Journal of Tropical Crop Science Vol. 3 No. 1, February 2016
www.j-tropical-crops.com

The Study of Organic Fertilizers Application on Two Soybean Varieties in Organic Saturated Soil Culture

Sandra Arifin Aziz*[A], Maya Melati[A], Elrisa Ramadhani[B]

[A]Department of Agronomy and Horticulture, Bogor Agricultural University, Darmaga Campus, Bogor 16680, Indonesia
[B]Agronomy and Horticulture Study Program, Department of Agronomy and Horticulture, Bogor Agricultural University, Darmaga Campus, Bogor 16680, Indonesia

*Corresponding author; email: sandra.a.aziz@gmail.com

Abstract

Indonesia is facing soybean shortage and the low productivity of soybean production from decreasing acreage. Saturated soil culture (SSC) could be one of the solutions for marginal land with drainage problem. Saturated soil culture is cultivation technology that gives continuous irrigation and maintains water depth constantly and makes soil layer in saturated condition. Farmers can use on-farm inputs that are normally available at the production site. An organic farming system may be able to ensure local and regional food security through continuous production. The study were conducted at Cikarawang Experimental Station of Bogor Agricultural University, Indonesia, from December 2009 to February 2011. The objective of the research was to determine the influence of organic fertilizer application on the productivity of two varieties of soybean, "Anjasmoro" and "Wilis", in organic saturated soil culture conducted in two cropping seasons. Prior to the experiment all plots were applied with 2 ton.ha^{-1} of dolomite, 2 ton.ha^{-1} of rice hull ash, and 10 ton.ha^{-1} of chicken manure. The experiment of the first season used split plot design with six replications. The main-plot was organic fertilizer that consisted of chicken manure only (20 ton.ha^{-1}), chicken manure (10 t.ha^{-1}) + *Centrosema pubescens* (4.2 t.ha^{-1}), chicken manure (10 ton.ha^{-1}) + *Tithonia diversifolia* (4.2 t.ha^{-1}). The sub-plot was soybean varieties "Anjasmoro" and "Wilis". The soybean productivity was not affected by the application of organic fertilizers. "Willis" productivity (1.98 t.ha^{-1}) was higher than "Anjasmoro" (1.80 t.ha^{-1}). The experiment of second season used split-split plot design with three replications. The main-plot consisted of 50 and 100% fertilizer rate of the first cropping season; the sub-plot was the same types of organic fertilizer with soybean varieties as sub-sub-plot. Rate of fertilizer, types of organic fertilizer and soybean variety did not affect productivity. Application of 50 and 100% rate of fertilizer in the second season produced 2.41 and 2.55 t.ha^{-1} of dry seeds, respectively. Soybean plants treated with chicken manure, green manure from *C. pubescens* and *T. diversifolia* produced 2.45, 2.50 and 2.49 t.ha^{-1} of dry seeds, respectively. "Anjasmoro" and "Wilis" produced 2.50 and 2.45 t.ha^{-1} of dry seeds, respectively. Productivity in the second season was 26.26-36.61% higher than those of the first cropping season.

Keywords: *Centrosema pubescens*, chicken manure, drainage, green manure, organic, saturated soil culture, soybean, tidal swamp, *Tithonia diversifolia*

Introduction

Indonesia has been facing soybean shortage and the low productivity from the decreasing farming acreage. Good quality agricultural land has increasingly become a limited resource, therefore efforts have started looking into utilizing marginal land with drainage problem for plant production, including tidal swamp.

Application of organic matter is one of the keys to successful and sustainable agricultural production in the tropics. Research on the process of crop residue decomposition is important to provide clues for a better management of soil organic matter (Ayanlaja and Sanwo, 1991; Dalal et al., 1991). Lowland humid tropics is characterized by high temperature, high relative humidity, high rainfall intensity and high microbial activity which all encourage rapid mineralization, depletion and erosion of organic matter leading to soil deterioration (Ayanlaja and Sanwo, 1991). Modern agricultural practices and operations have encouraged rapid depletion of soil organic matter build up, whereas practices like crop rotation, fallow, and manure application encourage soil organic matter accumulation. However, the effectivity of amending organic matter on agricultural land depends on (a) amount and frequency of residue application; (b) the nature and C/N ratio of the mulch or manure; (c) rainfall intensity and distribution, soil moisture and clay content. Land clearing with heavy machinery usually caused removal huge of biomass from the field, whereas conventional ploughing and harrowing usually lead to soil organic matter depletion. These practices should be discouraged or modified to reduce their negative effects on soil organic matter content.

In our previous studies we grew organic vegetable soybean which was harvested at R6 phase, which is full seed stage - pod containing a green seed that fills the pod capacity at one of the four uppermost nodes on the main stem (Iowa State University, 2007), or earlier than that of grain conventional soybean which was harvested at R8, which is full maturity with 95% of the pods have reached their full mature color for dry seeds production (Iowa State University, 2007). The information on production of organic soybean production at R8 phase is not available. Animal and green manure can be used as organic fertilizer for production of organic vegetable soybean (Barus, 2005; Melati and Andriyani, 2005; Sinaga, 2005; Kurniasih, 2006). The yields of vegetable soybean treated with chicken manure were higher than those treated with manure sheep manure (Sinaga, 2005), and application of green manure *Centrosema pubescens* resulted in a higher yield than those from *Calopogonium mucunoides* and *Crotalaria juncea* (Sinaga, 2005; Kurniasih, 2006). Farmers can use inputs that are available at the production site when growing soybean on tidal swamp areas. An organic farming system may be an option to ensure local and regional food security through continuous production, without having to use expensive chemical fertilizer and pesticides and produce safer foods. The demand for organic produce is rising along with the increasing awareness of health and environmentally friendly food production system.

Saturated soil culture (SSC) is a cultivation technology that gives continuous irrigation, maintains constant water depth at ± 5 cm under soil surface and makes soil layer in continuous saturated condition cultivation. In a saturated soil culture, watering is available from the beginning of plant growth to maturity stage (Hunter et al., 1980). By keeping the water-table constant soybean growth will be protected from negative effects of inundation, because soybean will be acclimatizing and adjusting its growth (Troedson et al., 1983). SSC technique can be applied in the area with moderate or poor drainage, and in many cases SSC improve soybean growth and production compared to conventional irrigation (Hunter et al., 1980; Nathanson et al., 1984; Troedson et al., 1984; Sumarno, 1986). SSC increased dry weight of root, nodule, and activity of nitrogen-fixing bacteria compared to that of conventional technique (Troedson et al., 1983), hence increase nutrient uptake and yield (Ghulamahdi et al., 2005). This technique has been successfully used to increase soybean productivity in South Sumatra, Indonesia (Ghulamahdi et al., 2016), and the combination of organic matter and SSC may be one of the alternative ways to meet the continuous increase of soybean demand of Indonesia.

This study was conducted to determine the influence of organic fertilizer application chicken manure, and green manure from *C. pubescens* and *T. diversifolia* on the productivity of two varieties of soybean, “Anjasmoro” and “Wilis”, in organic saturated soil culture.

Methods

The experiment was conducted at Bogor Agricultural University experimental farm at Cikarawang, Bogor, Indonesia from December 2009–February 2011. The soil type is latosol with flat topography. Materials used 40 $kg.ha^{-1}$ soybean seeds “Wilis” and “Anjasmoro”, 25 $kg.ha^{-1}$ of *C. pubescens* seeds to produce green manure, 2 $t.ha^{-1}$ of dolomite, 10 $t.ha^{-1}$ chicken manure to provide nutrients for *C. pubescens*, and *Tagetes erecta* and *Cymbopogon nardus* as repellent plants), 5 $t.ha^{-1}$ chicken manure as decomposition enhancer for *Tithonia diversifolia* and *C. pubescens* green manure. The first season used split plot design with six replications. The main-plot was organic fertilizer that consist of chicken manure only (20 $t.ha^{-1}$), chicken manure (10 $t.ha^{-1}$) + *Centrosema pubescens* (4.2 $t.ha^{-1}$), and chicken manure (10 $t.ha^{-1}$) + *Tithonia diversifolia* (4.2 $t.ha^{-1}$). The sub-plot was soybean varieties “Anjasmoro” and “Wilis”. The experiment in second season planting used split-split plot design with three replications. The main-plot is the rate organic of fertilizer, i.e. 50 and 100% rate of the first cropping season; the sub-plot was the same type of organic fertilizer; the sub-sub-plot was the soybean varieties. The data was analyzed using ANOVA, and Duncan Multiple Range Test (DMRT) using SAS Windows 9.1.

Every organic fertilizer treatment used 12 plots of 8 m^2 each. For chicken manure treatment, 2 $t.ha^{-1}$ of dolomite, 2 $t.ha^{-1}$ of rice hull ash, and 20 $t.ha^{-1}$ of chicken manure were applied two weeks before soybean planting.

Green manures produced outside of experiment plots for *Centrosema* sp. treatment. Two weeks after

2 t.ha^{-1} of dolomite and 10 t.ha^{-1} chicken manure application, 25 kg seeds per hectare of *Centrosema* sp. were sown. One-month-old of *Centrosema* sp. (4.2 t.ha^{-1}) were collected, weighed, chopped, and applied to the 12 *Centrosema*-treated plots, along with 2 t.ha^{-1} of dolomite, 2 t.ha^{-1} of rice hull ash, and 10 t.ha^{-1} of chicken manure. Incorporated *Centrosema* sp. as green manure was left to decompose for 1 month. For *Tithonia* sp. treatment, the 12 plots were applied with 2 t.ha^{-1} of dolomite, 2 t.ha^{-1} of rice hull ash, and 4.2 t.ha^{-1} of chopped *Tithonia* sp. were then incorporated into the soil along with 10 t.ha^{-1} of chicken manure. One row of *Tagetes erecta* was planted in a row in the middle of each plot. *Cymbopogon nardus*, a repellent species (Sinaga, 2005), was planted encircling the experimental plots to control plant pest and diseases. Planting spacing used for soybean was 40 cm x 10 cm. Before planting 5 g *Bradyrhizobium* sp. was inoculated for each kg of soybean seed. Experimental plots were irrigated at 10 cm height of water (10 cm under the soil surface) from four weeks after planting (WAP) until harvest.

Results and Discussion

"Anjasmoro" treated with full rate of chicken manure and green manure *C. pubescens,* and "Wilis" treated with green manure *T. diversifolia* had the highest leaf K compared to the other treatments. Figure 1-3 showed the effects of the green manure treatments on soybean productivity in two cropping seasons; soybean productivity of the second season was 26.26-36.61% higher than that of the first season (Figure 1 A and B).

rates) was higher than those in the first season (Table 1 and Figure 1). Santos et al. (2012) reported that organic practices have potential to increase microbial biomass content and soil organic matter. Santos et al. (2012) conducted ten years of farming using conventional system by applying 200 kg N + 80 kg P + 80 kg K ha^{-1} every year, the second treatment was two years of transitional organic farming system, and the third treatment was five years of organic farming system. Transitional and organic farming used composted cow manure, composted cow manure and rock phosphate, and composted cow manure at 20, 20 and 0.5, and 20 t.ha^{-1}, respectively. A transitional period is necessary to convert conventional to organic farming. For tropical soil two years of organic management may be a minimum duration to enhance microbial biomass. Soil microbial biomass increased gradually from conventional to organic farming, leading to consistent and distinct differences from the conventional farming at the end of the second year. Ayanlaja and Sanwo (1991) stated that the increase in the soil microbial biomass occurred through improvement of soil physical structure including soil aggregation, porosity, pore size distribution, water retention capacity, and soil microbial activities. Soil organic matter is the major nutrient storage for low-activity-clay soils in the tropics. Addition of organic matter can increase nutrient retention capacity, availability and mobility of macro and micro nutrients, and water use efficiency and consequently increase the productivity of the soil.

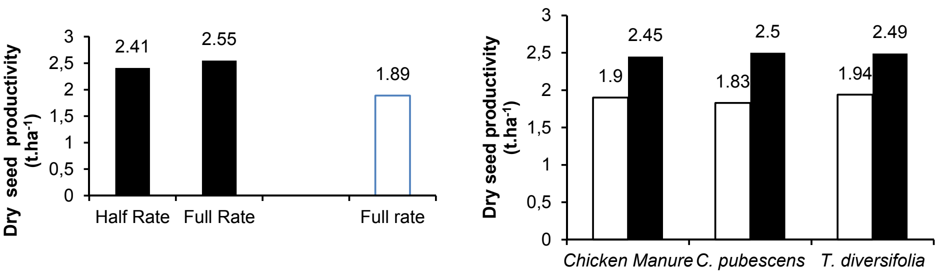

Figure 1. Soybean dry seed productivity at (A) half and full rates of organic fertilizers, and (B) treated with chicken manure, *C. pubescens*, and *T. diversifolia* in season I (▭) and II (■).

Soybean Response to Different Rates of Organic Fertilizer Application in Saturated Soil Culture System

Application of full (100%) organic fertilizer rate improved soybean vegetative growth in the first season. However, soybean productivity in the second season (treated with 50% and 100% organic fertilizer

Soybean Response to Different Sources of Organic Fertilizer in Saturated Soil Culture System

Organic fertilizer promoted vegetative growth in the first season compared to the second season, but dry seed productivity was higher in the second season than the first season (Table 2 and Figure 1B).

Table 1. The effects of organic fertilizer rates on organic soybean production in saturated soil culture

Variables	WAP	Season II		Season I
		50%	100%	
Plant height (cm)	4	32.56a	30.23b	-
	5	46.65b	53.68a	-
	6	-	-	65.09
	7	86.32	88.03	-
	14	91.99b	96.40a	-
Leaf number	4	6.90b	7.30a	-
	6	15.00a	13.30b	-
	7	18.6a	17.5b	17.71
Shoot FW per plant (g)	7	50.54	42.25	-
Leaf FW per plant (g)	7	18.62a	14.51b	-
Root FW per plant (g)	7	3.67a	2.65b	-
Root nodule FW per plant (g)	7	1.58a	0.82b	-
Shoot DW per plant (g)	7	12.60a	9.78b	-
Leaf DW per plant (g)	7	6.39	5.25	37.12
Root DW per plant (g)	7	1.29a	0.83b	6.46
Root nodule DW per plant (g)	7	0.54a	0.26b	2.00
Leaf N (%)	7	3.24b	3.64a	-
Leaf P (%)	7	0.51b	0.57a	-
Leaf K (%)	7	2.85b	3.29a	-
Leaf Mn (ppm)	7	3041.80b	4009.30a	-
N uptake (mg per plant)	7	408.47	357.38	-
P uptake (mg per plant)	7	64.89	55.65	-
K uptake (mg per plant)	7	366.03	315.77	-
Fe uptake (mg per plant)	7	121.24	100.41	-
Number of filled pod per plant		101.30	106.50	84.93
Number of empty pod per plant		2.00	1.90	1.68
Number of productive branch per plant		8.00b	11.00a	
Number of plants harvested		111.60a	101.80b	74.75
Seed DW per plant (g)		28.74b	31.53a	23.28
100-seed weight (g)		15.67a	14.72b	13.00
Seed water content (%)		7.00b	7.69a	
Seed DW (g) per plot (4.56 m^2)		1097.78	1162.72	866.00 (per 5.12 m^2)
Time of flowering (DAP)		45.5a	44.1b	-
Harvest time (DAP)		99.3b	99.9a	-
Seed K seed (%)		1.87b	2.12a	-
Seed N (mg per plant)		2051.8b	2287.7a	-
Seed P (mg per plant)		261.27b	285.79a	-
Seed K (mg per plant)		537.07b	671.45a	-
Seed Zn (mg per plant)		2.22b	2.49a	-
Dry seed productivity (ton per ha)		2.41	2.55	1.69

Note: Numbers followed by different letter in the same the same row and the same season is significantly different at 5% DMRT. The rates of organic fertilizer application in season I was 100%. DW = dry weight; FW = fresh weight; WAP = week after planting; DAP = day after planting.

Table 2. The effects of different organic fertilizer on soybean production in saturated soil culture

Variables	WAP	Season I			WAP	Season II		
		CM	CP	TD		CM	CP	TD
Plant height (cm)		-	-	-	3	16.66b	17.72a	18.24a
	6	65.59	62.45	67.20	6	74.35	75.43	76.03
	13	75.34	71.71	76.84	14	93.67	93.50	95.41
Leaf number	.	-	-	-	3	3.7a	3.7a	3.6b
	4	5.2	5.2	5.2	4	7.2 a	7.1ab	7.0b
	5	11.1	11.5	10.5	5	10.1a	9.4b	9.6b
Shoot FW per plant (g)	7	58.89	59.29	59.04	7	44.79	52.79	41.60
Leaf FW per plant (g)	7	24.35	25.25	25.42	7	15.87	18.83	15.00
Root FW per plant (g)	7	5.21	4.58	4.21	7	3.06	3.33	3.08
Root nodule FW (g)	7	1.77	1.51	1.47	7	1.17	1.21	1.22
Shoot DW per plant (g)	7	15.83	14.54	13.91	7	11.77	12.29	9.50
Leaf DW per plant (g)	7	9.92	9.33	8.59	7	6.65	6.08	4.73
Root DW per plant (g)	7	1.83	1.85	1.49	7	1.08	1.12	0.98
Root nodule DW per plant (g)	7	0.57	0.47	0.46	7	0.39	0.39	0.42
Leaf N (%)	7	3.82	4.02	4.05	7	3.51a	3.36b	3.45ab
Leaf P (%)	7	0.47	0.47	0.49	7	0.54	0.53	0.55
Leaf K (%)	7	1.20b	1.56a	1.78a	7	3.09	3.09	3.03
N uptake (mg per plant)	7	598.0	582.2	553.6	7	411.2	412.3	325.4
P uptake (mg per plant)	7	73.06	67.87	67.04	7	62.77	65.64	52.41
K uptake (mg per plant)	7	192.0	230.3	246.0	7	361.9	376.4	284.4
Number of filled pod per plant		81.8	88.6	84.3		111.8a	103.3ab	96.6b
Number of empty pods per plant		1.8	1.6	1.6		2.1	1.8	1.9
Number of productive branch per plant		7.3	7.3	8.8		10.1	9.5	9.0
Number of plants harvested		69.5	74.0	80.7		103.2b	102.8	114.0a
Shoot DW per plant (g)		17.1	17.3	18.2		27.5a	26.4	22.6b
Root DW per plant (g)		1.77	1.79	1.93		3.31a	2.81b	2.48b
Seed DW per plant (g)		22.12	23.56	24.17		33.59a	30.44b	26.38c
100-seed DW (g)		12.92	12.75	13.34		15.67a	15.17ab	14.75b
Seed water content (%)		8.63	8.15	8.32		7.43	7.36	7.22
Seed DW per 4.56 m^2 (g)		876.33	34.42	887.25		1115.92	1140.08	1134.75
Time of flowering (DAP)		36.9	36.8	36.2		44.7ab	45.2a	44.5b
Time of harvest (DAP)		95.7	95.5	95.8		99.7	99.7	99.4
Seed N (%)		5.58b	5.75ab	6.13a		7.11	7.32	7.13
Seed P (%)		0.51	0.50	0.47		0.93a	0.92	0.87b
Seed K (%)		1.69	1.79	1.88		2.01	1.95	2.02
Seed Ca (%)		0.36a	0.26a	0.26a		261.6a	228.1ab	191.4b
Seed N (mg per plant)		1232.3 b	1355.9 ab	1478.2a		2391.5a	2234.4a	1883.4b
Seed P (mg per plant)		11.9	117.5	113.1		310.8a	279.7b	230.2c
Seed K (mg per plant)		73.5	419.5	454.1		678.6a	598.6b	535.5b
Seed Fe seed (mg per plant)		-	-	-		8.8a	7.1b	4.9c
Seed Zn (mg per plant)		-	-	-		2.6a	2.4a	2.0b
Productivity ($t.ha^{-1}$)		1.90	1.83	1.94		2.45	2.50	2.49

Note: numbers followed by different letter in the same the same row and the same season is significantly different at 5% DMRT. DW = dry weight; FW = fresh weight; WAP = week after planting; DAP = day after planting; CM = chicken manure, CP = *Centrosema pubescens*, TD= *Tithonia diversivolia*.

Soybean plants treated with chicken manure had greener leaves, possibly due to a better uptake of soil nutrients. Park et al., (2010) stated that bioremediation is a natural process which relies on soil microorganisms and higher plants to alter metal(loid) bioavailability, and this process can be enhanced by addition of organic amendments to soils. Large quantities of organic amendments can serve as a source of nutrients and soil conditioner that can improve the soil physical properties. Soil is increasingly being seen as a major source of metal(loid)s reaching food chain, mainly through plant uptake and animal transfer. Bilgili et al. (2007) stated that recirculation is more effective on anaerobic degradation of solid waste than aerobic degradation. This condition occurred in saturated soil culture with the water coming in and out in the irrigation flow.

Application of green manure *C. pubescens* with chicken manure as decomposition enhancer had the C/N ratio of 12.28 at six weeks of application, whereas vegetable soybean productivity in an organic rain fed system using chicken manure as decomposition enhancer had the highest productivity (Hindratno, 2006). Melati et al. (2008) reported that chicken manure was the best organic manure when used as a single application on rain fed organic system. Chicken manure might function as the decomposition enhancer as well as contributing organic materials for soybean growth. Application of rice hull ash significantly reduced the intensity of pest infestation by 75% compared to control (Melati et al, 2008). *Tithonia* sp. can be used as a substitute for chicken manures when there was a shortage in chicken manure availability. Soil analysis before and after organic fertilizer application indicated that soil pH, soil N, P, Ca, Mg and K was higher after the organic fertilizer decomposed, whereas the CEC Fe, Cu, Zn, Mn were lower. Chicken manure has similar nutrient content to *Tithonia* sp. which was higher than *Centrosema* sp. This might explain the higher productivity of the soybean treated with chicken manure or *Tithonia* than with *Centrosema* sp. as green manure.

Production of Two Soybean Varieties in Saturated Soil Culture System

“Anjasmoro” grown in SSC system in the first season were taller at six WAP, had a greater leaf dry weight, and 100-seed dry weight in comparison to the second season. Similarly, “Wilis” had greater leaf number at six WAP, greater filled pod number, and dry seed weight per ha (Table 3 and Figure 3). “Anjasmoro” has a robust vegetative growth and larger seeds than “Wilis”, but had a fewer number of filled pods, which resulted in a significantly higher productivity in both seasons. Productivity of “Anjasmoro” in SSC system was similar to that of the conventional rain fed system, whereas “Wilis” slightly exceeded the production potential in the rain fed conventional system (1.6 t.ha^{-1}).

Extensive root system, but lower dry nodule weight in organic rain fed system was recorded in “Wilis” (Hindratno, 2006). SSC system increased dry weight of roots, nodules, and activity of nitrogen-fixing bacteria compared to the conventional systems (Troedson et al., 1983), hence increased nutrient uptake and yield (Ghulamahdi et al., 2005).

“Wilis” productivity in this experiment was higher than in the conventional rain fed systems. Experiments conducted at Nimbokrang, Bima and Dompu on rainy season 1999/2000 produced 1.50 t. ha^{-1} of dry seeds, plant height of 73.80 cm, 1000-seed weight of 72.83 g (LIPTAN, 1996), whereas Gani (2000) reported dry seed production of 1.75 t.ha^{-1}. Ghulamahdi et al. (2009) reported that the productivity of SSC conventional system in tidal area with a plant population of 400,000 per ha had exceeded the potential productivity by triple of that in conventional rain fed systems, i.e. 4.06 and 2.49 t.ha^{-1} for “Anjasmoro” and “Wilis”, respectively. It seemed that tidal condition provides good water supply and its exposure to high light intensity contributed to the higher soybean productivity as “Wilis” on conventional SSC system only produced 1.8t.ha^{-1} of dry seeds. Hindratno (2006) reported the productivity on rain fed organic “Wilis” using chicken manure as decomposition enhancer for *C. pubescens* and conventional rain fed system were 7.66 and 6.7 t.ha^{-1}, respectively.

Conclusions

Rate of fertilizer, sources of organic fertilizer and soybean variety affected number of leaves at three and six WAP, and leaf K concentration. Application of 50 and 100% rate of organic fertilizer in the second season produced 2.41 and 2.55 t.ha^{-1} of dry seeds, respectively. Application of chicken manure and green manure from *C. pubescens*, and *T. diversifolia* produced 2.45, 2.50 and 2.49 t.ha^{-1}, respectively. Productivity in the second season was 26.26-36.61% higher than the first cropping season; “Anjasmoro” and “Wilis” productivity in the second season was 2.50 and 2.45 t.ha^{-1}, respectively. Organic soil saturated culture is a potential solution to increase the soybean acreage to supply the increasing soybean demand in Indonesia. Soil saturated culture could potentially

Table 3. Productivity of soybean “Anjasmoro” and “Wilis” in a saturated soil culture system.

Variables	WAP	Season I		WAP	Season II	
		“Anjasmoro”	“Wilis”		“Anjasmoro”	“Wilis”
Plant height (cm)		-	-	3	19.54a	15.53b
	6	70.70a	59.46b	6	80.02a	70.52b
				7	91.02a	83.33b
	13	77.93a	71.33b	14	94.50	93.90
Leaf number per plant				3	3.7	3.7
	4	5.3	5.2	4	6.8b	7.4a
	5	9.3b	12.8a	5	8.7b	10.8a
	6	14.7b	20.7a	6	12.7b	15.6a
				7	16.9b	19.2a
Shoot FW per plant (g)	7	64.96a	53.19b	7	52.22a	40.57b
Leaf FW per plant (g)	7	28.76a	21.25b	7	19.61a	13.53b
Root FW per plant (g)	7	5.19a	4.14b	7	3.80a	2.51b
Nodule FW per plant (g)	7	1.71	1.45	7	1.41	0.99
Shoot DW per plant (g)	7	16.60	12.92	7	12.42	9.96
Leaf DW per plant (g)	7	10.45a	8.10b	7	6.39	5.25
Root DW per plant (g)	7	1.78	1.66	7	1.26a	0.86b
Nodule DW per plant (g)	7	0.51	0.49	7	0.46	0.34
Leaf N (%)	7	3.91	4.01	7	3.48	3.40
Leaf P (%)	7	0.47	0.47	7	0.55	0.54
Leaf K (%)	7	1.54	1.49	7	3.22a	2.92b
Leaf Ca (%)	-	-	-	7	1.77b	2.09a
Leaf Fe (ppm)	-	-	-	7	578.54a	487.41b
Shoot N (mg per plant)	7	637.63a	518.19b	7	427.83a	338.02b
Shoot P (mg per plant)	7	77.56a	61.09b	7	67.39a	53.15b
Shoot K (mg per plant)	7	255.11a	190.42b	7	393.91a	287.88b
Shoot Ca (mg per plant)	-	-	-	7	225.53	205.78
Shoot Mg (mg per plant)	-	-	-	7	126.54a	95.11b
Shoot Fe (mg per plant)	-	-	-	7	6.99a	4.83b
Shoot Mn (mg per plant)	-	-	-	7	42.69a	33.05b
Number of filled pods per plant		7.0b	100.2a		93.0b	114.9a
Number of empty pods per plant		1.6	1.8		2.00	1.9
Productive branch per plant		7.1b	8.5a		8.2b	10.9a
Number of plants harvested		73.2	76.3		96.6b	116.8a
Shoot DW per plant (g)		16.74	18.39		26.31	24.71
Root DW per plant (g)		1.88	1.78		2.77	2.96
Seed DW per plant (g)		22.79	23.77		31.81a	28.47b
100-seed DW (g)		15.89a	10.11b		18.50a	11.89b
Seed water content (%)		8.10	8.63		7.73a	6.94b
Seed DW per 4.56 m^2 (g)		821.9b	910.1a		1141.1	1119.4
Time of flowering (DAP)		36.6	36.7		42.6	47.1a
Time of harvest (DAP)		95.6	95.8		98.4b	100.9a
Seed N (mg per plant)		1359.3	1351.7		2324.2a	2015.3b
Seed P (mg per plant)		113.12	115.19		292.09a	254.98b
Seed K (mg per plant)		427.65	403.79		638.52a	570.00b
Seed DW productivity ($t.ha^{-1}$)		1.80b	1.98a		2.50	2.45

Note: Numbers followed by different letter in the same the same row and the same season were significantly different at 5% DMRT; DW = dry weight; FW = fresh weight; WAP = week after planting; DAP = day after planting.

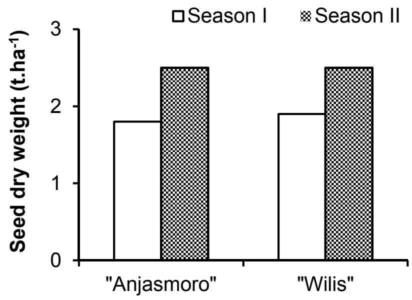

Figure 2. Productivity of soybean “Anjasmoro” and “Wilis” in two cropping seasons

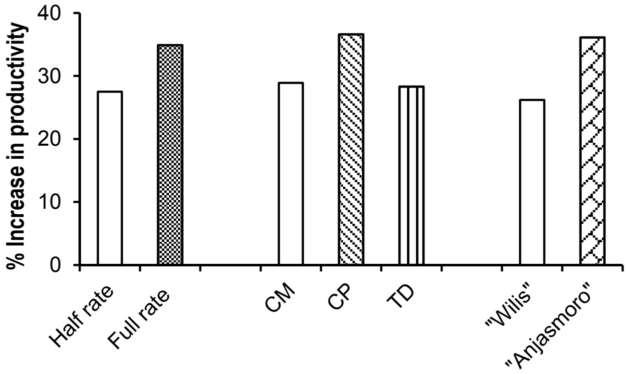

Figure 3. Percentage of increase in soybean productivity with half and full rate of organic fertilizer application in the second planting season; CM = *Chicken manure*, CP = *Centrosema pubescens*, TD= *Tithonia diversivolia.*

utilize the currently idle tidal swamps, and marginal lands with moderate or poor drainage.

Acknowledgement

This research was funded by I-MHERE (Indonesia–Managing Higher Education for Relevance and Efficiency) B.2C, Indonesian Ministry of Education.

References

Ayanlaja, S.A., and Sanwo, J.O. (1991). Management of soil organic matter in the farming systems of the lowland humid tropics of West Africa: a review. *Soil Technology* **4**, 265-279.

Barus, L.E. (2005). Pengaruh pemberian pupuk hijau dan fosfat alam terhadap pertumbuhan dan produksi kedelai (*Glycine max* (L.) Merr) panen muda dengan sistem pertanian organik. *Thesis*. Budidaya Pertanian, Fakultas Pertanian. Institut Pertanian Bogor. Bogor.

Bilgili, M.S., Demir, A., and Ozkaya, B. (2007). Influence of leachate recirculation on aerobic and anaerobic decomposition of solid wastes. *Journal of Hazardous Material* **143**, 177-183.

Dalal, R.C., Strong, W.M., Weston, E.J., and Gaffney, J. (1991). Sustaining multiple productions systems: II. Soil fertility decline and restoration of cropping lands in subtropical Queensland. *Tropical Grassland* **25**, 171-180.

Gani, J.A. 2000. “Varietas Unggul Baru”. Information sheet (Liptan) IP2TP Mataram No. 07/ Liptan/2000. *Instalasi Penelitian dan Pengkajian teknologi Pertanian Mataram* Desember. *Agdex,* 141.

Ghulamahdi, M., Aziz, S.A., Melati, M., Dewi, N., dan Rais, S.A. (2005). Aktivitas nitrogenase, serapan hara dan pertumbuhan dua varietas kedelai pada kondisi jenuh air dan kering. *Buletin Agronomi* **34**, 32-38.

Ghulamahdi, M., Chaerunisa, S.R.,Lubis, I., Taylor, P. (2016). Response of five soybean varieties under saturated soil culture and temporary flooding on tidal swamp.

Procedia Environmental Sciences **33**, 87-93.

Ghulamahdi, M., Melati, M., dan Murdianto. (2009). "Penerapan teknologi budidaya jenuh air dan penyimpanan benih kedelai di lahan pasang surut". *Unpublished Report.* Laporan Program Insentif 2009, Kementrian Negara Riset dan Teknologi. Indonesia.

Hindratno, T.P. (2006). Pengaruh lama dekomposisi pupuk hijau dan jenis pelapuk terhadap budidaya kedelai (*Glycine max* (L.) Merr) panen muda secara organik. *Thesis.* Program Studi Agronomi, Fakultas Pertanian, Institut Pertanian Bogor. Indonesia.

Hunter, M.N., De Fabrun, P.L.M., and Byth, D.E. (1980). Response of nine soybean lines to soil moisture conditions close to soil saturation. *Journal of Experimental Agriculture and Animal Husbandry* **20**, 339-345.

Kurniasih, W. (2006). Pengaruh jenis, dosis benih dan umur tanaman pupuk hijau terhadap produksi kedelai (*Glycine max* (L.) Merr) panen muda organik. *Thesis*. Agronomi dan Hortikultura, Fakultas Pertanian. Institut Pertanian Bogor. Indonesia.

LIPTAN (Lembar Informasi Pertanian). (1996). Paket teknologi tanaman kedelai varietas Lokon, Wilis dan Orba. LPTP Koya Barat, Irian Jaya, *Loka Pengkajian Teknologi Pertanian Koya Barat,* Februari 1996. *Agdex* **141***,* 20.

Melati, M., dan Andriyani, W. (2005). Pengaruh pupuk kandang ayam dan pupuk hijau *Colopogonium mucunoides* terhadap pertumbuhan dan produksi kedelai panen muda yang dibudidayakan secara organik. *Buletin Agronomi* **33**, 8-15.

Melati, M. Asiah, A., dan Rianawati, D. (2008). Aplikasi pupuk organik dan residunya untuk produksi kedelai panen muda. *Buletin Agronomi* **36**, 204-213.

Nathanson K., Lawn R.L., De Jabrun PLM, Byth DE: Growth nodulation and nitrogen accumulation by soybean in saturated soil culture. *Field Crop Research* **8**, 733-92.

Jin-Hee Park, Lamb, D., Paneerselvam, P., Choppala, G., Bolan, N., and Jae-Woo Chung. (2011). Role of organic amendments on enhanced bioremediation of heavy metal(oid) contaminated soil. *Journal of Hazardous Material* **185**, 549-574.

Ramadhani, E., Melati, M., and Aziz, S.A. (2011). Kajian aplikasi jenis pupuk pada dua varietas kedelai secara organik dengan system budidaya jenuh air pada dua musim tanam. *Thesis*. Program Studi Agronomi dan Hortikultura, Fakultas Pertanian, Institut Pertanian Bogor, Indonesia.

Santos, V.D., Araujo, A.S.F., Leite, L.F.C., Nunes, L.A.PL., and Melo, W.J. (2012). Soil microbial biomass and organic matter fractions during transition from conventional to organic farming systems. *Ganoderma* **170**, 227-231.

Sinaga, Y.A.S. (2005). Pengaruh pemberian pupuk organik terhadap pertumbuhan dan produksi kedelai (*Glycine max* (L.) Merr.) panen muda yang diusahakan secara organik. *Thesis*. Budidaya Pertanian. Institut Pertanian Bogor. Bogor, Indonesia.

Sumarno. (1986). Response of soybeans (*Glycine max* (L.) Merr.) genotypes to continuous saturated cultured. *Indonesia Journal of Crop Sci*ence **2**, 71-78.

Troedson, R.J., Lawn, R.J., Byth, D.E., and Wilson, G.L. (1983). Saturated soil culture in innovated water management option for soybean in the tropics and sub tropics. *In "*Proceedings of Symposium The Soybean in Tropical and Subtropical System" *(*S. Shanmugasundaran and E.W. Sulzberger, eds.) pp 171-180. Tsukuba, Japan.

Troedson, R.J., Lawn, R.J., Byth, D.E., and Wilson, G.L. (1984). "Nitrogen fixation by soybean in saturated soil". Australian Legume Nodulation Conference. Sydney, Australia.