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Agriculture and Agricultural Science Procedia 9 (2016) 525 – 531
Agriculture and Agricultural Science Procedia

International Conference on Food, Agriculture and Natural Resources, IC-FANRes 2015

Improving Physical and Chemical Soil Characteristic on Potatoes (*Solanum tuberosum* L.) Cultivation by Implementation of Leisa System

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Abstract

The use of compost and N, P, K as fertilizer in LEISA system as an effort to increase the productivity of potato in Bali so that up to 30 tones / ha performed in this study. Compost from chicken and cow dung is used at a dose of 10 to 25 tones / ha. Application of LEISA systems can improve the physical and chemical characteristics of the soil so as to achieve ideal conditions for the cultivation of potatoes. By 2015, the land has the characteristics: porosity of 47 ± 5.1%, the water holding capacity of 40.9 ± 4% w.b, organic matter content of 6.2 ± 1.2%, the cation exchange capacity 25-29 me / 100 g and pH 6.7 to 6.9. Productivity potatoes applied for land LEISA systems over 3 years is 28-34 tones / ha with tuber super quality as much as 11 to 22.2 tones / ha.

Peer-review under responsibility of the organizing committee of IC-FANRes 2015

Keywords: LEISA systems, compost, soil physical and chemical properties, the cultivation of potatoes, productivity

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Peer-review under responsibility of the organizing committee of IC-FANRes 2015
doi:10.1016/j.aaspro.2016.02.172

1. Introduction

The productivity of potato in Bali is 17 tones / ha in 2009, this productivity is less than the target BAPENAS as much as 30 tones / ha (Setiyo et al., 2012). Characteristic of soil in the root zone for cultivation potatoes in District Baturiti are the organic matter content of 3.32%, pH 6.5 to 6.7, 32% porosity and water-holding capacity of 28.7% wet basis (w.b). Farmers use compost and N, P, K as fertilizer to improve the productivity of potatoes. Compost from chicken manure or cow are used more than three years with an average dose 20 tones / ha, so that potato production in 2012 reached 22.5 tones / ha with chemical and biological characteristics of the soil as follows : N-organic = 1.38% ; C-organic = 4.9%; P2O5 = 649 ppm; K2O = 3.43 me / 100 g; Mg = 1.13 me / 100 g; Na = 0.62 me / 100 g; cation exchange capasity = 25.8 me / 100g; C / N = 16.6; pH = 6.8; and microbial populations 10 5.14 cfu (Setiyo et al., 2013).

LEISA system implementation in potato cultivation has been able to alert the process of in-situ bioremediation of pesticide residues. Pseudomonas Luella microbes in the compost decompose organophosphate pesticides with 84% effectiveness (Setiyo et al., 2013; Setiyo et al., 2014).

2. Soil physic characteristic

2.1. Soil texture and structure

The type of soil at potato cultivation in Baturiti is andosol soil, the composition of andosol soil is 55 % sand fraction, 35 % dust fraction and 10 % clay fraction (Arsa et al., 2013). Fertilizing with compost increased the fraction of dust on the soil, because decomposition of the compost is produced minerals constituent of dust produces minerals constituent of dust fractions such as Fe, Cu, Mg, Al, Ca, and Mn ([Setiyo et al, 2007; Arsa et al., 2013). During the cultivation of potatoes, structures or soil in the root zone depth of 0-30 cm is not structured or colloidal amorphous. The process of formation soil aggregates is very difficult, although the decomposition of compost is produced colloidal and enzymes that can assist in the formation of soil aggregates.

2.2. Soil porosity

Table 1. Soil porosity

Parameter		Dose of Compost From Chicken Manure (ton/ha)					Dose of Compost From Cow Manure (ton/ha)				
		15	17.5	20	22.5	25	15	17.5	20	22.5	25
Number macro pore , %	before potatoes planting	13.5	15.4	15.8	17.1	18.4	3.2	3.4	4.1	4.4	6.8
	after potatoes harvesting	13	14.2	15.1	16.3	17.4	2.5	3.1	3.6	4.1	4.6
Number micro pore , %	before potatoes planting	39	40.3	42.6	42.9	44.4	31.3	35.7	37.1	37.7	40.2
	after potatoes harvesting	37.6	37.7	40.8	41.2	41.8	30.9	34.2	37	37.4	39.8
Total pore	before potatoes planting	52.5	55.7	58.4	60	62.8	34.5	39.1	41.2	42.1	47
	after potatoes harvesting	50.6	51.9	55.9	57.5	59.2	33.4	37.3	40.6	41.5	44.4
Swpesific gravity, g/cc	before potatoes planting	1.29	1.27	1.26	1.26	1.24	1.39	1.35	1.32	1.3	1.29
	after potatoes harvesting	1.29	1.27	1.26	1.252	1.238	1.388	1.376	1.344	1.312	1.3

Soil porosity is presented in Table 1, fertilizing with compost at a dose of 15 to 25 tones / ha and carried out more than five years can increased soil porosity from 50.6 to 59.2%, this result is very closed to the results of the study by Hicliklenton et al. (2001); Arsa et al. (2013) and Setiyo et al. (2010). Component of chicken manure compost are: rice husks, leftover feed and chicken feces. Chemical elements rice husk is 50% cellulose, 25% -30 lignin and 15-20% silica (Ismail and Waliuddin, 1996), whereas cow manure compost component are: cellulose 15-l6%, l0- 30% hemicelluloses, lignin 5-3%, 5-40% protein, and minerals (ash) 3-5% (Sutanto, 2002). Hemicelluloses, lignin and silica are more difficult to disentangle from the other components, so that this element will increase the number of macro pores in the soil especially in the root zone.

On the cultivation of potatoes, compost decomposition into simple mineral is able to increase the number of pores in the soil macro and micro. Number of microspores for the land that once time is fertilized using cow dung compost at dose 15 – 25 tones/ha was 31.3 - 40.2%, and for the cultivated potato for more than 3 years and given compost from chicken manure at the same dose had a number of micro pores as much as 39 - 44.4%. Total microspores for both types of land as much as 70 - 91.1% of the total amount of soil pores, good soil will have micro pores as much as 60% of the total porosity, so that the soil at Baturiti field was classified as good soil. Soil micro pore number after potato tubers harvested decreased 0.02 to 4.1 %.

On land fertilized with compost chicken manure compost, the relationship between the dose of compost with amount of soil porosity presented by the equation $y = 0.953x + 38.95$ with $r = 0.99$, and the equation $y = 1.110x + 18:56$ with $r = 0.97$ for the land is fertilized with cow manure compost. The amount of compost in horticultural cultivation is maximum 40% of the volume of soil (Setiyo et al., 2011). The water content of field capacity and permanent wilting point, and the water holding capacity of the soil results from this study are expressed in Table 2. Increasing the number of micro pores in the soil especially in the root zone is followed by an increasing the field capacity moisture content and water-holding capacity. Field capacity moisture content is 30.5 to 40.9% wb and permanent wilting point water content is 8.2 to 9.7% w.b. Micro pores in the root zone can hold water capillary and hygroscopic water, but the macro pores are filled with air. The water content of field capacity for land fertilized using compost from the chicken manure is greater than the land fertilized with composted cow manure (Setiyo et al., 2009; Arsa et al., 2013; Setiyo et al, 2013; Setiyo et al., 2014; Rosen et al., 1993; Giusquiani et al., 1995).

Table 2. Moisture content at field capacity, permanent wilting point, and water availability for plant (Setiyo et al., 2013; and Setiyo et al., 2014)

Parameter of soil moisture content	Dose of Compost From Chicken Manure, (ton/ha)					Dose of Compost From Cow Manure (ton/ha)				
	15	17.5	20	22.5	25	15	17.5	20	22.5	25
Field Capasity Moisture Content, % w.b	31.8	32.0	35.4	37.7	40.9	30.5	33.5	35.3	36.9	38.0
Permanent wilting point moisture content, % w.b	8.2	8.5	8.2	9.7	9.0	8.2	8.5	8.3	8.4	8.4
Water holding capasity, % w.b	23.7	23.6	27.2	28.0	31.9	22.3	25.0	27.0	28.5	29.6
Moisture content at one month after planting, % w.b	15.7	16.6	22.3	23.3	23.7	22.7	24.5	24.6	24.4	26.3
Moisture content at two month after planting, % w.b	15.7	16.6	22.3	23.3	23.7	22.7	24.5	24.6	24.4	26.3
Moisture content at three month after planting, % w.b	15.7	16.6	22.3	23.3	23.7	22.7	24.5	24.6	24.4	26.3

On land fertilized chicken manure compost and cow manure, the relationship between the dose of compost fertilizer with water holding capacity is written with the equation $y = 0.832x + 10.24$ with $r = 0.95$ and $y = 0.724x + 12$, with $r = 0, 98$. If the dose of compost increased one ton / ha, the water holding capacity of the soil also increased by 0.7-0.8% w.b (Sutedjo, 2002; Setiyo et al., 2009; Arsa et al., 2013; Setiyo et al., 2013; Setiyo et al., 2014; Rosen et al., 1993; Giusquiani et al., 1995).

3. Soil chemical characteristic

Characteristics of soil fertility in potato cultivation is shown in Table 3, the number of micro and macro nutrient elements in the soil is influenced by the dose of compost that is used as an organic fertilizer. Fertilizing potatoes with chicken and cow manure compost with dose of 15 - 25 tones / ha can increased the content of organic matter in the soil exceeds 5% with a cation exchange capacity 23.95-29,0 me / 100g and pH 6.7 - 6,92.

Total organic matter in the soil Baturiti District at 2009 was 3.6% and it was increased to 6.2 % at 2015 (Setiyo et al., 2015). Macro nutrients such as C-organic, N-organic, P_2O_5 and K_2O at potato cultivation part is not absorbed by the roots of potato plants, so that after the potato tubers harvested several macro mineral increasing the amount of organic matter at the soil (Arsa et al., 2013).

Organic acids at the compost at neutral pH is accelerated the decomposition process ([15] Sutanto, 2002), demineralization of compost is produced : (1) minerals such as : Mg^{2+}, K^{+}, Al^{+}, Fe^{+2}, Ca^{2+} and other, (2) energy, (3) H_2O, and (4) CO_2 (Setiyo et al., 2007). At neutral pH micro and macronutrients are very easily absorbed by the roots of potato plants.

Table 3. Content C-organic, N-organic, P_2O_5 , K_2O, Ca, Mg, Fe, Al and Cation exchange capasity for potato cultivation fertilized by chicken and cow manure compost (Setiyo et al., 2013 and Setiyo et al., 2014)

Parametrs soil fertility at potatoes root zone		Compost of chicken manure fertilized dose (ton/ha)					Compost of cow manure fertilized dose (ton/ha)				
		15	17.5	20	22.5	25	15	17.5	20	22.5	25
Content of C-organic, %	before planting	4.62	4.62	4.83	4.87	4.91	4.2	4.2	4.37	4.23	5.02
	after harvesting	4.14	4.74	4.92	5.14	5.53	3.96	4.35	4.41	4.79	5.0
Content of N-organic, %	before planting	0.4	0.43	0.45	0.45	0.46	0.36	0.36	0.36	0.4	0.4
	after harvesting	0.25	0.25	0.28	0.29	0.31	0.23	0.33	0.33	0.33	0.35
Content of P_2O_5, ppm	before planting	786	786	774	792	814.4	840.4	840.4	729.4	802	841.6
	after harvesting	611	646.3	683.5	734.4	753.1	248.2	252.2	278.8	314	332.7
Content of K_2O, ppm	before planting	500	500	656	666	601.2	429.2	429.2	473.3	477	455.5
	after harvesting	148.9	149.9	154.2	1269	1424	155	158.8	163.3	173.5	184.3
Content of Ca mg/kg	before planting	1562	1782	1854	1888	4660	630	1060	1188	1286	1435
	after harvesting	1854	2765	3280	4190	4367	2215	8550	9200	11500	17800
Content of Mg, mg/kg	before planting	168	204	208	286	1164	82	123.2	168.2	204	286
	after harvesting	208	1915	4365	7650	8350	7.8	125	113.5	264.5	275
Content of Fe, mg/kg	before planting	61.5	120	188	1204	1892	1204	1204	1892	2121	2569
	after harvesting	5168	11094	11743	24879	32037	3796	4010	4911	8435	50847
Content of Al, mg/kg	before planting	308	5387	5387	12946	17526	12946	14340	17526	19618	22306
	after harvesting	485	2114	2388	4152	5387	387.6	449.4	599	839.6	4959
Soil pH	before planting	6.73	6.79	6.81	6.91	6.87	6.7	6.72	6.83	6.9	6.92
	after harvesting	6.8	6.82	6.87	6.91	6.9	6.8	6.81	6.84	6.9	6.92
Cation Exchange Capasity, me/100g	before planting	25.3	24.4	23.8	26.19	27.1	23.95	24.89	25.17	27.2	29
	after harvesting	17.99	20.7	20.06	21.93	25.73	19.92	21.22	21.3	21.86	25.5

4. Potato cultivation in Bali

4.1. Potato growing

Potato is planted at different soil physical properties and fertility at May-August 2015. Soil is fertilized with compost at doses of 15 to 25 tones / ha and it also fostered use of fertilizer N, P, and K at dose of 250 kg / ha. Potatoes are planted on the back of the ridges, the ridges have wide 80 cm, for every ridge planted with two grooves planting, the distance between the grooves is 40 cm and the distance between plants at each plot is 25 cm. Channel with a depth of 25 cm and a width of 30 cm is made between two ridge and the ridge is closed by plastic mulch type HDPE.

Seed potato varieties G3 class granola are used as seed. Potato tubers are used as seed with characteristics: (1) skin damage is less than 2 %, (2) high apical shoots is 0.5-1 cm, (3) tuber weight is 30-60 g, and (4) the power to sprout is more than 97%. The relationship between the old and tall potato plants is described in Figure 1.

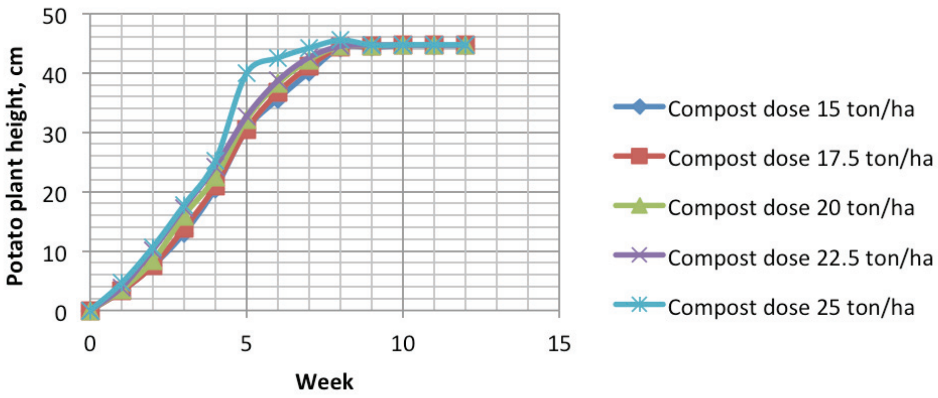

Figure 1 Relationship between old of plant and height of potato plant

At week 10 height of the potato plant was 44.69 ± 0.05 cm with diameter 5.5 ± 1.2 mm, this condition can be seen in Fig 1. At the vegetative growth (week 0 – 8), plant growth is linier, but started at week 9 or generative phase the plant growth rate is decreases and potato tubers weight are increasing. Increasing the weight of the potato tuber is presented in Figure 2.

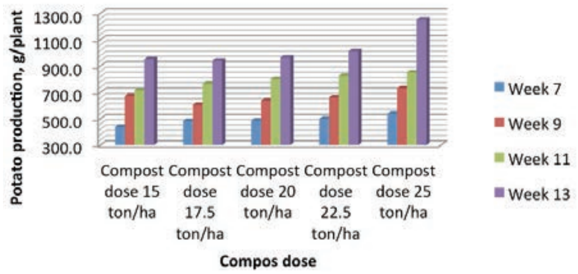

Figure 2. Relationship between doses of compost with increasing tuber

In Figure 2 described a linear relationship between age of the plant with weight of potato tubers. Tuber weight is depending on the dose of compost is used as fertilizer. Dose fertilization using compost more than 20 tons / ha is very efficient for planting potatoes, because the plant produces the number of tubers were 9 ± 2 with average weight of each tuber more than 100 g.

4.2. Potato production

The relationship between age LEISA system implementation, the dose of compost used and potato productivity is presented in Figure 3. Increasing the dose of compost followed by increasing the production of each crop and each unit area, the highest production achieved at a dose of fertilizer is 25 tones / ha for the application of the system LEISA more 3 years. The land is able to produce potatoes as much as 33 ± 1.3 tones / ha or 1303 ± 105 g / tree, and each plant produces 11 ± 2 potato tubers. Soil fertility, soil physical properties and the microclimate at the time of system implementation LEISA is optimal for growth of the potato crop.

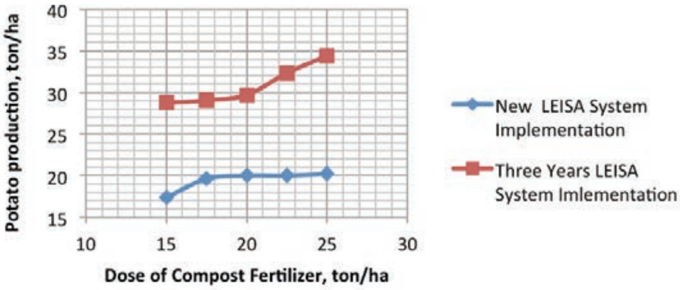

Figure 3 Relation between dose fertilizer with potatoes production

If the dose of fertilizer increased, the potato production will increase too. The relationship dose used of compost with total production of potatoes for the application of system more than three LEISA written with the equation $y = 0.584x + 19.14$ with $r = 0.94$ and for land newly implemented system LEISA that relationship written with the equation $y = 0.244x + 14.54$ with r = 0, 79. LEISA system was applied for 3 years on the cultivation of potatoes was enough to improve the physical properties and fertility of the soil in the root zone (Setiyo et al., 2013; Setiyo et al., 2014).

LEISA system application by farmers Baturiti is increased production from 17 tones / ha (2010) (Supartha et al., 2012) into: (1) 22 ± 1.6 tones / ha in 2011th (Setiyo et al., 2012), (2) 25 ± 2.1 tones / ha in 2012th (Arsa et al., 2013) (3) 29.2 ± 2.6 tones / ha in 2014th (Setiyo et al., 2014), and (4) 33 ± 1.3 tones / ha in 2015th. Seed potato varieties granola class G3, G4 and G5 are used by farmers, these seeds have been certified by the government. Potato is planted by farmers in the dry season or April to October every year.

Table 3 Potatoes production at field that implementation LEISA System

Parameters	Productivity of potatoes at new field that fertilizing with compost					Productivity of potatoes at field that fertilizing with compost along 3 years				
	15	17,5	20	22,5	25	15	17,5	20	22,5	25
Total production each plant, g	531	742	757	757	531	1088	1100	1125	1225	1303
Total production, ton/ha	14	19.6	20	20	14	28.7	29	29.7	32.3	34.3
Number potatoes, tuber/plant	9.4	10.9	8.6	8.6	9.4	10.8	14.3	11.1	12.2	15.9
Super (Weight > 200 g), %	3.1	11.4	9.1	0	3.8	11	12.5	17	19.8	22.2
A (Weight 100 – 200 g), %	45.7	49.2	56.8	48.2	29.4	64.7	55.6	44.2	53.3	47.6
A/B (Weight 61 – 100 g), %	32.7	25.4	19.1	25.4	31.9	20.5	21.3	27.6	18.1	15.5
B (Weight 30 – 60 g), %	15.3	10.2	10.7	21.6	25.3	4.5	7.9	8.6	6.8	9.3
Small Class (Weight < 30 g), %	3.2	3.8	4.3	4.9	13.4	2.2	2.8	2.7	2	5.4

Application of LEISA systems is capable to improving the productivity and quality of potato, this is illustrated in Table 4. Implementation of LEISA systems over three years are able to produce potatoes as much as 28-34 tonnes / ha. On land newly implemented system LEISA amount of potatoes super class is 0 to 11.4 % and for land applied with LEISA systems for more than three years super class of potatoes is 11 to 22.2%. Soil organic matter content more than 6%, the cation exchange capacity from 21.90 to 29.00 me / 100 g, neutral soil pH and soil porosity of more than 50% are the optimal conditions for the cultivation of potatoes.

5. Conclusion

LEISA system implementation in potato cultivation improve soil porosity amount approaching ideal conditions, so that the capacity of the soil in the root zone hold water available for plants to grow for 15-21 days in the dry season cultivation. For the rainy season, soil porosity and drainage channels are made to work optimally, so that soil erosion and leaching of minerals in the root zone can be minimized.

Chicken manure and cow manure compost is used in the cultivation of potatoes with a dose 15-25 ton / ha increased total organic matter content, so the status of the soil is very fertile with organic matter is more than 5% and the cat ion exchange capacity is 25-29 me / 100 g. Physical and chemical characteristics of the soil for the application of the system LEISA more than three years are able to produce potatoes as much as 28-34 tones / ha with potatoes super class is 11 to 22.2%.

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