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Plant growth and yield of soybean and sweet corn by application soil amendment and cropping pattern on podzolic soil

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Abstract

Efforts to improve the properties of podzolic can be done by application soil amendment for example cow dung and biochar. Application of soil amendment can be combined with cropping patterns to increase growth and yield of plant. This research aims to study the growth rate and yield of soybean and sweet corn by application of soil amendment and cropping patterns on podzolic soil. This research was conducted in Teurebeh Village, Kota Jantho, Regency of Aceh Besar, and in Plant Physiology Laboratory, Faculty of Agriculture, Syiah Kuala University from June 2016 to January 2017. This research used a Randomized Block Design with 3 replications and two factors, i.e. soil amendment (NPK 400kg ha^{-1}, biochar 10-ton ha^{-1}, cow dung 10-ton ha^{-1}, biochar 10-ton ha^{-1} + NPK 400kg ha^{-1}, cow dung 10-ton ha^{-1} + NPK 400kg ha^{-1}) and cropping pattern (soybean monoculture, sweet corn monoculture, intercropping (soybeans-sweet corn). The results showed that the soil amendment had not significantly affected on all parameters. In general, the cropping pattern had significantly affected on all parameters of observation where monoculture increase changes in plant height and yield of soybeans and sweet corn than intercropping. The highest level of sugar content was found in intercropping with NPK, while the highest LER value was shown in Biochar + NPK that was 1.45.

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Introduction

Growth and crop yield depend on soil fertility. Soil with conditions of unfavorable properties can adversely affect growth and crop yields. Damage to soil properties can be caused by several factors such as loss of nutrients and organic matter in the root zones, the accumulation of salt in the root zones, the accumulation of elements or compounds that are toxic to plants, the saturation of the soil by water, and the erosion (Rajiman, 2013).

Aceh has agricultural land with relatively low fertility, which are dominated with Podzolic soils. The Podzolic soil in the research location in Teureubeh Village, Kota Jantho, Regency of Aceh Besar has low organic matter content, low cation exchange capacity (CEC), significant nutrient deficiency and high exchangeable Al, therefore it is unfavorable for agricultural production (ACIAR Research Team, 2015). Soil acidity, organic C, and nutrient balance N, P, and K are the main factors for affecting microbial activity and enzymes in the soil, as well as soil quality in podzolic soil (Li *et al.*, 2013).

Efforts to improve the condition of podzolic soil properties need to be done so that the land can be utilized for cultivated land and produce maximum crop production. The process of improving soil properties on podzolic soils can be done by using soil amendments such as biochar and manure. The use of soil amendments such as biochar and manure influence increasing growth and yield of plants. Biochar can increase plant growth through reduction of Al toxicity and P efficiency, especially in acid red soils (Zhu *et al.*, 2014). Application of manure as organic fertilizer can increase the yield of corn growth (Hariadi *et al.,* 2016).

In addition to using soil amendments, cropping patterns can also affect the improvement of soil properties that influence increased growth and yield of crops. Cultivation of crops using intercropping can maintain or improve chemical properties and soil enzymatic activity (Wang *et al.*, 2015). On sloping land, intermittent planting of maize and potatoes can decrease surface flow and evaporation of soil, increase water content, then increase transpiration and crop yield (Fan *et al.*, 2015). Intercropping under rain-fed conditions may reduce agricultural risk, as economically similar results with soybean monoculture and lack of linkage between corn and soybean yields (Monzon *et al.,* 2014).

This study aims to determine the growth and yield of soybean and sweet corn due to the treatment of soil amendments and cropping patterns on podzolic soil.

Materials and methods

Location and time of research

The research was conducted in Teurebeh Village, Kota Jantho, Regency of Aceh Besar, from June 2016 to January 2017.

Experimental material

The materials used in this research are soil amendment (biochar charcoal husk and cow manure), NPK PHONSKA fertilizer, seed of sweet corn varieties of Bonanza and seed of soybean varieties of Dena 1.

Experimental design

This research used Randomized Block Design factorial 5 x 3 with three replications. Thus, there were 15 treatment combinations with 45 experimental units. The first factor is a soil amendment consisted of five levels: A0 = NPK 400kg ha^{-1} (Control), A_1 = biochar 10-ton ha^{-1}, A_2 = cow dung 10-ton ha^{-1}, A_3 = biochar 10-ton ha^{-1} + NPK 400 kg ha^{-1}, A_4 = cow dung 10-ton ha^{-1} + NPK 400kg ha^{-1}. The second factor is cropping pattern consisted of three levels, namely S1 = soybean monoculture, S2 = sweet corn monoculture, S3 = intercropping (soybeans-sweet corn).

Research procedure

The seeds of soybean and sweet corn are planted by five seeds per planting hole. The planting of soybean in monoculture and intercropping is done first 21 days before planting sweet corn in monoculture and intercropping. The populations of soybean on monoculture were 84 planting holes per plot and in intercropping, were 28 planting holes per plot, while the sweet corn population was monoculture and intercropping of 35 planting holes. Planting distance in soybean monoculture is 30cm x 30cm, in

monoculture of sweet corn is 70cm x 30cm, and in intercropping of soybean-sweet corn, sweet corn planting with two-row planting pattern interspersed with one soybean row in the middle with the distance between sweet corn 70cm x 30cm between sweet corn rows and 30cm between soybean rows.

Observation Variables

The observation of growth for soybean included the increase of plant height, which was completed from 3 weeks after planting (WAP), to 6 WAP, soybean production observation included the weight of soybean seed per plot and weight of 100 seeds. Observation of the growth of sweet corn includes changes in plant height from three WAP to seven WAP, observation of sweet corn production including weight of cob without husk per plot and sugar content. The height of soybean and sweet corn cultivation was obtained from the calculation of plant height of the n-week subtracted by the previous week. To measure the advantages of the intercropping system from the land use aspect, the calculation of the value of land equity ratio (LER) was calculated. LER = Yjk / Yjj + Ykj / Ykk where Yjk = yield of sweet corn in intercropping; Ykj = yield of soybean in the intercropping; Yjj = yield of monoculture of sweet corn and Ykk = yield of soybean monoculture.

Data analysis

The data obtained then analyzed using Analysis of variance (Anova), if there is a significant effect on the treatment, further test with DMRT 5% are performed.

Result and discussion

Plant Height of Soybean

The result of the variance analysis showed that a change in plant height on every observation week was not affected by the soil amendments. The cropping patterns had significant effect on changes in plant height of soybean at 3-4 WAP and 5-6 WAP and had highly significant effect on changes in plant height of soybean at 4-5 WAP. The monoculture cropping pattern showed higher on plant height than the intercropping, i.e. 8.59cm, 10.43cm, and 14.89cm in monocultures and 7.37cm, 8.66cm, and 12.57cm in intercropping respectively (Table 1). This is in line with the results of research Herliana *et al.* (2015) stated that monocropping have higher soybean height than multiple cropping. The higher height of soybean in monoculture may be due to soybean varieties used as seeds in the study are resistant for shade so that the growth of soybean on intercropping is normal even though shaded by sweet corn. This is unalike from the research of Myrna and Lestari (2010) which suggests that the soybean that gets 65% shoot with 75cm x 25cm maize spacing produced higher plant height when compared to other plants that get smaller shade. Susanto and Sundari (2011) argued that shade environments lead to higher soybean stems compared to unopened ones. According to Arifin *et al.* (2014), the highest soybean crop found in intercropping with maize using plant spacing of 150cm x 20cm accompanied by pruning of leaves and stems on cob. This difference in yield is probably due to the time of planting soybeans and sweet corn on the intercropping that is long enough that 21 days. At the time of soybean entering the peak of vegetative growth phase that is 5-6 WAP, the sweet corn still 3-4 WAP so vegetative growth phase soybean has not been shaded by sweet corn.

Weight of Soybean Seeds per Plot and Weight 100 of Soybean Seeds

The variance analysis showed that the weight of soybean seeds per plot and weight of 100 seeds was not affected by the soil amendments. The treatment of cropping pattern had significant effect on the weight of soybean seed per plot and did not affect 100 seeds weight. Table 1 shows that monoculture resulted is better seed weight per plot compared to intercropping patterns. This is very closely related to the number of plant populations, which is more in monoculture than the intercropping of 84 and 28 planting holes respectively. In the intercropping, soybeans are planted in one row every two sweet corn rows amounting to five rows, so that there are only four row soybean populations and seven holes each. According to Susanto and Sundari (2011), the weight of the soybean seeds is lower in the shaded environment compared to the environment without shade. The identical is stated Arifin *et al.* (2014) that the intercropping system causes a decrease in the number of pods by an average of 39% and the number of seeds average of 29%.

Table 1. The average of plant height, weight of seed and weight of 100 seed of soybean due to application soil amendments and cropping patterns at 3-4, 4-5, and 5-6 WAP.

Treatment	Plant Height of Soybean (cm)			Weight of Seed (kg plot^{-1})	Weight 100 Seed (g)
	3-4 WAP	4-5 WAP	5-6 WAP		
Soil Amendments (A)					
NPK	7.24	9.93	13.73	0.86	18.55
Biochar	8.01	8.42	12.81	0.86	18.44
Cow dung	8.18	10.24	14.52	1.00	18.37
Biochar + NPK	9.45	9.10	13.83	0.94	21.44
Cow dung + NPK	7.03	10.05	13.75	0.85	22.14
Cropping Patterns (S)					
Soybean Monoculture	8.59 b	10.43 b	14.89 b	1.34 b	20.83
Intercropping	7.37 a	8.66 a	12.57 a	0.46 a	18.75

The numbers followed by different letters in the same column are significantly different from the DMRT test of 5%.

Change in Plant Height of Sweet Corn

The result of variance analysis showed that the plant height of sweet corn on every observation week was not affected by soil amendments. While the cropping pattern has a highly significant, affect on plant height of sweet corn in i.e. 4-5 WAP, 5-6 WAP, and 6-7 WAP. In addition, there is also the interaction effect between the combinations of treatments on plant height in 6-7 WAP. The results showed that the monoculture patterns showed higher plant height compared with intercropping 30cm, 15cm, 40.65cm, 41.46cm and 35.28cm and 22.80cm, 30.21cm, 28.44cm and 23.79cm, respectively (Table 2). The result is in line with research conducted by Arifin *et al.* (2014) indicating that the height of maize crops in intercropping is shorter 6-15% (11% average) than monoculture or 85-94% (89%) on monoculture crops. The same opinion is also expressed by Herliana *et al.* (2015) that plant height in monocropping treatment is higher compared with multiple cropping patterns. The interaction between the soil amendment and the cropping pattern influenced plant height of sweet corn at 6-7 WAP. Table 3 shows that the increase plant height in monoculture is better than with intercropping on all soil amendment treatments.

The highest plant height was found on monoculture with NPK treatment that was 47.73cm and the lowest was found in intercropping with the treatment of manure that is 13.90cm. These results are in line with the explanations of Arifin *et al.* (2014) and Herliana *et al.* (2015) that the height of maize plants in monocultures is better than intercropping. This is allegedly caused by competition between corn and soybean in the struggle for nutrients in intercropping resulting in low plant height. The factor application of NPK on sweet corn monoculture shows that sweet corn has enough nutrients to support its growth.

Table 2. The average of plant height of sweet corn due to application soil amendments and cropping patterns at 3-4, 4-5, 5-6, and 6-7 WAP.

Treatment	Plant Height of Sweet Corn (cm)			
	3-4 WAP	4-5 WAP	5-6 WAP	6-7 WAP
Soil Amendments (A)				
NPK	31.84	35.24	35.14	36,99 c
Biochar	25.57	29.94	30.42	27,77 bc
Cow dung	33.92	36.99	35.15	18,75 a
Biochar + NPK	31.70	38.09	37.02	26,60 b
Cow dung + NPK	32.82	36.91	37.00	37,55 c
Cropping Patterns (S)				
Sweet Corn Monoculture	30.57	40.65 b	41.46 b	35,28 b
Intercropping	31.78	30.21 a	28.44 a	23,79 a

The numbers followed by different letters in the same column are significantly different from the DMRT test of 5%.

Table 3. The average of plant height of sweet corn at 6-7 WAP due to the influence of interaction between soil amendments and cropping patterns.

Treatment	Plant Height 6-7 WAP (cm)	
	Sweet Corn Monoculture	Intercropping
NPK	47.73 Cb	26.25 BCa
Biochar	39.37 BCb	16.17 ABa
Cow dung	23.59 Aa	13.90 Aa
Biochar + NPK	27.63 ABb	25.58 Ba
Cow dung + NPK	38.07 BCa	37.03 Ca

The numbers followed by same letter (capital letters in the same column, lower case on the same line) show no significant difference at the DMRT test level of 5%.

Weight of Cob without Husk and Sugar Content

The results showed that all parameters of weight of cob without husk per plot and sugar content was not affected by soil amendments. While the cropping patterns has a highly significant effect on the parameters of corn crops. The result of variance analysis shows the interaction effect between soil amendments and cropping patterns on all sweet corn products. The highest weight of cob without husk per plot was found on monoculture 2.61kg (Table 4).

The interaction between the soil amendments and cropping patterns produces the highest weight of cob without husk per plot obtained in monoculture with the addition of Biochar and cow dung + NPK 14.77kg and 15.00kg respectively, however it was not significantly different with the other treatments except for Biochar + NPK application (Table 5), the competition between sweet corn and soybean in the intercropping suspected to cause weight of cob without husk plot^{-1} produced in intercropping is lower than the monoculture with the same population. According to Maruapey (2011), an increase in the fresh weight of cob allegedly closely linked to the amount of photosynthate translocated to the ear where the greater part photosynthate translocated to the cob then the consequences increase the fresh weight of cobs. Permanasari and Kastono (2012) stated that the corn plants that can absorb more sunlight yield greater photosynthate used by plants for growth and the formation of plant organs. In addition to sunlight, according to Herliana *et al.* (2015) the adequacy of plant nutrients will also affect photosynthate generated by these plants. Thus, sweet corn monoculture can absorb more nutrients and get a better exposure resulting weight of cob without husk higher than intercropping.

The results of the analysis on the parameters of sugar content obtained the interaction between soil amendments and cropping patterns. The highest sugar content was obtained in the intercropping with NPK treatment and the lowest was found on monoculture with NPK treatment 11.83 and 9.53^{o} Brix respectively (Table 6). However, the highest value is not significantly different from Biochar and Cow dung+NPK, whereas in monoculture the highest amount of sugar content is found in the manure treatment but did not significantly different from Biochar, Biochar+NPK, and Cow dung+NPK.

Table 4. The average yield of sweet corn, sugar content and land equivalent ratio (LER) due to application soil amendments and cropping patterns.

Treatment	Weight of Cob Without Husk (kg plot^{-1})	Sugar Content (^{o}Brix)	Land Equivalent Ratio (LER)
Soil Amendments (A)			
NPK	10.05	10.68	1,11 bc
Biochar	10.18	10.85	0,70 a
Cow dung	9.62	10.33	1,02 ab
Biochar + NPK	10.20	10.43	1,45 c
Cow dung + NPK	12.70	10.53	1,01 ab
Cropping Patterns(S)			
Sweet Corn Monoculture	12.61 b	10.21 a	-
Intercropping	8.49 a	10.92 b	-

The numbers followed by different letters in the same column are significantly different from the DMRT test of 5%.

Table 5. The average weight of sweet corn cob without husk due to the influence of interaction between soil amendments and cropping patterns.

Treatment	Weight of Cob Without Husk (kg plot^{-1})	
	Sweet Corn Monoculture	Intercropping
NPK	11.50 ABa	8.60 ABa
Biochar	14.77 Bb	5.60 Aa
Cow dung	11.50 ABb	7.73 ABa
Biochar + NPK	10.27 Aa	10.13 Ba
Cow dung + NPK	15.00 Bb	10.40 Ba

The numbers followed by same letter (capital letters in the same column, lower case on the same line) show no significant difference at the DMRT test level of 5%.

The content of sugar content obtained from this study between 9.53-11.83^{o} Brix and it is still lower when compared with the description of sweet corn varieties Bonanza that is ranging from 13-15^{o} Brix. This is understood to be the result of several factors such as different harvesting ages that affect sweet corn sugar content (Surtinah, 2008). Then the storage of sweet corn at the certain temperature will affect the shelf life (Khatir *et al*., 2015). While Dinariani *et al*. (2014) stated that sweet corn with low plant density and goat manure at the highest doses would produce the highest sugar content.

Table 6. The average sugar content of sweet corn seeds due to the influence of interaction between soil amendments and cropping patterns.

Treatment	Sugar Content (^{o}Brix)	
	Sweet Corn Monoculture	Intercropping
NPK	9.53 Aa	11.83 Cb
Biochar	10.57 Ba	11.13 BCa
Cow dung	10.63 Bb	10.03 Aa
Biochar + NPK	10.47 ABb	10.40 ABa
Cow dung + NPK	9.87 ABa	11.20 BCb

The numbers followed by same letter (capital letters in the same column, lower case on the same line) show no significant difference at the DMRT test level of 5%.

Land Equivalent Ratio (LER)

The result of variance analysis showed that the soil amendment had significant effect on LER value. Table 4 shows that LER value> 1 found in almost all treatments except Biochar treatment. The highest LER value was obtained at biochar+NPK treatment that was 1.45. Biochar treatment contributed the lowest LER value of 0.70. The value of LER> 1 shows that intercropping is more advantageous than monoculture. Treatment of biochar+NPK in intercropping provides better result than other treatment. The results of this study are similar to those of other studies which suggest that intercropping is more advantageous than monoculture in increasing land productivity (Catharina, 2009; Wibowo *et al*., 2013; Stoltz and Nadeau, 2014; Herliana *et al*., 2015; Fan *et al*., 2015; Murdiono *et al*., 2016).

Conclusion

The treatment of soil amendments did not affect all parameters of growth and yield of soybean and sweet corn. Treatment of cropping pattern influenced all parameters observed in soybean and sweet corn. The interaction effect due to the soil amendments and the cropping patterns was found on plant height of sweet corn 6-7 WAP, the weight of cob without husk and sugar content of sweet corn. Biochar + NPK treatment with intercropping generated more favorable results compared to monoculture.

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