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RESEARCH ARTICLE

FERTILIZER MANAGEMENT OF TISSUE CULTURED CAVENDISH BANANA

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ABSTRACT

The experiment was conducted at the Campus Nursery of the Pangasinan State University-Sta. Maria Campus, Sta. Maria, Pangasinan, Philippines which is approximately three (3) kilometers from the town proper. This study generally aimed to evaluate the organic and inorganic fertilizer combination on the growth and yield performance of tissue cultured Cavendish banana. Specifically, it attempted to determine the best treatment level of organic and inorganic fertilizer and to determine the cost and return of the different treatments. The five (5) treatments replicated four (4) times were laid out in Randomized Complete Block Design (RCBD). The treatments were: Treatment 1 – 100% inorganic fertilizer, Treatment 2 – 100% organic fertilizer, Treatment 3 – 75% organic fertilizer + 25% inorganic fertilizer, Treatment 4 – 50% organic fertilizer + 50% inorganic fertilizer and Treatment 5 – 25% organic fertilizer + 75% inorganic fertilizer. Based from the results obtained, the combined application of organic and inorganic fertilizer regardless of rates had comparable effect with the pure inorganic fertilizer application in the final height of plants. In terms of mid-trunk diameter, higher rates of inorganic fertilizer combined with organic fertilizer have comparable effect with the sole inorganic fertilizer application. The equal rates of organic and inorganic fertilizer outperformed all other treatments in the weight of fruits per plot in kilograms. On the net income and return on investment, organically grown banana obtained the highest.

INTRODUCTION

Bananas (*Musa acuminata* L.) are grown in all tropical regions and play a key role in the economies of many developing countries. In terms of gross value of production, bananas are the world's fourth most important food crop after rice, wheat and maize. They are a staple food and an export commodity. As a staple, bananas (including plantains and other types of cooking bananas) contribute to the food security of millions of people in much of the developing world, and when traded in local markets they provide income and employment to rural populations. As an export commodity, they are key contributors to the economies of many low income food deficit countries. Bananas are the world's most exported fresh fruit in terms of volume and value **(**FAO, 2002). For Asian exporters, mainly the Philippines (the leading exporter in the region and the second largest supplier globally) has supplied 2.7 million. tonnes of banana to the market in 2013 (Alemu, 2017). In the same year, the global banana trade reached a new peak, marked by ample supplies due to production recovery in the major banana - producing areas and strong demand in all major markets. As a result, exports surpassed 17 million tons – 6.1 percent above the level in 2012 and marking a third consecutive year of strong export growth (Abalos and Sampaga, 2013).

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Bananas are an important food item for Filipinos, a source of income for local farmers and a foreign exchange earner for the country. They are the leading Filipino fruit crop in terms of area, volume and value of production (Bureau of Agricultural Research, 2002). It is a rich source of calorie, as well as most of the vitamins essential for human nutrition. Bananas are rich in carbohydrate, potassium and vitamins, including A, C, and B_6. They are a good source of dietary fiber and are fat-free (Hossain, 2014). It is often serve as a dessert after meal, it is eaten fresh or as an ingredient in salads or in pastries. It is one of the most common tropical fruits in the Philippines almost found growing in backyards of rural areas. The expansion and intensification of production in large plantations in the 1980s and early 1990s gave rise to a series of environmental problems. More importantly, the production of bananas for export is generally intensive, with high levels of external inputs. Most farms rely on the frequent use of agrochemicals to maintain fertility (FAO, 2002).

One of the major factors influencing banana yields is crop management, particularly plant nutrition. To sustain high production levels under low soil fertility and organic matter scenario, it becomes necessary, therefore, not only to meet the crop requirements but also improve soil fertility and organic matter levels. Banana which is a heavy feeder crop requires a large amount of nutrients (Panelo and Diza, 2017) for its growth, yield and biomass production (Hazarika *et al*., 2015).

The unabated increase in the cost of fossil fuel products such as the synthetic and inorganic fertilizer makes these necessary inputs in crop production limiting. Besides being expensive these synthetic fertilizers likewise are environment pollutants (Abalos and Sampaga, 2013), polluting land, watercourses and aquifers, and a reduction in biological diversity (FAO, 2002). Moreover, the use of synthetic fertilizers alone has deleterious effect on soil physical, chemical and biological properties and productivity in the long run (Ganapathi and Dharmatti, 2018). Thus, using synthetic fertilizers should be reduced or avoided. However, due to intensive cropping, total elimination of these synthetic fertilizers may not be feasible (Abalos and Sampaga, 2013).

Surely, the application of fertilizers is one of the most important factors to improve yield. But due to continuous use of synthetic fertilizers under intensive cultivation system, soils are being degraded physically as well as nutritionally. Proper plant nutrition is necessary not only to enhance yield, but to augment soil fertility. Farmers depend on their crop productivity and keeping the production cost low for better profit, however, improved fertilizer management would enable producers to optimize their production systems. With the right type of agriculture, emissions leading to climate change can be minimized and the capacity of nature to mitigate climate change can be harnessed to sequestrate significant quantities of atmospheric carbon dioxide – especially in the soil. Global adoption of organic agriculture has the potential to sequester up to the equivalent of 32% of all current man-made greenhouse gases (GHG) emissions. Organic Agriculture is a production system that sustains the health of soils, ecosystems and people. It utilizes ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. It combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved. The Food and Agriculture Organization of the United Nations (FAO) regards organic agriculture as an effective strategy for mitigating climate change and building robust soils that are better adapted to extreme weather conditions associated with climate change (IFOAM, 2009).

In view of the existing condition of soil quality and environmental security, and also because of the spiraling cost in the application of inorganic fertilizers, there is a need to look into alternative methods. The combined use of inorganic and organic fertilizers must be developed as strategy not only to satisfy the needs of the crops but also to increase organic matter content of the soil.One of the income-generating projects of the Pangasinan State University is the production of PSU organic fertilizer. In this study, the PSU organic fertilizer was considered due to its organic based source of nutrients that is concerned in activating soil microorganisms, subsequently, increasing the availability of nutrients that a plants feed on and at the same time improves soil properties.Agricultural diversification to meet our future needs call for the adoption of new technologies in agriculture. Utilization of the best cultural practices, fertilization, pest control measures will not give the necessary results without the use of best planting material. Tissue culture has been significant role in producing disease free planting materials of vegetative propagated crops in horticulture industry of many countries. Many research works have been conducted on the potential of in vitro plantlets over conventional one on productivity per unit area particularly in horticultural crops. Almost all research results revealed that in vitro plantlets significantly perform better than conventional in terms of uniformity, earliness, yield, and quality due to free from disease load. The limiting factor of using in vitro plantlets from the point of view of farmers is the higher price of the material if compared to conventional and tissue culture plants require additional care and improved management. Higher cost is justified by achieved high economic returns (Tegen and Mohammed, 2016). Due to its vigorous growth and high yields, the tissue cultured banana planting material has become increasingly important. It is the ideal method of producing banana planting material for the establishment of new or replacement of existing plantations that has gained global acceptance.

There are more than 1,000 varieties of bananas produced and consumed locally in the world, but the most commercialized is the Cavendish type banana, which accounts for around 47 percent of global production. Cavendish banana crops are able to achieve high yields per hectare and, due to their short stems, are less prone to damage from environmental influences such as storms. Cavendish banana plants are also known for recovering from natural disasters quickly. Approximately 50 billion tonnes of Cavendish bananas are produced globally every year (FAO, 2017). In January-March 2016, production of banana was estimated at 2,048.76 thousand mt, Cavendish variety accounted for 54.3 percent of the country's total banana production (Philippine Statistics Authority, 2016). It accounts for 95 percent of all bananas sold commercially, is seedless, making it extremely convenient to eat. It contains around 400milligrams of potassium per 100 g fresh fruit, comparable to many cooked pulses, meat or fish (FAO, 2016).

Objectives of the Study

Generally, this study was conducted to evaluate the organic and inorganic fertilizer combination on the growth and yield performance of tissue cultured Cavendish banana. Specifically, it attempted to determine the best treatment level of organic and inorganic fertilizer and to determine the cost and return of the different treatments.

MATERIALS AND METHODS

Site Description

The experiment was conducted at the Campus Nursery of the Pangasinan State University-Sta. Maria Campus, Sta. Maria, Pangasinan, Philippines which is approximately three (3) kilometers from the town proper. This study was conducted from October 6, 2015 to September 9, 2016 with a duration of 340 days. Climatic classification of Pangasinan belongs to Type 1. This type is characterized by a pronounced wet season from May to October and dry season during the months of November to April.

Planting Material

The tissue cultured Cavendish banana seedlings were taken from the Tissue Culture Laboratory of the Pangasinan State University-Sta. Maria Campus, Sta. Maria, Pangasinan. The tissue cultured Cavendish banana plantlets for transplanting were selected based on their approximate height of 30 cm and with the presence of three (3) leaves.

Fertilizers

The organic fertilizer was obtained from the PSU Organic Fertilizer Production Project of PSU-Sta. Maria Campus, one of the development projects of the university while the inorganic fertilizers were purchased from Samson Agricultural Supply (Urdaneta, Pangasinan, Philippines).

Experimental Design

The Randomized Complete Block Design (RCBD) with four (4) replications was used in this study. The design was specifically used to the measure of agronomic characteristics (quantifiable growth and yield).

Treatments

The treatments used were the following:

Treatment 1 –100% Inorganic fertilizer (140-60-60 kg/ha) (0.549 kg/plot 46-0-0 sidedress + 0.24 kg/plot 16-20-0 sidedress)

Treatment 2 –100% PSU-Organic Fertilizer (10,000 kg/ha) (24 kg/plot basal)

Treatment 3 –75% PSU-Organic Fertilizer + 25% Inorganic Fertilizer (18 kg/plot basal + 0.411 kg/plot 46-0-0 sidedress + 0.18 kg/plot 16-20-0 sidedress)

Treatment 4 –50% PSU-Organic Fertilizer + 50% Inorganic Fertilizer (12 kg/plot basal + 0.275 kg/plot 46-0-0 sidedress + 0.12 kg/plot 16-20-0 sidedress)

Treatment 5 – 25% PSU-Organic Fertilizer + 75% Inorganic Fertilizer (6 kg/plot basal + 0.137 kg/plot 46-0-0 sidedress + 0.06 kg/plot 16-20-0 sidedress

Soil Sampling

Prior to land preparation of the experimental area, soil samples were taken by digging 12 sites randomly selected in a zigzag pattern at 40 cm deep. A one inch thick column of soil was taken from each site.

Afterwards, all soil samples were thoroughly mixed, then from each site, a kilogram soil sample was obtained, air dried and submitted to the Bureau of Soils, Lingayen, Pangasinan for soil analysis.

Land Preparation

The land was plowed twice with an interval of one week. The field was properly harrowed until the desired tilt was attained. The holes were prepared with size of 30 cm in width and 30 cm in depth.

Distance of Planting

The tissue cultured Cavendish banana were transplanted in 4 meters between rows and 4 meters between hills in a square system of planting. Transplanting was done late in the afternoon.

Fertilizer Application

Before applying the organic fertilizer, dikes were constructed to enclose each treatment. Organic fertilizer was applied basally at the bottom of each hole following the different treatment levels then were covered with soil. The inorganic fertilizer was applied two (2) times at 2^{nd} and4^{th}month after transplanting following the recommended dosage of 120-20-0 kg/ha NPK/ha based on the result of the soil analysis.

Weed Control

The weeds were eradicated six (6) times through hand weeding throughout the duration of the study. This was done to minimize crop-weed completion and to maintain sanitation of the area.

Cultivation

Cultivation was done by hilling-up two (2) times using a shovel immediately after each application of the inorganic fertilizer.

Water Management

Water application was done to the plants everyday for three (3) weeks after planting. Irrigation with the used of water pump was done six (6) times (30, 60, 90, 150, 210 and 290DAP) throughout the duration of the study to make sure that the adequate soil moisture was available for the growth and fruit development of the plants and for the absorption of nutrients.

De-blossoming

The male flower buds were cut after the bunch has fully emerged to prevent competition for nutrients and to avoid shelter for pests as well as the last hand has emerged, and the fruits were starting to curve up.

Harvesting

Harvesting was done by cutting the bunch from the stem with the used of a bolo, eight (8) weeks after de-blossoming. The bunch was not allowed to touch the ground while harvesting by cutting the trunk slowly and partially and holding the tail end of the bunch before it touches the ground to avoid damaging the fruit.

Data Collection

Growth parameters

The initial and final height of the plants were taken by measuring the plant from the base up to the tallest leaves at the start and termination of the study using a meter stick. The initial and terminal number of leaves were taken by counting the number of leaves per plant at the start and termination of the study. Mid-trunk diameter was taken by measuring the circumference using a tape measure and it was divided by two (2).

Yield parameters

The number of hands per bunch and number of fingers per hand were taken by counting the number of hands per bunch and number of fingers per hand after harvest. The length of fingers were taken by measuring the finger length with the used of a foot rule after harvest while the diameter was measured with the used of a vernier caliper after harvest. Weight of fruits was taken by weighing the de-handed marketable banana fruits after harvest from each plot and was projected to per hectare basis.

Statistical Treatments of Data

All data gathered in this study were subjected to the following statistical procedures: all treatment means were derived from the raw data; to determine the statistical significance among treatments means, the analysis of variance (ANOVA) for RCBD was used; and to determine the degree of comparison among treatment means, the Duncan's Multiple Range Test (DMRT) was utilized.

RESULTS AND DISCUSSION

Soil Analysis

The physical and chemical properties of the soil in the experimental area is presented in Table 1. The experimental area was characterized by a heavy textured soil with a 6.4 pH. The organic matter was low while the P_2O_5 was high and the K_2O was sufficient. These show that the soil tested was made up largely of clay loam. A soil mixture that contains more clay than other types of rock or minerals is clay loam .Clay loam usually contains adequate plant nutrients and most types of plants and crops can be grown. The soil pH was slightly acidic due to the lower than 7value.

Table 1. Physical and chemical properties of the soil in the experimental area (Bureau of Soils, Lingayen, Pangasinan-Philippines)

Properties	Value
Texture	Heavy
pH	6.4
OM	Low
P_2O_5	High
K_2O	Sufficient

Organic Fertilizer Analysis

Table 2 shows the basic chemical properties of the PSU-Organic Fertilizer. The organic fertilizer had an organic matter content of 39.37%, moisture content of 34.38% and pH of 7.02. The macronutrient concentrations (N, P and K) were 3.30%, 2.24% and 5.07%, respectively (Table 2). The analysis demonstrates that the organic fertilizer has adequate organic matter and moisture content; and a neutral pH.

Table 2. Basic Chemical Properties of the PSU-Organic Fertilizer (Della *et al.* (2010)

Properties	Value
Organic Matter	39.37%
Moisture Content	34.38%
pH	7.02
Total N	3.30%
Available P_2O_5	2.24%
Soluble K_2O	5.07%

Influenced of Different Fertilizer Combinations on Growth Parameters

Summary Table 3 shows the influenced of different fertilizer combinations on growth parameters.

Initial Height

All fertilization treatments range from 0.50 - 0.77 m on the initial height of the plants. It can be noted that there were no significant differences existed among the treatment means. This was due to the fact that the tissue cultured Cavendish banana were newly transplanted and the basally applied nutrients were not yet utilized by the plants thus they have uniform height.

Final Height

On the final height of the plants, highly significant differences were observed among treatment means. It can be gleaned from the table that those treatments applied with different rates of organic fertilizer combined with inorganic fertilizer had similar effects with the pure application of the recommended rate of inorganic fertilizer. Significant result is attributed to the application of the recommended rate of inorganic fertilizer as well as to the mineral elements that were present on the organic fertilizer based on the nutrient analysis in Table 2 where it contained 39.37% (organic matter), 3.30% (total N), 2.24% (available P_2O_5) and 5.07% (Soluble K_2O). Moreover, the result of soil analysis of the experimental area, the P_2O_5 is high and the K_2O is sufficient (Table 1) that enhanced growth and development of the plants. This is in confirmation with the findings that banana responded favorably to organic manure, FYM, 100% recommended dose of chemical fertilizers and in combination with chemical fertilizers (Kuttimani *et al.*, 2013). Furthermore, the application of nitrogen at 200 g/plant i.e. 25 % N through FYM at the time of planting and 75 % N through inorganic fertilizers in seven splits, recorded maximum average plant height (209 cm) (Bhalerao *et al.,* 2010).

Mid-trunk Diameter

Higher rates of inorganic fertilizer combined with organic fertilizer had comparable effect with the sole inorganic fertilizer applicationon the mid-trunk diameter. Significant result is due to the effect of applied recommended rate of inorganic fertilizer and to the mineral elements contained in the organic fertilizer (Table 2) that had similar effect with the 100% inorganic fertilizer in addition to the high available P_2O_5 and sufficient Soluble K_2O of the soil analysis of the experimental area (Table 1) that helps induce nutritional needs of the plants which enhanced the development of mid-trunk diameter. These outcomes oppose the findings that neither soil amendments, nor fertilizer compositions had a significant effect on pseudostem height or girth of banana (Al-Busaidi, 2013). However, separate findings revealed that all vegetative growth of Grande Naine banana plants i.e., pseudostem height, and pseudostem circumference were greatly increased by the studied fertilization treatments (recommended dosage + different organic fertilizers + different bio-fertilizers as compared with control plants - recommended dose of chemical fertilizer (Baiea and EL-Gioushy, 2015).

Initial Number of Leaves

It can be gleaned from the table that the newly transplanted tissue cultured Cavendish banana in almost all the fertilization treatments had three (3) initial number of leaves and therefore there was no significant differences existed among treatment means.

Terminal Number of Leaves

Fertilizer application had significant effect on terminal number of leaves. The most number of terminal leaves was recorded in the equal rates of inorganic and organic fertilizer. This was due to the balance combined action of organic and inorganic fertilizer. These results corroborates on the significant effect on the integrated application of chemical fertilizers along with organic manures, which attributed the increase in nutrient levels of NPK; especially nitrogen that enhanced the vegetative growth like number of leaves (Kuttimani, *et.al.*, 2013). Likewise, green leaves number was greatly increased by the studied fertilization treatments (recommended dosage + different organic fertilizers + different bio-fertilizers as compared with control plants - recommended dose of chemical fertilizer (Baiea and EL-Gioushy, 2015). On the other hand, this contradicts with the result that there is no significant effect on the terminal number of leaves of banana applied with different farm manures (Panelo and Diza, 2017).

of hands per bunch (Summary Table 4). The result reveals a comparative effect in all the treatments used in the study.

Number of Fingers per Hand

Fertilizer application had no effect on number of fingers per hand. It can be noted that none of the treatments significantly affected the number of fingers per hand in all the parameters considered.

Length of Fingers per Hand

The 50% PSU-organic fertilizer +50% inorganic fertilizer produced significantly the longest finger per hand (19.00 cm), and the shortest finger per hand was noted in 100% PSU-organic fertilizer (10.28 cm). Significant result is due to the balance applications of organic and inorganic fertilizers that contributed to longer fingers per hand produced. The findings contradict the result of the study that neither soil amendments, fertilizer applications methods nor fertilizer compositions significantly affected the length of fingers per hands/bunch (Al-Busaidi, 2013).

Diameter of fingers per hand

The fertilizer treatments had no effect on the diameter of fingers in centimeters per hand of tissue-cultured Cavendish banana. A comparative effect in all the treatments used was noted.

Summary Table 3. Influenced of organic and inorganic fertilizer combination on the growth parameters

Treatments	Initial height (m) ^{ns}	Final height (m)**	Mid-trunk diameter (cm)*	Initial number of leaves ^{ns}	Terminal number of leaves **
T_1-100% IF	0.77	2.48 a	26.66 a	3.37	8.65 b
T_2-100% PSU-OF	0.73	1.48 c	22.80 b	3.07	7.11 e
T_3- 75% PSU-OF+25% IF	0.63	2.11 abc	23.40 b	3.00	7.69 d
T_4- 50% PSU-OF+50% IF	0.57	2.43 a	26.33 a	2.80	8.94 a
T_5- 25% PSU-OF+75% IF	0.50	2.18 ab	26.20 a	2.67	7.83 c

Summary Table 4. Influenced of organic and inorganic fertilizer combination on the yield parameters

Treatments	No. of hands/ Bunch ^{ns}	No. of fingers/ hand ^{ns}	Length of fingers/ hand (cm)**	Diameter of fingers /hand (cm) ^{ns}	Weight of fruits		
					Kgs/ plot **	Kgs/ ha	Tons/ha
T_1-100% IF	6.23	14.63	13.38 b	3.50	7.22bc	4,513	4.51
T_2-100% PSU-OF	5.77	12.17	10.28 e	3.33	6.79e	4,244	4.24
T_3- 75% PSU-OF+25% IF	6.07	12.47	10.88 d	3.43	7.02cd	4,388	4.39
T_4- 50% PSU-OF+50% IF	7.30	14.77	19.00 a	3.53	7.92a	4,950	4.95
T_5- 25% PSU-OF+75% IF	6.07	13.40	11.98 c	3.43	7.15bcd	4,469	4.47

Table 5. Cost and return analysis

Treatments	Items				
	Yield (Kg/ha)	Total Cost	Gross Income	Net Income	ROI (%)
T_1-100% Inorganic fertilizer	4,513	45,667.12	180,520.00	134,852.88	2.95
T_2-100% PSU-OF	4,244	64,360.00	297,080.00	232,720.00	3.62
T_3- 75% PSU-OF + 25% IF	4,388	60,624.28	175,520.00	114,895.72	1.90
T_4- 50% PSU-OF + 50% IF	4,950	55,638.56	198,000.00	142,361.44	2.56
T_5- 25% PSU-OF + 75% IF	4,469	50,562.84	178,760.00	128,197.16	2.54

Influenced of Different Fertilizer Combinations on Yield Parameters

Summary Table 4 reveals the influenced of different fertilizer combinations on yield parameters.

Number of Hands per Bunch

Neither inorganic fertilizer, PSU-organic fertilizer nor fertilizer combinations had a significant effect on the number

Weight of Fruits

The heaviest weight of fruits in kilograms per plot was noted in the 50% PSU-organic fertilizer + 50% inorganic fertilizer (7.92) application. This was due to the balance application of organic and inorganic fertilizer which enhanced the weight of fruits. The findings oppose the result of the study that neither soil amendments, fertilizer applications methods nor fertilizer compositions significantly affected fruit weight (Al-Busaidi, 2013). Moreover, these findings are in accordance with the results that the increase in fruit volume was attributed to the corresponding increase in mineral elements content by the different farm manures (Hazarika, *et al.,* 2011; Jeyabaskaran, and Mustaffa, 2010; Kuttimani, *et al.,* 2013). On the other hand, the result of the study (Summary Table 4) indicates that the greatest weight of fruits also had the greatest number of leaves. This may be another reason for the high weight of fruits in this treatment.

Cost and Return Analysis

The cost and return analysis of one-hectare tissue cultured Cavendish banana production treated with different fertilizer combinations (Table 5) shows that organically grown banana (Treatment 2 – 100% PSU-Organic Fertilizer) obtained the highest net income and return on investment (ROI). This was due to the higher market price of organically grown crops. Journal report stated that many of the consumers who purchase these products say paying more for organic produce, is a trade-off they are willing to make in order to avoid exposure to chemical pesticides and fertilizers (The Wall Street Journal, 2013). In a study published in the Journal of Environmental Health Perspectives in 2006 showed that within five days of substituting mostly organic produce for conventional produce in children's diets, pesticides disappeared from the children's urine (Chenseng, 2013).

Conclusion and Recommendations

Based from the results obtained the following conclusions were drawn: the combined application of organic and inorganic fertilizer regardless of rates have comparable effect with the pure inorganic fertilizer application in the final height of plants. In terms of mid-trunk diameter higher rates of inorganic fertilizer combined with organic fertilizer have comparable effect with the sole inorganic fertilizer application. The equal rates of organic and inorganic fertilizer outperformed all other treatments in the number of terminal leaves, length of fingers per hand and weight of fruits per plot. On the net income and return on investment, organically grown banana obtained the highest. A verification study be conducted along this line for a more conclusive results. However, other organic manures may also be considered in future studies as well as on other varieties of banana tissue cultured or not.

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