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Evaluating Two Varieties of Sweet Pepper Using Different Nutrient Sources to Increase Productivity

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Abstract

This experiment aims to increase sweet pepper production sustainably by using manures and a combination of manure and fertilizer. Manures are well known to improve soil health and maintain crop production for a relatively long period. This study was conducted under a tunnel house at the National Agricultural Research and Extension Institute at Mon Repos East Coast Demerara, Guyana. Plots were arranged according to strip plot design with two treatments (Aristotle and Sunsation), four rates (R1: 0 g/plant), (R2: 350 kg NPK/ha + 10 t vermicompost/ha), (R3: 10 t poultry manure/ha + 10 t vermicompost/ha and (R4: 350 kg NPK/ha + 10 t poultry manure/ha) and replicated thrice. These nutrients were applied in a split application at four weeks before planting, and four, eight, and twelve-week intervals after planting. The varieties did not differ from one another for the vegetative parameters tested. Plants treated with Rate 2 achieved significantly better growth parameters such as plant height, plant spread, and number of branches than the other rates. Sunsation obtained a significantly higher yield of 21.4 t/ha at the 5% level as compared to Aristotle (19.9 t/ha). The various rates recorded significant differences in yield. Rate 2 obtained a significantly higher yield of 32.8 t/ha followed by Rate 4 with 24.9 t/ha, then Rate 3 (17.0 t/ha). The lowest yield of 7.8 t/ha was attained by Rate 1. The interaction of varieties and rates showed statistically significant differences in yield. The interaction of Sunsation and Aristotle with Rate 2 achieved a superior yield of 34.8 t/ha and 30.7 t/ha respectively than other rates. Rate 4 also obtained significant interaction with Sunsation and Aristotle to achieve a yield of 25.7 t/ha and 24.1 t/ha respectively than Rate 3. Rate 3 interacted significantly with Sunsation and

Aristotle and obtained a yield of 16.5 t/ha and 17.5 t/ha compared to Rate 1. Rate 1 achieved the least interaction for both varieties tested. Rates differed significantly for fruit shelf-life at room temperature. Fruits obtained from Rate 3 recorded a significantly longer fruit shelf-life of 14.7 days for 50% decay when stored at room temperature (30.3˚C) than other rates. The lowest fruit shelf-life of 7.7 days was obtained from Rate 1. This study indicated that the Sunsation variety is better to cultivate because of superior improvement in growth and yield attributes. The application of Rate 2 can considerably increase yield and when combined with Sunsation variety superior yield and yield attributes can be obtained.

Keywords

Variety, Manure, Fertilizer, Yield, and Interaction

1. Introduction

Sweet pepper *(Capsicum annum L.)* is cultivated predominantly throughout the coastal regions. It is grown primarily for the local market and to a lesser extent the regional markets. Sweet peppers production in Guyana has increased considerably from 1493 metric tonnes in 2008 to 37,886 metric tonnes in 2018 [1]. This drastic increase in production is due primarily to substantial demand by fast-food chains, hotels, restaurants, supermarkets, and consumers. It is also a rich source of vitamins and minerals [1], which helps protect the human body from oxidative damage that may lead to heart disease, cancer, and ageing. This crop is gaining importance as a high-value crop recently and occupies a strong place among vegetables in Guyana. It can also add delicacy and pleasant flavour coupled with rich colours (green, red, yellow, purple, orange, etc.) to different cuisines.

The yield and quality of sweet pepper produced by growers are fairly low when compared to other countries. There is a need to introduce new varieties of sweet pepper to increase yield, quality, and production to meet the growing demand. As such Aristotle and Sunsation varieties were evaluated because of their high-yielding nature of approximately 20,000 kg/ha. They fetch a premium market price for their large bell-shaped fruits ranging from 12 - 13 cm. These varieties are also resistant to bacterial leaf spots (Race 1, 2, and 3), potato viruses, and Tobacco Mosaic Virus 31.

The current production system is heavily dependent on chemical fertilizers to increase crop yields. However, throughout it has led to environmental deterioration, loss of soil fertility, less agricultural productivity, and soil degradation [2]. [3] reported that the large-scale usage of chemical fertilizers with one or two nutrient elements had increased deficiencies of several secondary (S and Ca) and micronutrients (Zn, Mn, Fe, B, and Cu), which are causing serious concern for the sustainable production system. The price for this commodity is constantly increasing and may not be affordable especially for small-scale farmers to ensure that adequate nutrient is available for crop growth and yield. Compared to inorganic fertilizer organic manure is readily available to farmers at a cheaper price. Besides, it also restores soil organic matter in the form of humus, increasing microbial population thereby improving soil health, and also adds macro and micronutrients to the soil [4]. These manures can also improve soil properties such as better moisture retention, aeration, and nutrient conservation.

Vermicompost and poultry manure are two nutrient sources that are known to increase crop growth and yield. Vermicompost is worm excreta which is a rich source of macro (NPK) and micronutrients (Ca, Mg, Zn, and Mn) [5]. It can provide nutrients slowly and steadily which enables plants to absorb these nutrients over time and also improve root formation, elongation of the stem, and production of biomass for vegetable and ornamental plants [6]. Vermicompost also contains enzymes such as amylase, lipase, cellulase, and chitinase which can decompose organic matter in the soil (to release the nutrients in the available form to plant roots) even after being excreted. It also has many plant growth promoters, enzymes rich in plant nutrients, beneficial bacteria, and mycorrhizae [5]. Poultry manure can also improve soil physical and chemical properties thereby increasing crop growth and yield. It also contains higher levels of NPK compared to other types of manures. This manure can enhance microbial activity in soil, anion and cation exchange capacity, organic matter, and carbon content of the soil. It is also a source of all necessary macro and micronutrients in their available forms for plant growth and reproduction during mineralization. These nutrient sources may not be able to provide sufficient nutrients to encourage crop growth and yield for long periods. Thus, it is important to combine manures/compost with inorganic fertilizers to provide adequate nutrients for plant growth and yield in a sustainable manner. Consequently, a study was conducted to determine the best combination of manures and inorganic fertilizer for sweet pepper growth and yield.

1.1. Research questions

1) Which variety will flower the earliest or latest?
2) What are the differences in growth characteristics between the two varieties?
3) What is the yield among the different varieties using the different fertilizers?
4) What is the cost of production for sweet pepper using different fertilizers?
5) Is there significant differences among the varieties?

1.2. Literature Review

[7] The application of 3 tons/ha gives the highest yield of (265 fruits), followed by 2.5 ton/ha application rate (250.33 fruits).

[8] Found that the combination of poultry manure and fertilizer (15 t/ha + 45 kg/ha 15:15:15) gave the highest yield of 14,200 Kg/ha.

[9] They found that poultry manure at a rate of 8 tons/ha give the highest for

2012 and 2014 of 22,071 Kg/ha and 20,090 Kg/ha respectively.

[6] The application of 3 t ha of poultry manure gave a higher yield of pepper of 8395.15 and 7436.79 kg ha respectively for both locations.

[8] Poultry manure rates of 8 tons/ha, 10 tons/ha and 12 tons/ha attained the highest yield of 23,000 kg/ha.

The use of organic manure has been reported to enhance soil productivity, increase the soil's organic carbon content, soil micro-organism, improves soil structure, the nutrient status of the soil and enhance crop yield [1] [10] [11].

[12] observed that the application of 10 t/ha of poultry manure gave a significantly greater number of fresh pods and fresh pod weight in okra compared with 50 kg N + 22 kg P + 6 kg K·ha^{-1}.

[13] reported the beneficial effect of the combined application of organic and inorganic sources which increased fruit number, fruit weight/plant and fruit yield of chilli compared with either organic or inorganic fertilizer applied alone.

[14] observed that chemical fertilizer application could be brought down to 25 to 50 percent when applied with vermicompost. Further, the quantity of organic manure level also can be brought down by 50 per cent when vermicompost was used as a source of organic manure.

[15] found that the application of vermicompost and ammonium nitrate (1:1) which increased the sweet pepper yields but had no significant effect on radish yield.

[16] reported that the yield of sweet pepper has increased with organic treated plot than mineral fertilizers under field conditions. While dry matter increased with increased vermicompost (600 g) and root dry matter (400 g) in the greenhouse condition.

[17] observed that the application of vermicompost on soil conditions in combination with chemical and organic fertilizers significantly increased the growth and yield attributes of chilli as compared to organic and chemical fertilizers alone.

[18] observed maximum plant dry weight and fresh fruit weight in capsicum treated with organic manure like chicken manures, compost and vermicompost treatment than inorganic fertilizers and also increased microbial biomass in the field conditions.

[19] found that the higher chilli fruit yield was obtained with 50% poultry manure and 50% inorganic N.

Poultry manure at 9 t per ha resulted in a higher fruit yield of pepper compared to farm yard manure (FYM) at 30 t per ha and poultry manure has the highest manganese, zinc, and phosphorus contents [20].

1.3. Hypothesis

1.3.1. Null

There are no significant differences between the mean yield of red, green, and yellow varieties of sweet pepper.

1.3.2. Alternate

There are significant differences between the mean yield of red, green, and yellow varieties of sweet pepper.

1.3.3. Null

There are no significant differences in yield between inorganic fertilizer and a combination of fertilizer and manure the different fertilizers.

1.3.4. Alternate

There are significant differences in yield between inorganic fertilizer and a combination of fertilizer and manure.

1.4. Research Objectives

1) To determine which rates of fertilizers will give the best yield,
2) To determine which variety will obtain the highest yield,
3) To determine which variety is more susceptible to pests and diseases,
4) To determine the cost of production for each variety,
5) To determine which can improve the storage life of sweet pepper fruits.

2. Rationals/Description of Methodology

This experiment was done at NAREI Mon Repos, under a plastic house for a two-year period. Seeds were procured by NAREI and sown in seedling trays in the nursery. The plot size for this trial was 36.4 m^2. Seedlings were planted 0.45 m apart and 0.45 m between rows. The plot was set out according to the split-plot design with two varieties (Aristotle and Sunsation), four rates (R1: 0 g/plant), (R2:350 kg NPK/ha + 10 t vermicompost/ha), (R3: 10 t poultry manure/ha + 10 t vermicompost/ha and (R4: 350 kg NPK/ha + 10 t poultry manure/ha) and replicated thrice. Nutrients were applied in a split application at four weeks before planting, and four and eight-week intervals after planting. Data were collected on plant height, plant canopy, number of branches, number of fruits per plant, plant weight and length and width of fruits, and total yield.

Treatment rates are as follows:

R1: 0 kg.

R2: 10 t/ha vermicompost + 350 kg NPK fertilizer.

R3: 10 t/ha vermicompost + 10 t/ha poultry manure.

R4: 10 t/ha poultry manure + 350 kg NPK fertilizer.

This experiment was conducted during three crop cycles as follows:

Crop cycle 1 February 2018-August 2018.

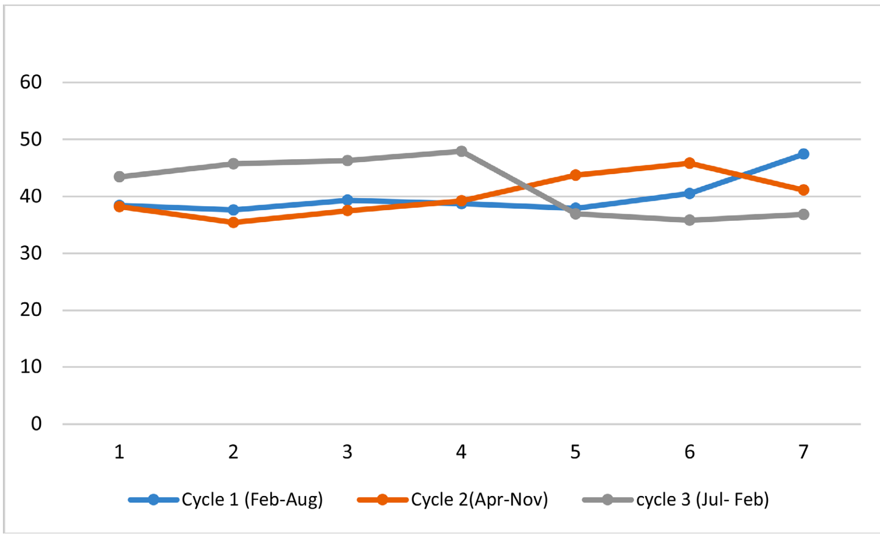
Crop cycle 2 April 2019-November 2019.

Crop cycle 3 July 2019-February 2020.

Information on the fruit shelf was collected where twelve fruits from each rate were stored at room temperature (30.3˚C) and refrigerated temperature (7˚C). And also the number of days until the onset of 50% decay (anthracnose) (**Table 1**, **Figure 1**).

Table 1. Nutrients Analysis was done by GuySuCo Laboratory.

Sample	pH	Corg	N	Ca	Mg	K	P
	%						
Vermicompost	7.89	8.65	1.59	0.24	0.18	0.06	0.01
Poultry manure	6.58	-	1.35	0.05	0.27	0.54	0.21



Data were collected on temperature thrice weekly for all crop cycles and the monthly average was determined.

Figure 1. Average temperature per crop cycle.

3. Results

3.1. Plant Growth

3.1.1. Plant Height

All growth parameters were influenced by varieties and also the interaction of varieties and rates. The result indicated that plant height did not differ significantly between the two varieties of sweet peppers at 30 DAT, 60 DAT, 90 DAT and 120 DAT (Table 2). Plants treated with Rate 2 recorded significantly taller plants of 42.6 cm (30 DAT), 60.5 cm (60 DAT), 76.5 cm (90 DAT) and 91.8 cm (120 DAT) when compared to other rates. Rate 3 and Rate 4 were at par as it relates to plant height. The shortest plants were obtained from Rate 1. The interaction of Rate 2 with Varieties 1 and 2, obtained considerably taller plants at all four growth periods compared to other treatment combinations.

3.1.2. Plant Spread

Table 3 shows no significant differences between the varieties as it relates to plant spread for the different growth stages. Rate 2 obtained notably wider plants at 30 DAT (38.3 cm), 60 DAT (55.5 cm), 90 DAT (76.1 cm) and 120 DAT (88.1 cm) when matched against the other rates. There were no significant differences between Rate 3 and Rate 4 for plant spread but differed considerably from Rate

1. Rate 1 (control/0 kg) gave the least plant spread for both varieties at all the growth stages. The interaction of Rate 2 with Varieties 1 and 2 led to a remarkable increase in plant spread at 30 DAT, 60 DAT, 90 DAT and 120 DAT as compared to the other treatment combinations.

3.1.3. Number of Branches

The varieties of sweet pepper did not differ as it pertains to the average number of branches (Table 4). The number of branches increased with all treated plants except the control. The application of Rate 2 increases the number of branches

Table 2. Represent the mean plant height (cm) for varieties and rates (Pooled data).

Rates	30 DAT			60 DAT			90 DAT			120 DAT		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
R1	25.1^{c}	24.5^{c}	24.8^{c}	37.2^{c}	34^{c}	43.5^{c}	44.3^{c}	40.7^{c}	42.5^{c}	55.3^{c}	52.5^{c}	53.8^{c}
R2	44^{a}	41.2^{a}	42.6^{a}	63.5^{a}	60.5^{a}	62^{a}	75.3^{a}	77.7^{a}	76.5^{a}	95.9^{a}	87.8^{a}	91.8^{a}
R3	37.4^{b}	34.6^{b}	36^{b}	53.3^{b}	53^{b}	53.2^{b}	64.9^{b}	67.2^{b}	66.1^{b}	77.1^{b}	80.1^{b}	78.6^{b}
R4	36.5^{b}	35.3^{b}	35.8^{b}	52.1^{b}	54.4^{b}	53.2^{b}	63.7^{b}	68.1^{b}	65.8^{b}	74.9^{b}	81.1^{b}	78^{b}
Mean	35.8^{a}	33.8^{a}		51.6^{a}	50.5^{a}		62^{a}	63.5^{a}		74.1^{a}	77.1^{a}	

Note: Means with the same letters are not significantly different from one another ($p > 0.05$).

Table 3. Effects of the various rates and varieties on plant spread (cm) (pooled data).

Rates	30 DAT			60 DAT			90 DAT			120 DAT		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
R1	23.3^{c}	21.8^{c}	22.6^{c}	36.1^{c}	32.2^{c}	34.1^{c}	44.2^{c}	40.7^{c}	42.4^{c}	55.6^{c}	48.6d	52.1^{c}
R2	38.5^{a}	37.9^{a}	38.3^{a}	55.1^{a}	56^{a}	55.5^{a}	71.2^{a}	76.1^{a}	73.6^{a}	85.8^{a}	90.3^{a}	88.1^{a}
R3	34.9^{b}	33.3^{b}	34.1^{b}	46.1^{b}	50.5^{ab}	48.2^{b}	62.1^{b}	67.6^{b}	64.9^{b}	73.8^{b}	80.3^{ab}	77^{b}
R4	34.1^{b}	32.6^{b}	33.3^{b}	45.8^{b}	50.3^{ab}	48^{b}	61.1^{b}	66.9^{b}	64^{b}	72.3^{b}	79.8^{ab}	76^{b}
Mean	32.7^{a}	31.4^{a}		45.7^{a}	47.2^{a}		59.6^{a}	62.8^{a}		71.9^{a}	74.7^{a}	

Note: Means with the same letters are not significantly different from one another ($p > 0.05$).

Table 4. Effects of the various rates and varieties on the mean number of branches.

Rate	V1	V2	Mean
R1	6.4^{c}	5.6^{c}	6^{c}
R2	11.8^{a}	11.3^{a}	11.5^{a}
R3	8.5^{b}	9.7^{b}	9.1^{b}
R4	8.9^{b}	10.2^{b}	9.5^{b}
Mean	8.9^{a}	9.2^{a}	

Note: Means with the different letters are significantly different from one another ($p < 0.05$).

(11.5) considerably more than the other Rates tested. Rate 3 and Rate 4 gave a similar number of branches, however, they differ considerably from the Rate 1 at the 5% level. The least number of branches six (6) was attained from Rate 1. Rate 2 interacted significantly with Varieties 1 and 2 for the number of branches.

3.2. Yield Parameters

3.2.1. Fruit Length and Width

The Rates did not have an effect on the fruit length and fruit width for the varieties tested (Table 5). Plants treated with Rate 2 (VC + chemical fertilizer) recorded the longest fruit (7.4 cm) and the widest fruits (7.3 cm) which differs considerably from all other Rates. Rate 3 and Rate 4 were at par for the length and width of fruits but differ considerably from Rate 1. Rate 1 attained the shortest fruit (5.5 cm) and smallest fruit (5.4 cm). A significant interaction was noticed as the length and width of fruit increased with the combination of Rate 2 with Varieties 1 and 2.

3.2.2. Fruit Weight

Varieties and rates differed significantly for fruit weight at the 5% level (Table 6). Sunsation (V2) had considerably heavier fruits (152.2 g) than Aristotle (V1).

Table 5. Effects of different rates on the mean length and breadth for the varieties of sweet pepper.

Rate	Fruit length (cm)			Fruit breath (cm)		
	V1	V2	Mean	V1	V2	Mean
R1	5.5^{c}	5.4^{c}	5.5^{c}	5.5^{d}	5.3^{d}	5.4^{c}
R2	7.4^{a}	7.3^{a}	7.4^{a}	7.4^{a}	7.2^{a}	7.3^{a}
R3	6.4^{b}	6.8^{a}	6.6^{b}	6.4^{c}	6.5^{c}	6.4^{b}
R4	6.9^{a}	6.8^{a}	6.8^{b}	6.5^{c}	6.8^{b}	6.6^{b}
Mean	6.5^{a}	6.6^{a}		6.5^{a}	6.4^{a}	

Note: Means with the different letters are significantly different from one another ($p < 0.05$).

Table 6. Effects of the four rates on the mean yield parameters for the two varieties of pepper.

Nutrient type	fruit weight (g)			No. of fruit/plant			Yield/Plant(Kg)			Yield/plot (Kg)			Total Yield		
	VI	V2	Mean	VI	V2	Mean	VI	V2	Mean	VI	V2	Mean	VI	V2	Mean
R1	61.4^{d}	80.0^{d}	70.7^{d}	11.5^{c}	11.4^{c}	11.5^{c}	0.8^{d}	0.9^{d}	0.8^{d}	8.4^{e}	9.6^{e}	9.0^{d}	7.4^{e}	8.4^{e}	7.8^{d}
R2	183.8^{a}	195.2^{a}	189.5^{a}	21.3^{a}	24.1^{a}	22.7^{a}	2.7^{b}	3.3^{a}	3.0^{a}	35.7^{b}	40.4^{a}	38.1^{a}	30.7^{b}	34.8^{a}	32.8^{a}
R3	128.3^{c}	144.1^{c}	136.2^{c}	11.3^{c}	13.8^{c}	12.5^{c}	1.5^{c}	1.7^{c}	1.6^{c}	20.4^{d}	19.2^{a}	19.8^{c}	17.5^{d}	16.5^{d}	17.0^{c}
R4	154.1^{c}	173.6^{b}	163.8^{b}	17.8^{b}	18.7^{b}	18.3^{b}	2.3^{b}	2.4^{b}	2.3^{b}	2&1^{c}	29.9^{c}	29.0^{b}	24.1^{c}	25.7^{c}	24.9^{b}
Mean	131.9^{b}	152.2^{a}		15.4^{b}	17.0^{a}		1.8^{b}	2.1^{a}		23.1^{b}	24.8^{a}		19.9^{b}	21.4^{a}	

Note: Means with different letters are significantly different from one another ($p < 0.05$).

The Rates obtained statistically significant differences for fruit weight, with effects of ranking Vermicompost + chemical fertilizer (189.5 g) > poultry manure + chemical fertilizer (163.8 g) > vermicompost + poultry manure (136.2 g) > 0 fertilizer (70.7 g). The interaction of varieties and rates recorded statistically significant differences in fruit weight. Sunsation and Aristotle interacted with Rate 2 to achieve significantly higher fruit weights of 195.2 g and 183.8 g respectively than any other combinations. The interaction of Sunsation with Rate 4 obtained a fruit weight of 173.6 g which had notable differences from the interaction of Aristotle and Sunsation with Rate 3 (128.3 g) and (144.1 g). The least fruit weight was noticed from the interaction of varieties with Rate 1.

3.2.3. Number of Fruit per Plant

There were no differences between the two varieties of peppers as it relates to the number of fruits per plant (**Table 4**). Rate 2 obtained significantly more fruits per plant (22.7) followed by Rate 4 (18.3). No differences were observed between Rate 3 (12.5) and Rate 1 (11.5) for the number of fruits. Treatment combination V2 R2 and V1 R2 had notably more fruits per plant (24.1) and (21.3) followed by V2 R4 (18.7) and V1 R4 (17.8). The least fruit per plant (11.3) was obtained from treatment combination V1 R3.

3.2.4. Plant Weight

The varieties and rates had remarkable differences with regard to plant yield at the 5% level. Variety two recorded significantly higher plant weight (2.1 kg) than variety one (1.8 kg). Plant weight obtained statistically significant differences for all rates tested, with effects of ranking Vermicompost + chemical fertilizer (3.0 kg) > poultry manure + chemical fertilizer (2.3 kg) > vermicopost + poultry manure (1.6 kg) > 0 fertilizer (0.8 kg). Rate 2 interacted significantly with Sunsation (V2) and obtained a weight of 3.3 kg compared to all other combinations.

3.2.5. Yield per Plot

The varieties and rates differed significantly for plot yield at the 5% level (**Table 6**). Sunsation obtained a considerably higher plot yield of 24.8 kg than Aristotle. Plot yield showed statistically significant differences for all rates, with effects of ranking Vermicompost + chemical fertilizer (38.1 kg) > poultry manure + chemical fertilizer (29 kg) > vermicompost + poultry manure (19.8 kg) > 0 fertilizer (9 kg).

3.2.6. Yield per Crop Cycle

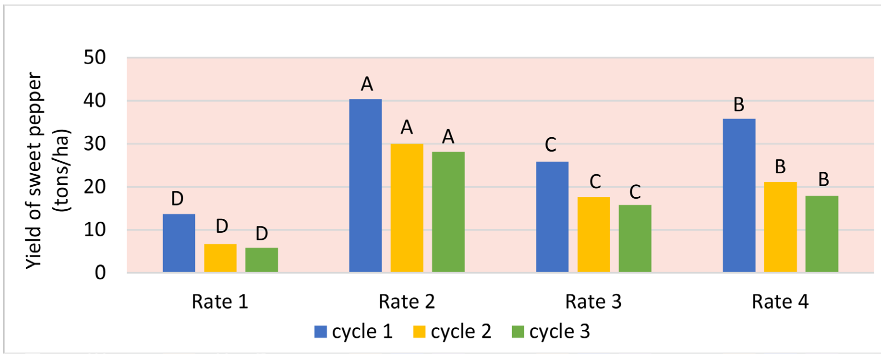
The Rates recorded remarkable differences among the crop cycles (**Figure 1**). Plants treated with Rate 2 recorded significantly higher yields for cycles 1, 2 and 3 (40.3 t/ha, 30 t/ha and 28.1 t/ha) followed by Rate 4 for cycles 1, 2 and 3 (35.8 t/ha, 21.1 t/ha and 17.9 t/ha) and Rate 3 for cycles 1, 2 and 3 (25.9 t/ha, 17.6 t/ha and15.3 t/ha). Rate 1 obtained the lowest yield for all cycles (13.7 t/ha, 6.7 t/ha and 5.8 t/ha). Yield declined sharply from cycle one to cycle three, due to an increase in temperature, pest incidence, and high percent unmarketable fruits.

3.2.7. Total Yield

The rates showed statistical differences for all rates tested ($p < 0.05$) (**Figure 2**). Rate 2 obtained a significantly higher mean yield of 32.8 kg/ha, followed by Rate 4 (24.9 kg/ha) then Rate 3 (19.7 kg/ha) and Rate 1 obtained the lowest yield of 8.7 t/ha at the 5% level. These increases in yield are directly related to the nutrient composition of the rates. The yield seemed to be affected by temperature increases, higher incidence of pests, and a greater percentage of unmarketable fruit especially in the last cropping cycle.

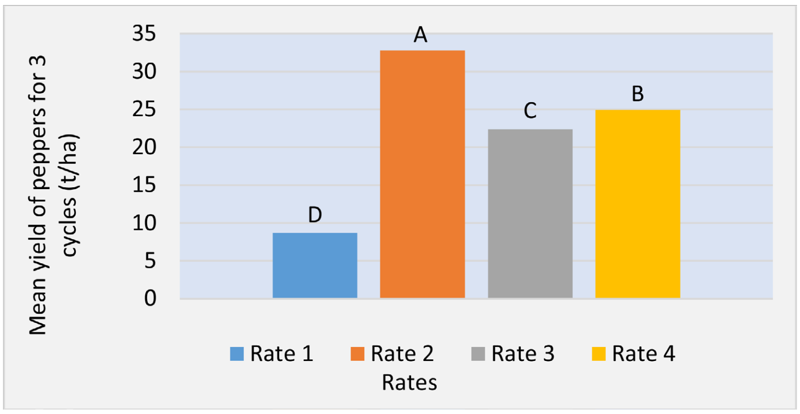
3.2.8. Fruit Storage at Different Temperatures

Sweet pepper fruits were significantly influenced by rates and storage temperatures (**Table 7**). Plants treated with vermicompost and poultry manure had a significantly longer shelf life of 14.71 days at room temperature (30.3˚C). Rate two (vermicompost + chemical fertilizer) and Rate 4 (poultry manure + chemical fertilizer) obtained a similar storage time of 13.29 and 13.04 days respectively at room temperature. Rate 1 (0 fertilizer) obtained the shortest storage period of 7.75 days. The rates did not differ for fruits stored at refrigerated temperature (7˚C), however, they differed significantly from Rate 1.



Note: Means with different letters are significantly different from one another ($p < 0.05$).

Figure 2. Effects of the various rates on the yield of sweet pepper per crop cycle.



Note: Means with the different letters are significantly different from one another ($p < 0.05$).

Figure 3. Effects of various rates on the mean yield of sweet pepper for three crop cycles.

Table 7. Effects of rates and storage temperature on fruit shelf life (days).

Rates	Room temperature (30.3˚C and RH 62%)	Refrigerated temperature (7˚C and RH 81%)
R1	7.75[c]	13.50[c]
R2	13.29[b]	21.16[ab]
R3	14.71[a]	21.42[a]
R4	13.04[b]	20.42[b]

Note: Means with different letters are significantly different from one another ($p < 0.05$).

4. Discussion

4.1. Effect of Varieties on the Growth and Yield Parameters of Sweet Peppers

Aristotle obtained significantly better growth parameters for varieties such as plant height, plant spread, and number of branches than Sunsation for crop cycle 1 due to lower average temperature (**Figure 2**). On the other hand, considerably better growth characteristics were achieved by Sunsation for cycles 2 and 3. Sunsation grew better at high average temperatures while Aristotle at lower temperatures. However, the average growth parameters for both varieties did not differ for the three cycles cultivated under the tunnel house (UV plastic) (**Tables 2-5**). Pest and disease also affected the growth of both varieties in the second and third cycles nevertheless, Aristotle seems to be more affected, especially in the dryer periods. This current study agrees with *[21]* reported that high temperatures can severely affect the growth and yield of peppers. [18] found that sweet pepper growth is retarded at a temperature above 32˚C. A similar result was obtained from this experiment as temperature increases plant growth declines rapidly.

Sunsation performed better for the weight of 12 fruits (152.2 g) number of fruits per plant [15], yield per plant (2.1 kg) and yield per plot (24.8 kg) as compared to Aristotle. These higher values of yield components can be attributed to the genetic capacity inherited which gave better growth in terms of higher plant height (72.5 cm), plant spread (65.1 cm), number of primary branches (2.2), and secondary branches (16.3). These superior growths and yield parameters as recorded in Sunsation have, in turn, resulted in higher yield (21.4 t/ha). It seems that the variety has a better genetic capacity to utilize natural resources like temperature, relative humidity, and nutrients as compared to the Aristotle variety. This variety is more adapted to the conditions under the tunnel house since it had less incidence of pest, disease, bird, and rodent damage as compared to Aristotle which seems to be more susceptible to damages as mentioned earlier. [18] conducted a study and found that plant weight for Sunsation declined from 1935 g in 2015 to 1338 g in 2016 a similar result was also obtained from this experiment. The findings from this trial disagree with [22] found no difference in fruit weight between Sunsation and Aristotle.

4.2. Effect of Various Rates on the Growth and Yield Parameters of Sweet Peppers

Growth parameters such as plant height, plant spread, and the number of branches increased significantly with the application of vermicompost + chemical fertilizer than the other treatments evaluated (**Tables 2-5**). These enhanced growth characteristics may be a result of better soil health, where vermicompost improved soil structure, aeration, soil compaction, and microbial activity and, therefore enhances water and nutrients uptake by plants. Vermicompost has good physiochemical properties (1.59% N, 0.01% P and 0.06% K, 0.24% Ca, and 0.18% Mg **Table 1**) and it is also comprised of enzymes such as amylase, lipase, cellulase, and chitinase which break down organic matter in the soil (to release nutrients and make it available to the plant roots). The addition of chemical fertilizer will further increase the nitrogen level in the soil, promote decomposition and provide adequate nitrogen for greater plant growth. These results are similar to [5] [7] [22] [23] also reported an increase in plant growth with the application of vermicompost. These results are consistent with previous research showing the application of vermicompost improved plant growth for sweet pepper and hyacinth bean [6] [10]. Plant growth was similar between Rate 4 (poultry manure + chemical fertilizer) and Rate 3 (vermicompost + poultry manure) (**Tables 2-5**). These rates may have also improved the physicochemical properties of the soil, where a large number of nutrients (macro and micro) may be released especially nitrogen to speed up the rate of decomposition and thus encourage plant growth.

Rate 2 (vermicompost + chemical fertilizer) had significantly higher yield components such as fruit length (7.4 cm), fruit breadth (7.3 cm), fruit weight (189.5 g), number of fruits (22.7), yield per plant (3.0 kg), yield per plot (38 kg) and total yield (32.8 t/ha) compared to the other treatments. The improvement in yield components can be attributed to the vegetative parameters such as an increase in plant height (91.8 cm), plant spread (88.1 cm), and number of secondary branches (11.5). The vermicompost component in this treatment combination is known to enhance microbial activity which might have improved the availability of macro and micronutrients. It can retain moisture and also regulate the availability of metabolic micronutrients to the plants and thus help in increasing plant growth and yield attributing traits by providing nutrients in the available form. Besides, vermicompost also contains significant quantities of nutrients, a large amount of beneficial microbial populations, and biologically active metabolites particularly gibberellins, cytokinins, auxins, and group B vitamins [24] all of which have a beneficial effect on photosynthesis, translocation and transformation into the development of fruits which are the economic part of the plant. These results are in agreement with findings of several earlier workers viz., [6] [7] [9] [25] in capsicum and [13] [14] [26] [27] in chilli. The use of vermicompost in combination with inorganic fertilizers can increase crop yield and the quality of diverse crops [24].

The application of Poultry manure + NPK fertilizer recorded the second-highest yield of 25 t/ha. These increases in yield components were because of the considerable improvement in fruit weight (163.8 g), number of fruits (18.3), yield per plant (2.3 kg), and yield per plot (29 kg). This may be due to enhancing soil physical properties such as aggregation, permeability, moisture retention, soil structure and aeration (24) which promote plant growth and development. It is also due to improved soil chemical properties (pH, EC, organic carbon, macro and micronutrients) (**Table 1**) which provided essential nutrients favouring the rhizosphere more congenial for nutrient uptake and utilization [28] [29].

Additionally, a notable amount of nitrogen present in poultry manure consists of uric acid and nitrogen in the fertilizer which was readily available to the plant promoting good growth right from the beginning of the crop. A similar observation was observed by [30]. This manure can also increase the soil microbial population responsible for the mineralization of plant nutrients and thus increase nutrient availability to support crop growth and development. The combination of manure and inorganic fertilizer can improve plant yield and quality of many different crop species [24].

4.3. Effects of Interaction of Varieties and Rates

The varieties and rates had a positive response to the growth and yield of sweet peppers. The positive interaction between varieties and rates may be due to the increased availability of macronutrients and micronutrients along with growth hormones and chelating agents which provided a favourable environment for the proper growth and development of sweet peppers. Among the interactions, plants of Sunsation variety treated with vermicompost + inorganic fertilizer recorded a considerably higher yield of 34.8 t/ha peppers. This may be due to the significant improvement in fruit weight (195.2 g), number of fruits per plant (24.1), plant weight (3.3 kg), and plot yield (40.4 kg). It seems that the Sunsation variety has a better inherited genetic capacity to utilize nutrients provided by vermicompost + inorganic fertilizer. These findings are supported by [7] [9] [25] [13] in capsicum and [13] [14] [26] [27] in chilli, who found that vermicompost increases the growth and development of bell peppers.

4.4. Effects of Rates on the Shelf Life of Peppers

The rates and storage temperature significantly influenced fruit shelf-life. Plants treated with vermicompost + poultry manure (Rate 3) recorded a significantly longer shelf life of 14.71 days at room temperature (30.3˚C). The application of vermicompost + inorganic fertilizer and poultry manure + inorganic fertilizer obtained a similar fruit shelf-life of 13.29 and 13.04 days respectively. These results agree with the findings of [3] for fruit shelf-life. The higher shelf-life achieved by Rate 3 may be due to lower respiration and transpiration rates which reduce shrinkage and ethylene metabolism. A similar result was obtained by [17] for tomato shelf-life. It seems that the use of inorganic fertilizer combined with manure or compost can also improve sweet pepper shelf-life to a great extent compared to no fertilizer application. This result agrees with [17] who found that the combined use of manure and inorganic fertilizer significantly increased tomato shelf-life as compared to inorganic fertilizer usage. At a refrigerated temperature of 7˚C, fruit shelf-life increased to about 21 days for all treatments except Rate 1. This higher shelf-life is a result of significantly lower rates of respiration and transpiration rates that reduces shrinkage and ethylene metabolism.

5. Conclusion

The result of this study indicated that the Sunsation variety gave better growth and yield attributes than Aristotle. The combined use of vermicompost + inorganic fertilizer has significantly influenced plant growth and yield compared to the other rates. Rate 2 (vermicompost + inorganic fertilizer) also had a positive interaction with the Sunsation variety and obtained significantly higher growth and yield responses than other interactions. Rate 2 also enhances fruit shelf-life at room and refrigerated temperatures. From the result, it is sufficient to suggest that the application of vermicompost + inorganic fertilizer will increase sweet pepper yield. Increasing yield and production of sweet pepper can thus translate into an increase in the standard of living of farmers who cultivate these peppers. The cultivation of Sunsation sweet pepper and the application of vermicompost + inorganic fertilizer obtained optimum yield which can be incorporated into the current farming practices to improve their livelihood, become self-sufficient, and ensure sustainable production. This will also reduce the dependence on inorganic fertilizer as the sole source of nutrients.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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