Response of Two Soybean Varieties to the Application of Organic Fertilizers In an Organic Farming System

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ABSTRACT

The national demand for soybeans is increasing in response to increasing population. Consequently, the cultivation of soybeans should be extended to new areas, including those of marginal fertility, and under various farming systems. Because farmers may have limited access to supplies of inorganic fertilizer and pesticides, and limited funds with which to buy them, organic farming can be a viable option. Farmers can use on-farm inputs that are normally available at the production site. An organic farming system may be able to ensure food security at the local level because continuity of plant production is possible. This study was conducted to investigate the response of two soybean varieties to different types of organic fertilizer in an organic farming system. The experiment was carried out at IPB experimental station, Bogor, Indonesia, in December 2009-July 2010. Split plot design was used with types of organic fertilizer as the main plot (poultry manure, *Centrosema pubescens* Benth, and *Tithonia diversifolia* Hemsl.) and soybean varieties as the sub plot (Anjasmoro and Wilis). The results showed that the application of *Centrosema* sp. and *Tithonia* sp. increased plant height and productivity, and reduced plant pest and disease intensity compared to poultry manure. Production of soybean applied with poultry, *Centrosema* sp., and *Tithonia* sp. manures was 1.16, 1.33, and 1.48 t ha^{-1}, respectively. On rainfed land, Anjasmoro was higher in vegetative characteristics and productivity compared to Wilis. The production of Anjasmoro and Wilis was 1.57 and 1.07 t ha^{-1}, respectively.

Key words: *Centrosema pubescens* Benth, *Glycine max* (L.) Merr., green manure, poultry manure, *Tithonia diversifolia* Hemsl.

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INTRODUCTION

National demand on soybean is about 2.2 million tonnes per year, but only 20-30% of this demand can be supplied from domestic production. 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, not inorganic, fertilizer, must be used in an organic farming system. Animal manure and green manure can be used in producing organic vegetable soybeans (Barus, 2005; Kurniasih, 2006; Melati and Andriyani, 2005; Sinaga, 2005). Yield of soybean was greater with with poultry manure than with sheep manure or *Centrosema pubescens* (Sinaga, 2005). In comparisons between green manures *Centrosema pubescens* was better than *Calopogonium mucunoides* and *Crotalaria juncea* (Sinaga, 2005; Kurniasih, 2006) for organic vegetable production. Green manure can be used for organic soybean production but Barus (2005), Melati dan Andriyani (2005), and Sinaga (2005) found that the use of *Calopogonum mucunides* and *Centrosema pubescens* increases the vegetative growth of the plant but may not support the generative phase. Leaf analysis has shown that *C. mucunoides* and *C. Pubescens* were high in N (2.47% and 3.49%, respectively) but low in P (0.23% and 0.36%) and K (0.75% dan 1.05%) (Barus, 2005; Kurniasih, 2006). Therefore, combinations of organic fertilizers were used, for example rice straw compost and rice hull ash. Melati *et al.* (2008) found that the application of a single organic fertilizer or a combination of organic fertilizers did not significantly affect soybean yield, but ash played an important role in reducing the incidence of disease in plants by 75% compared to the control.

A disadvantage of the use of green manures is that farmers may feel unable to miss a season of cash cropping in order to grow green manures for the benefit of soil improvement. As an alternative, non-crop plants which are commonly available close to agricultural areas may be used as green manure. *Tithonia diversifolia* Hemsl., a shrub of the family Asteraceae, has been used for lowland rice (*Oryza sativa*) in Asia and more recently for maize (*Zea mays*) and vegetables in eastern and southern Africa. The leaf biomass of *Tithonia* is high in nutrients, averaging 3.5% N, 0.37% P and 4.1% K on a dry matter basis, and can be a good sources of nutrients for crops (Jama *et al.*, 2000).

A series of experiments using an organic farming system to produce vegetable soybeans (R6) of variety Wilis found the yields to be inadequate, the highest filled pod number being only 30-55/plant (Melati *et al.*, 2008). Further study is needed of methods of increasing production. Information about the factors affecting the production of dry soybean seed in Indonesia is limited; the current experiment was designed to study the impact of a variety of organic fertilizers on the harvest of dry seed of two soybean varieties representing different sizes of seed.

MATERIALS AND METHODS

The experiment was carried out at IPB experimental station, Bogor, Indonesia, in December 2009-July 2010. Soil type was clay loam soil. Soil test indicated low fertility, i.e. soil pH was 6.0, C-organic was 0.95%, total N was 0.1%, P was 3.30 ppm, and K was 0.38%. Split plot design was used with types of organic fertilizer as the main plot (poultry manure, *Centrosema pubescens*, and *Tithonia diversifolia*) and soybean varieties as the sub plot (Anjasmoro and Wilis), 6 replications.

Nutrient analysis of *Centrosema* sp., *Tithonia* sp., and poultry manure showed that both green manures were high in nitrogen content, while poultry manure was high in phosphorus. *Tithonia* is also high in potassium (Table 1).

Table 1. Nutrients content of three organic fertilizers

	Nutrient content								
	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
	..... %					..... ppm			
*Centrosema pubescens**	3.49	0.36	1.05						
Tithonia diversifolia	3.06	0.25	5.75	1.69	0.16	297	32.4	157.8	235.9
Poultry manure	1.14	0.68	1.65	2.21	0.38	26600	214.0	360	920

*`Melati *et al.* (2008)

Table 2 describes the steps followed in applying organic fertilizers to the soil in preparation for soybean planting. Using estimates based on a study by Kurniasih (2006), it was expected that a yield of about 10 t biomass ha^{-1} was obtained from 25 kg seed of *Centrosema* sp. However dry conditions during the period of growth of *Centrosema* sp. resulted in the production of only 3.5 t biomass ha^{-1}. *Tithonia* sp., collected easily from a nearby area, was also applied at the rate of 3.5 t ha^{-1} to make appropriate comparisons with the use of *Centrosema* sp. Poultry manure was applied at the rate of 20 t ha^{-1} (Sinaga 2005).

Table 2. Schedule for organic fertilizers application

	Treatments (types of organic fertilizer)		
	Centrosema pubescens	*Tithonia diversifolia*	Poultry manure
-15 weeks before soybean planting (BSP)	Application of: • 10 t poultry manure ha^{-1} • 2 t dolomite ha^{-1}		
-13 weeks BSP	25 kg *Centrosema* seeds ha^{-1} were sown in rows		
-4 weeks BSP	*Centrosema* biomass harvested (roots included), chopped and applied in soybean planting rows with: • 5 t poultry manure ha^{-1} • 2 t rice hull charcoal ha^{-1} (followed Melati *et al.*, 2008)	Application of *Tithonia* shoot in soybean planting rows with: • 10 t poultry manure ha^{-1} • 2 t rice hull charcoal ha^{-1} • 2 t dolomite ha^{-1}	
-2 weeks BSP			Application of 20 t poultry manure ha^{-1} in soybean planting rows with: • 2 t rice hull charcoal ha^{-1} • 2 t dolomite ha^{-1}
0 week	Soybean planting date		

Note:
- 2 t dolomite ha^{-1} and 10 t poultry manure ha^{-1} were applied to soil to support the growth of *Centrosema* sp.; 5 t poultry manure ha^{-1} to promote *Centrosema* sp. decomposition;
- 15-cm length of *Tithonia* sp. was taken from from the plant tips. The application of 10 t poultry manure ha^{-1} was to promote decomposition of *Tithonia* sp. and to standardize this treatment with that of *Centrosema* sp.

Plots were 5 rows wide and 4 m long with 40-cm row spacing. Plots were seeded at the rate of 250,000 seeds ha^{-1}. Seeds were inoculated with 5 g "Rhizoplus" ™ kg^{-1} seed. "Rhizoplus"™ is a bio-fertilizer which contains four root nodule bacteria, *Bradyrhizobium japonicum*, phosphate solubilizing bacteria of the *Pseudomonas* spp. and Micrococcus which are tolerant to Al-acid and dry conditions. Main plots were separated with a row of *Tagetes erecta* and surrounded with *Cymbopogon citrates* Stapf. Grains were harvested 13 weeks after planting.

Data were analyzed using ANOVA in SAS. Mean comparisons were made using DMRT to compare 3 or more means.

RESULTS AND DISCUSSION

Plant height, disease intensity, and number of tetra-foliate leaves were affected by organic fertilizers (Table 3). A fertilizer types x soybean varieties interaction was significant at plant pest intensity and number of harvested plant (Table 4). The differences in plant height, pest and diseases intensities showed that *Tithonia* sp. had a better effect than the two other fertilizers. However, the formed tetra-foliate may reflect the ability of poultry manure to promote vegetative parts of the plant more than that of reproductive parts.

Examining characters used to describe plant varieties (plant heights of Anjasmoro and Wilis are 64-68 and 50 cm, respectively) this experiment showed that organic fertilizers can support soybean production with organic farming techniques as indicated. Plant characters and production of plants with green manures were better than those with poultry manure. Possible reasons for these results are as follows. Firstly, *Centrosema* sp. and *Tithonia* sp. had higher nitrogen content than poultry manure (Table 1) and they were applied as fresh biomass in the soil, while poultry manure was applied in the form of compost. Higher nitrogen content might be available for the plants from green manure than from poultry manure because poultry manure had lost some of its nitrogen before application. Secondly, *Tithonia* is more suitable than *Centrosema*. *Tithonia* might have been composted faster than *Centrosema* due to different water content, they were 62.2 and 59.0%, respectively. *Tithonia* also has higher content of potassium, which plays an important role in strengthening plant tissue. This could be the reason why plants fertilized with *Tithonia* application had lower pest and disease infestation than those with *Centrosema* or poultry manure. Thirdly, poultry manure contained high phosphorus (Table 1). A high concentration of phosphorus in plant tissue and lead to zinc deficiency. The interaction of phosphorus and zinc, called phosphorus-induced zinc deficiency, has been observed in many crops, for example in beans (Singh *et al.*, 1988) and wheat (Webb and Loneragan, 1988, 1990).

The result of our experiment, however, differed from the findings of Sinaga (2005) and Melati *et al.* (2008) who found that the production of vegetable soybean with 20 t poultry manure ha^{-1} was higher than that with 25 kg *Centrosema* seed ha^{-1}. The decomposition process of *Centrosema* was probably better than previous studies. The application of poultry manure and dolomite might have improved decomposition of *Centrosema*, hence the availability of nitrogen was better in this experiment.

Variety Anjasmoro responded well to the application of *Tithonia* sp. as shown by reduced pest infestation. This indicated that Wilis was more vulnerable to plant pest and diseases than Anjasmoro. Anjasmoro. Also the number of harvested plants of Wilis was consistently lower than that of Anjasmoro with all types of fertilizer (Table 4). This indicated that the ability of Wilis to grow on rainfed land in an organic farming system was less than that of Anjasmoro.

Table 3. Plant growth, yield, and yield components of soybeans with three different organic fertilizers

		Organic fertilizers			Means
		Poultry	*Centrosema*	*Tithonia*	
Plant height (7 WAP/R1) *	cm	55.3 b	58.17 ab	62.77 a	58.75
Trifoliate leaf number (7 WAP)		20.8	21.2	21.7	21.2
Tetra-foliate leaf number *		1.7 a	1.3 b	1.4 ab	1.4
Branch number (7 WAP)		3.1	2.9	3.0	3.0
Dry weight of leaves (7 WAP)	g	15.53	17.25	17.20	16.66
Dry weight of shoot (7 WAP)	g	23.05	26.13	26.57	25.25
Dry weight of root (7 WAP)	g	4.80	5.22	6.10	5.37
Disease intensity (6 WAP) **	%	10.7 a	5.3 b	5.1 b	7.0
Harvested plant number		82.0	86.4	89.4	86.0
Filled pod number		74.8	80.9	83.4	79.7
Empty pod number		3.6	2.4	2.3	2.7
Dry weight of seed/plant	g	18.97	21.57	22.06	20.86
Dry weight of seed/5.12 m^2 ***	g	595.79 b	680.02 a	756.69 a	677.50
Productivity ***	t ha^{-1}	1.16 b	1.33 a	1.48 a	1.32

Note: WAP = weeks after soybean planting; * = significant at P < 0.10; ** = significant at P < 0.05; *** = significant at P < 0.01

Table 4. Pest infestation and number of harvested plant of two soybean varieties with three different organic fertilizers

Variety	Organic fertilizers			Means
	Poultry	*Centrosema* sp.	*Tithonia* sp.	
	Plant pest infestation (%)			
Anjasmoro	16.0 ab	15.9 b	9.9 b	13.9 b
Wilis	17.1 a	16.0 a	15.5 b	16.2 a
Means	16.5	16.0	12.7	
	Number of plant harvested			
Anjasmoro	82.7 a	105.7 a	105 6 a	98.0 a
Wilis	81.3 b	67.2 b	73.3 b	73.9 b
Means	82.0	86.4	89.4	

Anjasmoro is taller than Wilis and although it has fewer leaves than Wilis its leaves are larger (data not shown); therefore the dry weight of shoots of Anjasmoro is greater than that of Wilis. The productivity of Anjasmoro is also greater than productivity of Wilis. Although weights of seed/plant from both varieties were not different, the number of harvested plant of Anjasmoro was more than number of Wilis resulting in a higher production of seed per plot (Table 5). Seed production in this organic farming system was comparable to the national average of soybean productivity which is 1.2 t ha^{-1}. The potential production of Anjasmoro and Wilis were 2.03-2.25 and 1.6 t ha^{-1}, respectively.

Table 5. Plant growth, yield, and yield components of two soybean varieties

	Unit	Varieties		Means
		Anjasmoro	Wilis	
Plant height (7 WAP) ***	cm	64.5 a	52.99 b	58.75
Trifoliate leaf number (7 WAP) ***		16.9 b	25.5 a	21.2
Tetra-foliate leaf number (7 WAP)		1.5	1.4	1.4
Branch number (7 WAP) ***		2.3 b	3.6 a	3.0
Dry weight of shoot (7 WAP)	g	26.8	23.7	25.25
Dry weight of leaves (7 WAP)	g	17.98 a	15.34 b	16.66
Dry weight of root (7 WAP)	g	5.32	5.42	5.37
Disease intensity (6 WAP)	%	6.4	7.6	7.03
Harvested plant number/ 5.12 m^2 ***		97.9 a	73.9 b	85.9
Filled pod number ***		68.8 b	90.6 a	79.7
Empty pod number		3.1	2.4	2.7
Dry weight of seed/plant	g	21.03	20.69	20.86
Dry weight of seed/5.12 m^2 ***	g	804.67 a	550.33 b	677.50
Productivity ***	t ha^{-1}	1.57a	1.07b	1.32

Note: WAP = weeks after soybean planting; *** = significant at P < 0.01

CONCLUSION

The use of *Tithonia diversifolia* Hemsl. as fertilizer in an organic farming system for soybean production resulted in the highest yield of soybeans and the least pest and disease infestations, but the results were not significantly different from those obtained when *Centrosema pubescens* Benth was used. The productivity of soybean plants in response to the application of *Tithonia* sp., *Centrosema* sp., or poultry manure was 1.48, 1.33, and 1.16 t ha^{-1} respectively. Anjasmoro grew better and produced more seed than Wilis, 1.57and 1.07 t ha^{-1} respectively. Anjasmoro with the application of *Tithonia* sp. had the largest number of harvested plants and the lowest incidence of pests and disease.

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