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The effect of vermicompost and other fertilizers on vegetative and reproductive parameters of sweet pepper (*Capsicum annuum*) plants

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Abstract
The present investigation aims to investigate the effects of vermicompost and other fertilizers on the vegetative and reproductive parameters of sweet pepper (*Capsicum annuum*) plants. The plants were treated with four fertilizers; Synthetic fertilizers - 15-15-15 (T_2), Poultry manure (T_3), Cow manure (T_4), Vermicompost (T_5), and a control medium (T_1), which had no fertilizers. The experimental design was in a complete randomized design and there was five experimental units for each treatment. The physicochemical soil analysis and microbial analysis was done for each treatment used and the plant parameters were recorded during the experiment. In the physicochemical analysis results, T3 had the highest available NPK for the initial soil samples, while T_5 had the highest NPK for the final soil samples. The pH results showed that there was a decrease in the final soil sample from the initial soil samples, while T_5 had the lowest electrical conductivity for both initial and final soil samples as compared to the other soil samples. Results obtained for the microbial analysis showed that T_3 had the highest total microbial count for the initial and final soil samples, while T5 had the lowest for the initial soil samples and T_2 for the final. Results obtained showed that T3 and T4 had a significant effect on the vegetative and reproductive growth parameters of the sweet pepper plants, along with the control medium (T_1). Experimental units treated with this treatment produced plants with better plant height at maturity, leaf surface area at maturity, dry shoot and root biomass, yield productivity, fresh and dry fruit weight, and fruit diameter. There was a relatively high level of pest and diseases in plants treated with chemical fertilizer affecting plant growth and productivity, also, a delay in plant growth, flowering and fruiting period were experienced with plants grown in vermicompost (T_5) due to weather conditions.

Keywords: Vermicompost, synthetic fertilizer, sweet peppers, poultry manure, cow manure, Guyana

1. Introduction
Sweet peppers are popular around the world for different purposes such as food and medical purposes, they vary in a variety of size, shapes and colours. *Capsicum annuum*, commonly known as the green sweet pepper, belongs to the family Solanaceae [1]. Sweet peppers are cultivated widely in all regions across Guyana and around the world grown using different fertilizers that are categorize as either organic fertilizer or chemical fertilizer.
The severity of using chemical products on plants have caused economic and environmental impacts. With an increasing number of populations around the world and higher living standard the built up of waste is becoming a bigger problem. In order to get rid of a vast amount of waste, the burning method is used and this results in overall physical and chemical composition alternation of the soils which results in destruction of helpful microbial populations, and reduction of soil organic materials. Recycling the large number of biowaste from different industrial and household resources in the form of a compost is an alternative way that helps farmers to increase the use of organic manures as an environmentally safe alternative to chemical fertilizers [2]. In a growing agricultural industry, researchers are experimenting and improving innovation for optimally increasing crop production and improving the farming systems in formulating proper waste management strategies by using organic waste as substrates for organic farming. The organic manures used in organic farming are a composition of organic waste materials [12]. One such innovation being researched is vermicomposting.

Vermicomposting is a scientific method of making compost, it is a non- thermophilic biological oxidation process in which organic material are converted into vermicompost. It is widely used to enhance the process of organic waste conversion and produce a compost with the use of earthworms. The earthworms feed on organic waste such as kitchen scraps and waste, converting waste materials into humus like substance called vermicompost. Vermicompost are fine granular peat material that have high porosity, aeration, drainage and water-holding capacity, a vast surface area which provides a strong absorbability and retention of nutrients [7]. Vermicomposting is different from other traditional composting because it is a mesophilic process, where microorganisms and earthworms is used that are active at 10-32 ºC in which they do not need to be at ambient temperature but the temperature within the pile of moist organic material [10]. In traditional composting the organic matters are buried in landfills that becomes anaerobic resulting in the release of methane which is a contributor to greenhouse gases and the plant nutrients are wasted, whereas, in vermicomposting the organic matter is recycled and it reuse these nutrients to grow plants and it helps to reduce the greenhouse gas emission [19]. As well as in traditional composting chemical fertilizers are added to the soil which releases their fertilizer quickly that are washed or depleted from the soil due to watersheds, kills beneficial microbes in the soil and destroy the soils natural fertility due to erosions. While in vermicomposting it releases fertilizer at a slower rate, helping to improve soil fertility, promote healthy plant growth, and suppress plant pest [19].

The *Eisenia fetida*, known as the California Red Earthworm, is used in the vermicomposting process because their body has a high rate of ingesting their food [17]. In the gut of earthworm, enzymatic activities lead to toxic metal immobilization that is an efficient process for the remediation of heavy metals from organic waste. Earthworms are more suitable in decomposing organic materials because they have a high-level ingestion and reproduction [17]. Earthworms are the engineers within soils because they form extensive burrows which loosen the soil and makes it porous, that helps to improve different physical and chemical mechanisms for the soil. To have the mentioned characteristics and mechanism of the soil the earthworms consume organic materials such as household scraps, that will be broken down into fragments of finer particles that will go through their digestive system by passing them through a grinding gizzard and derive their nourishment from microorganisms that grow upon them.

Along with earthworms, microorganisms are present in vermicompost because it helps in the acceleration of biological degradation of organic wastes, it breaks down of organic material in the decomposition process of vermicomposting. They are rich in bacteria, fungi, viruses, actinomycetes and various other organisms which characterizes healthy soil [7]. Bacteria has a broad range of enzymes that helps to chemically break down a wide variety of organic materials, so it is responsible for majority of the organic decomposition that takes place and heat generation in the composting process. Microorganisms and small invertebrates help to break down organic matter and produce carbon dioxide, water, heat, resulting in a richer soil that improves plant growth and production [7]. The microorganisms from the earthworms' cast along with those present in the soil works together to speed up the rate of decomposition of organic matter and the end product contains high amount of nutrients that will boost the soil aeration [11]. The vermicompost has a much larger populations of bacteria (5.7×10^7), fungi (22.7×10^4) and actinomycetes (17.7×10^6) compared with those in the conventional compost [5].

Vermicompost helps to improve the plants growth and productivity, it helps to speed up the rate of seed germination and result in rapid seedling growth and development, the fruit can be kept for 6-7 days, unlike fruits and vegetables grown with chemical fertilizers that can be kept for 2-3 days only [15]. The vermicompost possess pesticidal properties and contributes to the reduction of global warming and pollution [15]. However, the vermicompost does not only improve plants growth and productivity but it also increases the nutritional quality of crops [15].

In Guyana, vermicomposting will enable proper organic waste management and help to decompose waste in a safe manner, where it will be used to improve crop productivity and reduce the use of synthetic fertilizers in the agriculture system. Studies done on vermicomposting results showed that there are improvements in soil quality and the treatments that consist of a high ratio of vermicompost shows a positive effect of growth, yield and fruit quality of the crop [18]. Vermicompost can promote plant growth from 50% to 100% over traditional composts and 30% to 40% over chemical fertilizers which is a more costly that is at least 50 to 75% less as compared to the expense of buying chemical fertilizers. The vermicompost is added to soil releases fertilizers at a slower rate so nutrients are slowly released into the soils improving plant quality due to the amount of carbon found, as compared to traditional compost and synthetic fertilizers that releases nutrients faster [19].

The aim of this project is to assess and compare the different vegetative and reproductive growth parameters of sweet pepper plants with the use of a synthetic fertilizer (15-15-15), poultry manure, cow manure and vermicompost. Vegetative parameters such as plant height at maturity, dry root and shoot biomass, leaf surface area at maturity, and reproductive parameters such as number of fruits, fresh and dry weight per fruit, fruit diameter, days to first fruiting and flowering, fruiting and flowering period, will be observed, recorded, and analyzed when growing sweet pepper plants.

2. Methodology

2.1 Study location

The experiment was conducted at the researchers' resident at Lot 13B Kilcoy Road, Corentyne, Berbice, Guyana.

2.2 Experimental design

The experiment was carried out using the Complete Randomized Design method.

2.3 Preparation of the vermicompost unit

The vermicomposting unit (2.1×2.1×0.5m) was set up at a researcher resident at the above address.

1. First, the basal layer of the unit was layered with pebbles then it was layered with a course of sand approximately 5 inches for proper drainage.
2. Secondly, a layer of loam soil was added approximately 10 inches over the already established layer after which

200 locally collected *Eisenia fetida* earthworms were introduced to the unit.
3. Then cattle manure was scattered on every inch of the surface on the soil and then covered with 5 inches dried Coastal Bermuda grass (*Cynodon dactylon*).
4. Lastly, water was sprinkled using a water can to keep the unit moist in order to accommodate the worms. The unit was left to compost for a two months' period over 60 days and the harvesting of vermicompost was done every 45 days [12].

Fig 1: *Eisenia fetida* (earthworms) used for vermicomposting

2.4 Nursery management practice
1. The seeds were set in 10 inches by 20 inches seed tray and loam soils were used to fill up 25 plots on the tray.
2. The seeds were set in the loam soil and watered using a water can daily.
3. The seeds were left to germinate for a period of 2 weeks and it was transplanted after 21 days.

Fig 2: Seedlings before transplanted

2.5 Field preparation
1. A piece of land was used to make a total of 5 beds at a size 3.5 ft by 5ft for planting to take place.
2. The soil was turned up and broken into smaller pieces using a garden fork, then a drain of 3 inches was made between each bed using a shovel to ensure proper drainage.
3. Then each bed was barricaded using pieces of wood to ensure no runoffs or erosion of the soils on each bed.
4. After 21 days of germination, each plant was transferred to the beds with their respective treatments applied, 5 germinated seedlings were allocated to one bed and each was planted approximately 8 inches afar from each other.
5. Prior to the heavy rainfall in May-June 2021 that resulted in flooding, the plants were transplanted from the field to pots [6].

2.6 Potting preparation
1. The pots contained loam soil where each plant was planted per pot resulting in having a total of 25 pots.
2. When the soil preparation was finished, the pots was labelled according to the treatments assigned.
3. Each plant was carefully transplanted to a pot and the respective treatment was added to each pot.
4. The plants were watered daily with the use of a water can.

Table 1: Showing details of each treatment

Treatment	Components of each treatment
T_1 - Control	Red sand.
T_2 - Synthetic fertilizer (Inorganic)	15-15-15
T_3 - Poultry manure (Organic)	Composted bedding material (sawdust), wasted water, feathers, soil, spilt feed and total excrement.
T_4 - Cow manure (Organic)	Composted total excrement from cattle, soil.
T_5 - Vermicompost (Organic)	Dried Coastal Bermuda grass (*Cynodon dactylon*) and cattle manure vermicompost using *E. fetida*

2.7 Harvesting stage
1. When the plants reached the harvesting stage, they were removed from the pots.
2. The root was cut off from the shoot.
3. The shoot and root were placed on a white carboard and left in the sun to dry for approximately 4 days.
4. The dry weight of the shoot and root for each treatment were collected.
5. Data was collected on:

- Plant height at maturity
- Leaf surface area at maturity
- Dry shoot and root biomass
- Number of fruits
- Fresh and dry weight of fruit
- Diameter of fruit

2.8 Preparation of neem extract to avoid pest and insects
1. The neem extract was prepared using 500 g of neem leaves boiled in 1 liter of water.
2. When the extract was finished boiling, it was further diluted into 2 liters of water.
3. 50ml of the extract was sprayed onto each plant [6].

2.9 Microbial analysis and Physio-chemical analysis
The microbial analysis was conducted at the University of Guyana Johns Science Center and physio-chemical analysis was done for initial and final soils samples as follows:

2.9.1 Total microbial count

Materials

- Nutrient agar
- Distilled water
- Autoclave
- Heat source
- Soil sample
- Petri dishes
- Beakers
- Stirring rod

Method

1. 23g of nutrient agar was added to 1L of distilled water.
2. This was boiled and stirred well until the agar becomes transparent.
3. The agar was poured into a 1000ml conical flask using a funnel.
4. The opening of the conical flask was sealed using cotton wool and a piece of aluminum foil was used to wrap the sealed flask.
5. Then it was autoclaved at 121°C for 15 minutes and left to cool at 50°C.
6. The agar was poured into 30 petri dishes and left to cool until it becomes gel.
7. Using aseptic technique, the soil sample was streaked onto the agar by simmering 0.5g of soil samples.
8. The samples were inoculated at 35°C for 24 hours.

2.9.2 Gram Stain

Materials

- Crystal Violet
- Gram Iodine
- Decolorizer: 95% Ethyl Alcohol
- Safranin
- Distilled water
- Slides and cover clips
- Wire loop
- Bunsen burner

Method

1. The gram staining was done using a thin smear of bacterial colony identified on separate slide and left to air dry.
2. The smears were then fixed by swiftly heating by a Bunsen burner flame.
3. The slide was flooded with crystal violet and washed using distilled water.
4. The slides were then flooded with gram iodine and decolorized by tilting the slide and rinsed thoroughly with ethanol drop by drop.
5. The slides were flooded with safranin and then washed with distilled water.
6. Then the slides were blot dried and reviewed under a microscope for identification.
7. The shape of the bacteria and the gram action of the bacteria was identified under the microscopic lens [20].

a b

Fig 3: (a) and (b). Petri dishes prepared for microbial analysis.

2.10 Physicochemical analysis

2.10.1 NPK tests

The physicochemical analysis test was done on available NPK in the initial and final soil samples of each treatment used in this project. The NPK soil analysis was done at the Nand Persaud Farm Laboratory.

2.10.2 pH test

The pH test was done using a pH meter.

1. Five grams of the dried soil samples for both initial and final soil sample was weighed and placed into a test tube.
2. 25ml of distilled water was measured using a 25ml measuring cylinder, mixed in the test tube with the weighed soil sample.
3. Then shake well for 5 minutes.
4. The mixture was transferred into a little beaker and pH samples were tested using the pH meter.
5. The cathode tube of the meter was submerged into the beaker of sample and the results was recorded [9].

2.10.3 Electrical Conductivity Test

The electrical conductivity test was done using an electrical conductivity meter.

1. Five grams of the dried soil samples for both initial and final soil samples was weight and placed into a test tube.
2. This was mixed with 25ml of distilled water measured using a 25ml measuring cylinder and shake well for 5 minutes.
3. The mixer was transferred into a little beaker and the meter was switched on.
4. The electrode tube was inserted into the beaker of samples and the conductivity was recorded [9].

3. Results: Plants were treated with four different treatments (T_2-Synthetic fertilizers, T_3-Poultry manure, T_4-

Cow manure, T_5-Vermicompost) plus a control medium T_1. The results were tabulated and statistically analyzed.

Physicochemical analysis was done on the soil samples taken before plants were planted (initial) and after plants was harvested (final) to determine the physicochemical composition of the soil.

Table 2: Soil chemical analysis pH and Electrical conductivity (S/m). Data taken from three biological replicates

Treatment	Initial pH	Final pH	Change in pH	Initial electrical conductivity (S/m)	Final electrical conductivity (S/m)	Change in electrical conductivity (S/m)
T_1	6.12	6.16	+0.04	41.8	25.4	- 16.4
T_2	5.58	5.83	+0.25	40.4	14.4	- 26
T_3	6.02	6.47	+0.45	46.8	20.7	- 26.1
T_4	5.99	6.13	+0.14	39.1	16.55	-22.55
T_5	6.32	6.51	+0.19	26.1	23.9	- 2.2

(-) Decrease, (+) Increase

Table 3: Physicochemical analysis of Nitrogen (N), Phosphorus (N) and Potassium (K) in each treatment soil sample (ppm). Data represents Mean±Standard deviation of three biological replicates.

Treatment	Nitrogen (ppm)		Change in Av. N	Phosphorus (ppm)		Change in Av. P	Potassium (ppm)		Change in Av. K
	Initial	Final		Initial	Final		Initial	Final	
T1	14.36±0.55	13.03±1.26	- 1.33	124±0.21	79.43±6.63	- 45.22	604.9±3.11	268.1±7.63	-336.8
T2	14.12±0.14	14.62±1.02	+0.5	204.5±3.25	61.35±9.17	-143.15	660.15±3.3	194.8±5.65	-465.35
T3	16.66±0.49	23.39±1.08	+6.73	331.15±6.57	109.35±3.6	-221.8	785.35±2.2	355.85±4.17	-429.5
T4	7.37±0.87	21.22±0.93	+13.85	191.35±4.45	99.84±7.43	-91.51	612.95±3.9	198.55±1.06	-414.4
T5	5.34±6.05	29.16±0.72	+23.82	225.9±3.53	85.52±0.61	-14.38	696.6±4.9	205.25±1.62	-491.35

(-) Decrease, (+) Increase

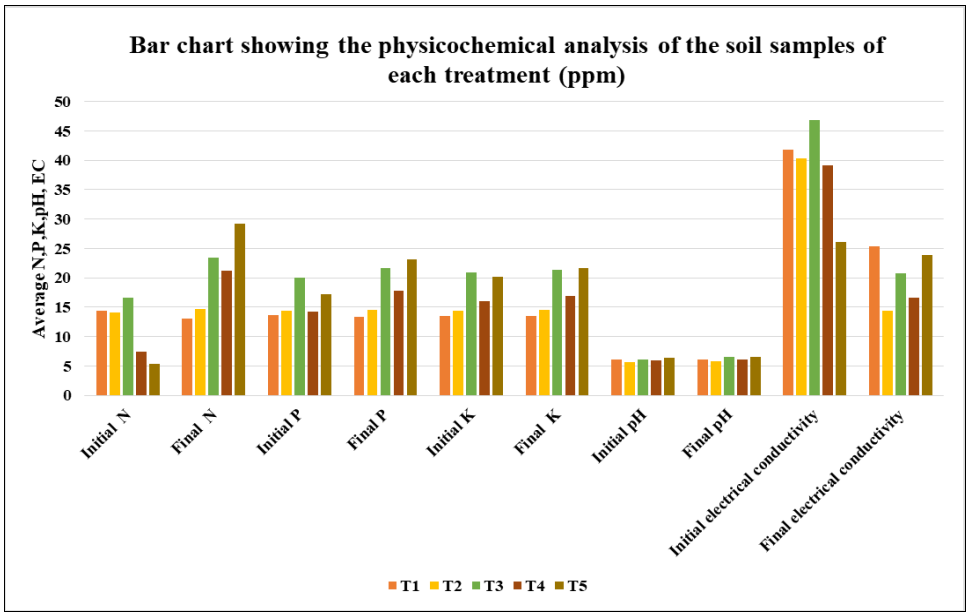


Fig 4: Bar graph showing the average initial and final available nitrogen, phosphorus, potassium, the pH level and the electrical conductivity of each treatment (ppm).

The initial testing of available nitrogen shown in Figure 4, T_3 (16.66 ppm) had the highest available nitrogen, followed by T_1 (14.36 ppm) which is the control treatment, T_2 (14.12ppm), T_4 (7.37ppm), leaving T_5 (5.345ppm) with the lowest available nitrogen. Analysis done for the post-harvest soil samples, T_5 (29.16ppm) had the highest available nitrogen, followed by T_3 (23.39ppm), T_4 (21.22ppm), T_2 (14.62ppm) and T_1 (13.03ppm) with the lowest available nitrogen.

Figure 4, showing the average initial and final phosphorus content of each treatment, for the initial analysis, T3 (331.15ppm) had the highest phosphorus content, followed by T_5 (225.9ppm), T_2 (204.5ppm), T_4 (191.35ppm) and T_1 (124.65ppm) with the lowest available phosphorus for the initial analysis. For the post-harvest analysis, T_3 (109.35ppm) had the highest phosphorus content, followed by T_4 (99.84ppm), T_5 (85.52ppm), T_1 (79.43ppm) and T_2 (61.35ppm) with the lowest phosphorus in the post-harvest analysis.

Figure 4, is showing the average initial and final available potassium of each treatment, for the initial analysis done, T_3 (785.85ppm) had the highest available potassium, followed by T_5 (696.6ppm), T_2 (660.15ppm), T_4 (612.95ppm) and T_1 (604.9ppm) which had the lowest available potassium. In relation to the post-harvest analysis, T_3 (355.85ppm) had the highest available potassium, while T_1 (268.1ppm) had the second highest, followed by T_5 (205.25ppm), T_4 (198.555ppm) and T_2 (194.8ppm) with the lowest available

potassium in the post-harvest analysis. Overall, T3 had the highest available potassium for both the initial and post-harvest (final) analysis of each treatment.

For the initial soil samples the pH ranges from acidic to neutral, having T_2 with the least number of pH (5.58) resulting in being acidic followed by T_4 (5.99), while the remaining treatments T_3 (6.02), T_1 (6.12), and T_5 (6.32), were within pH the ranges 6 - 6.5 resulting in a slight neutral scale. The results of the final soil sample analysis showed that the pH of all the treatments have increased, where, T_5 (6.51) had the highest pH level which is slightly neutral, followed by T_3 (6.47), T_1 (6.16), T_4 (6.13) and T_2 (5.83) with the lowest pH level. The overall results for both the initial and final soil samples showed that the final pH results increased from the initial results.

The electrical conductivity of the initial soil samples was lowest in T_5 being (26.1S/m) and the highest in T_3 (46.8S/m), followed by T_1 (41.8S/m), T_2 (40.4S/m) and T_4 (39.1S/m). The results of the final soil sample analysis for electric conductivity showed that there was a decrease in all the soil samples, where T_2 (14.4) with the lowest electric conductivity, followed by T_4 (16.55), T_3 (20.7), T_5 (23.9), and T_1 (25.4) with the highest. A measure of electrical conductivity is an important indicator of soil health and a high electrical conductivity shows that more nutrients are present in the soil [12]. The overall results both initial and final soil samples testing electric conductivity showed that the initial results were higher than the final results.

Table 4: Total microbial count of soil. Data represents Mean±Standard deviation of three biological replicates.

Treatment	Initial microbial count of soil (CFU x 10^2)/g	Final microbial count of soil (CFU x 10^2)/g	% Change in bacterial count
T_1	2376±465.65	1672±704	-704
T_2	2875±572.56	880±264	-1995
T_3	3315±1623.43	2112±1183.92	-1203
T_4	2376±1366.13	1789±366.37	-587
T_5	1613±599	968±549.56	-645

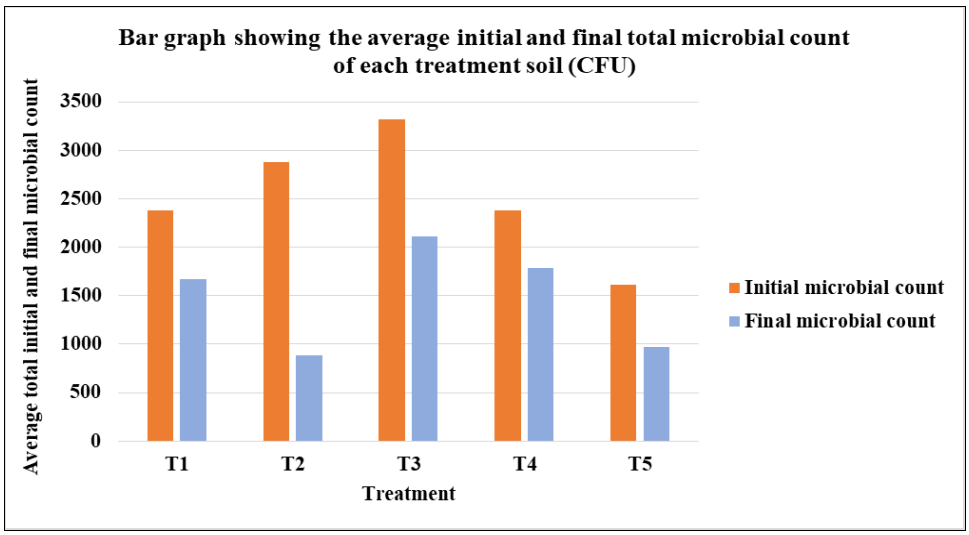


Fig 5: Bar graph showing total microbial count

Figure 5 shows the result of the microbial analysis done on the initial and final soil samples for each treatment, values are represented in the form of mean±standard deviation. The total microbial count was done to show a comparison of the number of microbes present before planting and after harvesting of the sweet pepper (*C. annuum*) plants.

There was a total of three (3) bacterial colonies present in both the initial and final soil samples. The initial soil samples showed that T_3 (3315) had the highest total microbial count of bacterial colonies, whereas T_5 (1613) had the lowest total microbial count of bacterial colonies. While T_1 and T_4 had the same average total microbial count of 2376, and T_2 had the second highest total microbial count of 2875 bacterial colonies. Results for the final soil samples showed that T_3 remained with the highest total microbial count of 2112 bacterial colonies, while T_2 has the lowest total microbial count of 880 bacterial colonies, followed by T_5 (968), T_1 (1672), and T_4 (1789) with the second highest total microbial count.

After the total microbial count, Gram staining was done on the different bacterial colonies present in the initial and final soil samples, the bacteria cell walls were stained purple with cocci and bacilli morphology, resulting in the bacteria colonies present are Gram-positive.

Germination of sweet peppers seeds was followed by transplanting when the seedlings were at a two-leaf stage as shown in Figure 2. The seedlings were transplanted to field, where the first set of treatment was applied to each planting station respectively. After 3 weeks period of transplanting, the plants were transferred into pots due to climatic conditions such as flooding from the heavy rainfall in May/June. Table 5. is showing the survival rate and mortality rate of sweet pepper (*C. annuum*) plants during the different stages of planting. As the plants continues to grow in the potting media, recording of results began. There was 60% survival rate of T5 in the potting media, some plants suffered greatly from flooding which resulted in them to become stunted and stressed due to transferring at such late

stage in their growing span and insufficient sunlight to regenerate themselves. The remaining treatments T_1, T_2, T_3, and T_4 had a 99% survival rate in the potting media, the plants that did not survive was affected by insect infestation, where the insect (*Gryllotalpidae*) were feeding and living in the potting soil, and cutting the plant roots causing the plants to die. Neem extract was used to help the plants against pest and insects.

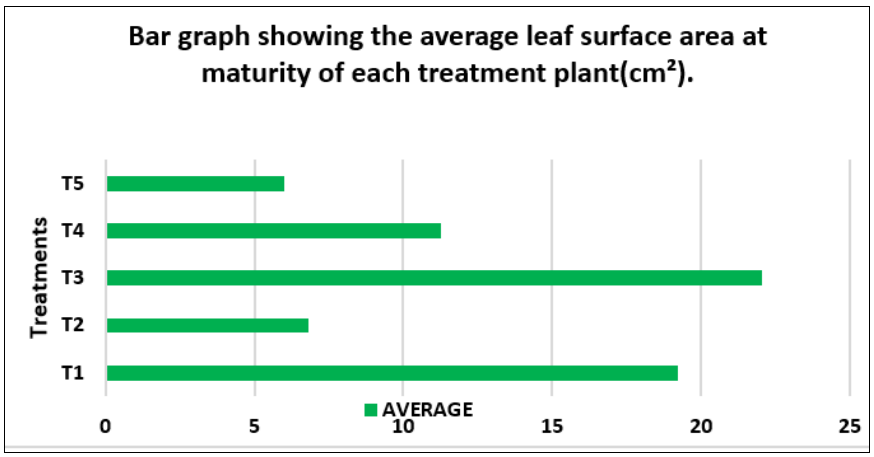
Table 5: Survival and mortality rate of sweet pepper plants of each treatment. Data represents Mean±Standard deviation of three biological replicates.

Treatment	Initial number of plants allocated per treatment	Survival rate of plant in field (%)	Survival rate of plant in potting media (%)
T_1	5	100	80
T_2	5	100	80
T_3	5	100	80
T_4	5	100	80
T_5	5	80	60

3.1 Vegetative plant parameters of each treatment.

Table 6: Leaf Surface Area at Maturity, Plant Height at Maturity. Data represents Mean±Standard deviation of three biological replicates.

Treatment	Plant height at maturity (cm)	Leaf surface area at maturity (cm^2)
T_1	34.42±7.38	19.22±2.36
T_2	21.87±5.51	6.80±1.19
T_3	42.87±12.39	22.06±7.44
T_4	52.75±27.72	11.25±4.11
T5	19.75±3	6±7.44



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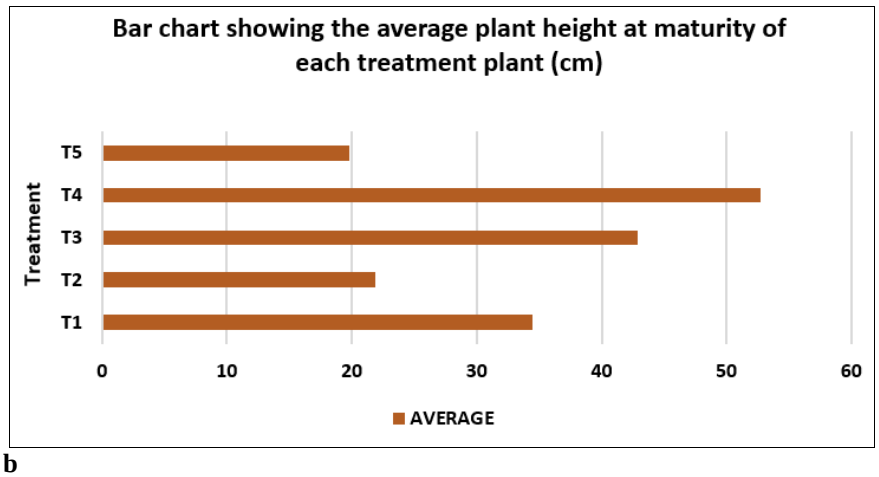


b

Fig 6: Bar graphs showing (a) average leaf surface area and (b) average plant height at maturity of each treatment.

Figure 6 (a) is showing the average leaf surface area at maturity of each treatment replicates, values in the Table 6 are represented in the form of mean± standard deviation. According to the graph T_3 (22.06) has the highest average of leaf surface area, followed by T_1 (19.22), T_4 (11.25), T_2 (6.81) and T_5 (6) with the lowest leaf surface area at maturity.

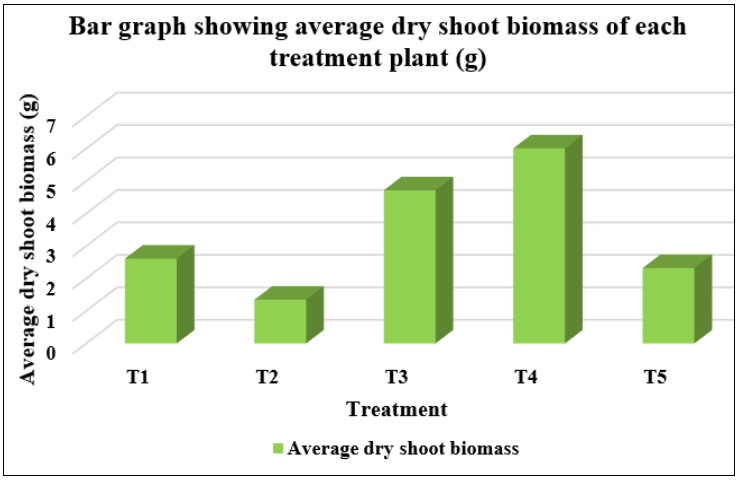
Figure 6 (b) is showing the average plant height at maturity of each treatment. The plant height was measured using a 30.5cm ruler. According to the results displayed, T_4 (52.75) had the highest average plant height at maturity, followed by T_3, T_1, T_2 and T_5 (19.75) with the lowest average plant height at maturity.

A complete randomized ANOVA statistical test was done for plant height at maturity, where the p-value (0.21) is more than 0.05, therefore we do not reject the null hypothesis and conclude that there is no significant difference between the plant heights at maturity of each plant grown with different treatment.

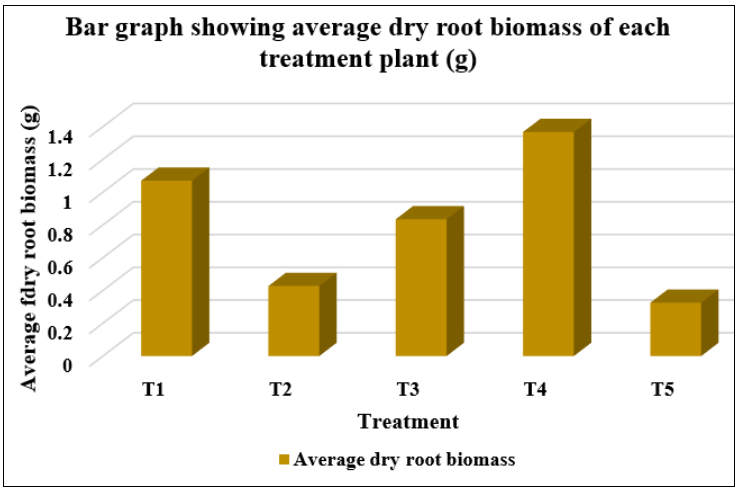
Statistical analysis done on the homogeneity of variances of the plant height of maturity, the Levene's test p-value (0.00) is less than 0.05, then the implication is that the variances are unequal.

Table 7: Dry shoot and root biomass at harvest. Data represents Mean± Standard deviation of three biological replicates.

Treatments	Dry shoot biomass(g)	Dry root biomass (g)
T_1	2.61±1	1.07±0.57
T_2	1.35±0.31	0.43±0.18
T_5	2.32±3.67	0.32±0.45
T_3	4.71±4.01	0.83±0.37
T_4	6.01±5.61	1.36±1.20



(a)



(b)

Fig 7: (a) and (b). Bar graphs showing the average dry shoot and root biomass at harvest.

Figure 7 (a) is showing the average dry shoot biomass of each treatment plant, T_4 (6.01g) had the highest average dry shoot biomass, followed by T_3 (4.71g), T_1 (2.61g), T_5 (2.32g) and T_2 (1.34g) with the lowest dry shoot biomass of each treatment plants weighed. Figure 7 (b) is showing the average dry root biomass of each treatment plant, T4 (1.36 g) had the highest average dry root biomass, followed by T_1 (1.07g), T_3 (0.83 g), T_2 (0.43) and T_5 (0.32g) with the lowest dry root biomass of the different treatment plants.

A complete randomized ANOVA statistical test was done for dry shoot and root biomass in Figure 9 (a) and (b), where p-value (0.41) and (0.40) is more than 0.05, therefore we do not reject the null hypothesis and conclude that there is no significant difference between the dry shoot and root biomass of each plant grown with different treatment.

Statistical analysis done on the homogeneity of variances of the dry shoot (a) and root (b) biomass, the Levene's test p-value (0.01) and (0.02) is less than 0.05, then the implication is that the variances are unequal.

3.2 Reproductive parameters of each treatment.

Table 8: Days to first flowering and fruiting (days)

Treatments	Days to first flowering	Days to first fruiting
T_1	35	42
T_2	49	56
T_3	37	42
T_4	44	49
T_5	70	0

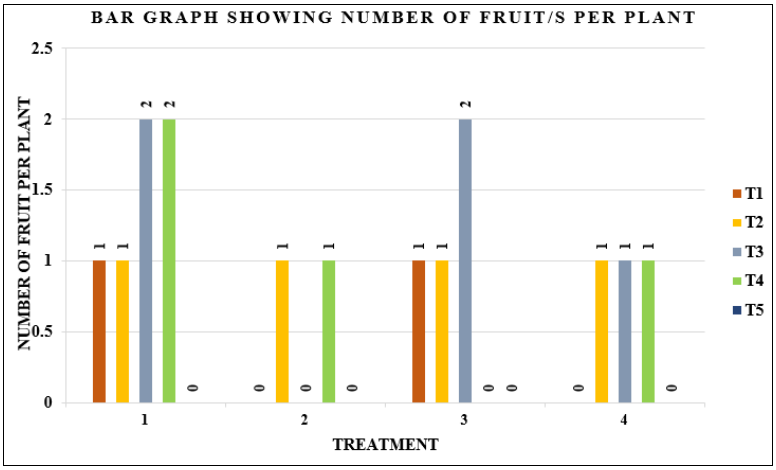
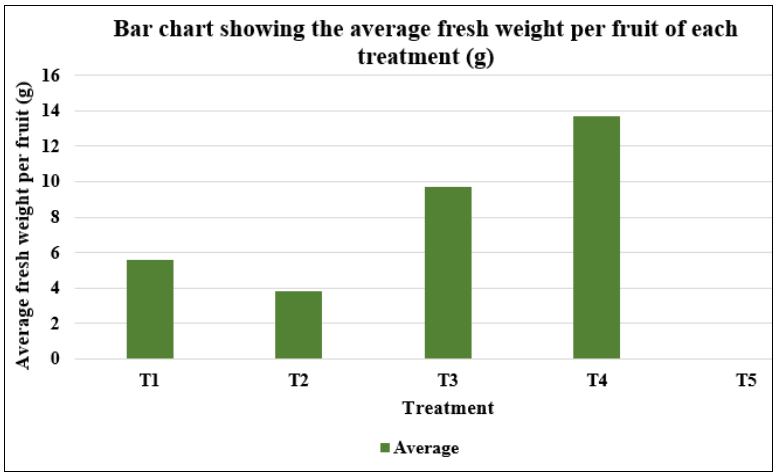


Fig 8: Bar graph showing the number of fruit/s per plant of each treatment.

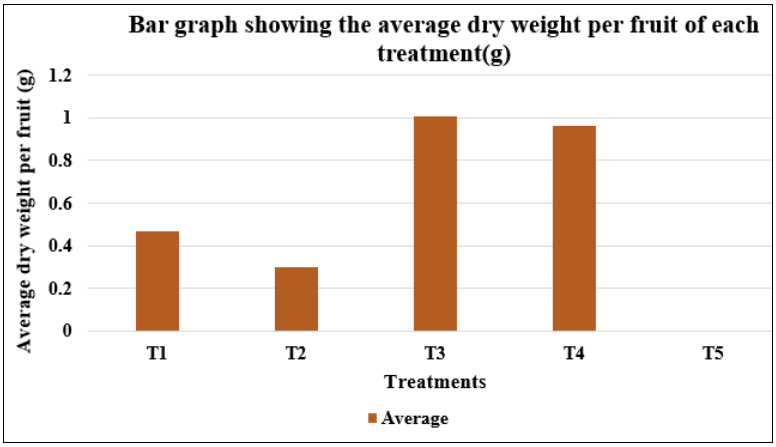
The results for the reproductive parameters were recorded from the days of first flowering and fruiting. Table 8 is showing the results recorded for days to first flowering and fruiting of sweet pepper for the different treatments. As shown in Table 8, T_2 and T_3 were the first set of plants to started flowering and fruiting, followed by T_4, T_2 and T_5. Figure 8 is showing the number of fruits collected from each treatment during the first harvesting. Plants amended with T_3 had the highest fruit yield, followed by T_4, T_2, T_1 and T_5, which produced no fruit due to the flowers drying up and falling off the plant.

Table 9: Fresh and dry weight per fruit of each treatment (g). Data represents Mean±Standard deviation of three biological replicates.

Treatments	Fresh weight per fruit (g)	Dry weight per fruit (g)	Av. Weight loss (g)
T_1	5.56±5.51	0.47±0.412	5.09
T_2	3.83±1.49	0.3±0.11	3.53
T_3	9.75±9.97	1.01±0.79	8.74
T_4	13.69±14.52	0.96±1.02	17.29
T_5	0	0	0



(a)



(b)

Fig 9: (a) and (b). Bar graphs showing the average fresh and dry weight per fruit of each treatment.

Figure 9 (a) and (b) shows the results obtained from the average fresh and dry weight of the sweet pepper (*C. annuum*) samples. The values in the Table 9 are represented in the form of mean±standard deviation. In relation of the fresh fruit weight of the sweet pepper samples, T_4 (18.25) had the highest fresh fruit weight followed by T_3 (9.73), T_1 (5.55), T_2 (3.82) and T_5 (0) where no fruit sample was collected due to the fruit bud drying and falling off. In terms of the dry fruit weight, T_3 (1.01) had the highest average weight, followed by T_4 (0.96), T_1 (0.46), T_2 (0.3) and T_5 (0) where no fruit was collected.

A complete randomized ANOVA statistical test was done for fresh and dry fruit weight, where the p-value (0.46) and (0.38) is more than 0.05, therefore we do not reject the null hypothesis and conclude that there is no significant difference between the fresh and dry fruit weight of each treatment.

Statistical analysis of the homogeneity of variances for fresh fruit weight (a) indicated that the Levene's test returned a p-value of 0.05. Since this value is equal to the significance level ($\alpha = 0.05$), the assumption of equal variances is considered to be met. In contrast, the analysis of dry fruit weight (b) produced a Levene's test p-value of 0.09, which exceeds the 0.05 threshold. This also indicates that the variances are homogeneous across groups.

Table 10: Diameter per fruit of each treatment. Data represents Mean± Standard deviation of three biological replicates.

Treatments	Diameter of fruit (cm)
T_1	1.32±0.93
T_2	1.27±0.27
T_3	1.67±1.19
T_4	1.71±1.25
T_5	0

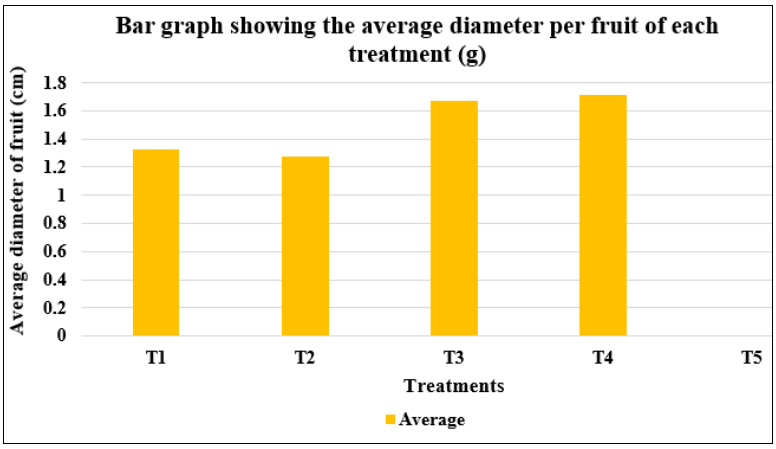


Fig 10: Bar graph showing the average diameter per fruit of each treatment.

Figure 10 is showing the average diameter per fruit of each treatment in a bar graph. The values in the Table 10 are represented in the form of mean± standard deviation. According to the bar graph T_4 (1.71) had the highest average diameter per fruit for each treatment, followed by T_3 (1.67), T_1 (1.32), T_2 (1.27) and T_5 (0), no results was obtained from T5 because no fruit sample was collected.

4. Discussion

Plant fertilizers provide nutrients that ensure growth and reproduction since the soil does not consist of sufficient nutrients for optimum plant growth and reproduction. Fertilizers used in modern farming can be organic or inorganic. Organic fertilizers are eco-friendly, it helps to improve soil fertility and growth yields. However, inorganic

fertilizers provide nutrients to ensure healthy plant growth and sustainable yields when it is used in the correct proportions, and when used excessively they can disrupt soil chemical composition and physical properties resulting to health hazards in the environment.

In this study the sweet pepper (*C. annuum*) plants were treated with four different fertilizers, both organic and inorganic, plus a control medium. The control medium is made up red sand which is a ready-made mixture that is comprised of high water holding capacity and nutrient retention for sustainable plant growth. The second treatment, a synthetic fertilizer, 15-15-15, it is ideal in providing the nutrients necessary for growth and productivity in correct proportions. The third treatment poultry manure, it has high values of biological index of fertility of soil that helps to improve soil physical properties since it is a combination of bedding material, wasted water, feathers, soil, spilt feed and total excrement. Poultry manure provides all essential nutrients in provided portion for all the requirements needed for plant growth [8]. Cow manure the fourth treatment, made up of grass and grains from certain grass eaten by the herbivorous animal, so it is rich in organic materials and nutrients. Composted cow manure is used more abundantly than fresh manures because cow manure has a high level of ammonia which can burn plant roots when it is directly applied [21]. Vermicompost the fifth treatment, it is a composition of organic matter from the decomposition of waste product from earthworms' activity. It is very beneficial in improving soil quality for fertility status and growth. Each treatment was used in different proportions during growth of the sweet pepper (*C. annuum*) plants at different stages to compare the different growth parameters.

The different parameters investigated throughout this project are; physicochemical analysis of soil samples of each treatment, vegetative parameters such as plant height at maturity, leaf surface area at maturity, dry shoot and root biomass and reproductive parameters such as first day of flowering and fruiting, number of fruits, fresh and dry weight of fruit, diameter of fruit of each treatment.

In the physicochemical analysis, the final soil sample analysis shown to have a significant increase of nitrogen in T_5, this is due to mineralization of the organic matter containing protein and the conversion of ammonium nitrogen into nitrate. In the vermicompost, earthworms can enhance nitrogen level during vermicomposting through digestion of substrates in their gut and the addition of nitrogenous excretory products, body fluid, enzymes, mucous. So, the significant increase of the nitrogen content value in the post-harvest analysis could be due to the nitrogenous metabolic products of the earthworms that are return as cast in the vermicomposting process [16].

There was a significant decrease of phosphorus level in the final soil analysis shown in Figure 4, this can be due to low soil temperature and poor soil aeration, with excessive soil moisture the soil oxygen supply is reduced and it decreases the ability of plant roots to absorb soil phosphorus. This may not be the only cause of low phosphorus level content in the final soil analysis. Compaction of the soil reduces aeration and pore space in the root zone of the plant so this also contributes to the reduction of phosphorus uptake and plant growth.

The decrease in available potassium in Figure 4 can be due to the leaching of soluble elements which is through the action of excess water draining. An increase in soil organic matter can result in the decrease of potassium fixation in the soil and there maybe changes in the distribution of potassium between exchangeable and non-exchangeable forms [16].

The microbial analysis of total microbial count for the initial and final soil samples of each treatment showed that there was a significantly rapid decrease of microbes in the final (post-harvest) soil sample. According to a study done by Wang *et al*., 2018 [24], the addition of nitrogen can affect the microbial diversity of soil, so the changes in soil nutrients can show the rapid change of microbial count with an increase in nitrogen. Figure 4 showed a significant increase of N in the final soil samples as Figure 5 depicted a decrease in total microbial count. So with the addition of N can result in the reduction of microbial count in the soil.

The results tabulated and analyzed on vegetative parameters showed that T_3 and T_4 had an accelerated vegetative growth in terms of the plant height, leaf surface area, and dry shoot and root biomass which was significantly rapid than the other treatments, except the control medium that showed a varied influence on the final attainable plant height. A study done by Van Ryssen *et al*., 1993 [23], stated that "poultry manure is an excellent soil amendment that provides nutrients for growing crops and improves soil quality when applied wisely, because it has high organic matter content combined with available nutrients for plant growth." In relation to the study done by Van Ryssen *et al*., 1993 [23], showed similar results of poultry manure for plant growth as did in this study. In support of a study done by Adhikari *et al*., 2016 [1], days to first flowering and fruiting was significantly accelerated by T_3-poultry manure. In relations to reproductive parameters, T_3 and T_4 had a significantly higher yield productivity in terms of fruit quantity produced per experimental unit of the treatments, fruit weight and fruit diameter as compared to the other treatments.

A study done by Ganeshnauth *et al*., 2018 [12], showed similar results in using chemical fertilizer as did in this study, where the negative impacts of using a chemical fertilizer was experienced, the plants were vulnerable to pests and diseases. In this study two plants from T_2-synthetic fertilizer, was exposed to the tomato spotted wilt virus (TSWV) according to the signs and symptoms identified on the plants. The TSWV is caused by various thrips species, the virus is acquired by the thrip larvae and transmitted by the adults. The symptoms of tomato spotted wilt virus includes; chlorosis of leaves and blotches of green tissues, also the leaves may become twisted and distorted [22]. Since viruses cannot be cured, the neem extract was used to help the plants fight against the vectors responsible for transporting this disease.

There was low survival rate of T_5-Vermicompost experimental units, along with a delayed in fruit productivity due to severe rain fall resulting in flooding of the plant beds that affected plant growth. Some plants became stunted with the excess amount of water, resulting in death. After a few weeks, the plant treated with T_5 fertilizers showed an improvement in vegetative growth since they were transferred from field to pots, however the fruit production was not successful because the plants flower buds fell off before the production of fruit. This may be due to plant stress encountered from flooding and lack of pollination can also result in the buds falling off.

5. Conclusions and Recommendations

In conclusion, traditional cow manure and poultry manure displayed great potential as an alternative fertilizer to chemical fertilizers with plants showing increases in plant growth and production. However, the benefits of vermicompost as an organic fertilizer cannot go unnoticed due to its high physio-chemical content such as nitrogen, phosphorus and potassium which are essential nutrients in the growth of pepper plants. It is therefore recommended that future studies explore several seasons of growth using the treatments to better understand the potential benefit of vermicompost.

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7. Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

8. Disclosure of conflict of interest

The authors certify that this submission is original work and is not under review at any other publication. The authors hereby declare that this manuscript does not have any conflict of interest.

9. Statement of informed consent

The authors declare that informed consent was obtained from all individual participants included in the study. All work utilized in this study was fully cited and referenced so authors of prior researches are given their due credentials for their work.

10. Data Availability

Data will be made available on request.

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