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Effect of Vermicompost on Soil Nutrient Status for Production of Capsicum inside a High-Tech Poly House

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Abstract—*Constant cycling of nutrients in soil and environment system affects the soil fertility and also the process between organic and inorganic forms. A high-tech poly house situated in hillock of Assam, India, has been utilised for growing of crops throughout the year. The continuous application of chemical fertilizer resulted an imbalance of soil fertility and also effected the crop growth and yield inside the poly house. So, there is need for organic, bio-fertilizer and vermicompost etc. As Capsicum is an energy rich crop, the nutrient requirement is very high throughout its growing period. Thus, a field experiment was carried out to study the effect of vermicompost on Capsicum crop inside the high-tech poly house. The experiment includes three replications with vermicompost and one control without vermicompost. The soil analysis revealed that the soil is of clay loam soil with bulk density of 2.48 g/cc. The field capacity for the soil layers of 0-10, 10-20, 20-30, 30-40 and 40-50 cm was found as 15.76, 14.49, 12.52, 11.94 and 9.79%, respectively and wilting point of 9.79, 8.21, 7.51, 5.95 and 4.21%, respectively. The soil contains pH of 4.90 and EC of 0.73 mS. The initial N, P and K status was found to be 950.00, 146.47 and 492.50 mg/kg for soil samples and 15600, 10000 and 5000 mg/kg, for vermicompost, respectively. The application of vermicompost in soil in two splits revealed the increase of N, P and K content as 2.32, 1.47 and 2.04 times than the controlled. And also increase of fruit weight of 4.74 times and fruit number of 3.28 times more than the control. Therefore, it is suggested to use vermicompost as one of the alternate source of nutrient for crop planning and maintenance of soil fertility inside the high-tech poly house.*

Keywords*: Capsicum, high-tech poly house, soil fertility, vermicompost.*

1. INTRODUCTION

The North Eastern (NE) region of India is characterised by hills and mountains with folded topography, plateaus and hills with near tropical to alpine climatic condition. The unique diversity in agro-climatic conditions coupled with fertile and well-drained soil makes this region suitable for growing a large number of horticultural crops like wide range of fruits, vegetables and plantation crops [4]. The climate in North East is temperate and solar radiations are sub-optimal which is unsuitable for growing off-seasonal vegetables namely Capsicum, Tomato, Brinjal, Cucumber, Okra, Chilli, etc., in open field condition because of excessive heat, rainfall and frost [1, 14, 16] which arises the necessity of cultivation in protected conditions such as high-tech poly house where the natural environment is modified by the use of sound engineering principles to achieve optimum plant growth and yield [12, 13, 15]. In NEH region poly house culture is in infant stage and has not become popular as yet. Therefore, there is a good potential to promote the technology in this region for cultivation of vegetables.

Mineral fertilizers have been widely used to increase crop yields all over the world but the rampant use of chemical fertilizers also contributes largely to the deterioration of the environment, loss of soil fertility, less agricultural productivity and soil degradation and pollution of surface and ground water resources [9, 17] which arises the need for using organic, bio-fertilizer and vermicompost etc.

Vermicompost is a kind of natural eco-manure, which is the product of organic matter degradation through the interaction between earthworms and microorganisms [6]. It also contains plant growth regulating substances such as auxins, gibberellins, cytokinins, fulvic and humic acids which are beneficial for plant performance [18]. Thus, vermicompost could be one alternative to maintain soil quality in hilly terrains for the growth and yields of greenhouse Capsicums.

Capsicum (*Capsicum annum* L.) or Bell Pepper is an important cool season vegetable crop of India and are also known for their versatility as a vegetable crop and are consumed both as fresh vegetables or dehydrated for spices. This crop requires day temperature of 25-30°C and night temperature of 18-20°C with relative humidity of 50-60%. If temperature exceeds 35°C or falls below 12°C, fruit setting is affected [5]. However, it can be grown round the year using protected structures where temperature and relative humidity (RH) can be manipulated. As Capsicum is an energy rich crop, the nutrient requirement is very high throughout its growing period. Therefore, judicious application of fertilizer can help in good yield of Capsicum. Thus, the present study envisaged to monitor the effect of vermicompost on the production of Capsicum in the high-tech poly house situated to maintain the soil fertility.

2. MATERIALS AND METHODS

2.1. Study area

The focus area of study was a 7.29 m^2 plot inside a high-tech poly house (100 m^2) situated in the hilly terrain of the Department of Agricultural Engineering, Assam University, Silchar, India.

2.2. Selection of Crop

Among the vegetables that are grown in North Eastern region and Assam, growing of Capsicum, in open field condition is very difficult because of certain environmental extremes like scorching heat, heavy rainfall etc. may negatively affect the plant growth and thus results in low yield. Capsicums grow best in deep (minimum of 30 cm) loamy and well drained soils. Soil pH should be in the range of 5.5-7.0. So, Capsicum saplings of Syngenta, Indra F-1 Hybrid were selected as experimental trials for the feasibility of the protective cultivation in hilly terrain.

2.3. Nutrient requirement

Proper nutrient management is the one alternative to maximize the growth and yield of Capsicum and to minimize the loss. So, for the present study, the recommended dose of N:P:K of 60:20:50 is considered for Capsicum production. Based on the initial soil nutrient status which was analysed using standard methods and instruments (Table 1), fertilization was incorporated 2 times (during transplanting and flowering).

2.4. Selection of fertilizer

Many researchers have reported that vermicompost could be used to control, manage and protect the soil from quality degradation like degradation of soil physical properties [10, 11, 3]. So, in the present study, vermicompost was selected to carry out the experimental trials. The initial status of N, P and K in vermicompost was analysed ICAR Complex, Manipur. Based on the composition status of vermicompost and the existing status of soil nutrient, the quantity of vermicompost was applied in the experimental site.

2.5. Soil sampling

In order to assess the suitability of soil inside the high-tech poly house for agriculture soil sampling was carried out using soil core cutter and sampler at three observation points and 5 depths (0-10, 10-20, 20-30, 30-40 and 40-50 cm). The depth wise samples were considered for the analysis of soil physico-chemical status and composite samples for the analysis of soil nutrient status.

2.6. Physico-chemical analysis

2.6.1. Soil texture. Soil texture refers to the proportion of the soil separates that make up the mineral component of soil. These separates are called sand, silt and clay. Hydrometer method and International pipette method are commonly used to determine the particle size of the soil. However, in the present study, hydrometer method was used to estimate particle size distribution.

2.6.2. Moisture content. Moisture content (MC) of soil was calculated by oven drying method (Soil Survey Standard Test method) using moisture box, electronic weight machine and soil core.

2.6.3. Bulk density. Bulk density is the proportion of the weight of a soil relative to its volume. It is expressed as a unit of weight per volume and is commonly measured in units of grams per cubic centimetres (g/cc). Bulk density of soil was estimated by Soil Corer method [1] using soil core with a known diameter (d) and height (h).

2.6.4. Soil moisture characteristics. Soil moisture characteristic parameter such as field capacity and wilting point was determined to find out the water holding capacity of the soil using pressure plate apparatus. The soil samples, collected from the study area were kept under a pressure of 0.3, 1, 5 and 15 bar. The moisture content for the sample under the pressure of 0.3 bar will be the field capacity of that particular sample and the moisture content for the sample under the pressure of 15 bar will be the wilting point of that particular sample.

2.6.5. pH. The pH of soil and vermicompost was analysed using Electrometric method using pH meter (REMI Instruments). The calibration of the electrode was done with standard buffer solution and the standard procedure [7].

2.6.6. Electrical conductivity. Soil utilizes organic materials for a variety of uses, including providing plants with nutrients, aiding in irrigation, lowering evaporation rates, increasing the nutrient holding capacity of the soil and providing food for worms, bacteria and other soil organisms. Electrical conductivity of soil and vermicompost was analysed with the help of a conductivity meter.

2.7. Nutrient properties analysis

2.7.1. Total nitrogen (N). Nitrogen is primarily responsible for vegetative growth. Nitrogen assimilation into amino acids is the building block for protein in the plant. It is a component of chlorophyll and is required for several enzyme reactions. Total nitrogen in soil and vermicompost was determined by Micro Kjeldahl method [8] which consists of three main steps such as digestion, distillation and titration.

2.7.2. Total phosphorous (P). Phosphorus is a major component in plant DNA and RNA. Phosphorus is also critical in root development, crop maturity and seed production. Total phosphorus in soil and vermicompost was estimated by Olsen's method [8].

2.7.3. Total potassium (K). The role of potassium in the plant is indirect, meaning it is important for a plant's ability to withstand extreme cold and hot temperatures, drought and pests. Total potassium in soil and vermicompost was determined by Flame Photometer method [8].

2.7.4. Organic carbon. Organic matter serves as a reservoir of nutrients and water in the soil, aids in reducing compaction and surface crusting and increases water infiltration into the soil. For testing of organic carbon in soil and vermicompost, Walkley and Black's Rapid Titration method was used [7].

2.8. Plantation bed and crops

The treatment area (7.29 m^2) inside the high-tech poly house was divided into 3 numbers of replication rows and 1 number of control row with 5 number of Capsicum plants in each row. In between each rows, polythene barrier was provided to restrict the lateral movement of nutrient. The 25 days old Capsicum saplings were then transplanted maintaining a row to row and plant to plant distance of 45 cm and supplied with drip irrigation.

Table 1: Details of Parameters, Methods and Instruments used for Experimentation

Parameters	Methods	Instruments/References
	Physical Parameters	
Soil texture	Bouyoucos Soil Hydrometer Method	Allen,1989
Wilting point and field capacity	Pressure Plate Method	Huang, Li, Sumner, 2011
	Chemical Parameters	
pH (Vermicompost and Soil)	Electrometric Method	pH meter
EC (Vermicompost and Soil)	Electrometric Method	Conductivity meter
	Nutrient Parameters	
Total nitrogen (Vermicompost and Soil)	Micro Kjeldahl Method	Jackson, 1958.
Total phosphorus (Vermicompost and Soil)	Olsen's Method	Jackson, 1973
Total potassium (Vermicompost and Soil)	Flame Photometer Method	Jackson, 1973
Organic carbon (soil)	Walkley Black Rapid Titration Method	Jackson, 1958

2.9. Growth and yield analysis

The parameters of agricultural production such as plant height in centimetres (cm), number of fruits per replication, yield per replication in kilograms (kg) and total yield in kg/hectare (kg/ha) were also evaluated. The growth parameters such as plant height was monitored at 10 days interval however the yield parameters such as fruits per replication, yield per replication and total yield were monitored after flowering.

3. RESULTS AND DISCUSSION

3.1. Soil physical properties status

3.1.1. Soil texture. The sample wise soil texture status of the study site is presented in Table 2. However, the depth wise variations of sand-silt-clay percentage in the treatment are presented in Fig. 1. It was found that soil at a depth of 0-10 cm was silt loam and the soil at depths 10-20, 20-30, 30-40 and 40-50 cm was clay loam. The percentage of sand was found to be highest among all the aggregates in the treatment site.

Table 2: Depth Wise Status of Soil Texture Observed in the Study Site

Profile depth (cm)	Sample wise			Depth wise avg. (%)			Depth wise standard deviation			Depth wise soil type
	Sand	Silt	Clay	Sand	Silt	Clay	Sand	Silt	Clay	
	26.59	48.53	26.34							
0-10	26.77	47.50	25.22	26.67	48.00	25.33	0.09	0.52	0.96	Silt loam
	26.65	47.98	24.44							
	35.56	38.49	27.23							
10-20	34.32	36.8	27.32	35.33	37.33	27.33	0.92	1.00	0.11	Clay loam
	36.12	36.71	27.44							
	39.99	36.15	23.98							
20-30	40.01	35.29	25.23	40.00	35.33	24.67	0.01	0.80	0.63	Clay loam
	39.99	34.55	24.79							
	46.12	35.37	29.62							
30-40	48.48	34.21	31.25	47.32	34.32	30.29	1.18	1.00	0.85	Clay loam
	47.37	33.38	30.00							
	51.98	38.5	28.90							
40-50	50.78	38.55	29.70	50.54	38.33	29.40	1.57	0.34	0.44	Clay loam
	48.87	37.93	29.61							
Treatment Average				39.97	38.66	27.40	9.54	5.45	2.45	Clay loam

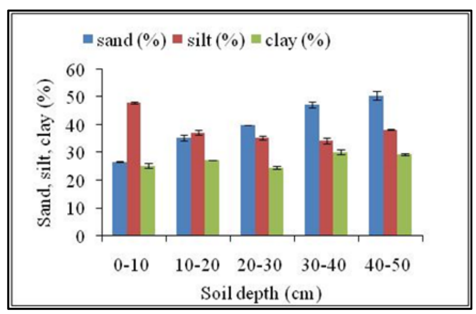

Fig. 1: Depth Wise Variations of Sand-Silt-Clay Percentage in the Study Site

3.1.2. Moisture content. The variation in the moisture content with respect to its soil depth of the study site is represented in Table 3 and it revealed that the moisture content was highest in the top layer soil (17.22%) while it was lowest in the bottom layer soil (4.62%). From Fig. 2, it can be seen that the trend of moisture content is decreasing with the increase in the soil depth due to high compactness of the soil.

3.1.3. Bulk density. The depth wise variation of bulk densities in the study site is represented in Table 3 and from Fig. 3 and 4, it can be seen that the bulk density is found more with the increase in soil depth due to compaction of the soil.

3.1.4. Soil water characteristics. The variations of the soil water characteristics of soil profile at

Table 3. Profile Depth Wise Status of Bulk Density and Moisture Content Observed in the Study Site

Profile depth (cm)	Sample wise bulk density (g/cc)		Depth wise Avg. bulk density (g/cc)		Depth wise standard deviation of bulk density		Sample wise moisture content (%)	Depth wise avg. moisture content (%)	Depth wise standard deviation of moisture content
	Wet	Dry	Wet	Dry	Wet	Dry			
	2.06	1.83					15.23		
0-10	2.21	1.53	2.20	1.69	0.13	0.15	16.58	17.22	2.38
	2.32	1.72					19.85		
	2.09	1.85					12.64		
10-20	2.53	1.61	2.40	1.77	0.27	0.14	11.28	10.08	3.32
	2.59	1.85					6.33		
	2.21	1.87					10.5		
20-30	2.61	1.75	2.52	1.95	0.27	0.24	9.69	9.08	1.81
	2.73	2.22					7.04		
	2.22	2.17					7.21		
30-40	2.72	2.32	2.61	2.28	0.35	0.09	5.52	6.13	0.94
	2.89	2.34					5.67		
	2.31	2.23					5.76		
40-50	2.81	2.56	2.70	2.43	0.34	0.18	4.35	4.62	1.03
	2.97	2.50					3.75		
Treatment Average			2.48	2.02	0.19	0.32		9.42	4.87

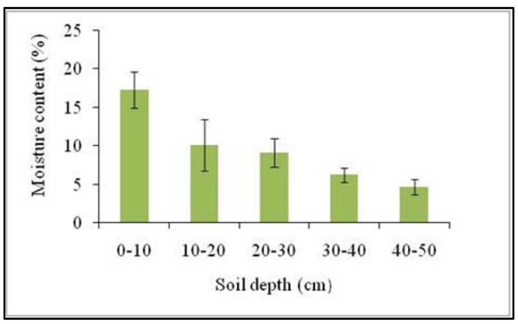

Fig. 2. Depth Wise Average Moisture Content Observed in the Study Site

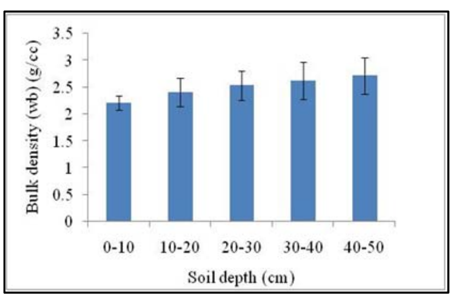

Fig. 3. Depth Wise Average Wet Bulk Density Observed in the Study Site

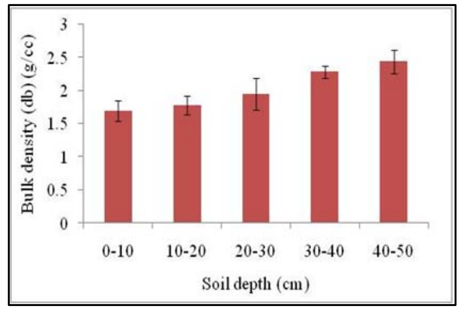

Fig. 4. Depth Wise Average Dry Bulk Density Observed in the Study Site

different tensions (0.3, 1, 5 and 15 bar) for different depth observed in the study site is presented in Table 4. From Fig. 5, the soil water content at field capacity (FC) and permanent wilting point (PWP) were found to be decreasing with depth of soil. This may be due to variation in topography and land use which affects the distribution of soil moisture and different management practice. The soil water content at field capacity was found to be maximum at depth 0-10 cm (15.76%) and minimum at the depth of 40-50 cm (9.79%) whereas, the wilting point was found to be maximum at the depth of 0-10 cm (9.79%) and minimum at the depth of 40-50 cm (4.21%).

Table 4. Depth Wise Soil Moisture Characteristics Observed in the Study Site

Depths (cm)	Soil moisture content (%) at different tensions (bar)			
	0.3	1	5	15
0-10	15.76	11.42	10.52	9.79
10-20	14.49	10.85	9.47	8.21
20-30	12.52	9.82	8.72	7.51
30-40	11.94	8.79	6.06	5.95
40-50	9.79	7.65	5.56	4.21

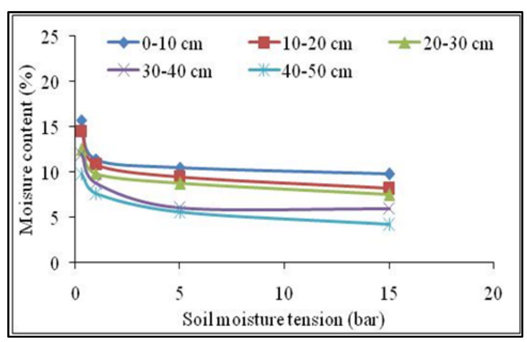

Fig. 5. Depth Wise Soil Moisture Characteristics Status on Dry Basis Observed in the Study Site

3.2. Chemical properties of samples

3.2.1. pH and electrical conductivity. The observed pH and EC of different soil samples for the study site are tabulated in

Table 5. The pH of all the soil samples were found to be in the range of 4.71 to 5.15 which indicates that the soil is acidic in nature and about 50% of applied fertilizer may be available to plants. Fig. 6 shows the variation of average pH with respect to various soil profiles observed in the study site. The pH was found to be more at a depth of 40-50 cm. The EC of the soil samples were found to be in the range of 0.63 to 0.77 mS. Fig. 7 shows the variation of the average EC's of soil profiles observed in the study site. It has been found from the Fig. that the EC is highest at the soil profile of 20-40 cm. However, the pH and EC of vermicompost was found to be 7.73 and 20 mS, respectively. The application of vermicompost could neutralize the acidity of the soil.

3.3. Nutrient status of soil with fertilization

Composite soil samples were collected from 3 locations of both the treatments and were analysed for the determination of total nitrogen, total phosphorous, total potassium and total organic carbon content before and after 2 splits of application of vermicompost using the standard procedures. The details of the effect on NPK are explained in the following section.

3.3.1. Total nitrogen. Total nitrogen content in soil of the study site was found in the range of 933.39 to 958.29 mg/kg before the application of fertilizer (vermicompost) (BF) and after the application of first split of fertilizer (vermicompost) (AF), the content varied from 1013.39 to 1058.29 mg/kg and 1045.54 to 1205.66 mg/kg, after second split of fertilization (Table 6).

3.3.2. Total phosphorous. Total phosphorous content in the soil of the study site was found in the range from 143.28 to 150.52 mg/kg before the application of fertilizer (vermicompost) however, after the first application of fertilizer (vermicompost), the content varied from 108.12 to 114.09 mg/kg and 98.49 to 112.03 mg/kg after second split of fertilization.

Table 5. Depth Wise Soil pH and EC Status Observed in the Study Site

Depth (cm)	pH	Avg.	Std. Dev.	EC (mS)	Avg.	Std. Dev.
	4.86			0.8		
0-10	4.56	4.71	0.15	0.8	0.73	0.12
	4.70			0.6		
	4.77			0.8		
10-20	5.29	4.93	0.31	0.6	0.70	0.10
	4.73			0.7		
	4.67			0.7		
20-30	5.11	4.83	0.24	0.8	0.77	0.06
	4.72			0.8		
	4.88			0.8		
30-40	4.62	4.89	0.28	0.8	0.77	0.06
	5.17			0.7		
	5.21			0.7		
40-50	4.48	5.15	0.64	0.6	0.63	0.06
	5.75			0.6		
Avg.		4.90	0.16		0.72	0.05

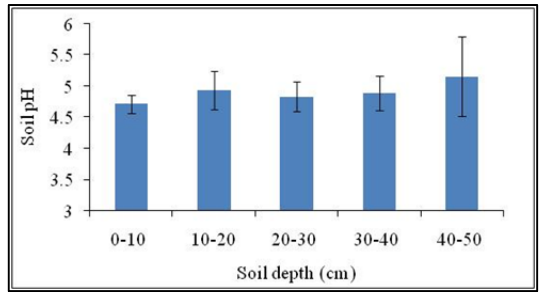

Fig. 6. Depth Wise Average Variation of Soil pH in the Study Site

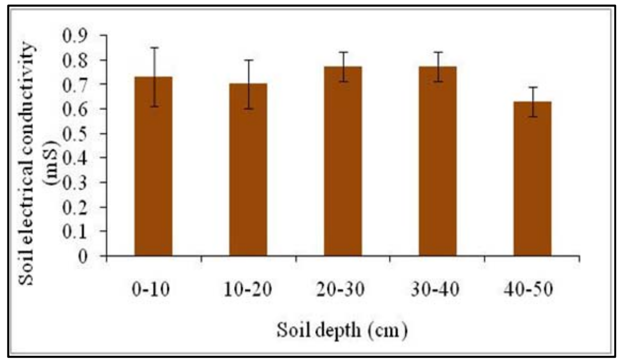

Fig. 7. Depth Wise Average Variation of Soil EC in the Study Site

3.3.3. Total potassium. Total potassium content varied from 479.91 to 515.98 mg/kg before the application of fertilizer (vermicompost) and after the first application of fertilizer (vermicompost) (AF), the content varied from 492.81 to 575.58 mg/kg. However, it varied from 419.50 to 526.00 mg/kg after second split of fertilization.

3.3.4. Total organic carbon. The total organic carbon content of the soil of the study site was found in the range from 6649.08 to 7689.8 mg/kg before the application of fertilizer (vermicompost) and after the first application of fertilizer (vermicompost), the content varies from 7873.08 to 7989.80 mg/kg whereas, after second split of fertilization, the content was found in the range from 7100 to 7900 mg/kg.

The variation of total nitrogen, phosphorous, potassium and organic carbon in both the treatment areas, before and after fertilization (2 split) is represented in Fig. 8. It is observed that there is increase in the amount of nitrogen which may be due to the quantity of nitrogen released from the soil organic matter or any nitrogen carried over from previous fertilizer applications, increase in potassium may be due to the fact that plants generally absorb the majority of their potassium at an earlier growth stage and increase in organic carbon content may be due to the microorganisms that breakdown soil organic carbon as an energy source, this occurs faster when the soil is moist and warm but there is a decrease in the quantity of phosphorous in the soil. This may be due to too wet or dry condition of soil, compacted soil, herbicide damage, insect damage or salinity of the soil. The increase in the other nutrient status clearly indicates change in the N, K and OC content of the soil after the application of vermicompost.

3.4. Nutrient status of vermicompost

Total nitrogen, phosphorous and potassium in vermicompost was determined by the Micro Kjeldahl method, Olsen's method and Flame Photometer method. Three replication of the sample was analysed and the average amount of total nitrogen, phosphorous and potassium was found to be 15600, 10000 and 5000 mg/kg, respectively.

Table 6: Average Nutrient Content of Soil Observed in the Treatment Areas after Second Split of Fertilization

Observation points	Total nitrogen (mg/kg)	Total phosphorus (mg/kg)	Total potassium (mg/kg)	Total organic carbon (mg/kg)
Before fertilization				
1	958.29	150.52	479.91	6649.08
2	933.39	143.28	515.98	6961.13
3	958.33	145.62	481.62	7689.80
Average	950.00	146.47	492.50	7100.00
After 1st split of fertilization				
1	1058.29	110.76	492.81	7873.08
2	1013.39	114.09	575.58	7987.13
3	1228.33	108.12	566.62	7989.80
Average	1100.00	110.99	545.00	7950.00
After 2nd split of fertilization				
1	1050.43	98.49	430.78	7600.00
2	1045.54	112.03	419.50	7900.00
3	1205.66	103.21	526.00	7100.00
Average	1100.54	104.58	458.76	7533.33

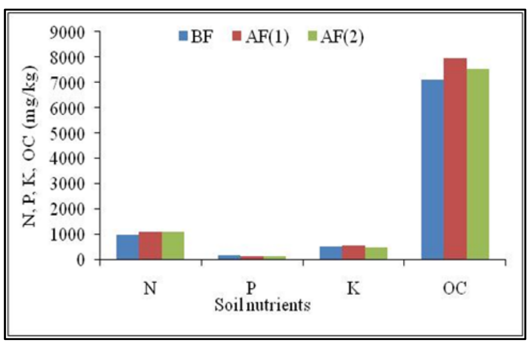

Fig. 8. Average Nutrient Content of Soil Observed in the Study Site before and after 2 Splits of Fertilizer

3.5. Response of growth and yield of Capsicum

The plant growth parameter such as plant height was also monitored to study the effect of vermicompost inside the high-tech poly house. The plant height was found to be highest in R_2 (33.71 cm) than the control (22.22 cm). The replication wise yield parameters such as variation of fruit weight and yield observed in the study site is presented in Table 7 and replication wise variation of fruit number observed in the study site is presented in Table 8.

The total yield was found to be 41.11 kg/ha. The variation of fruit weight throughout the growing season and variation of total yield per replication in the study site is illustrated in Fig. 9 and 10, respectively. However, the variation of fruit number throughout the growing season in the study site is illustrated in Fig. 11.

Table 7. Replication Wise Variation of Fruit Weight and Yield Observed in the Study Site

Harvesting period	Fruit weight (g)				Yield (kg/ha)
	Control	R_1	R_2	R_3	
1st harvest	921.32	950.37	969.28	964.75	
2nd harvest	890.72	821.05	940.32	962.28	
3rd harvest	800.27	820.49	905.88	920.93	41.11
Total (kg)	5.22	7.77	8.44	8.54	
Avg. (kg)	1.74	2.59	2.81	2.84	

Table 8. Replication Wise Variation of Fruit Number Observed in the Study Site

Harvesting period	Fruit number			
	Control	R_1	R_2	R_3
1st harvest	6	7	8	8
2nd harvest	7	8	7	9
3rd harvest	8	6	8	8

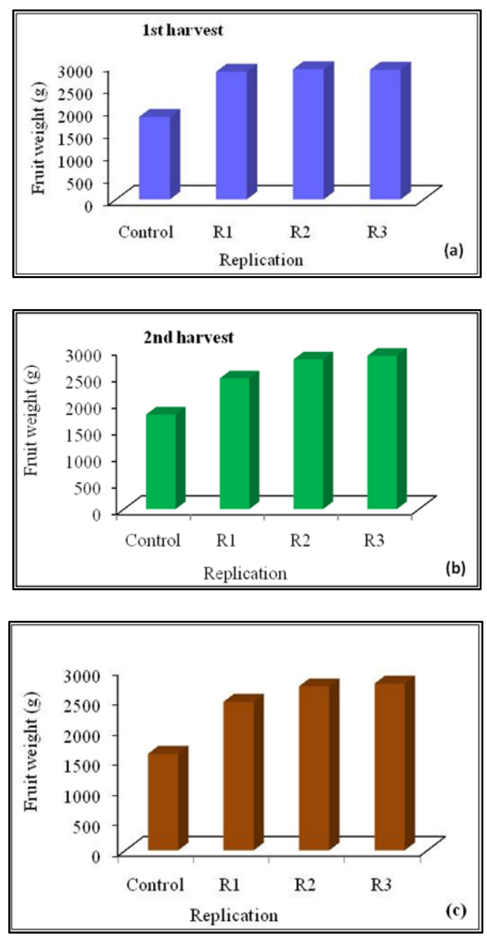

Fig. 9. Variation of Fruit Weight throughout the Growing Season (1st, 2nd and 3rd Harvest) in the Study Site

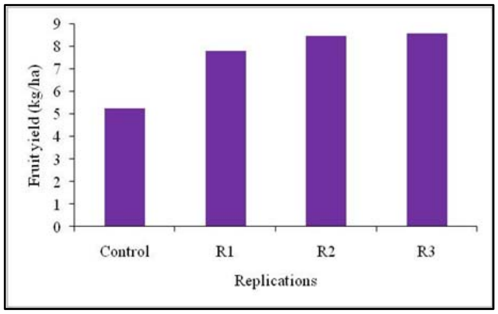

Fig. 10. Variation of Total Yield in the Study Site

4. CONCLUSION

The study on effect of vermicompost on soil nutrient status and productivity of Capsicum inside a high-tech poly house revealed that plants under protected cultivation system and vermicompost fertilization could be better option to increase the production round the year in a hilly terrain. The study revealed that the 4.74 times increase of fruit weight increased and 3.28 times increase of the fruit number than in the control. Therefore, it is suggested to use vermicompost as one of the alternate source of nutrient for crop planning and maintenance of soil fertility inside the high-tech poly house.

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