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Effect of organic and chemical fertilizers on the growth and production of soybean (*Glycine max*) in dry land

Estudio de la aplicación de fertilizantes orgánicos y químicos en la producción de soya (*Glycine max*) en suelo seco

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Ratih Sandrakirana[1]* and Zainal Arifin[1]

ABSTRACT

Soybean is known for its high protein content, which is the reason why it is widely used as one of the main food sources for humans and animals. In order to optimize soybean growth, farmers tend to add excessive dosage of chemical fertilizer to this crop. Furthermore, a continuous chemical fertilizer application without organic fertilizer addition may cause a rapid depletion of nutrients in the soil. This study aimed to evaluate the effectiveness of organic fertilizer treatment to reduce the amount of urea as chemical fertilizer needed in soybean cultivation. A complete randomized design was conducted using 21 treatments of organic and chemical fertilizer in triplicate with a 4x3 m plot size. Analysis of variance was carried out to compare the means of measurement data and Duncan multiple range test (DMRT 5%) was applied. The treatment 2,000 kg ha^{-1} compost + 50 kg ha^{-1} urea ($O_2K_2A_1$) resulted the highest dry yield in soybean and had significant differences with urea-only treatment. A mixture of chemical and organic fertilizers had no significant result over the yield compared to the use of chemical fertilizer only. Compost application of 1,000-2,000 kg ha^{-1} with urea 50-100 kg ha^{-1} ($O_2K_2A_1$ and $O_2K_1A_2$) showed an increase in seed yield of 35-38 % with a profit reaching 333-340 USD ha^{-1} compared to standard treatment using urea 50 kg ha^{-1} + SP-36 50 kg ha^{-1} + 50 KCl kg ha^{-1} ($O_0K_0A_1$).

Keywords:
Compost
Depletion
Manure
Nutrients
Yield

RESUMEN

La soya es conocida por su alto contenido en proteínas, por lo que es ampliamente usada como una de las principales fuentes de alimento para los seres humanos y animales. Para optimizar el crecimiento de la soja, los agricultores tienden a agregar una dosis excesiva de fertilizante químico a este cultivo. Además, una aplicación continua de fertilizantes químicos sin la adición de fertilizantes orgánicos puede causar un rápido agotamiento de los nutrientes en el suelo. Este estudio tuvo como objetivo evaluar la efectividad del tratamiento con fertilizantes orgánicos para reducir la cantidad de urea como fertilizante químico necesario en dicho cultivo. Se realizó una combinación de 21 tratamientos de fertilizante orgánico y químico, con diseño completamente aleatorio. Se llevó a cabo un análisis de varianza para comparar las medias de los datos de medición y se aplicó con la prueba de rango múltiple de Duncan (DMRT 5%). Los resultados mostraron que el tratamiento con 2.000 kg ha^{-1} de compost + 50 kg ha^{-1} urea ($O_2K_2A_1$) obtuvo el mayor rendimiento (en peso seco) de soya y mostró diferencias significativas con la aplicación de urea a dosis similares que fueron suministradas sin compost. Una mezcla de fertilizantes químicos y orgánicos no tuvo un resultado significativo sobre el rendimiento en comparación con el uso de fertilizantes químicos solamente. La aplicación de 1.000-2.000 kg ha^{-1} compost + 50-100 kg ha^{-1} urea ($O_2K_2A_1$) y ($O_2K_1A_2$) obtuvo un aumento en el rendimiento de semillas de 35-38% con una ganancia de USD 333-340 ha^{-1} en comparación con la fertilización estándar de 50 kg ha^{-1} urea + 50 SP-36 kg ha^{-1} + 50 KCl kg ha^{-1} ($O_0K_0A_1$).

Palabras clave:
Compost
Agotamiento
Estiércol
Nutrientes
Rendimiento

[1] BPTP Balitbangtan Jawa Timur (East Java Assesment Institute for Agriculture Technology), Indonesia. ratih_sandrakirana@yahoo.co.id, arifin_bptpjatim@yahoo.co.id
* Corresponding author

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Soybean (*Glycine max* (L.)) is one of the agricultural commodities with important value to humans. Soybean is known for its high protein content, making this commodity widely utilized as a main food source for humans and husbandry as well as oil producer (Capriotti *et al*., 2014; Pagano and Miransari, 2016). In order to optimize its growth, fertilization plays an important role to improve soybean productivity, especially in marginal soils. Chemical fertilizers can affect the microflora of the soil by modifying the chemical composition and physical character of the soil (Cwalina-Ambroziak and Bowszys, 2009; Klein *et al*., 2011; Wei *et al*., 2014; Wei *et al*., 2012). Naturally, the need of nitrogen (N)for legumes such as soybean has been partially met through the symbiosis of *Rhizobium* bacteria and root nodule, which absorbs nitrogen from the air. However, farmers tend to add chemical fertilizer excessively during soybean cultivation based on assumption that it may increase the yield (Abbasi *et al*., 2010). On the other hand, soybean can only absorb 35 to 70% of the entire nitrogen fertilizer applied. It means that chemical fertilizer would leave residues and contaminate the soil, deteriorating the soil quality. Therefore, organic fertilizer should be used to improve land productivity (Masaka *et al*., 2014), since this kind of fertilizer could be a better choice to mitigate the negative effects of chemical fertilizers by slowing soil degradation. According to some studies, organic fertilizers have a significant impact on soil nutrient availability, aggregate formation, and soil bacterial communities (Chai *et al*., 2019; Qaswar *et al*., 2020; Ye *et al*., 2019). Several researchers found that a high amount of chemical fertilizer would decrease root nodule formation and N-fixation from the air (Hinson, 1975; Saito *et al*., 2014; Dong *et al*., 2016). Furthermore, an overuse application of chemical fertilizers leads to a loss of soil fertility, bacterial diversity (Dinesh *et al*., 2010) and soil structure (Melero *et al*., 2011).

Several papers showed that treatments using organic fertilizer could solve this problem. Organic fertilizers play significant roles by fulfilling plants nutritional needs as well as improve the physical, chemical and biological properties in the soil. Organic fertilizers have a variety of beneficial effects on crop management, as they can be used as a source of various macro- and micro-nutrients for plants (Ahmad *et al*., 2019, Khan *et al*., 2020, Wajid *et al*., 2020). Organic substances might undergo decomposition by itself, it was considered to be a relatively slow process; therefore, human intervention was needed by adding compost decomposer. After such intervention, decomposition process would run faster and producing a better compost quality. In this context, this study aimed to evaluate the effectiveness of organic fertilizer treatment to reduce the amount of urea as chemical fertilizer needed in soybean cultivation.

MATERIALS AND METHODS

The research was conducted in wet season of 2018 in Bunbarat Village, Rubaru District, Sumenep Regency of Indonesia. Soil condition was relatively infertile; it was sandy in texture and contain C-organic matters. Content of P_2O_5 and K in the soil was very low (Table 1).

Table 1. Soil analysis before organic fertilization experiments were performed.

Analysis	Result	Interpretation
Soil Textures		
Sand (%)	82	-
Dust (%)	6	-
Clay (%)	12	-
Class	-	Sandy loam
pH: H_2O	5.9	A bit sour
C-organic (%)	0.7	Very low
N-Total (%)	0.06	Very low
Ratio C/N	11.67	-

Continuation Table 1

Analysis	Result	Interpretation
P-Olsen (ppm)	39	Very low
K (cmol(+) kg^{-1})	0.14	Low
Na (cmol(+) kg^{-1})	0.02	Very low
Ca (cmol(+) kg^{-1})	3.78	Low
Mg (cmol(+) kg^{-1})	0.66	Low
KTK (cmol(+) kg^{-1})	6.68	Low

Organic fertilizer was made from cow manure with liquid decomposer, urea, SP-36, and KCl. Using a complete randomized design, combination of 21 treatments were repeated 3 times with 4x3 m plot size. Analysis of variance was carried out to compare the means of measurement data and then a Duncan Real Difference Test (DMRT 5%) was performed (Gomez and Gomez, 1984). Organic and chemical fertilizer combination of the 21 treatments is described in Table 2.

Table 2. Combination of Organic and Chemical Fertilizer treatments.

Number	Code	Organic fertilizer	Organic fertilizer dosage (kg ha^{-1})	Urea fertilizer dosage (kg ha^{-1})
1	$O_0K_0A_0$	Without	0	0
2	$O_0K_0A_1$	Without	0	50
3	$O_0K_0A_2$	Without	0	100
4	$O_1K_1A_0$	Cow manure	1,000	0
5	$O_1K_1A_1$	Cow manure	1,000	50
6	$O_1K_1A_2$	Cow manure	1,000	100
7	$O_1K_2A_0$	Cow manure	2,000	0
8	$O_1K_2A_1$	Cow manure	2,000	50
9	$O_1K_2A_2$	Cow manure	2,000	100
10	$O_1K_3A_0$	Cow manure	3,000	0
11	$O_1K_3A_1$	Cow manure	3,000	50
12	$O_1K_3A_2$	Cow manure	3,000	100
13	$O_2K_1A_0$	Compost decomposer	1,000	0
14	$O_2K_1A_1$	Compost decomposer	1,000	50
15	$O_2K_1A_2$	Compost decomposer	1,000	100
16	$O_2K_2A_0$	Compost decomposer	2,000	0
17	$O_2K_2A_1$	Compost decomposer	2,000	50
18	$O_2K_2A_2$	Compost decomposer	2,000	100
19	$O_2K_3A_0$	Compost decomposer	3,000	0
20	$O_2K_3A_1$	Compost decomposer	3,000	50
21	$O_2K_3A_2$	Compost decomposer	3,000	100

O: kind of organic fertilizer (cow manure=1; compost decomposer=2); K: dose of organic fertilizer; A: urea fertilizer treatment.

Cow manure and compost decomposer used in this research were made from cow dung. An application of additional decomposer was done to produce the compost decomposer which is not applied on cow manure fertilizer. This decomposer contains many kinds of fungi and bacteria which are important to accelerate the decomposition process (Table 3).

Argomulyo soybean [(*Glycine max* (L) Merr var. Argomulyo] was cultivated with a distance of 40x15 cm, 2 grains per hole. Organic fertilizer was added during tillage while urea (according to treatment), SP-36 and KCl were provided after 7-10 dap (days after planting). Soil nutrients, plant height, number of branches, number of nodes, number of pods and seeds per plant, number of active root nodules, number of inactive root nodules, dry weight of roots (oven), weight of 100 grains and yield (kg ha^{-1}), also, financial analysis of soybean were quantitative parameters analyzed in a pre-experimental phase. Observations on these parameters and weight of dry roots were carried out using destructive method for plants at 60 dap. Active root nodule observations were recorded if the inner slice of the root nodule was dark red, while inactive root nodule was white to reddish white in color, which means that the soybeans have generated a symbiosis with *Rhizobium* by forming the root nodules.

Table 3. Analysis of the decomposer composition.

Parameter	Result	Agriculture Ministry of Indonesia Standard
Bacteria		
Bacillus sp	2.4×10^{12}	> 10^7 CFU mL^{-1}
Pseudomonas sp.	2.9×10^{11}	> 10^7 CFU mL^{-1}
Fungi		
Trichoderma sp.	4.1×10^7	> 10^7 CFU g^{-1} sample dry weight
Aspergillus sp.	2.7×10^7	> 10^7 CFU g^{-1} sample dry weight
Pathogenicity	Negative	Negative
Functional:		
Bacteria		
a. N-fixate	2.4×10^{12}	Positive
b. P- Solvent	2.9×10^{11}	Positive
Fungi		
a. N-fixate	-	10^3 CFU g^{-1}
b. P- Solvent	2.7×10^7	10^3 CFU g^{-1}
Contaminant:		
E. coli	3.0×10^7	Max 10^3 MPN g^{-1} or MPN mL^{-1}
Salmonella sp.	0	Max 10^3 MPN g^{-1} or MPN mL^{-1}
pH	5.5 – 7.41	5.0-8.0

CFU: colony forming unit; MPN: most probable number

RESULTS AND DISCUSSION

Soybean growth and yield

The growth of soybean was influenced by its genetic factors and environment. A mixture of chemical and organic fertilizer has a significant result on the plant height, number of branches, number of nodes, number of active and inactive root nodules and dry weight of roots and root nodules. Plant height and number of branches between 30 and 60 dap showed a noticeable difference according to the fertilization treatment, while differences in the number of plant nodes only was noticeable at 30 dap (Table 4).

Table 4. Effect of organic fertilizer on plant height, number of branches and soybean nodes in Rubaru District, Sumenep Regency, wet season 2018.

No	Treatment	Plant height (cm)*		Number of branches per plant*		Number of nodes per plant*	
		30 dap	60 dap	30 dap	60 dap	30 dap	60 dap**
1	$O_0K_0A_0$	30.00 a	58.47 a	0.13 a	1.00 cdef	7.60 a	12.67
2	$O_0K_0A_1$	39.87 defg	72.47 def	0.47 bcd	0.93 cde	8.53 ab	12.8
3	$O_0K_0A_2$	41.87 fg	73.40 def	1.07 hij	1.27 fghi	8.47 ab	13.47
4	$O_1K_1A_0$	40.67 defg	69.80 cde	0.73 defg	1.13 cdefg	8.47 ab	13.27
5	$O_1K_1A_1$	36.87 bcdefg	68.07 bcd	1.20 ij	1.40 ghij	8.00 ab	12.87
6	$O_1K_1A_2$	37.67 bcdefg	71.13 cdef	0.47 bcd	1.53 hij	8.20 ab	13.6
7	$O_1K_2A_0$	32.67 ab	65.13 bc	0.87 fgh	0.93 cde	8.27 ab	13.07
8	$O_1K_2A_1$	38.47 cdefg	68.13 bcde	0.40 bc	0.80 c	8.40 ab	12.6
9	$O_1K_2A_2$	35.33 abcd	76.80 f	0.33 ab	1.60 ij	8.40 ab	13.73
10	$O_1K_3A_0$	33.53 abc	64.87 bc	1.00 ghi	1.13 cdefg	7.87 ab	13.13
11	$O_1K_3A_1$	34.93 abcd	70.93 cdef	0.80 efgh	0.93 cde	8.47 ab	13.67
12	$O_1K_3A_2$	41.13 efg	72.60 def	1.33 j	1.33 fghi	8.87 ab	12.8
13	$O_2K_1A_0$	39.27 cdefg	69.40 cde	0.53 bcd	0.87 cd	8.20 ab	12.73
14	$O_2K_1A_1$	40.67 efg	67.80 bcd	0.80 efgh	1.00 cdef	8.60 ab	13
15	$O_2K_1A_2$	38.67 cdefg	72.07 def	0.53	1.40 ghij	8.47 ab	13.33
16	$O_2K_2A_0$	38.53 cdefg	62.00 ab	0.67 efgh	1.33 fghi	7.80 a	13.47
17	$O_2K_2A_1$	38.73 cdefg	68.80 cde	0.93 bcde	1.07 cdefg	7.93 ab	12.93
18	$O_2K_2A_2$	42.60 g	75.00 ef	1.20 ab	1.20 defg	9.13 b	13.07
19	$O_2K_3A_0$	35.73 bcde	71.13 cdef	0.47 ghi	1.67 j	8.53 ab	13.67
20	$O_2K_3A_1$	36.67 bcdef	67.67 bcd	0.73 efgh	1.07 cdefg	7.73 a	13.33
21	$O_2K_3A_2$	37.33 bcdefg	67.80 cde	0.67 efgh	1.47 fghi	8.13 ab	13.4
CV (%)		7.69	5	20.16	14.61	7.88	5.03
DMRT value		5.72	5.7	0.26	0.33	1.52	1.08

* Different letters in the same column represent results with statistical difference, according to the DMRT test at *P*<0.05.
** No significant statistical differences

Treatment ($O_2K_2A_2$) using 2,000 kg ha^{-1} compost with urea 100 kg ha^{-1} and treatment ($O_1K_2A_2$) using 2,000 kg ha^{-1} cow manure with 100 kg ha^{-1} urea at 30 and 60 dap showed the highest plant height for each period, respectively. Meanwhile, the largest number of branches was found in treatment ($O_1K_3A_2$) using 3,000 kg ha^{-1} cow manure with 100 kg urea ha^{-1}. At the age of 60 dap, the largest number of branches was obtained using 3,000 kg ha^{-1} compost without urea ($O_2K_3A_0$) treatment, but it did not show real difference with treatment of 1,000-2,000 kg ha^{-1} ($O_1K_1A_1$ and $O_1K_1A_2$) manure or compost 1,000 kg ha^{-1} with 100 kg of urea ha^{-1} ($O_2K_1A_2$). The differences in number of nodules were noticed significantly at 30 dap and treatment using 2,000 kg ha^{-1} compost + 100 kg of urea ha^{-1} showed the highest number of nodules ($O_2K_2A_2$). Results of this study demonstrated that the addition of organic and chemical fertilizer showed higher yield in soybean compared to treatment using only chemical fertilizer (Qaswar, 2020). Some research studies showed that the application of cow manure compost would increase both soil fertility and crop yield (Hernandez, 2014; Liu *et al*., 2018). Application of organic and inorganic fertilizer has showed effect for sustainability in soil and may positively affect soybean production (Choudhary *et al*., 2021).

The highest number of active root nodules (8.50 nodule) was found in treatment ($O_2K_3A_1$) 3,000 kg ha^{-1} compost with 50 kg of urea ha^{-1} (Table 5). On the other hand, the most inactive root nodule (15 nodules) was found in treatment ($O_1K_2A_1$) 2,000 kg ha^{-1} manure + 50 kg of urea ha^{-1}.

Table 5. Effect of organic fertilizer on the number of active and inactive root nodule per plant and dry weight of roots per soybean plant in Rubaru District, Sumenep Regency, wet Season 2018.

No	Treatment	Number of active nodules per plant*	Number of inactive nodules per plant*	Root dry weight per plant (g)*
1	$O_0K_0A_0$	5.17 f	-	6.97 fghi
2	$O_0K_0A_1$	2.50 c	3.33 def	6.57 efgh
3	$O_0K_0A_2$	2.33 c	5.00 gh	7.63 hij
4	$O_1K_1A_0$	8.17 f	4.33 fg	7.23 ghi
5	$O_1K_1A_1$	7.67 gh	3.83 ef	7.35 ghij
6	$O_1K_1A_2$	6.83 g	1.83 bc	7.20 ghi
7	$O_1K_2A_0$	3.67 d	5.50 h	5.90 ef
8	$O_1K_2A_1$	0.83 a	15.00 k	8.33 a
9	$O_1K_2A_2$	3.50 d	5.17 gh	7.26 ghij
10	$O_1K_3A_0$	8.17 h	0.20 a	6.70 fghi
11	$O_1K_3A_1$	2.17 bc	1.50 bc	6.31 efg
12	$O_1K_3A_2$	4.83 ef	4.33 fg	6.81 fghi
13	$O_2K_1A_0$	5.17 f	10.67 j	10.21 k
14	$O_2K_1A_1$	1.33 gh	3.00 de	5.55 e
15	$O_2K_1A_2$	5.33 f	0.30 a	7.32 ghij
16	$O_2K_2A_0$	5.00 f	3.17 de	6.96 fghi
17	$O_2K_2A_1$	5.17 f	2.33 cd	6.77 fghi
18	$O_2K_2A_2$	2.50 c	3.00 de	6.49 fghi
19	$O_2K_3A_0$	3.67 d	1.00 ab	7.84 ij
20	$O_2K_3A_1$	8.50 h	3.67 ef	6.62 efgh
21	$O_2K_3A_2$	4.00 cd	1.00 ab	6.01 ef
CV (%)		11.75	14.54	8.14
DMRT value		0.98	1.25	0.93

* Different letters in the same column represent results with statistical difference, according to the DMRT test at P<0.05.

The highest dry weight of roots per plant (10.21 g) was found in treatment ($O_2K_1A_0$), which used 1,000 kg ha^{-1} compost without urea fertilizer. In accordance with this result, it was confirmed that organic management has a significant impact in rhizobia genotype presentation in that area. Rhizobia numbers was increased in term of diversity in this kind of field, since organic fertilizer is a good medium for the development of the rhizobia genotype so that it has an effect on N-fixation from air (Grossman *et al*., 2011).

Soybean yield was determined by the development of the plant from the beginning of sowing to the harvest period, where the role of fertilization was of great importance. Application of different organic and chemical fertilizers would affect one or all of its yield components, namely: number of pods per plant, number of seeds per plant, weight of 100 dried seeds and yield of dried seeds. Number of pods per plant, number of seeds per plant, weight of 100 seeds and yield of dried seeds showed a significant difference during treatment using organic fertilizers and chemical fertilizers (Table 6).

Table 6. Effect of organic fertilizer on the number of pods, number of grains per plant, weight of 100 seeds and yield of soybean dried seeds in Rubaru District, Sumenep Regency, wet season 2018.

No	Treatment	Number of pods per plant*	Number of grains per plant*	Dry weight of 100 grains of soybean seeds* (g)	Dry yield* (t ha^{-1})
1	$O_0K_0A_0$	15.60 a	46.80 a	14.76 abcd	1.52 a
2	$O_0K_0A_1$	17.20 ab	51.60 ab	14.69 abcd	2.05 cde
3	$O_0K_0A_2$	20.40 cd	61.20 de	14.79 abcd	2.29 cdefg
4	$O_1K_1A_0$	16.60 ab	49.80 ab	15.07 bcdef	1.91 bcd
5	$O_1K_1A_1$	19.67 cd	59.00 de	15.51 cdefg	2.44 fghij
6	$O_1K_1A_2$	20.07 cd	60.20 de	15.10 cdefg	2.48 ghijk
7	$O_1K_2A_0$	16.47 a	49.40 a	14.91 abcde	2.08 cdef
8	$O_1K_2A_1$	16.60 a	49.80 a	13.92 ab	1.83 n abcd
9	$O_1K_2A_2$	24.47 e	73.40 e	13.85 a	2.28 efghi
10	$O_1K_3A_0$	21.07 d	63.20 d	16.11 fg	2.14 cdefg
11	$O_1K_3A_1$	24.73 e	74.20 e	15.71 defg	1.79 abc
12	$O_1K_3A_2$	24.27 e	72.80 e	15.12 bcdef	2.55 hijk
13	$O_2K_1A_0$	18.60 bc	55.80 bc	15.05 bcdef	1.62 ab
14	$O_2K_1A_1$	20.60 d	61.80 e	14.57 abcd	2.09 cdef
15	$O_2K_1A_2$	26.93 f	80.80 f	14.59 abcd	2.77 jk
16	$O_2K_2A_0$	20.87 d	62.60 e	16.05 efg	2.60 ijk
17	$O_2K_2A_1$	20.27 cd	60.80 de	16.37 g	2.82 k
18	$O_2K_2A_2$	20.93 d	62.80 e	14.45 abc	2.38 efghi
19	$O_2K_3A_0$	20.33 cd	61.00 de	14.70 abcd	2.20 defgh
20	$O_2K_3A_1$	19.80 cd	59.40 de	16.10 efg	1.84 abcd
21	$O_2K_3A_2$	27.00 f	81.00 f	15.15 cdef	2.62 ghijk
	CV (%)	4.98	4.98	3.96	8.87
	DMRT value	1.99	6.3	1.19	0.38

*Different letters in the same column represent results with statistical difference, according to the DMRT test at P<0.05.

The highest number of pods per plant (26.93-27.00 pods) was found in treatments ($O_2K_1A_2$ and $O_2K_3A_2$) 1,000 kg ha^{-1} and 3,000 kg ha^{-1} compost + 100 kg of urea ha^{-1}. Similarly, the largest number of seeds per plant was found in treatments 1,000kg ha^{-1} and treatment 3,000 kg ha^{-1} compost plus 100 kg of urea ha^{-1} ($O_2K_1A_2$ and $O_2K_3A_2$) with 80.80 seeds and 81.00 seeds, respectively.

The highest score in weight of 100 dried seeds was found in treatment 2,000 kg ha^{-1} compost + 50 kg of urea ha^{-1} ($O_2K_2A_1$), but it did not differ significantly with treatment 2,000 kg ha^{-1} compost without urea ($O_2K_2A_0$), or with in treatment 1,000 kg ha^{-1} compost and 3,000 kg ha^{-1} manure + urea 0-50 kg ha^{-1} ($O_1K_1A_1$, $O_1K_3A_0$, and $O_1K_3A_1$) and in treatment 3,000 kg ha^{-1} compost decomposer with 50 kg urea ha^{-1} ($O_2K_3A_1$).

Dry seed (water content 11%) yield found in treatment 2,000 kg ha^{-1} compost plus 50 kg of urea ha^{-1} ($O_2K_2A_1$) was 2,820 kg ha^{-1}, but it did not change manifestly from treatment 1,000 kg ha^{-1} compost + 100 kg of urea ha^{-1} ($O_2K_1A_2$) and treatment 2,000 kg ha^{-1} compost without urea ($O_2K_2A_0$) as well as treatment using 1,000 ha^{-1} compost and 3,000 kg ha^{-1} manure + 100 kg of urea ha^{-1} ($O_1K_1A_2$ and $O_1K_3A_2$).

Compost decomposer has been shown to be able to increase soybean crop. And interestingly, in this study, crop yield using treatment 2000 kg ha^{-1} organic fertilizer and 50 kg ha^{-1} chemical fertilizer combined with compost decomposer showed the highest results of all treatments considering the dry yield. As shown in laboratory analysis results, compost decomposer contained beneficial fungi and bacteria for plants (Table 3). Thus, microorganisms within the compost decomposer would be able to increase the positive effect of fertilizers. Inoculation of *Bacillus sp* and *Trichoderma asperellum* plays important role in supporting plant growth through phosphate solubilization process and auxin and hydrolytic enzymes synthesis (Moreira *et al.*, 2021).

Other parameters observed in this study, such as number of pods and number of seeds per plant also correlated with production yield. In line with prior study, higher results in dry weight of 100 grain soybeans indicate larger grain size which would contribute to higher production yield (Soverda, 2009). This study also showed that the number of active nodules did not significantly affect the production yield and this was contrary to a previous study suggesting that total active nodules in soybean was closely related to the *Rhizobium* activities in the root to bind N and increase soybean growth and production yield (Birnadi, 2014). The root nodule was a very complex organ from the nodule formation itself and in the transport between membranes that occurs in it (Oldroyd and Downie, 2008; van Hameren *et al.*, 2013). Although studies regarding root nodules have shown some progress, more studies were necessary to comprehend processes that occurred within this organ (Oldroyd and Dixon, 2014; Sulieman *et al.*, 2014).

The highest productivity value (per hectare) was obtained using 1,000 kg ha^{-1} compost decomposer and 50 kg ha^{-1} chemical fertilizer followed by the treatment of 2,000 kg ha^{-1} combination of compost decomposer and organic fertilizers along with 50 kg ha^{-1} chemical fertilizer (Table 7). The relationship between productivity and cost (fertilizer) showed the highest results using 2,000 kg ha^{-1} combination of compost decomposer and organic fertilizers along with 50 kg ha^{-1} chemical fertilizer followed by 1,000 kg ha^{-1} compost decomposer and 50 kg ha^{-1} chemical fertilizer. Moreover, comparison concerning the amount of energy consumed between each system should be considered. A study conducted in the province of Jilin, China showed that production cost in conventional systems was 33% lower and its net income was 25% higher compared to organic systems (Zhang *et al.*, 2015). Deficient energy use in organic farming is due to the use of fuel and plastic mulch, which result in a lower production yield (Lee and Choe, 2019).

Agricultural Analysis

Result of soybean analysis of this study was based on the increase of production cost after applying urea fertilization and organic fertilizer and also based on the seed yield as a result of fertilization treatment at the study site in Rubaru-Sumenep. Table 7 showed financial analysis of soybean at the study site.

Table 7. Financial analysis of organic fertilizer delivery of soybeans, Rubaru District, Sumenep Regency, Rainy season 2018.

Treatment	Fertilizer cost N+organic (USD ha^{-1})	Δ Fertilizer cost compared with standard N fertilizer (USD ha^{-1})	Grain Productivity (t ha^{-1})	Production value (USD ha^{-1})	Δ Productivity compared with fertilizer cost (USD ha^{-1})	Δ Productivity value (USD ha^{-1})
$O_0K_0A_0$	-	-6.42	1.52	813.06	-283.5	-277.08
$O_0K_0A_1$	6.42	-	2.05	1,096.56	-	-
$O_0K_0A_2$	12.48	6.42	2.29	1,224.94	128.38	121.96
$O_1K_1A_0$	35.66	29.24	1.91	1,021.67	74.89	-104.13
$O_1K_1A_1$	42.08	35.66	2.44	1,305.17	208.61	172.95
$O_1K_1A_2$	48.50	42.08	2.48	1,326.57	230.01	187.93

Continuation Table 7

Treatment	Fertilizer cost N+organic (USD ha^{-1})	∆ Fertilizer cost compared with standard N fertilizer (USD ha^{-1})	Grain Productivity (t ha^{-1})	Production value (USD ha^{-1})	∆ Productivity compared with fertilizer cost (USD ha^{-1})	∆ Productivity value (USD ha^{-1})
$O_1K_2A_0$	71.32	64.90	2.08	1,112.61	16.05	-48.85
$O_1K_2A_1$	77.74	71.32	1.83	978.88	-117.68	-189
$O_1K_2A_2$	84.16	77.74	2.28	1,219.59	123.03	45.29
$O_1K_3A_0$	106.98	100.56	2.14	1,144.70	48.14	-52.42
$O_1K_3A_1$	113.4	106.98	1.79	957.48	-139.08	-246.06
$O_1K_3A_2$	119.82	113.40	2.55	1,364.01	267.45	154.05
$O_2K_1A_0$	39.23	32.81	1.62	866.55	-230.01	-262.82
$O_2K_1A_1$	45.65	39.23	2.09	1,117.96	21.40	-17.83
$O_2K_1A_2$	52.06	45.65	2.77	1,481.69	385.13	339.49
$O_2K_2A_0$	78.45	72.03	2.60	1,390.76	294.20	222.16
$O_2K_2A_1$	84.87	78.45	2.82	1,508.44	411.88	333.43
$O_2K_2A_2$	91.29	84.87	2.38	1,273.08	176.52	91.65
$O_2K_3A_0$	117.68	111.26	2.20	1,176.80	80.24	-31.02
$O_2K_3A_1$	124.10	117.68	1.84	962.83	-112.33	-230.01
$O_2K_3A_2$	130.52	124.10	2.62	1,401.46	304.90	180.8

Description: Urea Price: USD. 0.13 kg^{-1}; manure=0.036 USD kg^{-1}; compost: 0.039 USD kg^{-1}; Consumption seed yield: USD. 0.53 kg^{-1}

A combination of 2,000 kg ha^{-1} compost and urea 50 kg ha^{-1} ($O_2K_2A_1$) resulted an additional yield about 770 kg ha^{-1} compared to application of 50 kg urea only. Thus, farmers could obtain additional gross profit up to 411.88- or 333.43 USD ha^{-1} for net profit. This profit number could be obtained by $O_2K_1A_2$ treatment.

CONCLUSIONS

Fertilization significantly increases the dry yield in comparison to the control treatment. This current study demonstrated the beneficial impact of chemical and organic fertilizer on promoting soybean yield. A mixture of chemical and organic fertilizers has higher result over the yield compared to the use of chemical fertilizer only. The application of 1,000-2,000 kg ha^{-1} compost with urea 50-100 kg ha^{-1} ($O_2K_2A_1$ and $O_2K_1A_2$) showed an increase in 35.12-37.56% seed yield with profit reaching USD 333-340 per hectare compared to standard treatment. These results suggest that combining chemical and organic fertilizers has the potential to sustain high grain yield mitigating the environmental impact caused by the overuse of chemical fertilizers. Furthermore, 1-2 t of compost treatment is recommended particularly for soil with low organic content or soil that has never been planted with soybean. In the future, studies regarding the effect of organic fertilizers in soybean cultivation might be done using rice fields or inundated soils and also using soil with medium to high organic content. Besides, comprehensive farming analysis for production cost components including price of labor and pesticides should be done to obtain more accurate economic estimation.

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