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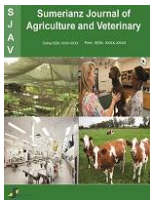

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Growth, Morphological and Yield Characteristics of Five Potato (*Solanum Tuberosum* L.) Varieties Treated with Organic-Based Fertilizers

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Abstract

The study was carried out to evaluate the best organic-based fertilizer for potato production as well as the best performing variety based on resistance to pests and diseases and yield characteristics, five potato varieties were grown under two different organic-based fertilizer with without organic fertilizer application as the control. The results showed that no significant difference among the treatments but plant applied with BSU grower's compost had the highest percent survival at 60 DAP. Plants with no application of organic fertilizer had moderately vigorous growth, while plants applied with BSU Grower's compost and vermicompost were highly vigorous. At 90 DAP all plants were vigorous and no significant differences were observed among the five varieties on plant vigour. There were significant differences among the plants applied with different organic-based fertilizers on treatments on the number and weight of marketable tuber yields. Similar results were obtained among the varieties with Igorota recording the highest number and heaviest marketable tubers with 209 and 17.8 kg/m2, respectively. Plants applied with BSU Grower's compost and vermicompost were observed to be highly resistant to leaf miner and with no significant differences among the five varieties. No significant differences were observed in the different treatments and the varieties on their resistance to late blight.
Keywords: BSU grower's compost; Vermicompost; Potato; Varieties and marketable yields.

1. Introduction

Potato (*Solanum tuberosum* L.) is one of the world's major staple crops after rice, wheat and maize. Potato crops occupied 19,278,549 ha and produce 365,365,367 tons of tubers in 2012 [1]. It is the fourth consumed staple food after cereals, and its importance is increasing as a vital food-security crop as well as a suitable alternative to costly imported cereals [1]. It is grown for its tubers, which are rich in phosphorus and vitamins B1, B2, and C. Reports showed that a potato crop produces more edible energy and protein per hectare and per unit of time than practically any other crops [2]. The major potato production in the Philippines is concentrated in high elevations particularly in Benguet and Mountain Province with a temperature below 21^{O}C. Potato is generally a cool-season crop grown in areas with elevation ranging from 1000 to 8000 meters above sea level. The growth of potato is greatly affected by temperature, day length, humidity, and soil conditions.

Potato production worldwide mainly depends on the intensive use of synthetic nitrogen fertilizers in order to achieve economic yields and high tuber quality. Meanwhile, the crop is characterized by low recovery of applied nitrogen, from 40-60%, leading to environmental risks and economic losses. Attempts to optimize nitrogen supply in potato fields for sustainable production systems have developed diverse approaches to better match N supply with potato uptake, improve N use efficiency, optimize yield and overcome environmental threats [3]. The use of organic residues can be the primary factor contributing to sustainable crop production by increasing the use of on-farm renewable resources and improving soil quality. Research attempts have reported the benefits of organic residues to improve soil properties as well as plant nutrient supply.

Organically grown food is attractive to both scientific and non-scientific communities [4]. Health benefits associated with organic food remains a focal point for research and production [5]. For potato, health benefits associated with organic production remains a debatable issue.

The use of organic fertilizers into soil increases yield due to increasing the efficiency of mineral fertilizers [6]. Many studies showed that yields of potato, pepper, and soybean grown under conventional and organic cultures are comparable.

The importance of this study cannot be overemphasized because of the vast uses of the crop not only as a vegetable for cooking at home but due to the increasing number of fast-food chains, hotels, and local potato-based snacks food manufacturers. Potatoes are also an important crop in the Philippine highlands and farmers grow the

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crop conventionally. The heavy use of fertilizers and pesticides cause problems such as soil depletion and recurrence of new pest and diseases.

Evaluation of potato cultivars for growth, yield and postharvest qualities across a range of organic based fertilizer is vital to the increase in production and product improvement. It also ensures continuity of supply to processors and the fresh market which will assure growers to have suitable varieties for use in their production systems. Unlike chemical fertilizers, organic-based fertilizers reduce acidity in the soil and do not cause leaching. These does not kill beneficial microorganisms in the soil and also help improve the structure of the soil including the circulation of air, which sustains beneficial microorganisms that help release nutrients in the soil [3].

2. Materials and Methods

The five potato varieties used in this study were acquired from the Northern Philippine Root Crops Research and Training Center (NPRCRTC). The varieties are Granola, Gloria, Igorota, Bengueta and Ganza.

2.1. Land Preparation

An area of 300 m^2 was thoroughly cleared of weeds and prepared using tractor. The area was divided into three blocks and further subdivided into plots measuring 1m × 5m.

2.2. Fertilizer Application

BSU Grower's compost and Vermicompost were the organic-based fertilizers that were used in this study. These were incorporated into the soil one week before planting at the rate of 10kg/5m^2.

2.3. Methods

The experiment was laid out in split-plot design with three replications. The main plot was the organic-based fertilizer and the subplot was the varieties. The treatments are as follows:

Main Plot: Organic-based Fertilizer

TREATMENT	COMPOSITION
MP1- Control	No Organic Fertilizer
MP2- BSU Grower's Compost	OM – 32.23%, N – 1.79%, P_2O_5 – 3.88% and K_2O – 4.11%.
MP3-Vermicompost	Vermicompost N – 2.36%, P – 4.50%, K – 0.40%, Organic C Ca – 8.60%, Mg – 0.50% and Fe – 0.80%.

Subplot: Variety

2.4. Care and Maintenance

Organic production practices were strictly adhered in this study such as planting of Marigold in all borders to act as insect repellant and barrier in order to promote diversity and application of non-synthetic pesticide. Wood vinegar was used as organic pesticide to protect the plants against insect pests' infestation. Other practices such as hilling up, weeding and irrigation were carried out when necessary.

2.5. The Soil Chemical Properties

Initial and final soil samples were taken before and just after harvest in order to determine the N, P, K, pH and OM of the soil.

2.6. Meteorological Data

The meteorological data such as air temperature, relative humidity, rainfall amount and sunshine duration the period of this study were gathered from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) based at BSU. The light intensity was taken on a weekly basis using the light intensity meter.

2.7. Growth Parameters

Plant survival (%). The number of plants that survived was recorded 30 days after planting (DAP) and were calculated using the formula:

$$\text{Plant survival (\%)} = \frac{\text{No. of plants survived}}{\text{Total number of plants planted}} \times 100$$

Plant height. The height of plants was taken at 30 and 90 DAP using a meter stick. In each plot, five sample plants were measured from the base up to the tip of the tallest shoot.

Canopy cover. This was taken at 30, 60 and 90 days after planting using a wooden frame measuring 120 cm × 60 cm with equal size of 12 cm × 6 cm grids.

Leaf area (mm^2). The leaf area of three sample plants were collected at 45, 60 and 90 DAP. Two green leaves from the upper parts of the plant was taken using the Tracing Technique Method by Saupe, *et al.* [7].

Plant vigour. This was rated at 30, 60, and 90 DAP based on rating scale by CIP as cited by Gonzales, *et al.* [8].

Reaction to leaf miner. The reaction to leaf miner was rated at 30, 45, 60, and 75 DAP based on rating scale by CIP as cited by Gonzales, *et al.* [8].

Reaction to late blight. The reaction to late blight was rated at 30, 45, 60, and 75 DAP based on rating scale by CIP [9].

2.8. Tuber Yield Parameters

i. Number and weight of marketable tubers per plot (g/ $5m^2$). All tubers of marketable quality (small, medium, big and super marble) were counted and weighed.
ii. Number and Weight of Non-Marketable Tubers per Plot (g/ $5m^2$). This included tubers that are malformed, damaged by pest and disease and those with more than 10% greening.
iii. Total yield per plot (5 m^2). This was the sum of total weight of marketable and non-marketable tubers per plot.

3. Results and Discussions

3.1. Meteorological Data

The minimum and maximum air temperature during the study period ranged from 12.8 to 15.5 °C to 22.6 to 23.5 °C respectively, while the relative humidity ranged from 87 to 91 % (Table 1). Harrdec [10], reported that potato is best cultivated with temperature ranging from 17 to 22 °C and with an average relative humidity of 86 %. Temperature and relative humidity during the period of the study were observed to be appropriate for potato production. Little rainfall (0.35, 0.07 and 0.1 mm) was recorded in November, January and February. Sunshine duration was highest in February with 425.3 mm and lowest in December with 296.5 mm (Table 1).

Table-1. Meteorological data during the conduct of the study in Balili, La Trinidad, Benguet from November 2017 to February 2018

Month	Temperature (°c		Relative Humidity (%)	Rainfall Amount (mm)	Light intensity (lux)
	Min.	Max.			
Nov.	15.5	23.4	91.0	0.35	322
Dec.	12.8	22.8	89.0	0.00	296.5
Jan.	14.1	23.5	87.0	0.07	312.1
Feb.	12.8	22.6	90.0	0.10	425.3
Mean	13.8	23.1	89.3	0.13	341.5

Source: BSU-PAGASA Meteorological Station, Balili, La Trinidad, Benguet

3.2. Soil Chemical Properties

Table 2 shows the chemical properties of the soil taken from the experimental area before and after harvest. The soil had a pH of 5.60 with organic matter content of 5.89 %. The nitrogen and phosphorus of the soil were 0.295 % and 17 ppm, respectively.

It was observed that there was an increase in the pH of the three treatments, BSU Grower's compost had the highest pH of 6.13 while vermicompost had the lowest pH of 5.74 after harvest. The result showed that application of BSU Grower's compost is favourable for the growth of potato since the optimum pH for potato production range from 5 – 6.5.

Table-2. Soil chemical properties before planting and after harvest

Soil Properties	Ph	Organic matter (%)	Nitro-gen (%)	Phos-phorus (ppm)	Potas-sium (ppm)
Before planting	4.60	5.89	0.30	17	_
After harvest					
No Organic Fertilizer	5.94	1.93	0.097	90.20	210.94
BSU Grower's Compost	6.13	2.53	0.13	173.13	988.65
Vermicompost	5.74	2.34	0.12_	93.06	332.98

Analysed by: BSU, Department of Soil Sciences Laboratory and Department of Agricultural, Regional Field Office l, Sevilla, San Fernando City, La Union

Lambert [11], reported that the optimum content of organic matter for potato production ranges from 1 – 4 %. The decrease in the organic matter content could be attributed to slow decomposing factors of organic-based fertilizers. There was an increase of phosphorus after harvest with application of BSU Grower's Compost recording the highest of 988.65 ppm.

Mujaya and Mereki [12], indicated the importance of phosphorous in potato production and lack of it during growth drastically reduced yield. Potassium in Compound C fertilizer is considered as one of the most important factors affecting the growth and yield of potato because it influences the physiological tubulisation process in potato plants. This is in agreement with those obtained by Humadi [13] who recorded an increase in yield and quality of Irish potato tubers due to increased levels of potassium (K) fertilization.

Organic-based fertilizers application had a substantial effect on availability of K, which plays a critical role in plant energy status and water transport [14].

3.3. Growth Parameters

Table-3. Plant survival of potato varieties applied with organic-based fertilizers

Treatment	**Plant Survival (%)**	
	30 Dap	**90 Dap**
ORGANIC-BASED FERTILIZER		
No Organic Fertilizer	61.67	19.58
BSU Grower's Compost	71.25	24.17
Vermicompost	66.75	21.67
VARIETY		
Bengueta	63.89	22.22
Ganza	62.64	20.83
Gloria	69.44	23.61
Igorota	74.31	23.61
Granola (check)	62.50	18.75
OBF x V	ns	Ns
CV (a) (%)	12	16
CV (b) (%)	14	22

Table-4. Plant height of potato varieties applied with organic-based fertilizers at 30 and 90 DAP

Treatment	**Plant Height (CM)**	
	30 Dap	**90 Dap**
ORGANIC-BASED FERTILIZER		
No Organic Fertilizer	28.45[b]	37.85
BSU Grower's Compost	33.27[a]	43.94
Vermicompost	32.51[a]	43.94
VARIETY		
Bengueta	33.27[a]	42.93
Ganza	31.49[a]	44.19
Gloria	31.49[a]	44.70
Igorota	30.98[a]	40.89
Granola (check)	26.67[b]	39.37
OBF X V	ns	Ns
CV (a) (%)	16.40	26.10
CV (b) (%)	12.80	13.10

Means with the same letter within a column are not significantly different at 5% level of significance using LSD.

Table-5. Canopy cover of potato varieties applied with organic-based fertilizers at 30, 60 and 90 DAP

TREATMENT		**CANOPY COVER (in^2)**	
	30 DAP	**60 DAP**	**90 DAP**
ORGANIC-BASED FERTILIZER			
No Organic Fertilizer	19.7[b]	21.2[b]	17.7
BSU Grower's Compost	23.0[a]	32.9[a]	22.4
Vermicompost	21.6[a]	27.7[a]	19.3
VARIETY			
Bengueta	19.4[bc]	25.8[b]	17.2
Ganza	22.3[a]	27.7[ba]	18.9
Gloria	22.5[a]	27.1[a]	18.5
Igorota	20.7[ab]	28.3[a]	18.5
Granola (check)	17.5[c]	24.5[b]	19.2
OBF X V	ns	Ns	Ns
CV (a) (%)	23.6	15.0	37.4
CV (b) (%)	14.7	11.6	14.0

Means with the same letter within a column are not significantly different at 5% level of significance using LSD.

Table-6. Leaf area of potato varieties applied with organic-based fertilizers at 45 and 60 DAP

Treatment	Leaf Area (cm^2)	
	45 DAP	**60 DAP**
ORGANIC-BASED FERTILIZER		
No Organic Fertilizer	12.7^{b}	13.5^{b}
BSU Grower's Compost	15.6^{a}	17.0^{a}
Vermicompost	15.3^{b}	16.5^{b}
VARIETY		
Bengueta	14.7	25.8^{bc}
Ganza	15.1	27.7^{bac}
Gloria	14.3	27.2^{ba}
Igorota	14.1	28.3^{a}
Granola (check)	15.1	25.5^{c}
OBF X V	Ns	Ns
CV (a) (%)	14.3	11.1
CV (b) (%)	10.6	8.1

Means with the same letter within a column are not significantly different at 5% level of significance using LSD

3.4. Number and Weight of Marketable Tubers

i. *Effect of organic-based fertilizer.* No significant differences were observed on the application of organic-based fertilizers on the number and weight of marketable tubers of potato as shown in Table 7. Plants applied with vermicompost produced the heaviest marketable yields of 2,310 g/ $5m^2$. This result also collaborated the findings of Shagol [15] who reported that potato plants had better growth and yield if applied with different organic fertilizers. Davis, *et al.* [16], also acknowledged the importance of phosphorous availability at tuber initiation, maximum tuber set and number of tubers per plant. Studies by Grewal, *et al.* [17] also showed the positive influence of potassium on number of tubers produced per plant. Similarly, AL-BALIKH [18] showed that plants provided with organic fertilizer of N, P, K produced more tubers as compared to those with a deficit of these.

Significant differences were noted on the average number of tubers produced per plot with the highest number of tubers recorded with plants applied with BSU Grower's compost, while no organic fertilizer application had the lowest number of tubers per plot. These results indicated that organic-based fertilizers provide plants with necessary nutrients such as N, P and K that lead to an increase in the tubers [19]. Studies carried out by various authors also showed positive influence of N, P and K on Irish potato production.

ii. *Effect of variety*. Significant differences were observed among the varieties in terms of the number and weight of marketable tuber yield. Igorota produced the highest number and heaviest marketable tubers of 1,780 g/ $5m^2$ but in comparison with Bengueta with 1,250 g/ $5m^2$. Other varieties had yields ranging from 840 to 1,140 g/ $5m^2$.

The high yield among varieties may be correlated with the wide canopies and the leaf area of the variety. Balas [20], reported that there was a positive correlation between marketable yield and canopy cover. Granola was the lowest yielder among the varieties. This may be attributed to its slow growth rate as shown by it low canopy cover and plant height.

This result corroborated with the study conducted by Simongo [21] who reported low yield of Granola and concluded that Granola may not be suited or adapted for organic production.

The number of tubers per variety was significantly different with Igorota having the highest number of tubers of 209 tubers as compared with Granola (check) with 98. The development of more number of tubers per plant with higher tuber weight has resulted in recording higher weight of tubers per variety. These findings support the observations of Verma, *et al.* [22] that the yield of potato was significantly increased from 16.63 mt ha-1 in Granola to 24.75 mt ha-1 in Jallenie.

Plate-1. Tubers of five potato varieties treated with organic-based fertilizers

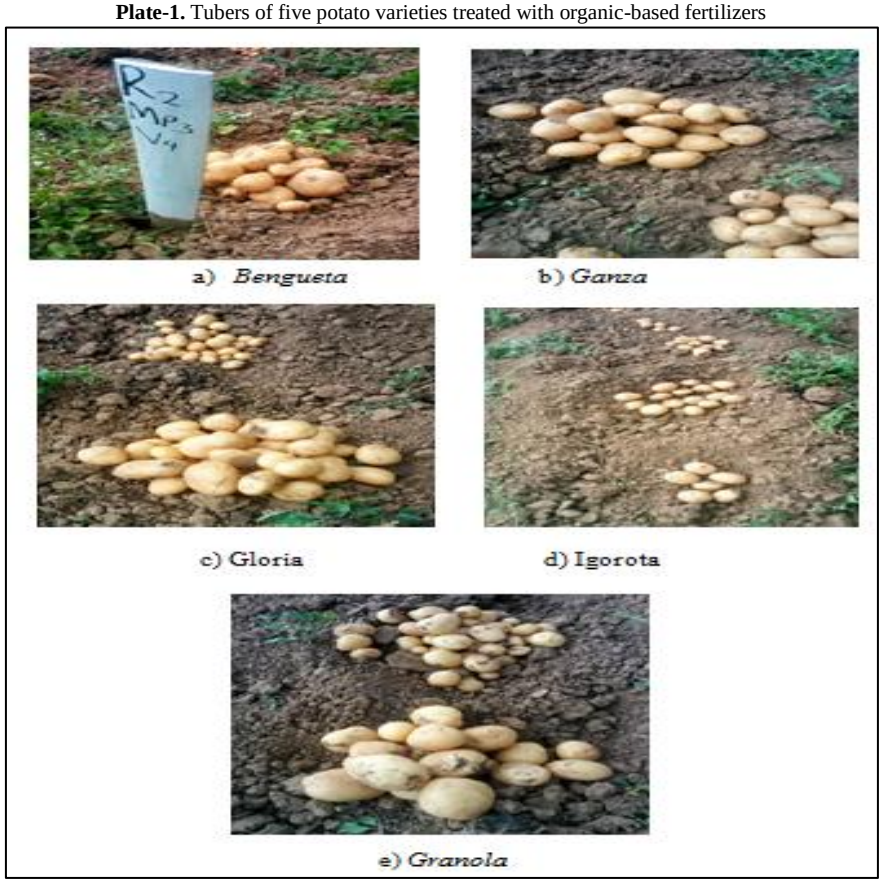
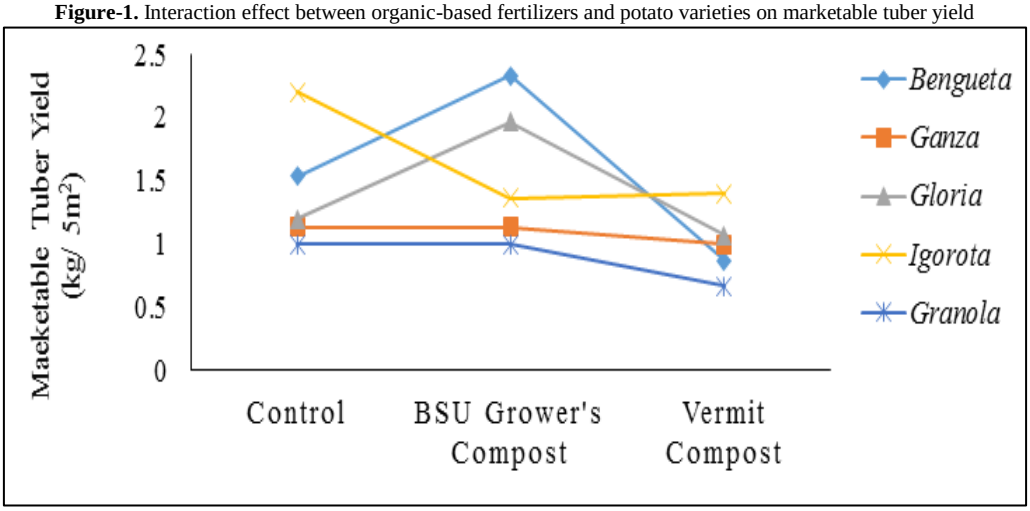


Table-7. Number and weight of marketable and non-marketable tubers, total yield per plot and computed yield of potato varieties treated with organic-based fertilizers

Treatment	Marketable			Non-market-able	Total yield (g/5m^2)
	Number	Weight (g/5m^2)	Number	Weight (g/5m^2)	
Organic Based Fertilizer					
No Organic Fertilizer	331	1,500^{b}	38	1,530	3,030
BSU Grower's Compost	380	2,120^{a}	23	1,450	3,570
Vermicompost	374	2,310^{a}	25	1,640	3,950
VARIETY					
Bengueta	145	1,250^{ab}	14	940	2,190
Ganza	129	1,140^{c}	15	1,060	2,200
Gloria	113	920^{b}	18	900	1,820
Igorota	209	1,780^{a}	10	610	2,390
Granola (check)	98	840^{c}	15	1,010	1,850
OBF x V	ns	*	ns	Ns	*
CV (a) (%)	8.30	32.90	12.70	17.50	4.50
CV (b) (%)	17.50	18.50	32.20	29.30	16.40

i. *Interaction effect.* There was a significant interaction effect observed between the organic-based fertilizer treatments and the potato varieties on the weight of marketable tuber yield (Figure 1). Varieties Bengueta and Gloria applied with BSU Grower's compost produced the heaviest marketable tubers while Granola produced the lowest weight of tubers applied with different organic-based fertilizers.

Figure-1. Interaction effect between organic-based fertilizers and potato varieties on marketable tuber yield



4. Correlation Analysis among Different

4.1. Characters of the Potato Varieties

Plant height. Significant correlation was observed between plant height and canopy. While between plant height and survival, it was observed to be significant but with no significant correlation on the total yield (Table 8). This indicated that taller plants produce greater canopies and had higher survival rates. This is true as taller plants will naturally produce more branching leading to greater canopy cover. Statistically, the extent to which character influence each other's pathway to yield depends upon the strength or correlation among them and their respective direct effect on yield [23].

Canopy cover. Canopy cover was significantly and positively correlated with plant vigor (Table 8). Vigorous plants tend to produce more canopy; hence, they are called vigorous. Ambrose, *et al.* [24] reported positive correlation between canopy cover and plant vigor. This result is similar to the findings reported by Yerima [25], which stated that leaves, terminal leaflet area, length of primary stolon exerted the maximal direct positive effect on yield.

Plant vigour. The correlation between plant vigour and leaf miner was positive and significant. This shows that vigorous plant maybe an attribute of resistant to leaf miner and other pests and diseases conditions. However, negative correlation between leaf miner and marketable yield was not significant (Table 8).

Marketable yield. Marketable yield was significantly and positively correlated with total yield. Higher marketable yield contributes to higher total yield. In fact, Singh, *et al.* [23], reported that in order to get a clear picture of the interrelationships between traits, the direct and indirect effects of the different characters should be worked out.

Table-8. Correlation analysis among different characteristics of potato varieties treated with organic-based fertilizers

Characters	H	CC	S	LB	PV	LAI	MY	NMY	TY
H									
CC	0.685**								
S	0.305*	0.434**							
LB	0.046	0.019	-0.129						
PV	0.134	0.385**	0.217	0.065					
LAI	0.151	0.19	0.187	-0.088	0.073				
MY	0.178	0.14	0.156	-0.234	0.091	0.167			
NMY	0.138	-0.04	-0.006	0.027	0.076	-0.131	-0.245		
TY	0.208	0.124	0.153	-0.235	0.108	0.144	0.969**	-0.015	

, * - Highly significant relationship at 5% and 1% level of probability respectively

H – Height, CC – Canopy cover, S – Survival, LB – Late blight, PV – Plant vigour, LAI – Leaf area index, LM – Leaf miner, MY – Marketable yield, NMY – Non-marketable yield, TY – Total yield

5. Conclusion

BSU Grower's compost and vermicompost can be used for organic production of potato. Igorota, Bengueta and Ganza are also recommended for organic potato production.

Bengueta applied with BSU Grower's compost showed highest marketable tubers on the interaction effect between the organic-based fertilizers and the potato varieties.

Based on the results of the study the following conclusions are drawn:

1. Among the different treatments plants applied with BSU Grower's compost were observed to be the best performer.
2. Igorota and Bengueta had the highest number of marketable tubers and yield per plot indicating that these varieties are the most adoptable under organic production.

3. Ganza was observed to have a stable interaction effect on all the three different treatments on the yield of marketable tubers.

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