

THE USE OF ENRICHED ORGANIC FERTILIZER TO REDUCE ORGANIC AND INORGANIC FERTILIZER APPLICATION AND INCREASE POTATO YIELDS IN THE HIGHLANDS OF INDONESIA

EL USO DE FERTILIZANTES ORGÁNICOS ENRIQUECIDOS PARA REDUCIR LA APLICACIÓN DE FERTILIZANTES ORGÁNICOS E INORGÁNICOS Y AUMENTAR LOS RENDIMIENTOS DE PATATA EN LAS TIERRAS ALTAS DE INDONESIA

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ABSTRACT

Potato production requires a reasonable quantity of Nitrogen, Phosphorus and potassium in the soil. These nutrients could be obtained from organic manures or inorganic fertilizers application. However, the quantity of NPK derived from organic manure is little and needs to be enriched. Experiment was conducted at Experimental Station of Indonesian Vegetable Research Institute (the elevation of this site is 1250 meters above sea level) during June to November, 2017. The objective of the experiment was to obtain an efficient technology of nutrient management in terms of organics and biological fertilizers and to obtain appropriate technology for potato tuber. The implementation of the research was preceded by making compost manure using Bio-decomposer for one month and enriched by

using Bio-Phosphate and beneficial Micro-organism, dolomite, ash husk and rock phosphate, then continued with its application in the field with potato as an indicator plant. The treatments were arranged in a randomized complete block design (RCBD) with four replications. The treatments included the use of organic fertilizer in terms of horse manure enrichment at a rate of 20 and 40 t/ha and inorganic fertilizer at a rate of 0, 500 and 1000 kg NPK and horse manure 40 t/ha + 1000 kg NPK/ha as control (farmer's practice). Results of the experiments indicated that the use of horse manure enriched by microorganism can reduce a rate of horse manure from 40 ton/ha to 20 t/ha to produce growth and yield of potato. Enriched horse manure can also reduce the use of inorganic fertilizers by half rate (500 kg NPK / ha). Combination of enriched horse manure 20 t / ha + 500 kg NPK / ha is more efficient to increase yield of potato tubers. The use of enriched horse manure does not seem to affect the improvement of soil fertility, especially for the availability of soil P and soil biological activity.

Keywords: *Solanum tuberosum*, horse manure, decomposer microbes, inorganic fertilizers, tuber yields.

RESUMEN

La producción de papa requiere una cantidad razonable de nitrógeno, fósforo y potasio en el suelo. Estos nutrientes podrían obtenerse de abonos orgánicos o aplicación de fertilizantes inorgánicos. Sin embargo, la cantidad de NPK derivada del abono orgánico es pequeña y necesita ser enriquecida. El experimento se realizó en la Estación Experimental del Instituto de Investigación de Vegetales de Indonesia (la elevación de este sitio es de 1250 metros sobre el nivel del mar) durante junio a noviembre de 2017. El objetivo del experimento era obtener una tecnología eficiente de gestión de nutrientes en términos de productos orgánicos y fertilizantes biológicos y para obtener la tecnología adecuada para el tubérculo de papa. La implementación de la investigación fue precedida por la fabricación de estiércol de composta utilizando Bio-decomponer durante un mes y enriquecido con Bio-Fosfato y Microorganismos beneficiosos, dolomita, cáscara de ceniza y fosfato de roca, luego continuó con su aplicación en el campo con papa como una planta indicadora. Los tratamientos se organizaron en un diseño de bloques completos al azar (RCBD) con cuatro repeticiones. Los tratamientos incluyeron el uso de fertilizante orgánico en términos de enriquecimiento de estiércol de caballo a razón de 20 y 40 t / ha y fertilizante inorgánico a razón de 0, 500 y 1000 kg de NPK y estiércol de caballo 40 t / ha + 1000 kg de NPK / ha como control (práctica del agricultor). Los resultados de los experimentos indicaron que el uso de estiércol de caballo enriquecido con microorganismos puede reducir la tasa de estiércol de caballo de 40 ton / ha a 20 t / ha para producir crecimiento y rendimiento de

papa. El estiércol de caballo enriquecido también puede reducir el uso de fertilizantes inorgánicos a la mitad (500 kg de NPK / ha). La combinación de estiércol de caballo enriquecido 20 t / ha + 500 kg NPK / ha es más eficiente para aumentar el rendimiento de los tubérculos de papa. El uso de estiércol de caballo enriquecido no parece afectar la mejora de la fertilidad del suelo, especialmente por la disponibilidad de P del suelo y la actividad biológica del suelo.

Palabras clave: *Solanum tuberosum*, estiércol de caballo, microbios descomponedores, fertilizantes inorgánicos, rendimientos de tubérculos.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is the fourth most important food crops in the world after rice, maize and wheat in terms of human consumption (Karam *et al.* 2009, Kandil *et al.* 2011). Buurma *et al.* (1989) reported that in Indonesia potato was cultivated in the highland. The use of inorganic fertilizer become a basic necessity, meaning to be a determinant of potato productivity. However, the long-term use of inorganic fertilizers will have an effect on soil structure which can further reduce fertility and crop production. Kumar *et al.* (2016) stated that the sole application of major nutrient (N, P and K) without concurrent use of micronutrients may not be adequate to improve growth and productivity of potato tuber (Jasim *et al.* 2013, Jafari-Jood *et al.* 2013, Banerjee *et al.* 2016).

High population growth of around 2% per year in Indonesia requires adequate food supply, so it is needed to increase the production of food crops such as potato through intensification programs including the use of superior (improved) varieties and the use of chemical fertilizers in order to overcome plant nutrient deficiency symptoms (Shaaban & Kisetu 2014, Tetard-Jones *et al.* 2013, Wadas & Dziugiel 2015, Adhikari 2009). These superior varieties are highly responsive to production input such as agrochemical materials (inorganic fertilizers and pesticides).

Currently, increased production of potatoes is still focused on chemical fertilizers N, P and K. Nevertheless, the continued use of chemical fertilizers without offset by the use of adequate organic fertilizers can lead to a lack of micro elements and soil compaction. To accelerate the decomposition of organic matter the organic fertilizer should be enriched with natural ingredients such as dolomite and beneficial microorganism (biological fertilizer) (Kumar *et al.* 2016, Sharif Hossain *et al.* 2003, Girma *et al.* 2017, Onwudike 2010). Various kinds of bio-fertilizers containing useful microbes have been widely used for food crops and horticultural crops.

Biological fertilizers that have been studied and developed by the Bogor Soil Research Institute are Bio-decomposers, Bio-phosphate, and Multipurpose Micro-flora. Bio-decomposers is a biological organic material remodel (microbial consortium of cellulose and lignin shrubs) to improve the decomposition efficiency of crop residues, reduce the cause of disease and environmental problems in sewerage systems (Zaghloul 2002, Shaheen et al. 2017). Bio-phosphates is an effective microbial mixture of soluble phosphate microorganisms, *Pseudomonas spp.* GRT2, *Micrococcus spp* GRT3, *Aspergillusniger* NHJ2, *Mycorrhizal glomusmanihots* enriched with natural organic compounds and equipped with appropriate carrier formulations while Multipurpose Micro-flora is an N fixing crops.

The objectives of this research was to get the technology of organic fertilizer nutrient management and efficient biological fertilizer for potato plant, and to obtain appropriate technology for potato production system.

MATERIALS AND METHODS

Experiment was conducted at Experimental Station of Indonesian Vegetables Research Institutes (IVEGRI), Lembang, Indonesia from June to November 2017. The experimental site is located at Lembang, 20 km North of Bandung, capital city of West Java Province with an elevation of 1250 meters above sea levels (m asl).

A randomized complete block design (RCBD) with four replications was used. Treatments consist of 7 (seven) treatments:

- (1) Horse Stable (40 t/ha) + 1000 kg NPK/ha as Control plot.
- (2) Enriched Horse dung (20 t/ha) + 1000 kg NPK/ha
- (3) Enriched Horse dung (20 t/ha) + 500 kg NPK/ha
- (4) Enriched Horse dung (20 t/ha) + 0 kg NPK/ha
- (5) Enriched Horse dung (40 t/ha) + 1000 kg NPK/ha
- (6) Enriched Horse dung (40 t/ha) + 500 kg NPK/ha
- (7) Enriched Horse dung (40 t/ha) + 0 kg NPK/ha

Potato variety GRANOLA obtained from seed grower was grown with plant spacing of 80cm x 30cm. The treatment of horse dung was banded in an open row on the ridges of the horse dung treatments and was covered by 2 cm of soil. NPK fertilizer was given simultaneously at planting time. Enriched horse dung are manure composted by decomposer micro-M-Dec (1 kg M-dec for 1 ton of manure) for 4 weeks and after composting (C / N = 12-18) plus rock phosphate (w / w 0.25%), husk ash (w / w 0,5%), dolomite (0,5%), bio-phosphate (w / w 0,2%), multipurpose micro-flora (w / w 0,2 %). Enriched horse dung and

un-enriched horse dung are spread over potato plant bunds before planting. Control of the main pest of potatoes is done by spraying Agrimex and Trigard once a week.

Surface soil sample (0 – 30 cm) before and after research were randomly collected (following zig zag way) and composited before planting. At harvest seven surface soil samples were collected from each replicated treatment, and composited for each treatment. The soil samples were air dried and ground to pass through a 2 mm sieve and 0.5 mm sieve (for total N) before analysis. The soil sample bags were well identified, labelled and analyzed at the IVEGRI Soil and Plant Laboratory. The soil sample were then analyzed according to standards procedures (Cottenie 1980).

First earthing up or hilling and weeding of ridges followed immediately after the application of N fertilizer.

Second weeding and hilling was done at 8 weeks after planting. Weeding was done manually. Fungal treatments with Antracol was done three times before harvesting.

Data collection: Data were collected on the growth and yield of potato, nutrient uptake and soil chemical properties:

1. Growth of plants (plant height, leaf area, fresh weight)
2. Dry weight and nutrient uptake of plants (N, P and K)
3. Potato results. Harvesting is done when the plant age 90 days after planting
4. Soil chemical properties (N, P, K, C-org, pH) and organic fertilizer (C-org, N, P, K, Ca, Mg, micro nutrients) and soil biological activity. Observation of soil chemical and biological analysis was done in IVEGRI laboratory.

The analysis used is Fisher test followed by Duncan Multiple Range Test (DMRT) at 5 percent level (SAS Institute, 2000).

RESULTS AND DISCUSSIONS

Chemical Properties of Horse Dung: The Results of chemical analysis of horse dung compost presented in Table 1 shows that the composting process lasted for four weeks to reach the expected C / N ratio (10-20), ie 18. The first week of composting of organic C content reached 33.72% and organic N 1.39 % with C / N ratio of 24.26. The longer the composting time more decreases the organic C manure, but the organic N increases. This is because the decomposition process is in progress and C-organic manure is overhauled into organic N. It is also characterized by decreasing C / N ratio, until the age of about 4 weeks C / N ratio reaches 17.7 or 18 or the compost is mature enough. As for the controls used

ordinary horse manure derived from the same material but only left in the open without composting for four months (Lundgren & Petterson 2009, Sarwar et al. 2008).

Tabel 1. Chemical analysis of the compost of horse dung done every week

Observation time	Org-C (%)	Organik N (%)	C/N
First week of composting	33.72	1.39	24.26
Second week of composting	31.83	1.47	21.65
Third week of composting	30.29	1.51	20.06
Fourth week of composting	29.67	1.67	17.77

Mature Horse dung compost is then enriched with Phosphate Solvent Fungi (BioPhos), N-fixing bacteria (Multipurpose Micro-flora), ash husk, dolomite and rock phosphate and the nutrient content was analyzed as listed in Table 2. In general, enriched horse dung compost have a lower C / N ratio than un-enriched horse dung one. The similar trend onspatial variation of C/N in wheat-maize was obtained by Shi et al. (2017). This means that the compost of the enriched horse dung is more mature than ordinary horse dung. This is seen from lower organic C but higher organic N. While P total is higher than ordinary horse dung, but the total K content is lower. The presence of phosphate solvent fungi and the addition of rock phosphate which resulted in higher P total of enriched horse dung compost. Nutrient (secondary macro and micro) content were also generally high. The prominent content of Al and Fe micro elements is very high on the compost of enriched horse manure, while in ordinary manure either Fe or Mn and Cu was high.

Results of the soil analysis in Table 2 showed that the organic matter content of Andisol has undergone further weathering which is characterized by a slightly lower C / N ratio (<10) having a slightly higher acidity level, with high organic C and high N-total content (> 0.5%). The C / N ratio is belong to moderate, which means the organic matter has undergone weathering. The soil P content is low (<15 ppm), which is usually in acidic soil P is fixed by Al or Fe (Hilman 1988). Highly available K content (> 40 ppm). The exchangeable content of cations such as Ca, Mg, K and Na are low to moderate, with low base saturation percentage. While the cation capacity of andisol soil is high due to the high content of soil organic matter.

Table 2. Chemical analysis of Soil, Ordinary Horse Dung, and Enriched manure compost

Chemical Properties	Soil	Ordinary Horse Dung	Enriched manure Compost
pH H ₂ O	5.3	-	-
Watercontent (%)	-	66.39	65.12
Organic-C (%)	5.32	28.91	24.42
Total-N (%)	0.72	1.60	1.71
C/N	7	18	14
Available P ₂ O ₅ (ppm)	12.8	-	-
Available K ₂ O (ppm)	159.12	-	-
P ₂ O ₅ (%)	-	1.38	1.98
K ₂ O (%)	-	2.46	1.91
CaO (%)	-	-	1.95
MgO (%)	-	-	1.75
S (%)	-	-	0.44
Ca	4.38	-	-
Mg	1.15	-	-
K	0.38	-	-
Na	0.11	-	-
KTK	22.81	-	-
KB (%)	26	-	-
Fe (ppm)	-	6316	13911
Mn (ppm)	-	5841	538
Cu (ppm)	-	1211	66

Zn (ppm)	-	18	176
Al (ppm)	-	29	26379

Growth and Yield: the result of variance analysis showed no significant effect between the dose of organic fertilizer and inorganic fertilizer on the growth of potato in terms of plant height 30, 44, and 58 days after planting (dap) (Table 3). Likewise, the area of leaves of the potato plant showed no significant difference between the compost treatment and the dosage of NPK fertilizer (Table 4). This response is almost similar to the result obtained by Adhikari (2009).

Tabel 3. Effect of Enriched Horse Dung Compost and Chemical Fertilizers on Plant Height

Treatment	Plant height (cm)		
	30 dap	44 dap	58 dap
Horse dung (40 t/ha)+1000 kg NPK/ha as Control [A]	21.38 a	31.42 a	46.79 a
Enriched Horse dung (20 t/ha) + 1000 kg NPK/ha [B]	23.50 a	31.67 a	45.04 a
Enriched Horse dung (20 t/ha) + 500 kg NPK/ha [C]	23.00 a	33.79 a	46.33 a
Enriched Horse dung (20 t/ha) + 0 kg NPK/ha [D]	21.58 a	31.21 a	43.83 a
Enriched Horse dung (40 t/ha) + 1000 kg NPK/ha [E]	23.38 a	32.59 a	45.92 a
Enriched Horse dung (40 t/ha) + 500 kg NPK/h [F]	23.58 a	33.09 a	47.80 a
Enriched Horse dung (40 t/ha) + 0 kg NPK/ha [G]	21.08 a	32.50 a	45.29 a
CV (%)	14.60	9.06	14.39

Note: CV (Coefficient of Variance); dap (day after planting)

The fresh weight of the plant is affected by the application of manure and the dosage of NPK fertilizer (Table 4). The result of statistical analysis shows that un-enriched horse manure (40 t / ha) + 1000 kg NPK / ha (treatment A) has the highest wet weight. The fresh weight of the plant was not significantly different from the treatment of compost of horse manure enriched 20 t / ha + 1000 kg NPK / ha. However, with other treatments the fresh weight on the treatment is significantly different.

Tabel 4. Effect of Enriched Horse Dung Compost and Chemical Fertilizers on Plant Height

Treatment	Leaf Area (cm ²)	Fresh Weight of Potato Plant (gram)
Horse dung (40 t/ha) + 1000 kg NPK/ha as Control [A]	2680.27 a	745.00 a
Enriched Horse dung (20 t/ha) + 1000 kg NPK/ha [B]	2929.48 a	643.00 ab
Enriched Horse dung (20 t/ha) + 500 kg NPK/ha [C]	2376.44 a	479.00 c
Enriched Horse dung (20 t/ha) + 0 kg NPK/ha [D]	2373.33 a	447.25 c
Enriched Horse dung (40 t/ha) + 1000 kg NPK/ha [E]	2546.18 a	570.25 bc
Enriched Horse dung (40 t/ha) + 500 kg NPK/ha [F]	2788.77 a	450.25 c
Enriched Horse dung (40 t/ha) + 0 kg NPK/ha [G]	1833.77 a	554.50 bc
CV (%)	25.49	16.77

Note: CV (Coefficient of Variance)

The weight of large size of potato tubers (class A) was significantly different among the treatments as shown in Table 5. Treatment B (yields the highest large-sized potato weights (10,525 kg / 12 m²). The high yield for large tuber size was also shown by treatment of A, E and F respectively 9.4 kg / 12 m², 9.625kg / 12 m² and 89 kg / 12 m². The lowest large tuber size is produced by treatment D (horse fertilizer enriched 20 t / ha + 0 kg NPK / ha) and G (horse fertilizer enriched 40 t / ha + 0 kg NPK / ha). So it is seen that without large amount of NPK fertilizer tuber yield obtained fewer. The short and long-term experimental data suggest that farmyard manure (FYM) increased potato tuber yield by 35 - 82 %, depending on chemical fertilizer combinations (Baniuniene & Zekaite. 2008, White et al. 2009, Tetard-Jones et al. 2013, Janssen 2017).

For medium tuber size (class B) and small (class C) there is no difference among treatments. The results of statistical analysis showed that there was a difference between treatments for total tuber weight per plot. The apparent differences were shown among treatment A, B, E and F with treatment D (enriched manure 20t / ha + 0 kg NPK / ha). Meanwhile, total tuber weight per plot among treatment A, B, C, E, F and G showed no significant difference. To obtain tuber yield, treatment C (enriched horse manure 20 t / ha + 500 kg NPK / ha) is sufficient. Judging from the use of organic and inorganic fertilizers, this treatment is more efficient than the control treatment.

Table 5. Effect of Enriched horse dung compost and inorganic fertilizers on the yield of Potato

Treatment	Weight of Potato Based on Tuber Size (g/petak)			Total Tuber Weight of Potato per Plot (kg/plot)
	Class A	Class B	Class C	
A	9.400 ab	7.650 a	6.100 a	23.075 a
B	10.525 a	7.300 a	4.225 a	22.049 a
C	6.625 bc	8.550 a	5.375 a	20.549 ab
D	5.625 c	6.775 a	5.675 a	18.075 b
E	9.625 a	7.275 a	4.625 a	21.525 a
F	8.900 ab	8.625 a	4.800 a	22.075 a
G	5.000 c	9.775 a	5.025 a	19.799 ab
CV (%)	17.47	18.33	17.39	7.08

Note: CV (Coefficient of Variance)

Nutrient Uptake: The result of further DMRT analysis test at 5% level shows there is significantly different of effect of manure + NPK fertilizer on dry weight of potato plant (Table 6). The provision of treatment B (enriched horse dung 20 t / ha + 1000 kg NPK / ha) has the highest dry weight of potato plant, but not significantly different from treatment A (un-enriched manure 40 t / ha + 1000 kg NPK / ha), treatment C (enriched horse dung 20 ton / ha +1000 kg NPK / ha) and treatment E (enriched horse manure 40 t / ha + 500 kg NPK / ha). From the data collected it appears that to obtain high dry weight of plants there is an indication that the reduction of fertilizer needs to be done by 50% from both organic fertilizer from 40 ton/ha to 20 ton/ha and inorganic fertilizers from 1000 kg NPK to 500 kg NPK. This is as a result of the availability of nutrient from the enrichment of horse dung, increasing rate of both organic and inorganic fertilizer did not increase plant height anymore.

Table 6 also shows that nutrient uptake is not always consistent with the dry weight of the plant. This is because the uptake of plant nutrients, in addition, is affected by the dry weight of the plant also by the concentration of nutrients in the plant (Rens et al. 2016, Kumar & Singh 2016). Treatment A has the highest N, P₂O₅ and K₂O plant uptake, in contrast to the dry weight of the plant, where the highest is in treatment B, since the concentration of nutrients in treatment A is higher than that of the other treatments (Thomas et al. 1967). For N uptake, treatments B, C and E were not significantly different from treatment A, and the absorption rate was above 400 g / plant. Treatments C, E and F have P₂O₅ uptake which is no

different from treatment A, whereas for plant K_2O uptake, treatments B, C, and E also have no different uptake. From these data, it appears that the reduction of an enriched and inorganic organic fertilizer by half still has nutrient uptake that is not different from the usual dosage or control (treatment A).

Table 6. Effect of Enriched horse dung compost and in-organic manure on dry weight of plant and nutrient uptake of potato plants

Treatment	Dry Weight of Plant (g/plant)	Nutrient Uptake by plant (g/plant)		
		N	P_2O_5	K_2O
A	148.130 ab	511.049 a	108.549 a	939.200 a
B	160.183 a	413.441 abc	81.960 bc	881.885 ab
C	123.415 bc	435.697 ab	91.706 ab	722.767 abc
D	115.677 c	321.583 cd	68.875 c	647.588 bc
E	154.568 a	486.888 ab	99.108 ab	869.675 abc
F	148.363 ab	386.090 bcd	91.115 ab	615.097 c
G	108.520 c	301.503 d	66.171 c	648.870 bc
CV (%)	13.09	16.81	13.2	20.49

Note: CV (Coefficient of Variance)

Nutrient Residue: The soil nutrient residue after the experiment in Table 7 showed that the organic C, total N and K were high. Only soil P_2O_5 was very low. Soil nutrient status is not different from that of initial condition. Only N content reduces and K increases. However, P residue status was low. Although the enriched organic matter or ordinary one, it is shown that P content was high, however, nutrient residue of P did not increase. It was seen that the low P residue of soil was a result of high micro nutrient content and either enriched organic matter (horse dung) or ordinary one was due to Al and Fe which can fix P (see table 2). In general, the use of enriched horse dung and ordinary stable manure did not indicate any significant difference on soil chemical properties.

Table 7. Effect of enriched horse dung compost and inorganic fertilizers on nutrient residue in the the soil

Treatment	pH	Organik-C (%)	Total-N (%)	C/N	P ₂ O ₅ (ppm)	K ₂ O (ppm)
A	5.0	5.88	0.52	11	3.9	598.8
B	5.0	6.12	0.58	10	2.6	401.4
C	5.4	6.33	0.57	11	4.0	290.5
D	5.6	6.84	0.57	13	2.0	236.6
E	5.3	7.19	0.57	13	3.8	297.3
F	5.3	6.18	0.50	12	6.3	481.1
G	5.3	6.66	0.56	12	4.4	273.1

Graph 1 indicates that soil microbial activity through its respiration. It is shown that among treatments, there is no significantly different on soil microbial respiration (soil biological activity). The greater plant growth the lower microbial activity which is reflected from the lower respiration. Similar Graph is also indicated from percentage of soil microbial dehydrogenase (Graph 2). Decrease in soil biological activity is probably due to many microbial population was died by pesticides that are sprayed on to the plant.

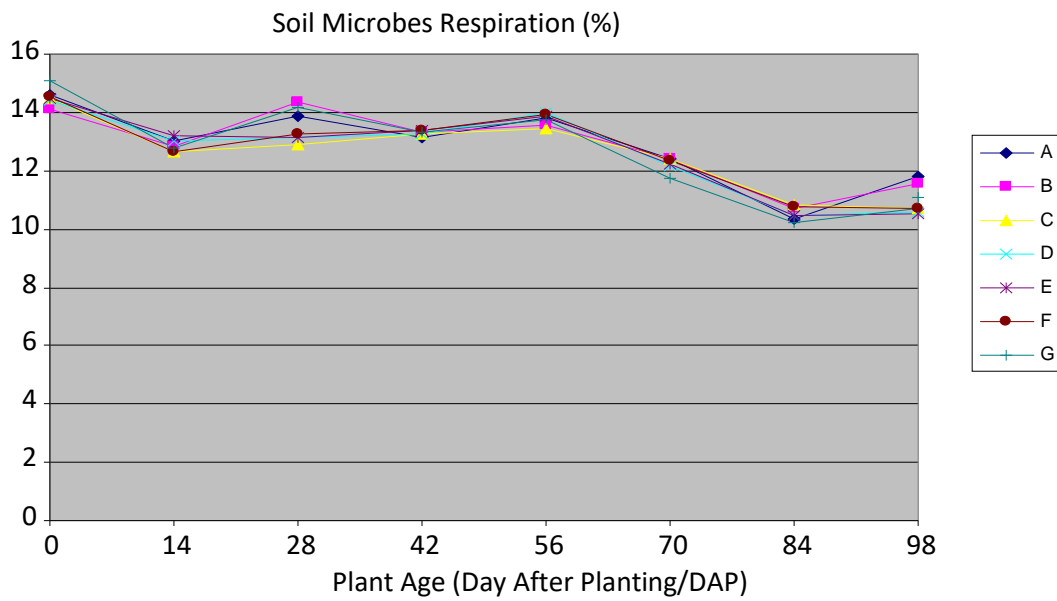


Figure 1. Graph of observation of microbes respiration on potato crop every 2 weeks

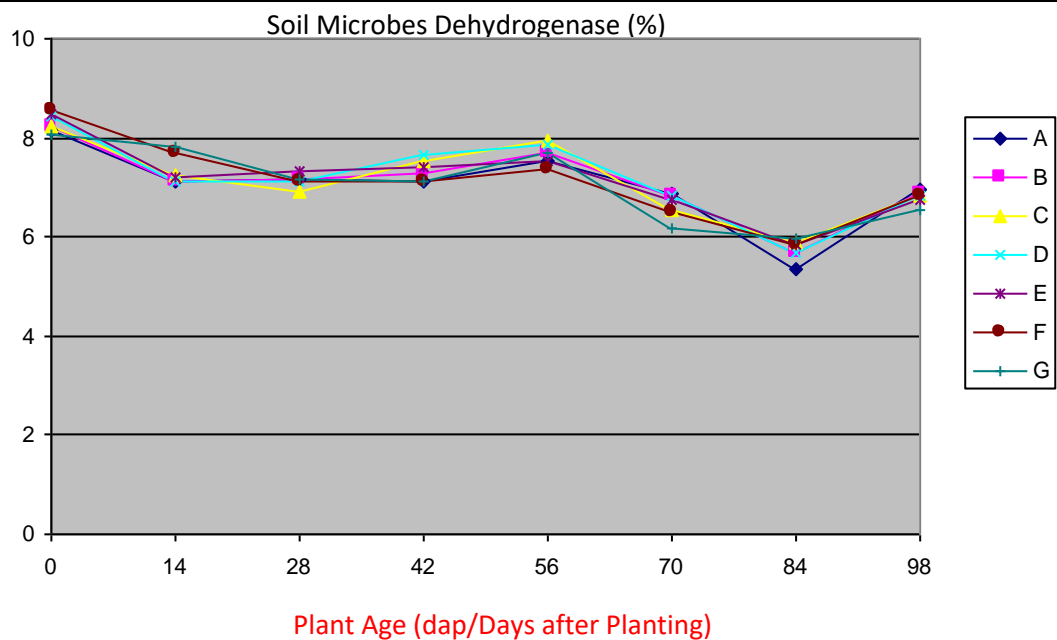


Figure 2. Graph of observation of microbe dehydrogenase of soil

From the obtained results, It can be concluded that: 1) The creation of enriched horse manure takes place over four weeks with a C / N ratio of 18. 2) Enriched horse dung at a rate of 20 t/ha in combination with 1000 kg of NPK compounds fertilizer is sufficient to produce class A tuber size, total tuber weight per plant and fresh weight of potato plant. 3) Soil nutrient content in treatment of enriched horse dung does not differ from that of ordinary horse dung. 4) Activity of soil biology (respiration) in enriched horse dung compost does not differ from that of ordinary horse dung.

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