-1} of urea fertilizer. Without the application of organic fertilizer the index of leaf area increases by 0.93 for each additional 150 kg ha^{-1} of urea fertilizer.

Figure 2A shows the response of the SPAD value of the leaves increases linearly. Application of organic package fertilizer can increase the SPAD value is higher than without the provision of organic fertilizer. With the addition of Urea fertilizer up to 450 kg ha^{-1} can still increase the chlorophyll SPAD of sweet corn. With the addition of organic package fertilizers, the SPAD values of the leaves will increase by 1.68 unit per additional 150 kg ha^{-1} of urea fertilizer. Without the application of organic fertilizers, SPAD values of the leaves increase by 1.14 unit with each addition of 150 kg ha^{-1} of urea fertilizer.

The results showed that the leaf carotenoid pigment content increased quadratically (Fig. 2B). With the application of organic package fertilizer, the optimum dose of urea fertilizer is 103.39 kg ha^{-1} to reach maximum leaf carotenoid pigment of 790.88 μmol g^{-1}. Without organic fertilizer treatment, the optimum dose of urea fertilizer was 310.28 kg ha^{-1} to reach maximum leaf carotenoid pigment of 596.98 μmol g^{-1}.

Application of organic package fertilizer and urea fertilizer gave a significant effect on the length of cobs, the diameter of cobs, production per hectare and the content of sucrose. The application of organic package fertilizer increased the length of cobs by 6.12%, the cob diameter by 4.97%, the production by 18.57%, and the sucrose content 8.60% higher than that without the application of organic fertilizer (Table 2).

Figure 3A shows the length of the cob increases quadratically. With the application of organic package fertilizer, the optimal urea fertilizer is 219.33 kg ha^{-1} to reach the maximum cob length of 22.47 cm. Without organic fertilizer, the optimum dose of Urea fertilizer was 372.12 kg ha^{-1} to reach the maximum cob length of 21.12 cm.

The results showed that the cob diameter response increased linearly (Fig. 3B). With the addition of urea fertilizer up to 450 kg ha^{-1} still increase the diameter of the cob of sweet corn. Application of organic package fertilizer can increase the cob diameter, which is higher than without the application of organic fertilizer. With the addition of organic package fertilizer, the cob diameter increases by 0.84 mm each by adding 150 kg ha^{-1} of urea fertilizer. Without the application of organic fertilizer the cob diameter increases by 0.99 mm per additional 150 kg ha^{-1} of urea fertilizer.

The results showed that the yield response increased quadratically (Fig. 4A). With organic package fertilizer, it requires a urea fertilizer of 236.85 kg ha^{-1} to achieve maximum sweetcorn yield of 17.98 tons. Without organic fertilizer, the urea fertilizer dose of 278.49 kg ha^{-1} is required to achieve a maximum yield per hectare of 16.26 tons of sweet corn.

Figure 4B shows the sucrose content increases quadratically. Providing organic fertilizer, urea fertilizer of 220.29 kg ha^{-1} is the optimum dose with the maximum sucrose level is 15.57°Brix. Without organic fertilizer, the optimum dose of urea fertilizer was 289.9 kg ha^{-1} at maximum sucrose content of 14.86°Brix.

The results showed that the microbial response of soil to organic fertilizer gave a significant effect on the microbial variables of the fungi, the number of bacteria and soil respiration of the crops while the urea fertilizer did not give a significant effect (Table 3). Urea fertilizer did not give a significant effect because the time of soil sampling was done at the beginning of the crop before the application of urea fertilizer. Application of organic package fertilizer can increase the amount of fungi microorganisms at early cultivation by 38.92% and bacteria by 41.24% and soil respiration by 65.93% higher than without organic package fertilizer (Table 3). Organic fertilizer increased the final number of microbial fungi 41.06% and final number bacteria 37.87% and final respiration of soil equal to 57.08% higher than without organic fertilizer (Table 3).

Figure 5A shows the fungal microbe increases quadratically. In the application of organic package fertilizer, the optimum dose of urea fertilizer is 192.33 kg ha^{-1} to reach the maximum number of microbial fungi 70.04 CFU ml^{-1}. Without organic fertilizer, the optimum dose of urea fertilizer is 291.48 kg ha^{-1} to reach the maximum number of microbial fungi 44.65 CFU ml^{-1}.

Figure 5B shows the bacterial microbe increases quadratically. With organic package fertilizer application, the optimum dose urea was 168.5 kg ha^{-1} urea to achieve the maximum bacterial microbial amount of 65.12 CFU ml^{-1}, while for the without organic fertilizer treatment, the optimum dose of urea fertilizer was 252.66 kg ha^{-1} to achieve the maximum bacterial microbial amount of 48,01 CFU ml^{-1}.

The respiration microbe increases quadratically (Fig. 5C). At the organic package fertilizer treatment optimal combination of organic fertilizer and urea fertilizer was 227.34 kg ha^{-1} to achieve maximum soil respiration of 734.42 mg/hr m^2. Without organic fertilizer treatment, the optimum dose of urea fertilizer was obtained at 309.66 kg ha^{-1} to achieve maximum soil respiration of 333.45 mg/hr m^2.

Table 1. Effect of organic fertilizer and urea fertilizer on plant height, leaf area index, SPAD value and carotenoid pigment

Comparison	PH	LAI	SV	CP
	(F-counted and number on brackets is % of difference)			
Organic fertilizer (O)				
C1 : O1 vs O2	309.55* (15.97%)	86.87* (23.41%)	33.91* (3.19%)	105.99* (20.39%)
Urea fertilizer (U)				
C2 : U-Linear	141.13*	55.17*	136.80*	38.64*
C3 : U-Quadratic	235.32*	48.87*	20.80*	23.96*
Interaction O X U				
C4 : C1 x C2	102.33*	4.98*	5.09*	7.87*
C5 : C1 x C3	5.08*	9.60*	4.80*	4.89*

* = significantly different at the level of 5%
PH: Plant Height, LAI: Leaf Area Index, SV: SPAD value, CP: Carotenoid pigment.

Table 2. Effect of organic fertilizer and urea fertilizer on length of cob and diameter of cob, production per hectare and sucrose content

Comparison	LC	DC	PH	SL
	(F-counted and number on brackets is % of difference)			
Organic fertilizer (O)	58.87* (6.12%)	11.42* (4.97%)	56.53* (18.57%)	107.14* (8.60%)
C1 : O1 vs O2				
Urea fertilizer (U)	35.12*	11.78*	11.35*	20.89*
C2 : U-Linear	69.62*	5.31*	29.15*	42.92*
C3 : U-Quadratic				
Interaction O X U	46.79*	0.08^{ns}	8.02*	23.09*
C4 : C1 x C2	6.33*	0.09^{ns}	5.64*	9.89*
C5 : C1 x C3				

* = significantly different at the level of 5%; ns = not significantly different at the level of 5%
LC: Length of Cob, DC: Diameter of Cob, PH: Production Per Hectare, SL: Sucrose Level.

Table 3. Effect of organic fertilizer and urea fertilizer on microbial quantity and initial soil respiration of cultivation and end of cropping.

Comparison	IFM	IBM	FFM	FBM	IR	FR
	(F-counted and number on brackets is % of difference)					
Organic fertilizer (O)						
C1 : O1 vs O2	174.01* (38.92%)	1666.13* (41.24%)	1978.55* (41.06%)	461.27* (37.87%)	222.39* (65.93%)	400.22* (57.08%)
Urea fertilizer (U)						
C2 : U-Linear	0.01^{ns}	0.10^{ns}	22.83*	0.33^{ns}	0.05^{ns}	8.19*
C3 : U-Quadratic	0.01^{ns}	0.02^{ns}	737.89*	246.90*	0.00^{ns}	42.28*
Interaction O X U						
C4 : C1 x C2	$0,01^{ns}$	0.08^{ns}	375.05*	54.81*	0.11^{ns}	6.43*
C5 : C1 x C3	$0,01^{ns}$	1.22^{ns}	7.85*	13.25*	0.06^{ns}	4.98*

* = significantly different at the level of 5%; ns = not significantly different at the level of 5%

IFM: Initial Fungi Microbe, IBM: Initial Bacterial Microbe, FFM: Final Fungi Microbe, FBM: Final Bacterial Microbe, IR: Initial Respiration, FR: Final Respiration.

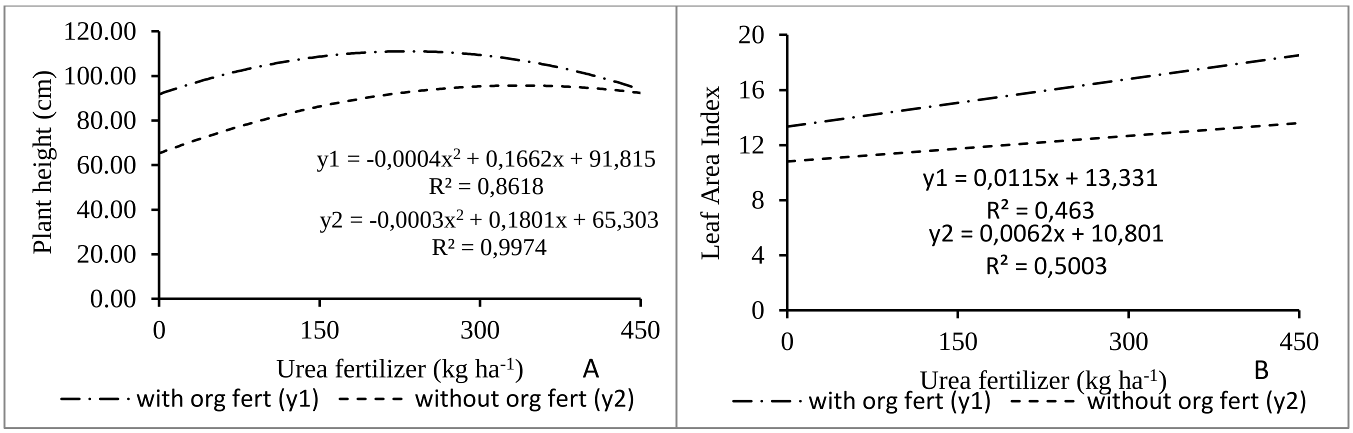


Figure 1. Interaction of organic fertilizer and urea fertilizer to plant height (A) and leaf area index (B).

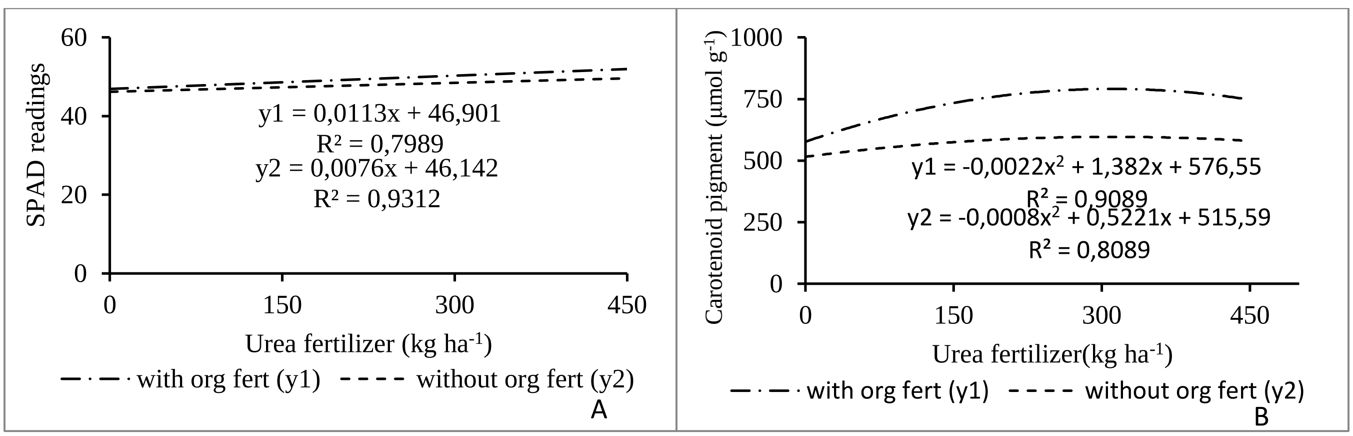


Figure 2. The interaction of organic fertilizer and urea fertilizer on SPAD value (A) leaf carotenoid content (B)

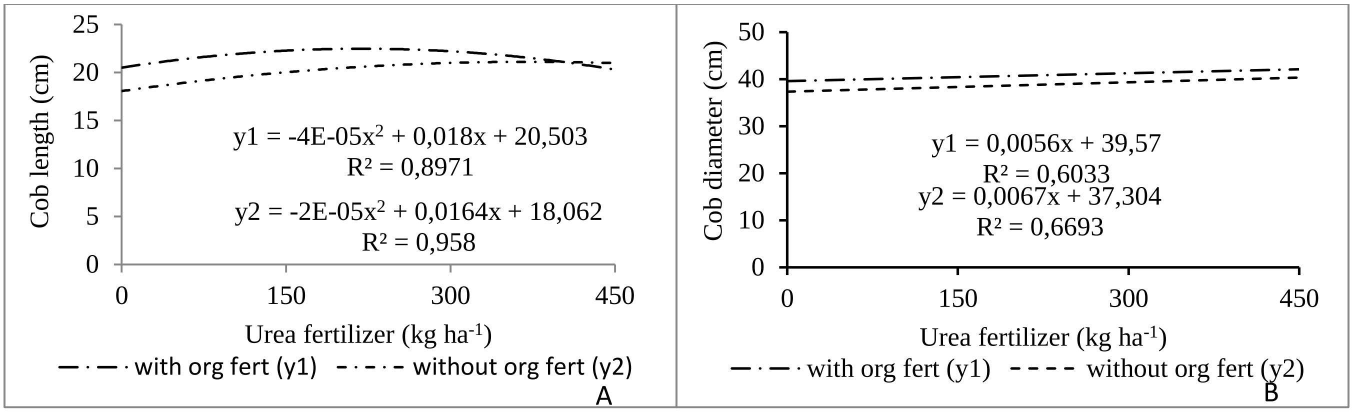


Figure 3. The interaction of organic fertilizer and urea fertilizer on the length of the cob (A) and the diameter of the cob (B)

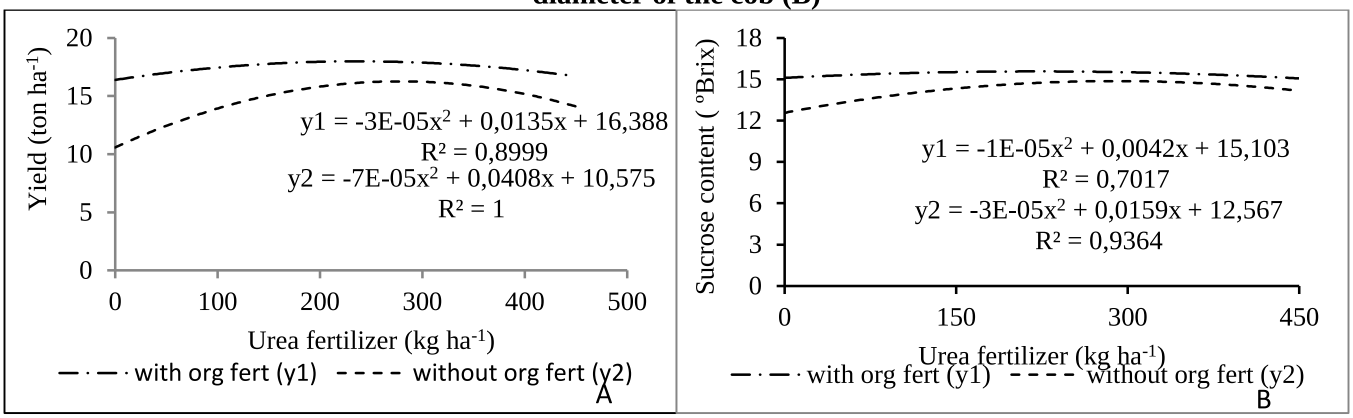


Figure 4. Interaction of organic fertilizer and urea fertilizer to yield (A) and sucrose content (B)

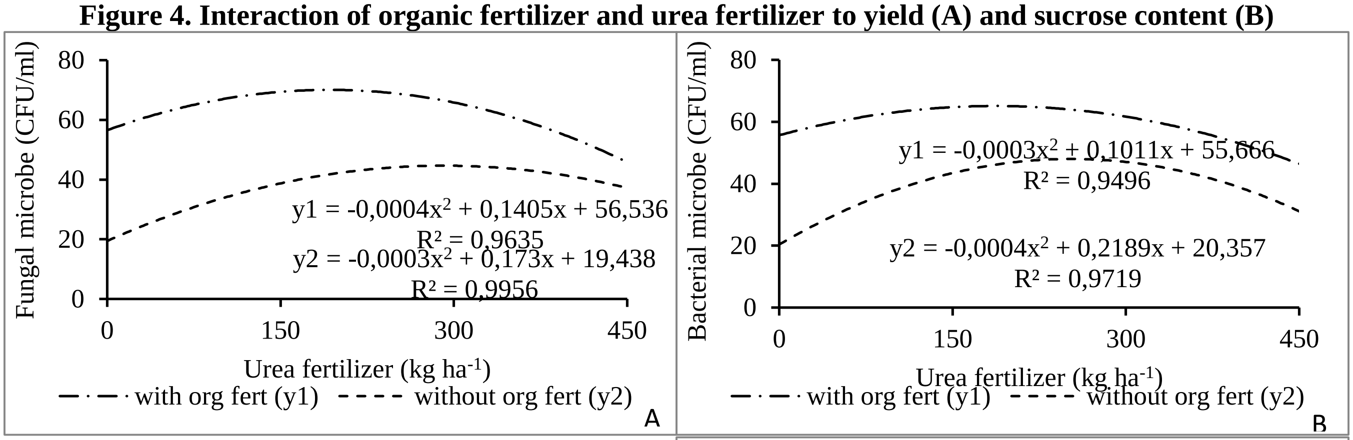
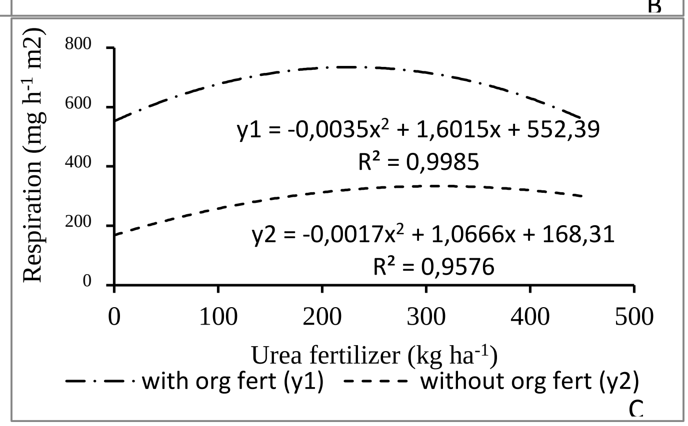


Figure 5. Picture of interaction of organic fertilizer and urea fertilizer to the population fungi (A) bacteria (B) and final respiration (C)



Discussion

Organic fertilizer improved the vegetative growth. Application of organic package fertilizer and urea fertilizer gave a significant effect on plant height and leaf area index. This result is supported by Uwah et al. (2014). The wider leaves will support the capture of sunlight for more photosynthesis. The more sunlight is absorbed, the more photosynthate generated (Duy et al. 2004). Photosynthesis is very crucial in the process of growth and development of plants. Moreover photosynthesis plays a major role in the vegetative as well as generative phase in forming flowers, seed filling, and postharvest quality.

N elements are very important in the vegetative phase. The higher the dose of urea fertilizer gives the higher SPAD value and the more carotenoid content in the leaves (Table 1). SPAD value measurements reflect absolute chlorophyll content per leaf. According to Sonbai et al. (2013) that increased levels of chlorophyll indicated that the inorganic nitrogen fertilizer (urea) can be absorbed by plant roots and used to form more chlorophyll. Plants grown with sufficient nitrogen levels become greener (Bambang et al., 2006). According to Ai and Banyo (2011), chlorophyll is the main pigment in plants that serve to capture the sun's energy, triggering CO_2 fixation to produce carbohydrates which are then converted into energy. The result of this carbohydrate catabolism is utilized by plants for vegetative and generative growth.

Application of organic fertilizer package can increase SPAD value and carotenoid content. Based on research of Iriyani and Nugrahani (2014), chlorophyll content is positively correlated with carotenoid content. Chlorophyll has the role of the photosynthetic machine components, in harvesting light energy, in the stabilization of membranes, and energy transduction (Shah et al., 2017). Carotenoid consists of carotene and xanthophyll, and represents another key photosynthesis pigment group, that harvest light energy for photosynthesis (Zakar et al., 2016). Amujoyegbe et al. (2007) found higher chlorophyll content for the combination of inorganic fertilizers and the treatment of poultry fertilizers. Since the basic of carotenoid's chemical structure is composed of carbon and hydrogen, then organic fertilizer compost with 22.63% of C organic in this experiment would increase the level of carotenoid pigment.

Biomax-Grow fertilizer is containing *Azotobacter* sp. bacteria and *Azospirillum* sp. bacteria, which depend on outside carbon sources to fix nitrogen (Suliasih and Widawati, 2005). According to Surya and Suyono (2013), the fermented chicken manure increases the cation exchange capacity (CEC) and releases the N-nutrient available up to 70%. Increasing levels of CEC, will increase the availability of N-nutrients derived from urea. The application of organic fertilizers provides more nitrogen nutrients than without organic fertilizer. Nitrogen then would be absorbed by plants and plays a role in chlorophyll formation indicated by increased green leaf color.

Organic fertilizer applied to the soil would stimulate the generative growth. Combination of organic package fertilizer and urea fertilizer can increase the length of cobs by 6.12% and cob diameter by 4.97%. This result is in line with research Ramadhani et al. (2016), that the treatment of 75% N of urea given 2 times + 25% N manure at a dose of 184 kg N ha^{-1} capable of producing a higher cobs and cob diameter.

Biomax-Grow is the biofertilizer needed for composting and stimulated the better soil environment. One of microbe content contained in *Biomax-Grow* is *Pseudomonas* sp. which is a phosphate solubilizing bacteria. According to Dermiyati (2015), phosphorus nutrients in the soil can be dissolved by phosphate solubilizing bacteria. These bacteria dissolve phosphate as well as an organic matter which then produces organic acids that chelate metals in the soil so that phosphate becomes available to plants. The utilization of bacteria solubilizing phosphate and organic material can overcome the problem of the high fixation of P on acid soils which can also suppress the use of inorganic fertilizers (Khan et al., 2009). *Biomax-Grow* fertilizer containing N binding bacteria and phosphate solubilizing also contribute N and P nutrients indirectly, so the two nutrients are available more in the soil. According to the results of Fitriatin et al. (2009) that *Pseudomonas* sp can contribute significantly phosphatase activity of 144.72% in the soil. Nitrogen is a nutrient absorbed in higher quantities and is one of the limiting factors for obtaining high maize yields (Ciampitti and Vyn, 2012).

Organic package fertilizer gives a higher yield than without organic fertilizer. Application of organic fertilizer resulted in the production value of 17.98 ton ha^{-1} at the urea fertilizer 236.85 kg ha^{-1}. Compared to without application of organic fertilizer, the addition of organic fertilizer can reduce the use of urea fertilizer by 21.05%. Manure improved the physical and biological properties of the soil (Hepperly et al, 2009) and although in a small quantity manure provided all necessary macro-and micro-nutrients in available forms (Belay et al., 2001) and this leads to a better root development of sweet corn and consequently a higher yield. The increased yield is confirmed by the result of soil analyses after harvesting that showed the improvement in C-org after organic fertilizer application. The result showed that C-org before treatment was 1.04% and after harvesting it was 2.08%. The research confirmed that integrated use of organic fertilizer and inorganic fertilizer would then be recommended in sweetcorn cultivation for the Ultisol soil in the tropics because it would reduce the use of inorganic fertilizer such as nitrogen fertilizer.

Sugar content in sweet corn will determine the quality of post-harvest. The higher the sugar content, the better the quality. Organic fertilizer gives a greater sugar content of sweet corn. The potential sugar content of sweet corn cultivars Jambore is 13.5°Brix, while the average of sweet corn sugar content produced in this research for application without organic fertilizer is 13.98°Brix and for application with organic fertilizer is 15.30°Brix. According to Pangaribuan et al. (2017), the application of 150 kg N ha^{-1} not only increases the yield of sweet corn but also increases the quality of grains as shown in higher sucrose content. The availability of nutrients nitrogen for plants can increase the process of carbohydrate metabolism which will certainly affect the increase sugar levels in seeds (Sirajuddin and Lasmini, 2010).

Application of organic package fertilizer gave a significant effect on soil health that indicated by the microbial amount, the number of bacteria and the soil respiration (Table 3). Application of organic fertilizer is very crucial on the number of microbes and fungi due to the organic matter content contained in the organic fertilizer. Organic matter is a food source for soil microbes. According to Handayanto and Hairiah (2007), soil microbes involved the weathering process of organic materials that contribute to soil health. Healthy soil is a soil that can support plant growth and soil microbial activity. Application of NPK fertilizer with a dose of 200 ml per plant in chili planting by Mujiyati and Supriyadi (2009) can increase the population of soil bacteria by 43% in rizhosphere area. The more microbial populations, the higher the respiration rate will occur. Soil respiration can serve as an indicator of microorganism activity in the soil. The higher the rate of soil respiration, the higher the rate of decomposition of organic matter into nutrients available in the soil (Nguyen and Marschner, 2017). By knowing the amount and activity of microbes in the soil could indicate whether the soil is fertile or not. Because high microbial population indicates the presence of adequate food supply, appropriate temperature, adequate water availability and soil ecology conditions that support the development of microbes (Hastuti and Ginting, 2007). According to the study of Zhong et al. (2010), the application of organic fertilizers and NPK fertilizers that are balanced or not excessive can increase the biomass and soil microbial activity.

Conclusion

(a) Application of organic package fertilizer increased production per hectare 18.57% higher than that without organic fertilizer. (b) Integrated use of organic fertilizer and urea fertilizer would decrease the use of urea by 21.05%. (c) Poultry manure that has been composted and combined with *Biomax-Grow* fertilizer gives a greater sugar content of sweet corn and better soil health.

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