Organically Production of Soybean Supported by Fertilizers Residue under Saturated Soil Culture

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Abstract

Organic farming system can use natural on-farm inputs that are normally available at the production site. Saturated Soil Culture (SSC) is a technology in cultivation that gives water permanently, maintains and keeps its depth constantly; this makes soil layer in saturated condition. SSC technology can be implemented in land with poor drainage or in cultivating soybean on rice field in the period between two rice plantings when the soils may still be in water saturated conditions. The experiment was conducted to study the response of two soybean varieties to the residues of different types of fertilizer in an organic farming system. The experiment was carried out at IPB experimental station, Bogor, Indonesia, in October 2010-February 2011. Split plot design was used with types of fertilizer as the main plot (chicken manure, *Centrosema pubescens* Benth, and *Tithonia diversifolia* Hemsl.) and soybean varieties as the sub plot (Anjasmoro and Wilis). To study the effectiveness of fertilizers residue, the current experiment applied 50% fertilizer rates (10 t chicken manure only/ha, 5 t chicken manure mixed with 2.1 t *C. pubescens*/ha, and 5 t chicken manure with 2.1 t *T. diversifolia*/ha) of those applied in the previous soybean planting (May-August 2010). The results showed that chicken manure yielded the highest seed weight and filled pod number per plant. However, seed yields per hectare were not affected by fertilizer types. The soybean plant with the application of chicken manure, *C. pubescens*, and *T. diversifolia* produced 2.37, 2.42, and 2.43 t seed/ha, respectively. Wilis had higher number of filled pod per plant than Anjasmoro, but the yields per hectare of both varieties were not different. Production of Anjasmoro and Wilis was 2.43 and 2.38 t/ha, respectively.

Keywords: Centrosema pubescens *Benth, chicken manure,* Glycine max *(L.) Merr., green manure,* Tithonia diversifolia *Hemsl*

Introduction

National demand on soybean is about 2.2 million tons per year, but only 35-40% of this demand can be supplied from the domestic production, and the government has to import about 1.3 t soybean/year. Low productivity, decreasing agricultural land area, and limited access of farmers to technology and funding, are some of the factors restricting the national production of soybeans.

Organic farming is an alternative to currently used methods of farming; its use might increase soybean production. Currently the marketing of produce from organic farms is targeted only at consumers who are interested in it because they view it as being healthier. However, organic farming systems could be useful to farmers who have limited access to production inputs (e.g. inorganic fertilizers and pesticides) and funds. Because of the presumed lower productivity of organic systems as opposed to conventional farming the ability of organic systems to support food security is questioned; nevertheless organic farming may be able to provide local food security. Farmers can use on-farm inputs normally available to them on the site of production.

Organic farming system had been used to produce vegetable soybean with various types of fertilizer, for example chicken manure, green manure of *Calopogonium mucunoides*, *Centrosema* *pubescens*, and *Crotalaria juncea*, rock phosphate, charcoal and ash or rice hull (Barus, 2005; Melati and Andriyani, 2005; Sinaga, 2005; Kurniasih, 2006). Some of those organic fertilizers had resulted significant differences in plant performances, but not in production. The experiment had also been conducted to produce dry seed of soybean to investigate whether organic farming system supported plant production not only at less mature seed but also at fully mature stage. Kurniansyah (2010) found that chicken manure only or its combination with green manure produced dry seed of 1.16-1.48 t/ha on upland, while Ramadhani (2011) found that soybean yield was 1.83-1.94 t/ha on soil with saturated soil culture technology.

Saturated Soil Culture (SSC) is a technology in cultivation that gives water permanently, maintains and keeps its depth constantly (about 5 cm under soil surface); this makes soil layer in saturated condition. In saturated soil culture, watering is started from the beginning of plant growth to maturity stage (Hunter *et al.,* 1980). By keeping the water-table constantly, soybean will be avoided from negative effect of inundation on soybean growth, because soybean will acclimatize and improve its growth (Troedson *et al.*, 1983). Ghulamahdi (2007) found that under SSC, growth and production of soybean was improved related to the increase of ACC, ethylene, glucose content, and neck diameter of roots, and the increase of nodules' weight, nitrogenase activity, and nutrient uptakes. SSC technology can be implemented in land with poor drainage or in cultivating soybean on rice field in the period between two rice plantings where the soils may still be in water saturated conditions. Ghulamahdi *et al.* (2009) also showed that SSC can be implemented in cultivating soybean in tidal swamp area with the production of more than double of those in upland.

The availability of nutrient provided by organic fertilizers is not as quick as from inorganic fertilizers; this may result in available nutrient in the following cropping season. Melati *et a*l. (2008) showed that the residue of fertilizers supported the production of organic vegetable soybean on upland soil. The current experiment studied the possibilities of producing dry seed of soybean with the residue of fertilizers under SSC technology. Two types of soybean cultivar (they differ in seed sizes) were used to investigate their responses to the treatments.

Materials and Methods

A field study was conducted in October 2010-February 2011 at the Cikarawang Experiment Station of Bogor Agricultural University (IPB), in Bogor, Indonesia. The soil is a silty clay loam soil. The experiment was the second crop sequence. The experimental design was a randomized complete block with spilt plot arrangement and three replicates. Types of fertilizer included in the study were chicken manure only (10 t/ha), chicken manure combined with *Centrosema pubescens* (5 + 2.1 t/ha), and chicken manure combined with *Tithonia diversifolia* (5 + 2.1 t/ha) were considered as main plots, and assigned to an area of 4 x 4 m. Subplots were assigned within each main plot, each differing by soybean cultivar, i.e. Anjasmoro and Wilis. Subplots dimensions were five 4-m long rows spaced 0.4 m apart and 0.1 m apart within row.

Those fertilizer rates were half of rates in the first crop sequence to evaluate the effectiveness of fertilizers residue. In the first crop sequence, the rate of chicken manure was applied at the rate of 20 t/ha followed Sinaga (2005) and the rates of green manure biomass was determined based on a study of Kurniasih (2006). It was expected that a yield of about 10 t biomass/ha was obtained from 25 kg seed of *C. pubescens.* However, dry conditions during the growth period of *C. pubescens*. (December 2009-April 2010) resulted in the production of only 3.5 t *C. pubescens* biomass/ha. Although *Tithonia diversifolia* could be easily collected from a nearby area, it was also applied at the rate of 3.5 t/ha to make appropriate comparisons with the use of *C. pubescens.* Besides those fertilizers according to the treatments, all plots were added with 1 t rice hull charcoal and 1 t dolomite per hectare. Green manure (combined with chicken manure, rice hull charcoal and dolomite) was applied 4 weeks before soybean planting, while chicken manure (plus rice hull charcoal and dolomite) was applied 2 weeks before soybean planting. All materials were applied in planting rows; they were then below the position of soybean seed.

SSC technique was conducted by providing water permanently since 4 weeks after planting (WAP), maintained and kept water depth constantly at about 5 cm under soil surface in 20-cm depth furrow. Ghulamahdi (2007) found that plants normally experience chlorosis in saturated soil, therefore, in the current experiment liquid manure (1 L liquid manure/10 L water) was added as foliar application to the plants at the 3rd, 5th, and 7th day after irrigation began.

Other cultural practices were seed treatment by using *Rhizobium* inoculants with the rate of 6.25 g/kg seed, and the planting of *Tagetes erecta* and *Cymbopogon nardus* near soybean plants to control plant pest and diseases. *Tagetes erecta* and *Cymbopogon nard*us had been used in producing organic vegetable soybean (Kusheryani and Aziz, 2006).

Analysis of variance was used to analyze the data and Duncan' Multiple Range Test (DMRT) was used to compare means value.

Results and Discussion

Plant characters as shown in vegetative phase and yield component in generative phase were not different among fertilizer types. Variables were only different in number of filled pod and seed yield per plant with the highest values were in plants with the application of chicken manure only. Since the number of harvested plant in plot with chicken manure only was lower than those with other fertilizers, seed yields per hectare were not different among treatments (Table 1).

Table 1. Plant characters and production with three types of fertilizer

Variables	F test	Fertilizers			Means
		Tithonia diversifolia	Chicken manure only	*Centrocema pubescens*	
Vegetative phase					
Plant height at 7 WAP (cm)	ns	88.05	85.85	84.99	86.30
Plant height at harvest/ 14 WAP (cm)	ns	94.09	91.28	90.46	91.94
Trifoliate leaf numbers/plant	ns	18.5	19.5	18.3	18.8
Pest intensity (%)	ns	28.9	30.8	29.4	29.7
Disease intensity (%)	ns	8.8	10.6	8.5	9.3
Dry weight of leaves (g/plant)	ns	5.92	6.04	7.21	6.39
Moisture content of leaves (%)	ns	64.9	64.5	67.2	65.5
Nitrogen content in leaves (%)	ns	3.3	3.2	3.2	3.2
Phosphorus content in leaves (%)	ns	0.5	0.5	0.5	0.5
Potassium content in leaves (%)	ns	2.9	2.8	2.9	2.9
N uptake of leaves (mg/plant)	ns	19.47	19.66	23.04	20.72
P uptake of leaves (mg/plant)	ns	3.17	3.01	3.70	3.29
K uptake of leaves (mg/plant)	ns	17.26	16.99	21.52	18.59
Generative phase					
Dry weight of shoot (g/plant)	ns	20.77	26.60	26.25	24.54
Numbers of filled pod/plant	*	93.0b	111.7a	99.3b	101.3
Numbers of harvested plant/4.56 m^2	ns	118.8	104.0	112.0	111.6
Seed weight (g/100 seeds)	ns	15.17	15.83	16.00	15.67
Seed yield (g/plant)	**	25.33b	32.65a	28.25ab	28.74
Seed yield (g/4.56 m^2)	ns	1109.67	1082.50	1101.17	1097.78
Seed yield (ton/ha)	ns	2.43	2.37	2.42	2.41

Note: ns = not significant; * and ** = significant at $p < 0.05$ and $p < 0.01$, respectively. Numbers followed by letters indicating different at $\alpha = 5\%$ with DMRT.

Seed yield per plant may be related to the soil nutrient content. After the 1st crop season, C-organic, N-total, available P and K were higher in plots with the application of chicken manure only compared to those with other fertilizer treatments. These conditions were also detected in the 2nd crop sequence before soybeans were planted (Table 2). The amount of nutrients in the soil with chicken manure application had supported the seed yield of single plant.

Table 2. Soil characteristics

Treatments		pH H_2O	Walkly & Black	Kjeldhal	Bray I	N NH_4Oac pH 7.0				
Fertilizers	Varieties		C-org	N-Total	P	K	Mg	Ca	Na	KTK
			..(%)..	..(%)..	(ppm)	..(me/100g)..				
After 1st crop sequence										
Chicken m.	Anjasmoro	6.37	2.20	0.20	25.43	0.89	2.83	6.37	0.74	16.56
Chicken m.	Wilis	6.63	2.04	0.20	17.23	0.85	2.82	7.98	0.54	15.87
Tithonia sp.	Anjasmoro	6.53	1.84	0.18	9.20	0.86	2.60	7.42	0.59	15.80
Tithonia sp.	Wilis	6.67	1.89	0.19	15.57	0.60	2.41	6.66	0.51	14.77
Centrosema	Anjasmoro	6.40	1.76	0.17	6.15	0.69	2.74	6.98	0.45	16.68
Centrosema	Wilis	6.40	1.68	0.17	5.55	0.52	2.24	6.39	0.41	15.86
After application of fertilizers in the 2nd crop sequence										
Chicken m.	Anjasmoro	6.30	2.63	0.22	33.50	n.a.	3.06	7.94	0.61	17.76
Chicken m.	Wilis	6.50	2.55	0.22	28.80		2.90	7.82	0.48	18.36
Tithonia sp.	Anjasmoro	6.40	1.60	0.15	8.50		3.57	8.72	0.47	21.45
Tithonia sp.	Wilis	6.60	1.68	0.15	12.70		3.26	8.32	0.64	18.37
Centrosema	Anjasmoro	6.60	2.00	0.19	25.00		3.78	8.46	0.80	18.16
Centrosema	Wilis	6.30	1.92	0.18	28.70		4.76	9.23	0.75	21.76
After 2nd crop sequence										
Chicken m.	Anjasmoro	7.40	2.79	0.26	31.20	1.42	3.40	8.38	1.16	19.13
Chicken m.	Wilis	7.50	2.39	0.22	20.60	1.19	3.00	8.19	1.09	17.95
Tithonia sp.	Anjasmoro	7.60	2.23	0.21	14.40	1.11	2.90	7.76	1.06	17.76
Tithonia sp.	Wilis	7.50	2.15	0.22	9.00	0.86	2.65	7.42	0.70	16.78
Centrosema	Anjasmoro	7.20	2.55	0.23	5.20	0.93	2.55	7.34	1.08	18.35
Centrosema	Wilis	7.40	2.55	0.25	16.10	1.18	2.95	8.66	1.07	18.73

Note: Soil samples were composite of 3 replicates from the same treatment, therefore they were not statistically analyzed. n.a. = valid data were not available

There are some differences in plant characteristics and yield components of the two varieties in this experiment. These were accordingly with the characteristics of each variety. Anjasmoro has less number but larger leaves than those of Wilis, therefore, the nutrient uptake was higher in Anjasmoro. Anjasmoro has less number of filled pod but it has larger seed size, this resulted in similar seed yield of both varieties (Table 3).

Table 3. Plant characteristics and production of two soybean varieties

Variables	F test	Varieties		Means
		Wilis	Anjasmoro	
Vegetative phase				
Plant height at 7 WAP (cm)	*	83.32b	89.29a	86.31
Plant height at harvest/ 14 WAP (cm)	ns	91.98	91.91	91.90
Trifoliate leaf numbers/plant	*	20.3a	17.2b	18.80
Pest intensity (%)	ns	28.9	30.6	29.70
Disease intensity (%)	ns	8.8	9.9	9.30
Dry weight of leaves (g/plant)	ns	5.39	7.39	6.39
Moisture content of leaves (%)	ns	65.5	65.6	65.50
Nitrogen content in leaves (%)	ns	3.2	3.3	3.20
Phosphorus content in leaves (%)	ns	0.5	0.5	0.50
Potassium content in leaves (%)	**	2.7b	3.1a	2.90
N uptake of leaves (mg/plant)	*	17.47b	23.97a	20.72
P uptake of leaves (mg/plant)	*	2.77b	3.82a	3.30
K uptake of leaves (mg/plant)	*	14.41b	22.76a	18.59
Dry weight of shoot (g/plant)	ns	24.77	24.31	24.54
Numbers of filled pod/plant	**	115.4a	87.2b	101.30
Numbers of harvested plant/4.56 m^2	**	122.8a	100.4b	111.60
Seed weight (g/100 seeds)	**	12.11b	19.22a	15.67
Seed yield (g/plant)	ns	28.00	29.49	28.75
Seed yield (g/4.56 m^2)	ns	1087.11	1108.44	1097.78
Seed yield (ton/ha)	ns	2.38	2.43	2.41

Note: ns = not significant; * and ** = significant at $p < 0.05$ and $p < 0.01$, respectively.

Conclusions

The experiment concluded that in the second crop sequence, with half rates of fertilizer, all types of fertilizer and both varieties could be used to produce similar seed yield per hectare of organic soybean. In the second crop sequence, there was indication that soil characteristics had been improved under organic farming system.

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