JOURNAL OF DEGRADED AND MINING LANDS MANAGEMENT
ISSN: 2339-076X (p); 2502-2458 (e), Volume 5, Number 3 (April 2018): 1171-1179
DOI:10.15243/jdmlm.2018.053.1171

Research Article

Effects of organic fertilizer and plant spacing on early-medium maturity soybean

Henny Kuntyastuti, Sri Ayu Dwi Lestari*, Sutrisno

Indonesian Legumes and Tuber Crops Research Institute (ILETRI), JL. Raya Kendalpayak KM 8, PO BOX 66, Malang 65101, East Java, Indonesia

*corresponding author: estawinasa@gmail.com

Received 8 January 2018, Accepted 28 February 2018

Abstract : Efforts to increase soybean productivity must be synergy with the improvement of soil fertility through fertilizer, especially organic fertilizer. Population density of a crop determines to a greater extent its performance in terms of soybean yield. Based on the two cultivation techniques mention above, that is expected to increase soybean productivity. The objective of this research was to obtain organic fertilizer and plant spacing that can support the development of early-medium maturity soybean (Lokal Jateng soybean lines/Sinabung-1036) to achieve 3 ton dry seed per hectare. The research was conducted at Alfisol soil Muneng Station Research, Probolinggo and at Entisol soil Genteng Station Research, Banyuwangi on dry season (DS) 2012. The experiment used split plot design with three replications. As the main plot was plant spacing, namely: 1) 40 cm x 10 cm, 2 plants/hole, 2) 40 cm x 15 cm, 2 plants/hole, 3) 40 cm x 20 cm, 1 plant/hole, and 4) 40 cm x 20 cm, 2 plants/hole. As the sub plot were four doses and types of organic fertilizer, namely: 1) without organic fertilizer, 2) 2.5 t manure/ha, 3) 5 t manure/ha, and 4) 2 t Santap NM-2/ha. The result showed that the potential yield of 3 t/ha for large, early-medium maturity soybean could not be achieved at Alfisol soil Probolinggo and at Entisol soil Banyuwangi by planting soybean of Lokal Jateng soybean lines/Sinabung-1036 with plant spacing 40 cm x 10-20 cm, 1-2 plants/hole and application of 2.5-5 t manure/ha or 2 t Santap NM-2/ha.

***Keywords**: Lokal Jateng soybean lines/Sinabung-1036, organic fertilizer, plant density*

To cite this article: Kuntyastuti, H., Lestari, S.A.D. and Sutrisno. 2018. Effects of organic fertilizer and plant spacing on early-medium maturity soybean. J. Degrade. Min. Land Manage. 5(3): 1171-1179, DOI: 10.15243/jdmlm. 2018.053.1171.

Introduction

Recently, efforts to increase soybean productivity have been done by assembling early-medium maturity, large seed, and high potential yield of soybean variety. These varieties require certain cultivation technology components to be able for achieve productivity near their potential. Fertilization technology and plant spacing arrangement (plant population) is a components of cultivation technology that can determine the seed yield production (Fatkur et al., 2010). Efforts to increase soybean productivity must be synergy with the improvement of soil fertility through fertilizer, especially organic fertilizer. The use of organic fertilizers can help to modify the plant microclimates, can increase the cation exchange capacity of the soil, which in turn can optimally improve soybean production (Enujeke et al., 2013). Organic fertilizer was also reported to increase number of pods per plant and seed yield of mungbean (Moller, 2009; Abbas et al., 2011). Yagoub et al. (2015) reported that application of 2.5 t chicken manure/ha had positive influence on growth and yield of soybean which gave the highest means in most growth and yield attributes. Arrangement of plant spacing is intended to provide enough growing space for plants cultivated thus reducing competition among plants. Differences in plant spacing can improve plant physiological growth index (Farahani and Valadabadi, 2009), increasing soil evaporation, plant transpiration (Chen et al., 2010), and

suppress the growth of weeds (Mayadewi, 2007). Soybean is grown at different spacing in different countries, can vary from 19 to 76 cm. A row spacing (RS) of 60 cm for forage soybean in Mediterranean environments in Turkey (Acikgoz et al., 2009), a 45 cm row by 5 cm plant spacing is commonly used in Kenya (Misiko et al., 2008), and a RS of less than 76 cm gave consistently higher yield than a RS of more than 76 cm in mid-western and southern Canada (De Bruin and Pedersen, 2008). Based on the above, this study aimed to obtain organic fertilizer and plant spacing that can support the development of early-medium maturity soybean to achieve 3 ton dry seed per hectare.

Materials and Methods

The research was conducted at Alfisol soil Muneng Station Research, Probolinggo and at Entisol soil Genteng Station Research, Banyuwangi, East Java province during dry season (DS) of 2012. The soybean seed used in this research was Lokal Jateng soybean lines/Sinabung-1036 (large seed). The experiment used split plot design with three replications. As the main plot was plant spacing, namely: 1) 40 cm x 10 cm, 2 plants/hole, 2) 40 cm x 15 cm, 2 plants/hole, 3) 40 cm x 20 cm, 1 plant/hole, and 4) 40 cm x 20 cm, 2 plants/hole. As the sub plot were four doses and types of organic fertilizer, namely: 1) without fertilizer, 2) 2.5 t manure/ha, 3) 5 t manure/ha, and 4) 2 t Santap NM-2/ha. Soybean seeds mixed with 350 g/L triametoksam insecticides, were sown on plot sizing of 4 m x 4.5 m without basic fertilizer. Between plots treatment, separated with channel width 20 cm and depth 25 cm. At Entisol soil Banyuwangi no tillage, but at Alfisol soil Probolinggo with tillage. Weeding, pest, and disease control conducted according to their conditions. The plant was harvested at physiological maturity. Observation consisted of chemical and physical properties of soil before planting with density of 0-20 cm and 20-40 cm; organic fertilizer analysis; NPK nutrient content uptake at 40 DAP (day after planting); yield component from 2.4 m x 3.6 m harvesting plot; and seed yield.

Results and Discussion

Soil properties

The research was conducted at Alfisol soil Muneng Station Research, Probolinggo with silty clay class texture and at Entisol soil Genteng Station Research, Banyuwangi with clay class texture (Table 1). At the beginning of the study, the soils in both locations have similar physical properties, such as the content weight of 1.2 g/cm^3, density 2.4-2.5 g/cm^3, and porosity 53%. Differences in physical properties occur in saturated hydraulic conductivity, penetration, and water holding capacity. The value of saturated hydraulic conductivity (flow velocity in saturated condition) at Entisol soil Banyuwangi (6.19 cm/h) was higher than at Alfisol soil Probolinggo (3.25 cm/h) and vice versa on soil penetration value. Soil penetration is the power that an object needs to enter the ground. The high value of soil penetration can inhibit the development of soybean roots. Sand fraction on Entisol soil Banyuwangi (48%) was higher than silt fraction (33%) and vice versa on Alfisol soil Probolinggo (32% sand and 54% silt). High level of sand fraction caused soil structure more loose or crumb, making it easier to pass water or plant roots.

Table 1. Physical properties of soil at Alfisol Muneng, Probolinggo and at Entisol Genteng, Banyuwangi before planting, DS 2012

Physical properties	Alfisol Muneng, Probolinggo		Entisol Genteng, Banyuwangi	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm
Khj (cm/hour)	3.25	2.45	6.19	4.82
Content weight (g/cm^3)	1.15	1.20	1.17	1.16
Density (g/cm^3)	2.43	2.38	2.51	2.68
Porosity (%)	52.7	49.5	53.5	56.6
Penetration (kg/cm^2)	8	10	6	5
Water content pF 2.5 (%)	29.8	28.3	36	36
Water content pF 4.2 (%)	13.4	11.9	17	10
Water holding capacity (%)	16.4	16.4	19	26
Sand fraction (%)	32	43	48	41
Silt fraction (%)	54	50	33	52
Clay fraction (%)	14	7	19	7
Texture class	Silty clay	Silty clay	Clay	Silty clay

Table 2. Chemical properties of soil at Alfisol Muneng, Probolinggo and at Entisol Genteng, Banyuwangi before planting, DS 2012

Chemical properties	Alfisol Muneng, Probolinggo		Entisol Genteng, Banyuwangi	
	0-20 cm	20-40 cm	0-20 cm	20-40 cm
pH H_2O	7.30	6.96	5.96	7.01
pH KCl	6.32	5.88	4.71	5.43
Total N (%)	0.63	0.34	0.08	0.02
C-organic (%)	1.25	1.10	0.48	tu
Available P (ppm P_2O_5)	29.0	24.00	56.10	61.40
SO_4 (ppm)	30.9	11.56	2.74	5.62
Exchangeable K (me/100 g)	1.64	0.36	0.67	0.83
Exchangeable Na (me/100 g)	2.28	0.86	0.52	0.51
Exchangeable Ca (me/100 g)	24.46	18.60	10.37	6.16
Exchangeable Mg (me/100 g)	7.21	6.93	5.31	5.36
CEC (me/100 g)	19.2	17.04	19.80	13.83
Exchangeable Al (me/100 g)	0.0	0.0	0.0	0.0
Exchangeable H (me/100 g)	0.63	0.20	0.3	0.1
Fe (ppm)	34.6	31.71	-	-
Mn (ppm)	13.4	5.61	721.0	376.7
Cu (ppm)	12.4	10.47	196.2	286.9
Zn (ppm)	2.52	1.74	-	-

Soil in Alfisol Probolinggo is neutral (pH H_2O 7.30), has many elements of N, P, K, Na, Ca, and Mg (Table 2), and a small amount of S. On neutral soil reaction, the availability of macro nutrients is at a maximum. In contrast, soil reaction in Entisol Banyuwangi is somewhat acid, has many elements of P, K, Ca, and Mg, but poor elements of N and S.

Organic fertilizer quality

Nutrient rich organic fertilizer non-acid-2 (raw material using sulfur as much as 5%) has acid reaction, has many organic matter, and nutrients of N, P, K, and S. In contrast, cow manure used in this research is poorer organic material and nutrients of N, P, K, and S compared to nutrient rich organic fertilizer non-acid-2, but has higher pH (Table 3). The C/N ratio of both organic fertilizers is les than 10, which means that the nutrients contained in both fertilizers can be quickly utilized by soybean crops.

Alfisol soil, Muneng Station Research, Probolinggo

Planting activities of soybeans were conducted at the end of February 2012. Soil tillage was done perfectly and at the time of planting when soil conditions were still a bit wet. The first irrigation was done after planting. In that condition, the germination of Lokal Jateng soybean lines/Sinabung-1036 in the field reached average of 73%. Plant spacing, dosage, and type of organic fertilizer treatment did not affect the germination (Table 4). The average root dry weight and shoot dry weight of 0.62 g/plant and 4.93 g/plant were not affected by plant spacing and organic fertilizer treatment (Table 4). However, plant spacing treatment affected plant height at harvest. The lowest growth was obtained at plant spacing 40 cm x 20 cm, 1 plant/hole, only 53 cm, the other reached 56-60 cm. The low growth of soybean in plant spacing treatment 40 cm x 20 cm, 1 plant/hole was also seen in NPK nutrient content uptake at 40 DAP.

Table 3. Chemical composition of organic fertilizer, DS 2012

Chemical properties	Santap NM-2	Cow manure
pH H_2O	5.25	6.21
C-organic (%)	14.12	6.93
N-organic (%)	1.77	1.18
N-NH_4 (%)	0.56	0.22
N-NO_3 (%)	0.16	0.66
N-total (%)	2.49	2.07
P_2O_5 total HNO_3+$HClO_4$ (%)	6.19	0.32
SO_4 total HNO_3 + $HClO_4$ (%)	12.01	1.61
K total HNO_3 + $HClO_4$ (%)	1.61	0.70
Na total HNO_3 + $HClO_4$ (%)	0.90	0.40
Ca total HNO_3 + $HClO_4$ (%)	0.67	1.79
Mg total HNO_3 + $HClO_4$ (%)	0.35	0.61
Fe total HNO_3 + $HClO_4$ (%)	2.09	1.94
Zn total HNO_3 + $HClO_4$ (%)	0.06	0.01
Cu total HNO_3 + $HClO_4$ (%)	0.01	0.01
Mn total HNO_3 + $HClO_4$ (%)	0.11	0.08

The low growth was due to the lower uptake of NPK nutrient content compared to the content uptake in other plant spacing treatment.

Table 4. The effects of plant spacing and organic fertilizer on germination, root dry weight at 40 DAP, shoot dry weight at 40 DAP, plant height at harvest, and NPK nutrient uptake of Lokal Jateng soybean lines/Sinabung-1036 in Alfisol soil Probolinggo, DS 2012

Treatment	Germination (%)	Root dry weight at 40 DAP (g/plant)	Shoot dry weight at 40 DAP (g/plant)	Plant height at harvest (cm)	N (g/plant)	P (g/plant)	K (g/plant)
Plant spacing (cm, /hole)							
40x10, 2 plants	68.9 a	0.55 a	4.38 a	60.1 a	0.684	0.077	0.923
40x15, 2 plants	71.8 a	0.61 a	4.65 a	57.2 a	0.650	0.067	0.673
40x20, 1 plant	75.8 a	0.73 a	6.17 a	52.5 b	0.487	0.053	0.638
40x20, 2 plants	75.4 a	0.61 a	4.52 a	55.8 a	0.629	0.070	0.778
Organic fertilizer (/ha)							
Without organic fertilizer	70.3 a	0.64 a	4.95 a	57.0 a	0.678	0.067	0.624
2,5 t manure	72.9 a	0.61 a	4.96 a	56.8 a	0.553	0.064	0.651
5,0 t manure	73.7 a	0.62 a	4.92 a	55.5 a	0.603	0.071	0.724
2.0 t Santap NM-2	75.0 a	0.62 a	4.88 a	56.3 a	0.615	0.066	1.013
Means	73.0	0.62	4.93	56.4	0,613	0.067	0.753
Interaction	ns	ns	ns	ns	-	-	-
CV (%)	9.46	7.30	13.19	6.5	-	-	-

Note: Numbers followed by different letters in a column were significantly different (P<0.05) using LSD test; DAP (day after planting).

Table 5. The effects of plant spacing and organic fertilizer on branch number, filled pod number, soil penetration, plant population, seed yield, 100 seeds weight, and seed weight of Lokal Jateng soybean lines/Sinabung-1036 in Alfisol soil Probolinggo, DS 2012

Treatment	Branch no./plant	Filled pod no./plant	Soil penetration (kg/cm^2)	Plant population/ha	Seed yield (t/ha) of moisture content 12%	100 seeds weight (g)	Seed weight (g/plant)
Plant spacing (cm, /hole)							
40x10, 2 plants	1.9 a	42.0 c	1.86 a	364873 a	2.70 a	14.89 a	16.34 b
40x15, 2 plants	2.3 a	46.9 b	1.54 a	278164 b	2.82 a	15.01 a	18.63 b
40x20, 1 plant	2.9 a	53.7 a	1.86 a	158179 c	2.30 b	15.26 a	26.62 a
40x20, 2 plants	2.3 a	48.0 b	1.65 a	275366 b	2.80 a	14.85 a	19.53 b
Organic fertilizer (/ha)							
Without organic fertilizer	2.4 a	46.9 a	1.58 a	267747 a	2.63 a	14.68 a	19.25 a
2,5 t manure	2.4 a	48.3 a	1.87 a	263310 a	2.70 a	15.09 a	21.45 a
5,0 t manure	2.1 a	47.7 a	1.81 a	273245 a	2.60 a	15.07 a	20.13 a
2.0 t Santap NM-2	2.4 a	47.7 a	1.63 a	272280 a	2.68 a	15.17 a	20.30 a
Means	2.3	47.6	1.73	269145	2.65	15.00	20.28
Interaction	ns	ns	ns	ns	ns	ns	ns
CV (%)	16.83	7.68	9.53	8.94	7.93	5.17	13.40

Note: Numbers followed by different letters in a column were significantly different ($P<0.05$) using LSD test; DAP (day after planting).

Table 6. The effects of plant spacing and organic fertilizer on germination, shoot dry weight at 40 DAP, and plant height at harvest of Lokal Jateng soybean lines/Sinabung-1036 in Entisol soil Banyuwangi, DS 2012

Treatment	Germination (%)	Shoot dry weight at 40 DAP (g/plant)	Plant height at harvest (cm)
Plant spacing (cm, /hole)			
40x10, 2 plants	82.7 a	4.45 a	57.0 a
40x15, 2 plants	81.9 a	4.79 a	52.1 ab
40x20, 1 plant	69.8 a	4.88 a	45.6 c
40x20, 2 plants	80.4 a	4.76 a	47.3 bc
Organic fertilizer (/ha)			
Without organic fertilizer	79.7 a	4.93 a	49.6 a
2,5 t manure	77.3 a	4.94 a	49.8 a
5,0 t manure	80.1 a	4.56 a	50.3 a
2.0 t Santap NM-2	77.7 a	4.45 a	52.2 a
Means	78.7	4.72	50.5
Interaction	ns	ns	ns
CV (%)	12.78	19.10	8.69

Note: Numbers followed by different letters in a column were significantly different (P<0.05) using LSD test; DAP (day after planting).

Table 7. The effects of plant spacing and organic fertilizer on branch number, filled pod number, soil penetration, plant population, seed yield, 100 seeds weight, and seed weight of Lokal Jateng soybean lines/Sinabung-1036 in Entisol soil Banyuwangi, DS 2012

Treatment	Branch no./plant	Filled pod no./plant	Soil penetration (kg/cm^2)	Plant population/ha	Seed yield (t/ha) of moisture content 12%	100 seeds weight (g)	Seed weight (g/plant)
Plant spacing (cm, /hole)							
40x10, 2 plants	1.6 b	25.1 b	4.36 a	344792 a	2.62 a	21.45 a	11.39 b
40x15, 2 plants	1.9 ab	28.4 b	4.53 a	262500 b	2.45 ab	21.00 a	12.42 b
40x20, 1 plant	2.5 a	38.9 a	4.57 a	162760 d	2.14 b	20.65 a	18.20 a
40x20, 2 plants	2.0 ab	29.8 b	4.79 a	211806 c	2.24 b	20.98 a	13.30 b
Organic fertilizer (/ha)							
Without organic fertilizer	2.0 a	30.5 a	4.54 a	256076 a	2.39 a	20.74 a	13.34 a
2,5 t manure	2.1 a	30.2 a	4.58 a	233160 a	2.35 a	21.03 a	14.41 a
5,0 t manure	2.0 a	31.3 a	4.44 a	242708 a	2.35 a	21.19 a	14.06 a
2.0 t Santap NM-2	1.8 a	30.3 a	4.68 a	249913 a	2.37 a	21.12 a	13.48 a
Means	2.0	30.6	4.56	245464	2.36	21.02	13.82
Interaction	ns	ns	ns	ns	ns	ns	ns
CV (%)	18.95	16.06	18.95	10.48	7.14	4.04	12.44

Note: Numbers followed by different letters in a column were significantly different ($P<0.05$) using LSD test; DAP (day after planting).

The highest K nutrient content uptake was obtained by application of 2 t nutrient rich organic fertilizer non-acid-2/ha, which was 1.013 g/plant compared to control treatment and application 2.5-5 t manure/ha (0.624-0.724 g/plant). Application organic fertilizer did not increase N and P nutrient content uptake (Table 4). Plant spacing treatment did not affect the branch number/plant and soil penetration. The highest filled pod number was 54 filled pods/plant and more 6-12 filled pods/plant than other plant spacing treatment.

Application of organic fertilizer did not affect the branch number/plant, filled pod number/plant, plant population, 100 seeds weight, seed weight/plant, and seed yield of Lokal Jateng soybean lines/Sinabung-1036 (Table 5). Plant spacing of 40 cm x 20 cm, 1 plant/hole decreased seed yield, lower 0.51-0.76 t/ha compared to the plant spacing of 40 cm x 10 cm or 15 cm or 20 cm, 2 plants/holes. The low seed yield was caused by the number of crops harvested only 158000 plants/ha, lower 117000-206000 plants/ha compared other plant spacing. Increase of the filled pod number and seed weight/plant at plant spacing 40 cm x 20 cm, 1 plant/hole did not increase the seed yield of soybean to 3.25-3.5 t/ha, as could be achieved with other plant spacing treatment. The 100 seeds weight could reach by approximately 15 g.

The result showed that the average yield of 2.65 t/ha of soybean seeds with 12% seed moisture content was achieved in the planting area with the number of plant population as much as 269000 plants/ha, root dry weight 0.62 g/plant, and shoot dry weight 4.93 g/plant. In addition, supported by the formation of 2.3 branch/plant, 48 filled pod/plant, 100 seeds weight of 15 g, and seed weight 20.28 g/plant in Alfisol soil Probolinggo. In agreement with previous studies conducted in various environments, row spacing had significant effects on seed yield (Acikgoz et al., 2009; Worku and Astatkie, 2011; Markos et al., 2012; Worku and Astatkie, 2015).

Entisol soil, Genteng Station Research, Banyuwangi

The optimal initial growth of Lokal Jateng soybean lines/Sinabung-1036 can be an indicator that soybean can grow well in the next growth phases. The germination in the field reached an average of 79%, plant spacing and application of organic fertilizer did not affect it. Application of organic fertilizer did not affect the variables of shoot dry weight and plant height at harvest. The optimal growth of soybean caused shoot dry weight at 40 DAP reaching average of 4.72 g/plant. As well as in the Alfisol soil Probolinggo, the plant spacing also influenced the variation of plant height during the harvesting time in Entisol Banyuwangi. The plant spacing treatment of 40 cm x 20 cm, 1 plant/hole caused the shortest growth, only 46 cm. If using plant spacing 40 cm x 10-15 cm, 2 plants/hole, the plant height during harvest time could reach 52-57 cm.

The availability of wider space at plant spacing 40 cm x 20 cm, 1 plant/hole could provide the opportunity for soybean to development more branches. As a result, the filled pods number were also the most common, with 39 filled pods/plant and only 25-30 filled pods/plant on other plant spacing treatment (Table 7). Traces of good research management are still visible until soybean crops reach the harvesting phase. However, the application of organic fertilizer did not affect all observed variables, such as growth components, yield components, and yield of soybean (Tables 6 and 7).

Plant spacing treatment also did not affect the 100 seeds weight. The 100 seeds weight was large, reaching an average of 21.02 g (Table 7). The high number of filled pods reached with the plant spacing treatment 40 cm x 20 cm, 1 plant/hole, followed by higher seed weight/plant, which are 18.20 g/plant. This value was higher than 4.50-6.81 g/plant of other plant spacing treatment (Table 7). However, the higher number of filled pod and seed weight/plant could not increase the yield of soybean seed to reach the potential yield of 3 t/ha. The implementation of 40 cm x 20 cm, 1 plant/hole resulted in the number of crops harvested only 162000 plants/ha, lower 49000-182000 plants/ha compared to other plant spacing. As a result, the yield of soybean could reach 2.14 t/ha. The seed yield was lower than 0.31-0.48 t/ha of seed yield at plant spacing 40 cm x 10-15 cm, 2 plants/hole, which could reach 2.45-2.62 t/ha. Based on Chauhan and Opena (2013) research, grain yield ranged from 1.3 to 1.9 t/ha at different spacing. The highest grain yield was produced by plants at 40 cm x 10 cm. However the difference among grain yield was not significant.

Conclusion

The results showed that the potential yield of 3 t/ha on large seed, early-medium maturity soybean could not be achieved by planting Lokal Jateng soybean lines/Sinabung-1036, plant spacing of 40 cm x 10-20 cm, 1-2 plants/hole with application of 2.5-5 t manure/ha or 2 t nutrient rich organic fertilizer non-acid-2 at Alfisol soil Probolinggo and at Entisol soil Banyuwangi.

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