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Research Article

Effect of application of organic and inorganic fertilizer on soybean yield in lowland Vertisols

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Abstract: Application of organic fertilizer can maintain and improve physical, chemical, and biological soil fertility and plant productivity. However, the use of manure requires a long time and a relatively large amount to have a positive impact on the soil and plants. In this regard, a study was carried out to evaluate the effect of the application of organic fertilizer and NPK inorganic fertilizer on soybean in lowland Vertisol. The study was conducted in lowland Vertisols in Ngawi and Madiun. The experiment used a randomized block design with three replications, with combination treatments of cow and chicken manure, Santap NM1 and NM2 fertilizer, and Phonska. The soybean seed used in this research was Local Central Java/Sinabung-1036 soybean line. The results showed that in lowland Vertisol of Ngawi which is rich in P element, application of 5,000 kg of cow manure/ha, 3,000 kg of chicken manure/ha, 1,500-2,500 kg/ha Santap NM1 and NM2 fertilizers, and 300 kg of Phonska/ha is not required. The yield of Local Central Java/Sinabung-1036 soybean line reached 1.95 t/ha. The lowland Vertisol of Madiun which has poor P element requires the addition of 5,000 kg of cow manure/ha, 1,500-2,500 kg/ha of Santap NM2 fertilizer, and 150 kg of Phonska/ha to increase soybean yield by 21-27% (0.42-0.55 t/ha). The quality and productivity of soil and crop cultivation in sustainable agriculture can be maintained by alternative recommendations for the use of organic and inorganic fertilizer inputs.

Keywords: *inorganic fertilizer, lowland Vertisol, organic fertilizer, soybean*

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Introduction

Vertisols have a characteristic that is very hard when in the dry season and very sticky when in the rainy season (Hati et al., 2015). The soil is rich in clay fraction with characteristic periodically expanding and contracting (Juita, 2016). The high clay content in this soil causes cracks in the dry season and expands in the rainy season (Utomo, 2016). As a result, soil tillage is only workable in a very limited range of soil moisture to improve the physical properties of the soil. Minimum soil tillage or zero tillage with balanced fertilization is an alternative way to sustain soybean production system on the soil (Hati et al., 2015). Sholihah et al. (2016) explained that Vertisol is a problem soil that requires certain management techniques in order to keep the soil productive to be used in agriculture. The limited soil organic carbon (SOC) storage in the Vertisol in a tropical region, despite continuous seasonal inputs of plant-derived C from the C_4-dominated grassland system at the sampling field site (Fang et al., 2017). SOC, arylsulfatase activity, and available P are the most effective discriminant factors among the conventional and organic nutrient management practices in Vertisols of India (Ghosh et al., 2020). Soybean in lowland contributed most of the soybean needs for food, feed, and industry. In general, efforts to increase soybean yield are carried out by adding organic and inorganic fertilizers. Application of fertilizers of 50 kg ZA +

50 kg SP-36 + 100 kg KCl/ha (10.4 kg N + 11.9 kg S + 18 kg P_2O_5 + 60 kg K_2O/ha) in lowland Vertisol of Ngawi increased the soybean yield from 0.16 t/ha to 0.26 t/ha on cropping pattern rice-rice-soybean and 0.37 t/ha on cropping pattern rice-soybean-soybean (Kuntyastuti et al., 2011; 2012a). Purwaningrahayu et al. (2011), however, reported that application of 50 kg ZA + 50 kg SP-36 + 100 kg KCl/ha did not increase soybean yield in the cropping pattern rice-rice-soybean. Fertilization of 50 kg ZA + 50 kg SP-36 + 5,000 kg rice straw/ha increased soybean yield by 0.49 t/ha, from 1.14 t/ha to 1.63 t/ha. Application of 5,000 kg cow manure/ha produced 1.48 t/ha of soybean, and soybean yield of 1.77 t/ha was obtained by the application of 5,000 kg burnt rice straw/ha.

Other research results in the lowland Vertisol of Ngawi have also been reported by Kuntyastuti et al. (2012b). After two planting seasons of soybean-rice (plant I and II), residual organic and NPK inorganic fertilizer increased macronutrient uptake by 25-76%, but they did not increase soybean yield as plant III. The residue of 5,000 kg manure + 5,000 kg burnt rice straw/ha increased soil penetration by 60 N/cm^2, decreased (Ca, Mg)-P by 31%, and increased (Fe, Al)-P by 132%. The residual of 5000 kg manure/ha reduced the sorption of the P element in the form of Al-P and Fe-P (reducing Al-P and Fe-P by 45%) higher than that of 5,000 kg burnt rice straw/ha (reducing Al-P by 18% and Fe-P by 19%). Without rice straw, soybean requires 50 kg ZA + 200 kg SP-36/ha to achieve a yield of 2.16 t/ha. With burnt rice straw, soybean needed 50 kg ZA + 50 kg KCl/ha to achieve a yield of 2.32 t/ha (Kuntyastuti et al., 2013a). Large seed size soybean such as Grobogan variety requires 2,500 manure/ha to increase yield from 1.65 t/ha to 1.84 t/ha. Aochi/W-C-6-62 soybean as a promise line requires 7,500 kg manure/ha or 50 kg ZA + 150 kg SP-36 + 50 kg KCl/ha to increase yield from 1.75 t/ha to 2.05 t/ha (Kuntyastuti and Lestari, 2017).

In soil with C-organic content of 0.7-1.7%, the addition of 2,500-7,500 kg manure/ha by spreading, extracting, or making holes in the soil, without or with 25-50 kg ZA, 50-100 kg SP-36, and 50-100 kg KCl/ha did not increase soybean yield (Kuntyastuti et al., 2013b). Soybean yield was positively correlated with levels of soil P_2O_5 before planting with a regression equation of $Y = 0.188 + 0.426 \text{ Ln } (P_2O_5 \text{ Bray-1})$, $R^2 = 90.1\%$. In an Entisol of Mojokerto with clay texture and 42 ppm P_2O_5 Bray-1, fertilization of 200 kg ZA/ha increased soybean yields by 26% compared without fertilizer (Sutrisno et al., 2014). Application of 200-600 kg SP-36/ha also increased soybean yield, reaching a maximum at a dose of 348 kg SP-36/ha (equivalent to 125 kg P_2O_5/ha) (Kuntyastuti and Suryantini, 2015). Suryantini and Kuntyastuti (2015) reported that planting soybean after rice required 30 kg N/ha from Urea or 90 kg N/ha from ZA to increase yield by 0.5 t/ha from 2.9 t/ha to 3.4 t/ha. Conversely, planting soybean after soybean did not need N fertilizer, the yield reached 3.0 t/ha.

The use of organic manure can maintain and improve soil physical, chemical, and biological fertility that, in turn, increases soil and plant productivity. However, the use of manure takes a long time and in relatively large quantities to have a positive impact on the soil and plants. The use of organic manure + NPK inorganic fertilizers can increase the weight of roots, shoot, and yield of soybean by 98% compared to without fertilizer. Leaf area index of 4.88, biomass 633 g/m^2 during the maturing phase and a maximum growth rate of 18.4 g/m^2/day were obtained by application of manure + NPK. The efficiency of the use of non-renewable energy is also higher than NPK inorganic fertilizers when using manure + NPK inorganic fertilizers (Mandal et al., 2009). Bandyopadhyay et al. (2010) explained that the use of 4,000 kg manure + 30 kg N + 26 kg P + 25 kg K/ha for four years in Vertisols reduced soil bulk density by 9.3% and soil penetration by 42.6%, increased hydraulic conductivity by 95.8%, and increased soil organic C by 45.2% compared to without fertilizers. Application of fertilizers also improves the allocation of dry matter to the pods, increases the efficiency of water use, and increases the use of soybean N compared to using only NPK inorganic fertilizers or no fertilizers. The use of 4,000 kg manure + 30 kg N + 26 kg P + 25 kg K/ha in each growing season is an alternative to improve soil physical properties and soybean productivity because it increases the efficiency of water and nutrient use.

Addition of organic fertilizers can increase soil organic-C content. Continuous use of soil without the addition of organic fertilizers can reduce C-organic by 39-43% compared to soil with the addition of organic fertilizer. Ghosha et al. (2012) reported that application of organic manure, rice straw, and green manure increased soil organic-C by 26, 18, and 6%. Long-term use of manure is the best alternative to improve soil quality and microbial activity. The use of manure for 15 years can increase organic matter, total N, enzyme activity, invertase, b-glucosidase, urease, acid and base phosphate, and dehydrogenase in soil (Liang et al., 2014). Substitution of 50% recommended P fertilizer by inoculating PSB (phosphate solubilizing bacteria), and VAM (vesicular-arbuscular mycorrhiza) can improve root growth and increase soybean yield compared to 100% recommended P fertilizer (Mahanta et al., 2014). Application of 20 kg N + 60 kg P + 20 kg K/ha produced 1.28 t soybean/ha. Fertilization of NPK + 10 kg PSB/kg seed + 10 g Rhizobium/kg seed produced 1.69 t soybean/ha, and the use of 10,000 kg manure/ha produced 1.85 t soybean/ha (Gautam and Pathak, 2014). Application of 5,000 kg manure/ha also produced the highest cowpea that was higher than that of 300 kg NPK fertilizer/ha (Kuntyastuti and Muzaiyanah, 2017). The policy implication of this study is to reduce the burning potential of inorganic fertilizer in areas where there is frequent drought and erratic rainfall, application manure and soil conservation methods are important (Hassen, 2018). The objective of this study was at evaluating the effect of the application of organic fertilizer and NPK inorganic fertilizer on soybean in lowland Vertisols.

Materials and Methods

The study was conducted on lowland Vertisols owned by farmers, in Tawun Village, Kasreman District, Ngawi Regency and in Muneng Village, Pilangkenceng District, Madiun Regency. The lowland Vertisols of Ngawi and Madiun are rather alkaline, poor in organic matter, poor N and S elements, but rich in Ca and Mg elements. The Vertisol of Ngawi is very rich in P element, whereas the Vertisol of Madiun soil is poor in P element (Table 1). The soils in two locations have clay texture, and the sand fraction in the Vertisol of Madiun is higher than in the Vertisol of Ngawi, in addition to the less clay fraction. The movement of water in saturated conditions in the Vertisol of Madiun (saturated hydraulic conductivity) of 0.19 cm/hour is higher than that in the Vertisol of Ngawi (0.10 cm/hour).

The experiment that was carried out after the harvest of second rice with cropping pattern rice-rice-soybean. Twelve treatments (Table 2) were arranged in a randomized block design with three replications. Three seeds of Local Central Java/Sinabung-1036 soybean line per hole were planted at a 5 m x 4 m plot with a planting space of 40 cm x 15 cm. Land preparation was carried out without tillage. Between plots were made a drainage channel of 25 cm wide with a depth of 15 cm. Santap NM1 and NM2 fertilizers were supplied at planting time by making a hole in the soil beside the seedling hole of about 5 cm apart. Santap NM1 is a nutrient-rich organic fertilizer composed of 47.5% cow manure, 20% chicken manure, 15% rock phosphate, 15% ash from sugar factory waste, and 2.5% sulfur. Santap NM2 is a nutrient-rich organic fertilizer composed of 45% cow manure, 20% chicken manure, 15% rock phosphate, 15% ash from sugar factory waste, and 5% sulfur. Santap NM1 and Santap NM2 fertilizer are suitable for non-acidic land (lowland and dry land). Phonska (a compound fertilizer containing 15% N, 15% P_2O_5, 15% K_2O, and 10% S), chicken manure, and cow manure were given in a channel about 5 cm beside the planting line at the time of planting.

Table 1. Chemical and physical properties of lowland Vertisols of Ngawi and Madiun.

Properties	Ngawi Vertisol	Madiun Vertisol
Chemical properties		
pH H_2O	7.7	7.9
pH KCl	7.3	7.1
Total-N (%)	0.14	0.15
Organic-C (%)	1.58	1.62
P_2O_5 Bray-1 (ppm)	47.8	10.7
SO_4 (ppm)	32.1	31.7
K (me/100 g)	0.21	0.27
Na (me/100 g)	0.49	0.43
Ca (me/100 g)	40.56	40.15
Mg (me/100 g)	3.30	3.42
CEC (me/100 g)	70.2	69.9
Al-dd (me/100 g)	0	0
H-dd (me/100 g)	0.64	0.42
Fe (ppm)	5.55	7.00
Mn (ppm)	4.75	8.90
Cu (ppm)	16.6	17.8
Zn (ppm)	1.13	1.33
Physical properties		
Saturated hydraulic conductivity (cm/hour)	0.10	0.19
Bulk Density (g/cm^3)	1.16	1.21
Particle Density (g/cm^3)	2.51	2.57
Porosity (%)	53.8	53.0
Water content pF 2.5 (%)	48	39
Water content pF 4.2 (%)	33	22
Water holding capacity (%)	15	17
Sand fraction (%)	4	18
Silt fraction (%)	26	26
Clay fraction (%)	70	56
Texture class	Clay	Clay

Characteristics of chicken and cow manure used for this study are presented in Table 3. Cow and chicken manures are alkaline, while Santap NM1 and Santap NM2 are acid. The chicken manure has the highest levels of P, K, and Ca elements. The C/N ratio for organic fertilizer is smaller than 11, meaning that the nutrients contained therein can be utilized by plants without immobilization by soil microbes. The highest total microbial population is in chicken manure, and the lowest total microbial population is in Santap NM2 fertilizer. The content of *Salmonella* sp. in cow manure is 14 x 10^3 cfu/g of material, which is higher than the requirements of Permentan No. 28/Permentan/OT.140/2/ 2009 concerning organic fertilizer standards, namely the content of *Salmonella* sp. <10^2 cfu/g. Weed, pest and disease controls were carried out intensively according to to the field conditions. Water was supplied from technical irrigation and underground water pumps. Plant height was observed at 45 DAP (days after planting) and at harvest (75 DAP). Leaves chlorophyll was observed at 45 DAP and 60 DAP. At 45 DAP, N, P, K, Ca, Mg and C contents in the fully developed youngest leaves, and soil microbial population were measured. Parameters of soybean yields measured at harvest were plant population, number of filled pods, weight of 100 seeds, and soybean yield with moisture content 12%. Data obtained were subjected to analysis of variance followed by the Duncan Multiple Range Test (DMRT) at a significant level of 5%.

Table 2. Fertilization treatment on soybean in lowland Vertisols of Ngawi and Madiun.

No	Description
1	Without fertilizer (control)
2	300 kg Phonska/ha
3	5,000 kg cow manure/ha
4	3,000 kg chicken manure/ha
5	1,500 kg Santap NM1/ha
6	1,500 kg Santap NM1/ha + 150 kg Phonska/ha
7	2,500 kg Santap NM1/ha
8	2,500 kg Sa ntap NM1/ha +150 kg Phonska/ha
9	1,500 kg Santap NM2/ha
10	1,500 kg Santap NM2/ha + 150 kg Phonska/ha
11	2,500 kg Santap NM2/ha
12	2,500 kg Santap NM2/ha + 150 kg Phonska/ha

Remarks: Phonska is a compound fertilizer containing 15% N, 15% P_2O_5, 15% K_2O, and 10% S. Santap NM1 is composed of 47.5% cow manure, 20% chicken manure, 15% rock phosphate, 15% ash from sugar factory waste, and 2.5% sulfur. Santap NM2 is composed of 45% cow manure, 20% chicken manure, 15% rock phosphate, 15% ash from sugar factory waste, and 5% sulfur.

Table 3. Nutrient levels in cow manure, chicken manure, Santap NM1, and Santap NM2 fertilizers.

Properties	Cow manure	Chicken manure	Santap NM1	Santap NM2
pH H_2O	8.54	8.32	6.35	5.50
Organic-C (%)	4.40	11.80	5.75	6.53
Total-N (%)	0.35	1.54	0.73	0.97
N-NH_4 (%)	0.04	0.37	1.03	1.34
N-NO_3 (%)	0.03	0.07	0.27	0.11
P_2O_5 HNO_3 + $HClO_4$ (%)	0.69	2.16	1.93	1.78
SO_4 HNO_3 + $HClO_4$ (%)	0.13	2.43	9.06	16.9
Total K HNO_3 + $HClO_4$ (%)	0.74	2.30	1.48	1.67
Total Ca HNO_3 + $HClO_4$ (%)	5.42	11.42	3.28	2.00
Total Mg HNO_3 + $HClO_4$ (%)	3.45	2.73	2.14	1.44
Total microbial population (cfu/g material)	28 x 10^3	19 x 10^2	23 x 10^2	36 x 10^1
Escherichia coli (cfu/g material)	0	0	0	0
Salmonella sp. (cfu/g material)	14 x 10^3	0	0	0

Results and Discussion

On lowland Vertisol of Ngawi, the initial growth of the Local Central Java/Sinabung-1036 soybean line was quite good. Drainage channels that were made between treatment plots could accelerate surface water flow so that the study area was protected from possible flooding due to high rainfall. During the flowering phase before destructive sampling for nutrient analysis, the soybean plants were also infected by a foliar disease, downy mildew (*Peronospora manshurica*) that changed the leaves colour into yellow in all treatment plots. Hot environmental conditions with high humidity due to continuous rain triggered an attack or the appearance of downy mildew on soybean plants. At the age of 45 days after planting (DAP), application of organic and inorganic fertilizers did not affect the chlorophyll index of soybean leaves, an average of 40.2 (Table 4). At the age of 60 DAP, the leaf chlorophyll index in the treatment without fertilizer was 36.8 which was lower than the age of 45 DAP of 40.5. Fertilization increased the leaf chlorophyll index from 36.8 to 41.7-46.6 (Table 4). Similar information was also reported by

Muzaiyanah et al. (2015) that application of 300 kg Phonska/ha, 5,000 kg cow manure/ha, 3,000 kg chicken manure/ha, 1,500-2,500 kg Santap NM1 and NM2 fertilizer/ha with or without 150 kg Phonska/ha increased soybean leaves chlorophyll index of 3.8-7.6 compared to that without fertilizers.

On the other hand, organic and inorganic fertilizers did not affect the height of soybean plants at 45 DAP, with an average of 43 cm, and at harvest time with an average of 45 cm. Soybean vegetative growth was quite good, so it supported the process of pod formation and filling. In Vertisol of Ngawi, the application of 1,500 kg Santap NM1/ha did not increase soybean yield. However, the application of 2,500 kg Santap NM1/ha or 1,500-2,500 kg Santap NM2/ha increased soybean yield from 0.61 t/ha (without fertilizer) to 1.72-1.84 t/ha. The application of 1,500 kg Santap NM1 or NM2 with 150 kg Phonska/ha increase soybean yield from 0.61 t/ha (without fertilizer) to 2.21-2.56 t/ha (Muzaiyanah et al., 2015). The fertility of Vertisol of Ngawi is sufficient for soybean plant for nutrients. On the treatment without addition of fertilizer, the nutrient levels of P, K, Ca, Mg, and S in Local Central Java/Sinabung-1036 soybean line at 45 DAP were included in the sufficient category, except for N element (Table 5).

Downy mildew (*Peronospora manshurica*) that attacked at flowering phase caused the low of N nutrient level in soybean. Application of 3,000 kg chicken manure/ha increased N level into a sufficient category of 4.27% N. Application of other organic and inorganic fertilizers did not affect the uptake of macronutrients. According to Solanki et al. (2018), the use of 43.4 kg N + 500 kg P + 33.3 kg K + 5,000 kg manure/ha increased chlorophyll content, nutrients uptake, and soybean yields. In this study, the optimal NPK uptake efficiency and reduction of N-fertilizer loss or washing were obtained. The application of organic and inorganic fertilizers affected the yield variable of Local Central Java/Sinabung-1036 soybean line that was harvested at 74 DAP. The average number of plant harvested was 247,000/ha, 74% of the full plant population. These conditions allowed soybean plants to form as many as 29 pods/plant with the weight of 100 seeds on average of 15.62 g (classified as large seed soybean strains). Even though soybean plants were affected by downy mildew, it turned out that the application of 1,500 kg Santap NM1/ha without Phonska, cow manure and chicken manure could increase soybean yield by 19% (0.35 t/ha) from 1.80 t/ha to 2.15 t/ha (Table 6). In the lowland Vertisol of Madiun, first growth of Local Central Java/Sinabung-1036 soybean line was relatively optimal, continuing until the soybean plants reached the generative phase Under these optimal growth conditions, the application of organic and inorganic fertilizers did not affect the leaves chlorophyll index at 45 and 60 DAP, nor the height plants at 45 DAP and at harvest (Table 4). The average of leaves chlorophyll indices at 45 and 60 DAP were 38.8 and 41.7. The average plant height was 56 cm at 45 DAP and 61 cm at harvest. Ragagnin and de Sena Junior (2013) delivered the opposite information that giving chicken manure to soybean plant increased leaves chlorophyll content, plant height, root dry weight, shoot dry weight, and nodulation. However, rhizobium bacteria inoculation on sandy textured soil with a pH of 7.5 reduced leaves chlorophyll content in the flowering and pod filling phases (Moghadam et al., 2014).

As with the lowland Vertisol of Ngawi, the levels of N and K elements in Local Central Java/Sinabung-1036 soybean line at 45 DAP (average 3.09% N and 1.43% K) did not meet enough criteria according to Jones et al. (1991). In contrast, the levels of P, Ca, Mg, and S elements were included in the sufficient criteria (Table 5). Application of 5,000 kg cow manure/ha increased the levels of element K from 1.34% to 1.82%, and that could be included in the sufficient category. Other fertilization treatments could not increase levels of N and K elements into sufficient categories. According to Hapsoh et al. (2019), application of compost could increase leaf N content, leaf K, and soybean production components such as number of filled pods, number of seeds/plants, weight of seeds/plants, and weight of 100 seeds. The combination of rice straw compost and 125 kg NPK fertilizer/ha could increase levels of N and P leaves, as well as filled pods/plants. In the lowland Vertisol of Madiun, there was an increase in total soil microbial population at 45 DAP, compared to that in the soil before planting. The application of 300 kg Phonska/ha reduced non-symbiotic N-fixing microbes (Table 7).

The application of cow manure and chicken manure increased the population of non-symbiotic N-fixing microbes and *Rhizobium* sp. in the soils compared to those without manures. Nutrient enrichment in Santap NM1 and Santap NM2 fertilizers could increase the population of non-symbiotic N-fixing microbes, P-solubilizing microbes, and *Rhizobium* sp. (Table 7). Cow manure containing 14 x 10^3 cfu/g of *Salmonella* sp. (Table 3) was brought to rice fields which initially did not contain *Salmonella* sp. At 45 DAP, *Salmonella* sp. population was still 5 x 10^2 cfu/g (Table 7).

Table 4. Leaves chlorophyll index and plant height of Local Central Java/Sinabung-1036 soybean line at 45 and 60 DAP (days after planting), and at harvest in lowland Vertisols of Ngawi and Madiun.

Fertilizer treatment	Vertisol of Ngawi				Vertisol of Madiun			
	Leaves chlorophyll index		Plant height (cm)		Leaves chlorophyll index		Plant height (cm)	
	45 DAP	60 DAP	45 DAP	Harvest	45 DAP	60 DAP	45 DAP	Harvest
Without fertilizer (control)	40.5	36.8 b	40.5	41.8	38.9	41.4	47.7	59.1
300 kg Phonska/ha	40.3	42.6 a	44.0	46.2	38.3	40.6	60.3	64.2
5,000 kg cow manure/ha	39.9	41.7 a	41.3	45.8	39.1	42.6	59.8	58.8
3,000 kg chicken manure/ha	39.3	42.7 a	43.7	42.3	38.1	41.2	55.7	56.9
1,500 kg Santap NM1/ha	40.7	44.3 a	46.3	47.2	39.4	42.2	54.5	58.7
1,500 kg Santap NM1/ha + 150 kg Phonska/ha	41.7	44.2 a	42.6	47.5	38.8	41.5	58.3	63.1
2,500 kg Santap NM1/ha	41.1	44.3 a	45.1	46.7	39.1	42.1	54.5	58.4
2,500 kg Santap NM1/ha +150 kg Phonska/ha	40.3	46.6 a	43.4	43.0	38.2	41.4	55.7	63.3
1,500 kg Santap NM2/ha	40.7	46.0 a	44.0	44.7	36.9	42.1	60.3	60.6
1,500 kg Santap NM2/ha + 150 kg Phonska/ha	38.7	46.0 a	42.7	44.2	39.1	42.4	57.3	65.1
2,500 kg Santap NM2/ha	39.8	41.7 a	43.0	45.0	38.8	41.9	57.0	62.0
2,500 kg Santap NM2/ha + 150 kg Phonska/ha	40.0	46.3 a	44.6	44.2	40.6	41.5	52.8	58.8
Average	40.2	43.6	43.4	44.9	38.8	41.7	56.2	60.8
CV (%)	3.80	6.02	6.28	9.35	4.52	2.57	12.26	6.77
DMRT 5%	ns	*	ns	ns	ns	ns	ns	Ns

Note: Numbers followed by different letters in a column were significantly different according to DMRT test (P<0.05); CV = coefficient of variation.

Table 5. Nutrient content in the youngest leaves of Local Central Java/Sinabung-1036 soybean line at 45 DAP (days after planting) grown on lowland Vertisols of Ngawi and Madiun.

Fertilizer treatment	**Vertisol of Ngawi**						**Vertisol of Madiun**					
	N (%)	**P (%)**	**K (%)**	**Ca (%)**	**Mg (%)**	**S (%)**	**N (%)**	**P (%)**	**K (%)**	**Ca (%)**	**Mg (%)**	**S (%)**
Without fertilizer (control)	3.43	0.49	2.77	3.30	0.40	0.47	3.11	0.34	1.34	1.52	0.38	0.26
300 kg Phonska/ha	3.57	0.34	2.57	2.05	0.36	0.32	3.04	0.33	1.35	1.43	0.36	0.25
5,000 kg cow manure/ha	3.71	0.34	2.80	1.80	0.35	0.33	3.32	0.35	1.82	1.33	0.35	0.29
3,000 kg chicken manure/ha	4.27	0.45	2.87	2.71	0.39	0.41	3.11	0.33	1.63	1.46	0.35	0.30
1,500 kg Santap NM1/ha	3.64	0.48	1.89	3.67	0.42	0.39	1.99	0.32	1.50	1.49	0.37	0.29
1,500 kg Santap NM1/ha + 150 kg Phonska/ha	3.08	0.38	2.06	2.28	0.37	0.31	3.39	0.36	1.43	1.43	0.37	0.31
2,500 kg Santap NM1/ha	3.08	0.39	2.43	2.38	0.39	0.37	3.25	0.35	1.59	1.45	0.36	0.31
2,500 kg Santap NM1/ha +150 kg Phonska/ha	3.08	0.40	2.30	2.22	0.37	0.36	3.11	0.33	1.56	1.56	0.37	0.28
1,500 kg Santap NM2/ha	3.29	0.44	2.57	2.41	0.38	0.37	3.53	0.35	1.62	1.68	0.38	0.31
1,500 kg Santap NM2/ha + 150 kg Phonska/ha	3.50	0.44	2.05	1.75	0.34	0.36	3.39	0.33	1.31	1.43	0.36	0.31
2,500 kg Santap NM2/ha	3.92	0.35	1.55	2.15	0.37	0.34	3.11	0.32	1.56	1.54	0.36	0.27
2,500 kg Santap NM2/ha + 150 Phonska/ha	3.57	0.40	1.99	2.01	0.36	0.34	2.69	0.31	1.43	1.49	0.36	0.30
Average	3.51	0.41	2.32	2.39	0.38	0.36	3.09	0.34	1.43	1.48	0.36	0.29
Nutrient levels are sufficient according to Jones et al. (1991)	4.01-5.50	0.26-0.50	1.71-2.50	0.36-2.00	0.26-1.00	0.21-0.40	4.01-5.50	0.26-0.50	1.71-2.50	0.36-2.00	0.26-1.00	0.21-0.40

Note: Numbers followed by different letters in a column were significantly different according to DMRT test ($P<0.05$); CV = coefficient of variation.

Table 6. Plant population, number of filled pods, weight of 100 seeds, and soybean yield with moisture content 12% of Local Central Java/Sinabung-1036 soybean line grown on lowland Vertisols of Ngawi and Madiun.

Fertilizer treatment	**Vertisol of Nawi**				**Vertisol of Madiun**			
	Plant population /ha	**Number of filled pods/plant**	**Weight of 100 seeds (g)**	**Yield with moisture content 12% (t/ha)**	**Plant Population /ha**	**Number of filled pods/plant**	**Weight of 100 seeds (g)**	**Yield with moisture content 12% (t/ha)**
Without fertilizer (control)	256559	26.6	15.82	1.80 b	225694	34.8	14.53	2.00 b
300 kg Phonska/ha	258102	28.1	15.65	2.02 ab	242669	33.8	14.90	2.37 ab
5,000 kg cow manure/ha	222608	31.0	15.23	1.85 ab	269675	32.9	15.07	2.48 a
3,000 kg chicken manure/ha	271991	24.2	15.60	1.93 ab	219521	32.0	14.13	2.17 ab
1,500 kg Santap NM1/ha	285108	29.7	15.17	2.15 a	218749	32.7	15.00	2.20 ab
1,500 kg Santap NM1/ha + 150 kg Phonska/ha	216435	31.5	15.20	1.86 ab	240740	34.3	14.93	2.26 ab
2,500 kg Santap NM1/ha	250772	28.3	16.05	1.95 ab	206018	29.4	15.17	2.17 ab
2,500 kg Santap NM1/ha +150 kg Phonska/ha	256142	29.2	15.57	1.94 ab	219135	30.2	14.67	2.25 ab
1,500 kg Santap NM2/ha	256944	28.9	15.72	2.07 ab	234182	31.7	14.90	2.55 a
1,500 kg Santap NM2/ha + 150 kg Phonska/ha	237654	32.3	15.34	1.86 ab	244598	35.1	14.93	2.42 a
2,500 kg Santap NM2/ha	233410	31.8	16.11	1.98 ab	245370	35.7	14.83	2.25 ab
2,500 kg Santap NM2/ha + 150 kg Phonska/ha	237269	28.5	16.05	1.98 ab	213348	33.2	15.47	2.43 a
Average	247749	29.2	15.62	1.95	231642	33.0	14.88	2.30
CV (%)	11.70	13.72	5.88	9.68	10.04	12.15	4.31	10.74
DMRT 5%	ns	ns	Ns	*	ns	ns	Ns	*

Note: Numbers followed by different letters in a column were significantly different according to DMRT test ($P<0.05$); CV = coefficient of variation.

Table 7. Effect of fertilizer on soil microbial populations on Local Central Java/Sinabung-1036 soybean line at 45 DAP (days after planting) in lowland Vertisol of Madiun.

Fertilizer treatment	Non-symbiotic N microbes	P solubilizing microbes	*Rhizobium sp.*	*Escherichia coli*	*Salmonella sp.*
Initial soil (before planting)	34 x 10^3	29 x 10^2	29 x 10^2	0	0
Soybean at 45 DAP					
Without fertilizer (control)	33 x 10^3	23 x 10^2	29 x 10^2	0	0
300 kg Phonska/ha	22 x 10^3	25 x 10^2	32 x 10^2	0	0
5,000 kg cow manure/ha	46 x 10^3	24 x 10^2	14 x10^3	0	5 x 10^2
3,000 kg chicken manure/ha	35 x 10^3	23 x 10^2	15 x 10^3	0	0
1,500 kg Santap NM1/ha	43 x 10^3	14 x 10^3	23 x 10^3	0	0
1,500 kg Santap NM1/ha + 150 kg Phonska/ha	22 x 10^3	11 x 10^3	25 x 10^3	0	0
2,500 kg Santap NM1/ha	17 x 10^4	23 x 10^3	23 x 10^3	0	0
2,500 kg Santap NM1/ha +150 kg Phonska/ha	23 x 10^3	22 x 10^3	26 x 10^3	0	0
1,500 kg Santap NM2/ha	35 x 10^3	24 x 10^3	31 x 10^3	0	0
1,500 kg Santap NM2/ha + 150 kg Phonska/ha	29 x 10^3	15 x 10^3	35 x 10^3	0	0
2,500 kg Santap NM2/ha	34 x 10^3	13 x 10^3	28 x 10^3	0	0
2,500 kg Santap NM2/ha + 150 kg Phonska/ha	38 x 10^3	22 x 10^3	31 x 10^3	0	0

From an environmental perspective, cow manure is not recommended for use as organic fertilizer. If it is to be used, it is necessary to minimize *Salmonella* sp. Abundant energy sources in the root region of organic compounds released by plant roots (root exudates) are good habitats for various types of microbes to develop and at the same time as a place of competition between microbes (Sorensen, 1997). Each plant emits root exudates with a different composition. Root exudates act as microbial selectors. The effect of exudates can increase or otherwise inhibit the development of specific microbes (Grayston et al., 1998); hence the use of suitable host plants is a determining factor for the success of organic farming. The density of indigenous microbial populations determines the biological process of providing plant nutrients.

On the lowland Vertisol of Madiun, Local Central Java/Sinabung-1036 soybean line was harvested at 76 DAP before soybean leaves fell. The number of plants harvested was about 69% (an average of 231,000) of the full plant population (Table 6). The application of organic and inorganic fertilizers did not affect the number of filled pods (an average of 33 pods) and the weight of 100 seeds (an average of 14.88 g). However, fertilizer treatment affected soybean yield. The highest yield of 2.55 t/ha with moisture content 12% was obtained by application of 1,500 kg Santap NM2 fertilizer/ha, an increase of 0.55 t/ha (27%) compared to without fertilizer. Application of 1,500-2,500 kg Santap NM2 fertilizer/ha + 150 kg Phonska/ha increased soybean yield by 0.42-0.48 t/ha compared to without fertilizer. On the lowland Vertisol of Ngawi which is rich in P element (48 ppm P_2O_5 Bray-1), application 1,500-2,000 kg Santap NM1 and Santap NM2 fertilizers/ha, with or without 300 kg Phonska/ha did not increase the yield of Local Central Java/Sinabung-1036 soybean line.In contrast, on the lowland Vertisol of Madiun which is poor in P (11 ppm P_2O_5), application of 5,000 kg cow manure/ha, 1,500-2.500 kg Santap NM2 fertilizer/ha + 150 kg Phonska/ha increased soybean yield by 21-27% (0.42-0.55 t/ha) compared to without fertilizer. On the lowland Vertisol of Ngawi with 82 ppm P_2O_5 Bray-1, application of 2,000 kg Santap NM2/ha increased soybean yield 0.25 t/ha (Kuntyastuti et al., 2013a). On an Alfisol of Probolinggo and an Alluvial of Banyuwangi, application of 2,500-5,000 kg organic fertilizer/ha or 2,000 kg Santap NM2 fertilizer/ha did not increase the yield of Local Central Java/Sinabung-1036 soybean line. Soybean yield reached 2.77 t/ha in an Alfisol of Probolinggo, and 2.54 t/ha in an Alluvial of Banyuwangi (Kuntyastuti et al., 2018). In Vertisols of Ngawi and Madiun, application of 300 kg Phonska/ha did not increase soybean yield. However, the application of cow manure or Santap NM1 and Santap NM2 fertilizers with or without Phonska increased soybean yield. Dozet et al. (2014) reported that soybean with the application of 15 kg organic fertilizer/ha produced 3.57 t/ha lower than conventional methods (fertilized with 100 kg N/ha) which was 4.44 t/ha. Although soybean cultivation is often reported to improve land quality, it turns out that continuous soybean cultivation is also less profitable. Olewe et al. (2014) reported that soybean cultivated in a rotational cropping system could produce 2.45-2.76 t/ha. If soybean is cultivated continuously or in a conventional planting system, it only produces 1.34-2.56 t/ha. Therefore rotation cropping patterns are highly recommended for sustainable organic crop production systems in the wet tropics. The use of cow or chicken manures combined with N, P, K, Ca inorganic fertilizers increased the yield and quality of soybean seeds while improving soil fertility status (Khaim et al., 2013). In soybean-corn intercropping, there is no difference in biomass production and protein content in plants that are fertilized with 100% NPK (conventional method) and those that are fertilized with 50% NPK + chicken manure (Baghdadi et al., 2018). Application of 7.5 t cow manure or goat manure/ha is more efficient in producing organic soybeans compared to the dose of 10 or 15 t/ha (Sudarsono et al., 2013). However, according to Zerihun and Haile (2017), the application of 3 t manure/ha can save 70-85% of input costs for the purchase of inorganic fertilizer. Mamia et al. (2018) recommend the use of 10 t chicken manure/ha + 75% recommendation of inorganic fertilizer or 2 t vermicompost/ha + 75% recommendation of inorganic fertilizer compared to 100% of inorganic fertilizer to obtain soybean yield of 2 t/ha because it is more environmentally friendly. The general recommendation that can be delivered is to maintain the quality and productivity of soil and plants that are cultivated in a sustainable way, and then the input of organic and inorganic fertilizers is a viable alternative.

Conclusion

On lowland Vertisol of Ngawi which is rich in P element (48 ppm P_2O_5 Bray-1), application of 5,000 kg cow manure/ha, 3000 kg chicken manure/ha, 1,500-2,500 kg Santap NM1 and NM2 fertilizer/ha, and 300 kg Phonska/ha is not needed. The yield of Local Central Java/Sinabung-1036 soybean line reached 1.95 t/ha. The Vertisol of Madiun which is poor in P element (11 ppm P_2O_5

Bray-1), requires the addition of 5,000 kg cow manure/ha, 1,500-2,500 kg Santap NM2 fertilizer/ha, plus 150 kg Phonska/ha to increase soybean yield by 21-27% (0.42-0.55 t/ha). The quality and productivity of soil and crop cultivation in sustainable agriculture can be maintained by alternative recommendations for the use of organic and inorganic fertilizer inputs.

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