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Comparative Analysis of Integrated Use of Vermicompost and Inorganic Fertilizer on Chili Crop (*Capsicum annum L.*) Growth and Productivity

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ABSTRACT

The purpose of this study is to compare the growth, productivity, and capsaicin content of chilli plants grown with chemical fertiliser alone to those with vermicompost alone and vermicompost in conjunction with chemical fertiliser in a field experiment. The four distinct treatments were C (control), T1 (NPK 100%), T2 (vermicompost 100%), and T3 (vermicompost + NPK 50:50). The experiment lasted 160 days, or until the fruits matured. Capsaicin content of the chilli was assessed from fruits obtained from each of the four treatments. The results demonstrated that T2 (vermicompost) has a significantly positive effect on the morphological and growth characteristics of chilli plants, with better shoot growth, number of leaves, number of branches, stem diameter, higher fruit yield, fruit weight, fruit biomass, and significantly higher capsaicin content compared to the other three treatments. The integrated application of T3 (vermicompost + NPK 50:50) on chilli plants did not exhibit any appreciable differences in crop growth and productivity compared to other treatments.

Key words: Vermicompost, chemical fertilizer, integrated, chilli, growth parameters, capsaicin.

INTRODUCTION

Continuous soil cultivation using inorganic fertilisers has been linked to decreased soil organic carbon and organic matter, nutritional imbalances, and a lack of secondary macronutrients and micronutrients (Osundare 2004). One of the most important commercial vegetables is the chilli (*Capsicum annum* L.), which is mostly farmed in India as both green fruit vegetables and dried spices. The productive potential of the genetic material, soil or substrate characteristics, an adequate supply of nutrients, the availability of water, temperature, luminosity, crop management practises, and pathogen pressure are some of the factors that affect the productivity of chillies, as with other vegetables (Pereira et al. 2013, Taiz 2017).Traditionally, inorganic insecticides and fertilisers were used to grow chillies, the excessive use of these killed the beneficial soil organisms, destroying its natural resilience, and weakening the power of "biological resistance" in crops, making them susceptible to pests and diseases .Also Continued usage of chemical fertilisers results in health and environmental risks, such as nitrate leaching that pollutes ground and surface water (Eswaran and Mariselvi 2016).In order to reduce soil acidity, improve the physical characteristics of the soil, and improve its nutrient status, organic manures are used (Ano and Agwu 2005). A method of organic farming known as vermicomposting uses earthworms to break down organic waste, promote microbial activity, and quicken the soil's mineralization process. The pungency of pepper fruits and their by-products is caused by chemicals called capsaicinoids (Perucka and Materska 2001). Most of the intense kinds of chilli peppers include capsaicin (8-methyl-N-vanillyl-trans-6-nonenamide), which makes up around 90% of all capsaicinoids (Kosuge and Furuta 1970). The purpose of this study thus is to examine how vermicompost used alone as organic manure and in combination with chemical fertilizer affect the development and yield of pepper plants (*C. annum*). This research will be of major benefits to farmers in improving their understanding of how vermicomposting can improve the quality of crops production on sustainable basis, increase the fertility of the soil, and reduce the need to purchase synthetic fertilisers.

STUDY AREA

The study locations are situated in the Indo-Gangetic alluvial plains in the semi-arid region of Raebareli district of Uttar Pradesh (latitudes 25°49' and 26°36'

North and longitudes 80°41' and 81°34' East), in Agroecoregion 4, which is characterised by a hot, semi-arid habitat with alluvial soil deposits (Sehgal et al. 2002). Soils are sandy loam to loam, dark grey, coarsely textured, and have very low amounts of organic carbon and nitrogen. They also have poor permeability. The average minimum and maximum temperatures during the winters (November to February) are 7.8 and 25°C, respectively. The summer months of March through June are hot and dry, with typical low and high temperatures of 38 and 42.2°C, respectively.

METHODS

Vermicompost production

The vermicompost was produced in the experimental set up available in the college campus.

Seed germination assay

The experiments were conducted using 20 medium-sized Petri plates, with five replicates of each treatment (5 petri plates/treatment). *Capsicum annuum* L G4 certified seeds were purchased from Harsha Ram Seed Corporation in New Delhi, India. A completely randomised block design with three-replications were used for this experiment.

Treatments

The treatment combinations are: C - control, no fertilizer application; T1- The plot in which only NPK were added (100%); T2- only vermicompost was added (100%); and T3- NPK +vermicompost were added (50%+50%). In all the treatments, seeds were not pre-treated with chemicals. They were soaked in only tap water for 24 hours, and placed at an average relative humidity of 75±3% and room temperature 30.2 ± 0.4°C. 100 seeds/ treatment were put into the soil in rounded plastic pot. Soil used for germination in plastic pots was from the same field plots where they would be transplanted. One kg of soil was placed in plastic pots that were 10 inches in diameter and 8 inches high. The amounts of chemical fertiliser and vermicompost used were based on the basal doses used by the farmers (urea, 71 kg/ha; DAP, 44 kg/ha; potash, 26 kg/ha; and vermicompost, 2500 kg/ha).

All the treatments in plot experiment were replicated five times thus the treatments in the plot experiments were as follows: TI: Urea added at the rate of 7.1 g/m^2, DAP 4.4 g/m^2, and potash 2.6 g/m^2; T2: added corresponding basal dose of chemical fertilizer, 25 kg of vermicompost in 1 m^2 plot. The concentration of nutrients of the vermicompost was 500 g/m^2 N; 250 g/m^2 P and 375 g/m^2 of K; T3: NPK + vermicompost used - urea 3.5 g/m^2, DAP 2.2g/m^2, and potash 2.2 g/m^2 and 12.5 kg/m^2 of vermicompost having 250 g, 25 g and 187.5 g NPK, respectively.

The quantity of chemical fertilizer and vermicompost added to the pot soil were calculated based on the plot experiment, One kg of soil was collected from the study site and used in the pot experiments and the quantity of chemical fertilizer and vermicompost added to the pots under each treatment was: T1 : Urea 0.71 g/kg; DAP 0.44 g/kg: Potash 0.26 g/kg of soil; T2 : 2.5 kg/pot vermicompost with 50 g, 2.5 g and 37.5g of NPK, repectively; T3 : Chemical fertilizer + vermicompost 50 : 50 ratio - Urea 0.71 g/kg; DAP 0.44 g/kg: Potash 0.26 g/kg and 1.25 kg/pot vermicompost with 25 g, 1.25g and 18.75g NPK, respectively.

The soil in the pots was irrigated with normal tap water. Over-watering was avoided because it could result in fungal development on the seeds, which would impair their ability to germinate and cause seed rot (Matthews 2010). The germination percentage, root length, shoot length, and seedling length were all measured after 10 days.

Agronomic practices and growth yield measurements

NPK and vermicompost were applied as source of manure during experiments. Five replicate plots (1×1 m) were demarcated. All plots were selected on college campus. In order to calculate the vermicompost's equivalent amounts of N, P, and K, basal doses of nitrogen (120 kg/ha), phosphorus (60 kg/ha), potassium (50 kg/ha), and vermicompost (2500 kg/ha (50 kg, 25 kg and 37.5 kg NPK, respectively)) were utilised. All the agronomic practices were done as recommended by the farmers and by the Department of Agriculture. The seedlings were transplanted in the field after 50 days (17 November 2018). In each plot 9 seedlings were transplanted. Each experimental plot was irrigated with normal tap water when soil moisture content was lower than 30%. Each treatment was replicated five times. Five plants (1 plant/plot) were chosen from a total of 45 plants (9 plants/plot * 5 replicates) for growth and yield measurements such as leaf area index, root length, shoot length, shoot diameter, number of branches, number of leaves, average number of buds, average number of flowers, average number of fruits per plant, total fruit yield for each plant, plant biomass, and capsaicin content of the fruits. The plants planted along the border inside the experimental plots (5 repetitions) were randomly selected and pulled out to lessen the spacing effect, which would have been more pronounced if the plants were plucked out from the middle row of the plots. These measurements were taken using destructive random sampling. The germinated seeds were allowed to grow under field condition till they attained maturity and bore fruits.

Soil physico-chemical analyses

Soil analysis was carried out in accordance with the TSBF guidelines (Okalebo et al. 1994). Semi-microkjeldal method was used to determine nitrogen, EDTA method was used to determine calcium and magnesium; an automatic flame photometer PGI 2000 was used to determine potassium; and colorimetric method for P.

Capsaicin extraction

All the Chilly samples were collected from the plot experiments under four different treatments (control, T1, T2, and T3). The samples were first dehydrated, and then the extraction process was slightly modified (Collins et al. 1995). Each sample of powdered peppers (5 g) was added to ethanol (5 ml) in a 120 mL glass bottle with a Teflon-lined top to extract the capsaicin. For four hours, bottles were swirled and frequently capped in an 80°C water bath. The samples were taken out of the water bath and allowed to cool to room temperature. Using a 5 ml disposable syringe, the supernatant layer of each sample (5 ml) was processed through 0.45 m filter paper into an HPLC sample vial. When not in use, the vial was sealed and kept in a refrigerator at 5°C. Double-distilled water was used throughout the experiment, and other solvents and substances were of analytical purity.

$$\gamma = \alpha \times c^* v / \beta$$

Where, γ = Concentration of the analyte in the sample µg/g; α = Peak area of sample aliquot; β = Peak area of respective standard; c = Concentration of standard solution µg/ml; v = Volume of the sample extract; The capsaicin content in pepper dry weight was multiplied by the coefficient corresponding to the heat value for pure capsaicin, which is 1.6 10^7 Scoville heat units (Sanatombi and Sharma, 2008).

Pest and disease management

Five kg of fresh vermicompost were removed from the vermicompost pit and soaked in a bucket filled with 25 litres of water. An aerator was then used to continuously stir the mixture for four hours. The supernatant was filtered through a screen with a 1 cm mesh size after the mixture had been allowed to stand for an hour without being disturbed. This vermiwash was sprayed onto leaves once each in December and January to look for bugs.

Statistical analysis

To evaluate the statistical significance of treatment effects, a one-way ANOVA was performed. The standard error of the mean data was used to compute the sample standard error. The statistical analyses were conducted using the SPSS 20 programme for the window package (Zar 2014). The F test in ANOVA was used to determine whether there were significant differences between the treatments. The Standard Error of Mean Value (SE mean) was used to examine concentrations and their interactions with plant development. The mean values from all the treatments were compared using the NewMan-Keuls multiple range test (q Test) with a significance level of $P<0.05$.

RESULTS

Soil physico-chemical analyses

Soil was sandy loam with a bulk density of 1.68 and mildly alkaline pH. It is rich in organic matter but relatively low in nitrogen content. The soils of the study sites are relatively richer in potassium (Table 1).

Number of germinated seeds

In all experiments, seeds began to grow three to four days after being sown. When compared to other treatments, treatment T2 significantly enhanced the percentage of seeds that germinated (F = 6.52, P

Table 1. Physico-chemical properties of the soil at the study site (mean ± standard error)

Parameter	Value
pH (1:5)	7.3
Sand%	55±4.9
Silt%	32±2.7
Clay %	13±.87
Bulk density %	1.68
C%	0.51±0.04
N%	0.18±0.01
OM.%	0.48±0.03
$PO_{4-}P$ mg\100g	1.08±0.09
Ca meq/100g	7.8±0.65
Mg meq/100g	11.14±0.99
K meq/100g	3.23±0.25

0.01). Between T1, T2, and T3, there was a significant variation in the percentage of seeds that germinated. The number of germinated seeds was significantly higher in T2 and lower in T3 (Fig.1).

Shoot growth

All four treatments varied significantly (F=6.57 P<0.05) after 20 days of seed sowing, and the shoot length increased significantly (F=6.57, P<0.05) under treatment T2 as compared to other treatments. However, there was no significant difference observed among all other treatments. This result became more evident as, after 40 days, the increase in shoot length became significantly more prominent under T2 (q 0.05,8,4= 6.15) as compared to treatments T1, T3, and control. This pattern continued over 120 days of increasing shoot length, but after 140 days of the experiment, the shoot length was significantly higher (F=522.85 P<0.05) in T1 than in T2. There was a significant difference in shoot diameter between the four treatments (F 23.5, P = 0.05). Although there was no significant difference between T3 and T1 and T2 and control in the early phases of the experiment, the shoot diameter was significantly higher under T2 (q 0.05,8,4=9.78) than under other treatments. The shoot diameter was significantly greater in T2 and lower in T3 up till 160 days of seed sowing (q 0.05,8,4=17.2) (Fig. 2a, b, c).

Root length

As of 50 days into the experiment, T2 had considerably longer roots than T3, T1, and control (q 0.05,8,4= 20.9). However, there was no statistically significant difference between treatments T3 and T1 20 days after the seed was sown (F=87.13

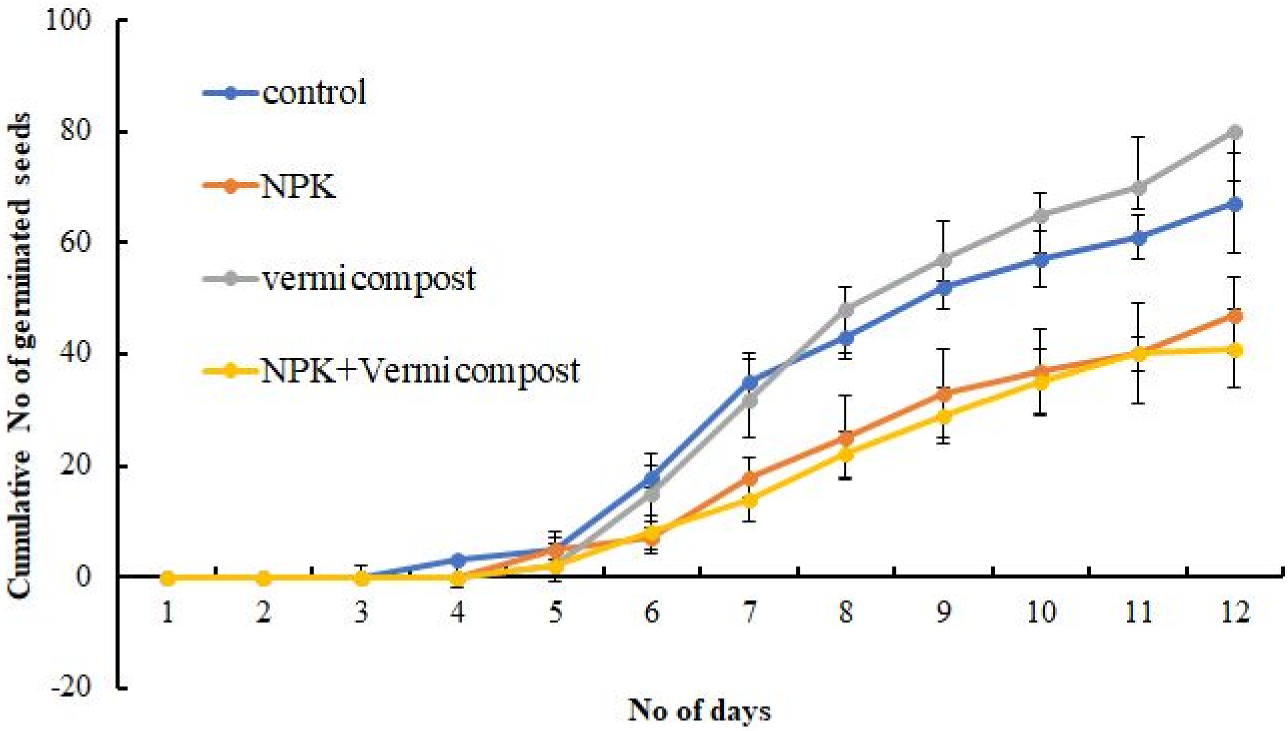


Figure 1. Effect of integrated use of vermicompost and inorganic fertilizer on seed germination

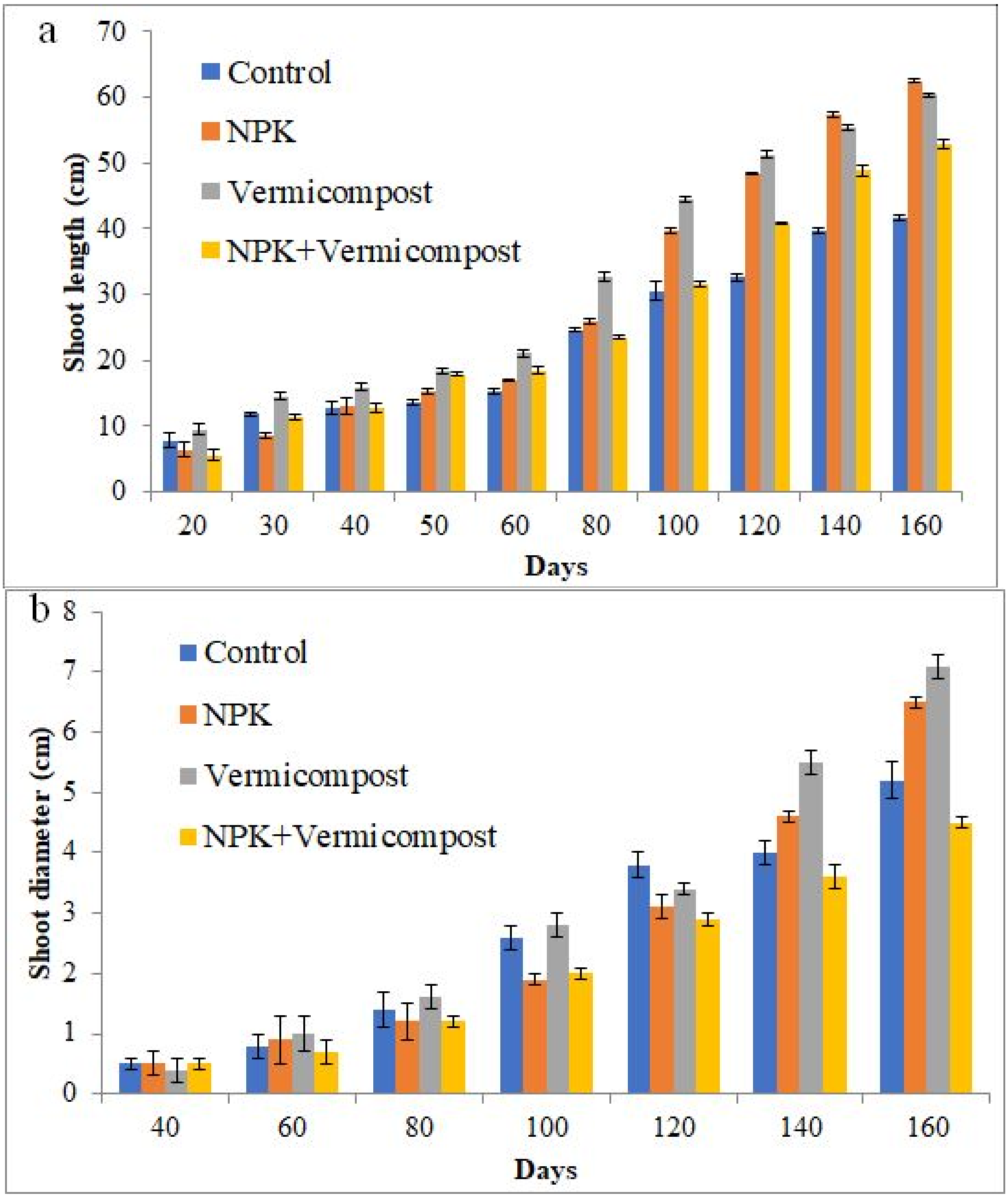


Figure 2. Effect of integrated use of vermicompost and inorganic fertilizer on (a) shoot length (b) shoot diameters

P< 0.05). The root length in T2 (q0.05,8,4=30) and T3 (q0.05,8,4=30) was significantly different after 60 days (F = 149.33, P< 0.05) and higher in T2. This pattern of root growth was maintained for 160 days, although no statistically significant difference was seen after 100 days between control and T2 or again after 140 days between treatments T1 and T3 (Fig. 3a, b)

Number of branches

The significant growth of number of primary and secondary branches showed after 100 days. It increased significantly (F=44.3 P<0.05) in the T2 treatment in comparison of T1 and T3. The number of branches was significantly lower in control. after 140 days of seed sowing the No. of branches was significantly (F=12.88 P<0.05) higher in T2 (q0.05,8,4=8.19) and lower in control (q0.05,8,4=2.45). There was no significant difference between T1 and T3 and T3 and control (Fig.4).

Number of leaves /plant

All four treatments varied significantly (F=147.5 P<0.05) 60 days after seed sowing. After 60 days of seed sowing the number of leaves per plant increased significantly (F=147.5, P<0.05) under treatment T_1 (q0.05,8,4=28.57) as compared to other treatments. Significant difference was identified among the four treatments during the entire period of the experiment. During 100 days, control had a significantly higher (F=200.33 P <0.05) and during 140 days the treatment T2 had a significantly higher (F=413.56 P<0.05) number of leaves as compare to other treatments (Fig.5).

Number of buds/plant

Bud formation in chilli plants started after 70 days of seed sowing, and after 80 days significant (F=28.53 P<0.05) difference observed between treatment T2 and control, T2 and T3, T2 and T1 and T1 and control. there was no significance difference between T1 and T3 and T3 and control. Number of buds was highly significant (q0.05,8,4=12.61) in T2 and lower in control (q0.05,8,4=3.60). During 120 days the significant difference observed in four treatments. The number of buds is significantly higher (F=124.8 P<0.05) in T2 treatment till 160 days of experiment as compared to other treatments (Fig.6).

Number of flowers/plant

Flower production varied significantly between the four treatments ($F_{0.05,3,16}$=37.06), T2 treatment produced substantially more flowers per plant ($q_{0.05,8,4}$=14.41) than C, T1 and T3 treatments. Throughout the observation period, the T1 treatment produced more flowers per plant than the control and T3 treatment. Flower production did not differ considerably between the control and T1 treatments (Fig.7).

Number of fruits/plant and biomass g/m²

After fruiting, all four treatments differed significantly ($F_{0.05,3,16}$=87.33 P<0.05). After 100 days, the number of fruits in treatment T2 was substantially higher ($q_{0.05,8,4}$=14.41) than in other treatments, and this tendency lasted until the crop was harvested. After 140 days, there was no significant difference between T3 and control, with control producing the fewest fruits. T2 produced considerably more fruits per plant, fresh fruit weight per plant, and total fruit

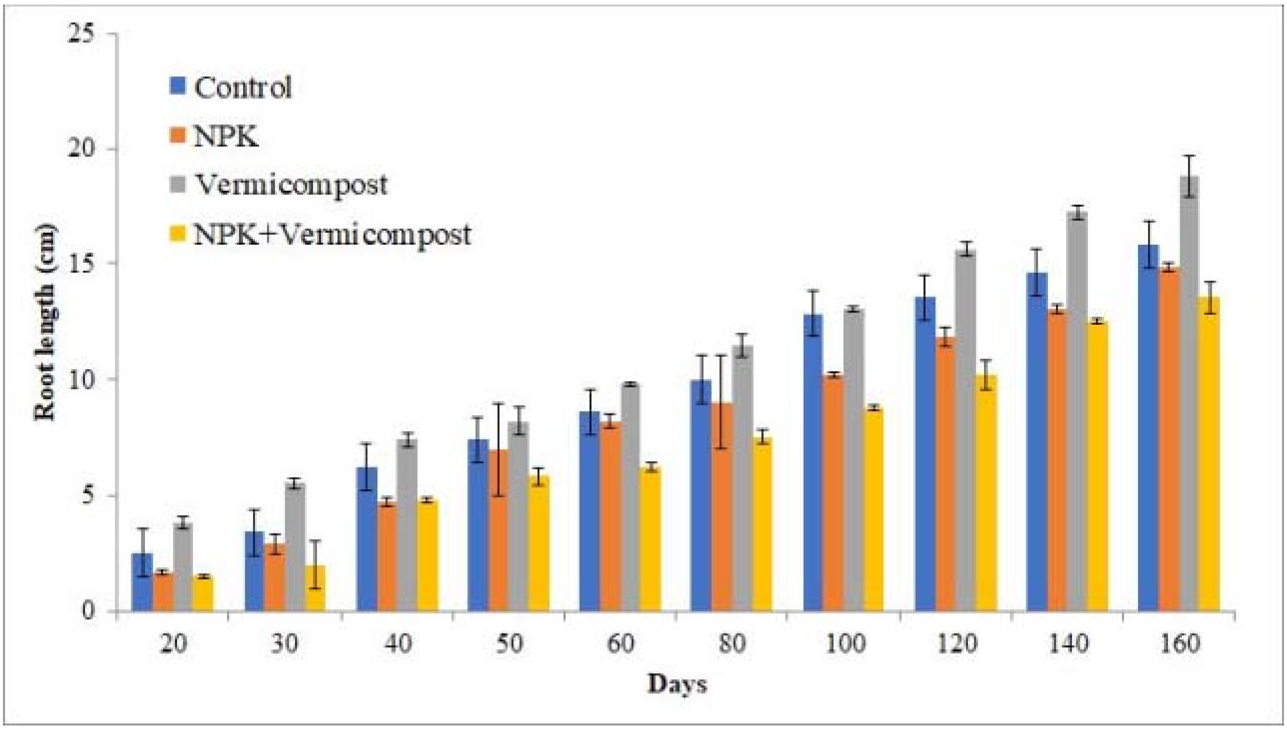


Figure 3. Effect of integrated use of vermicompost and inorganic fertilizer on root length

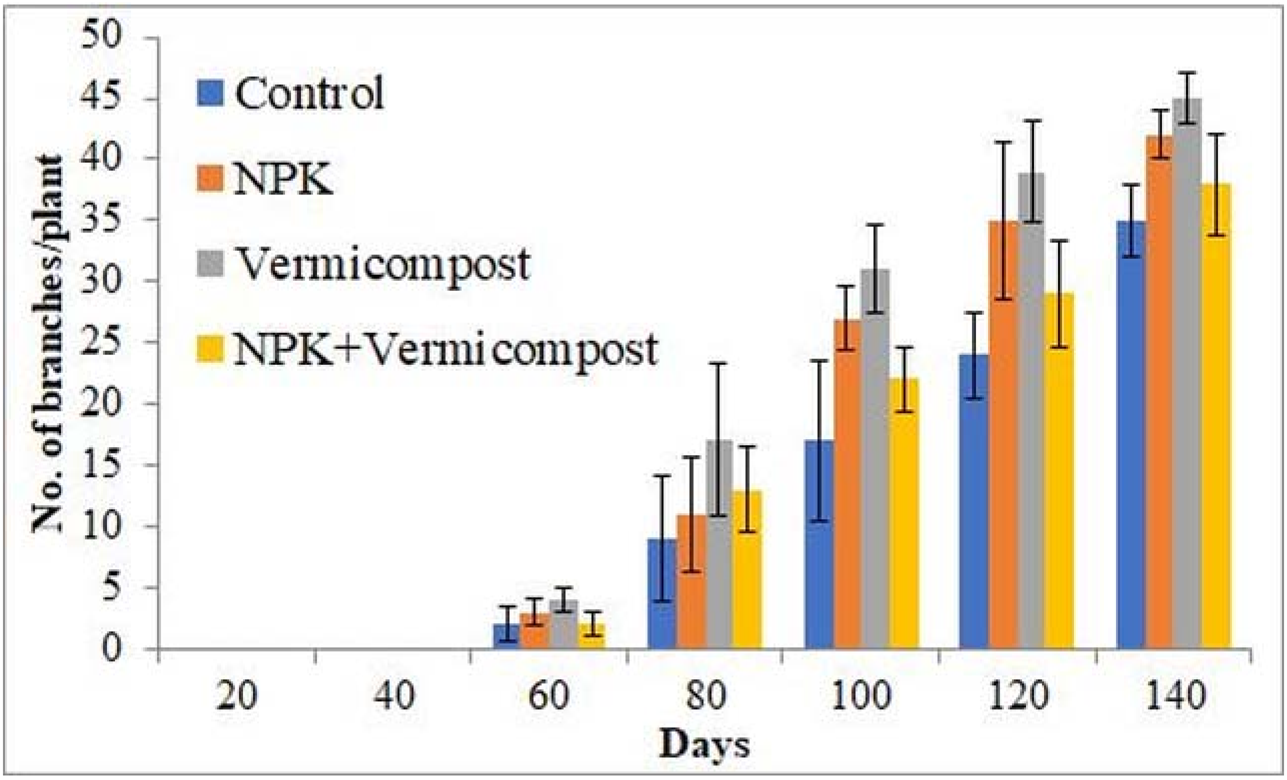


Figure 4. Effect of integrated use of vermicompost and inorganic fertilizer on number of branches/plants

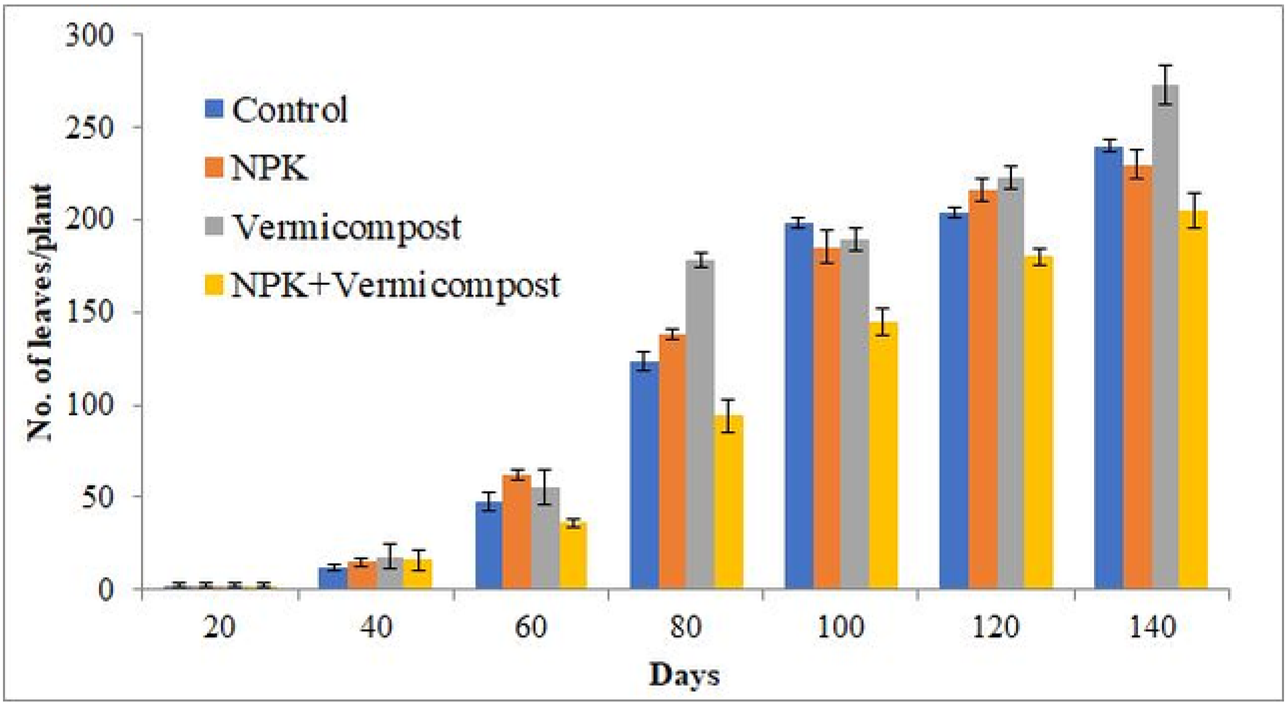


Figure 5. Effect of integrated use of vermicompost and inorganic fertilizer on number of leaves/plants

output per plant ($P<0.05$) than the other treatments. Compared to the control, T1, and T3 treatments, the total amount of fruit biomass in the T2 treatment was highest (P0.05) (Fig. 8a, b).

Capsaicin content

Following extraction, HPLC tests were carried out to identify and quantify capsaicin in control, T1 (NPK 100%), T2 (Vermicompost 100%) and T3

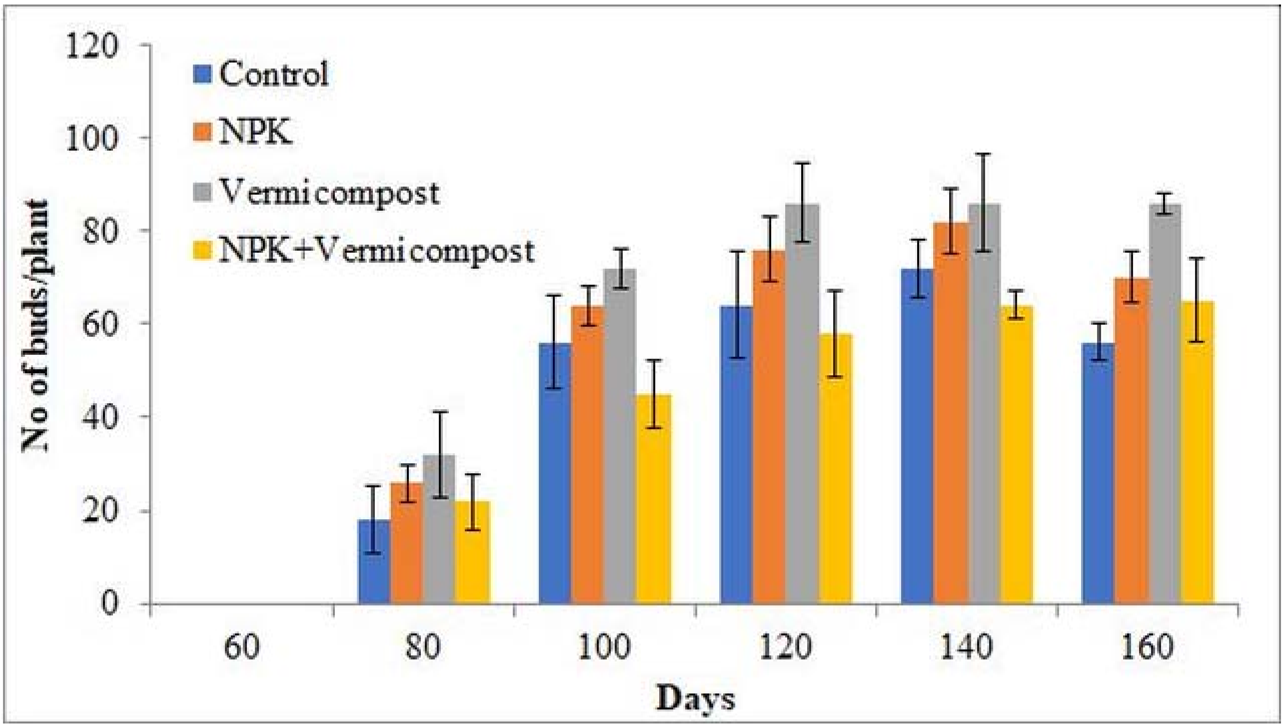


Figure 6. Effect of integrated use of vermicompost and inorganic fertilizer on number of buds/plants

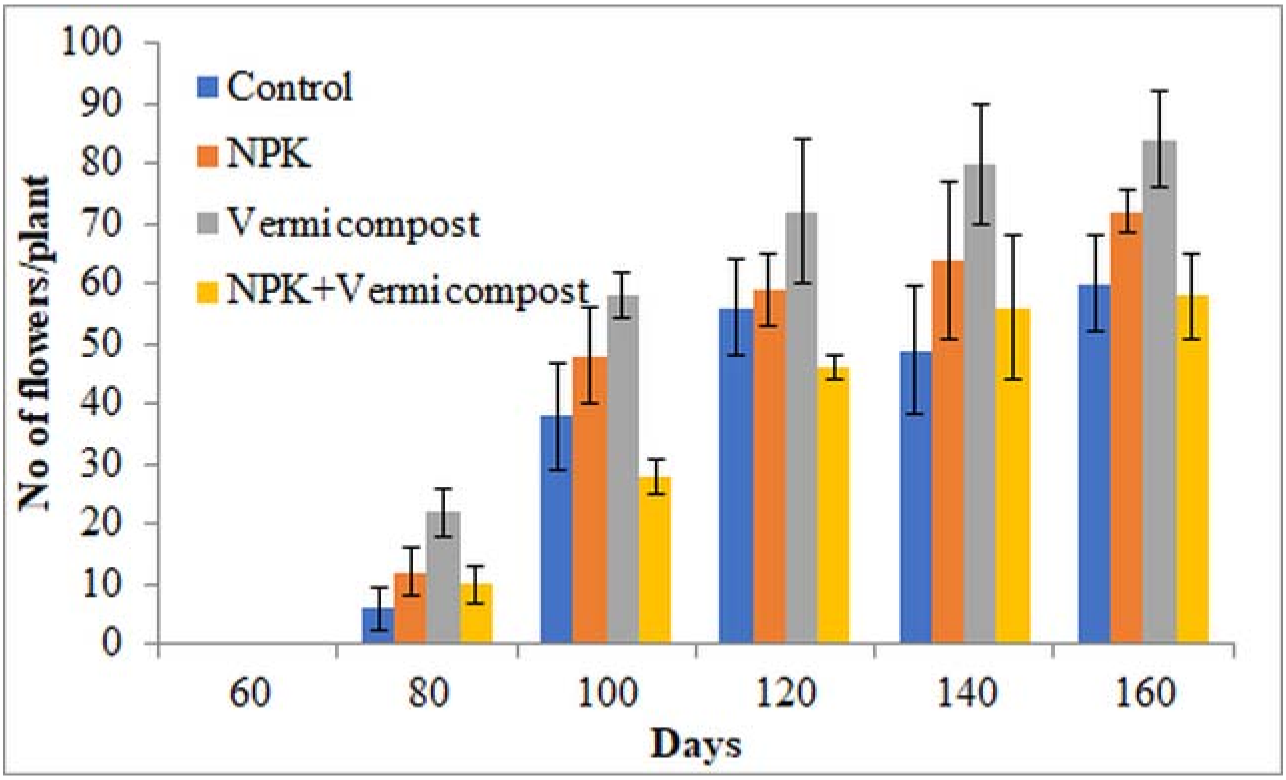
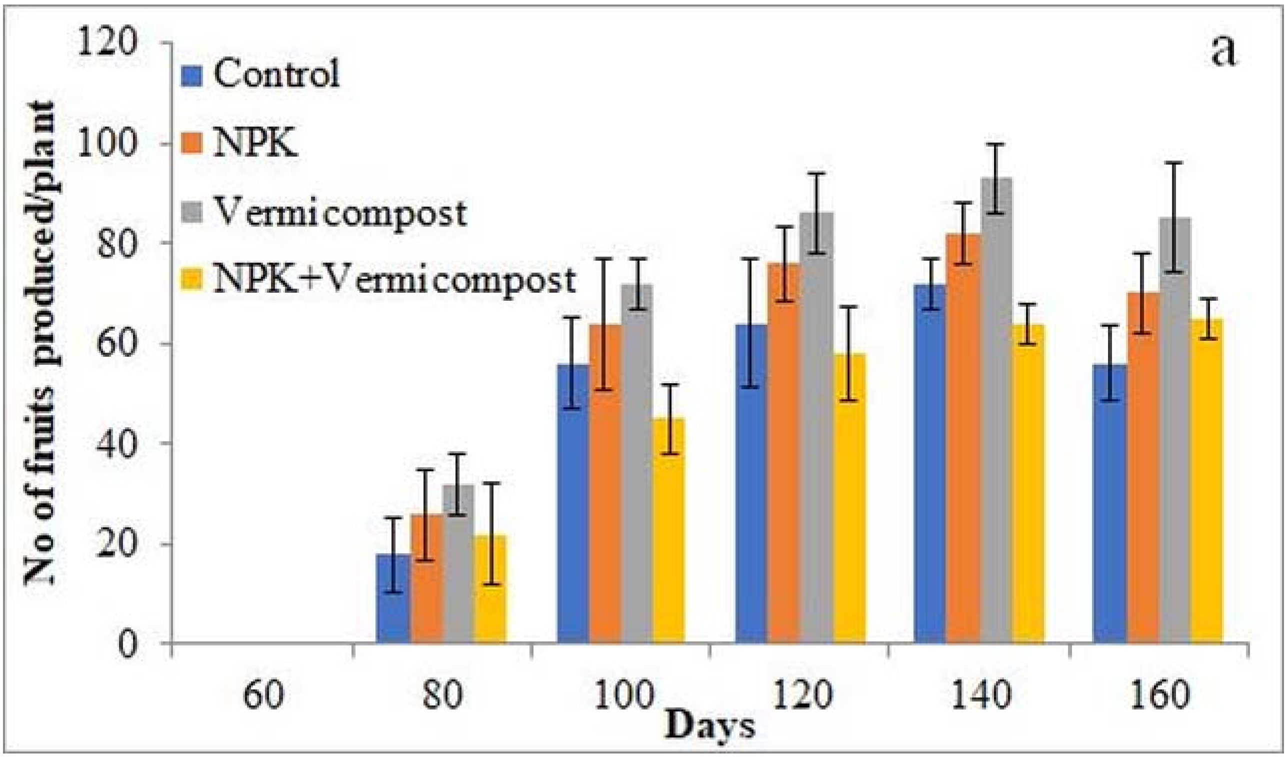


Figure 7. Effect of integrated use of vermicompost and inorganic fertilizer on number of flowers/plants



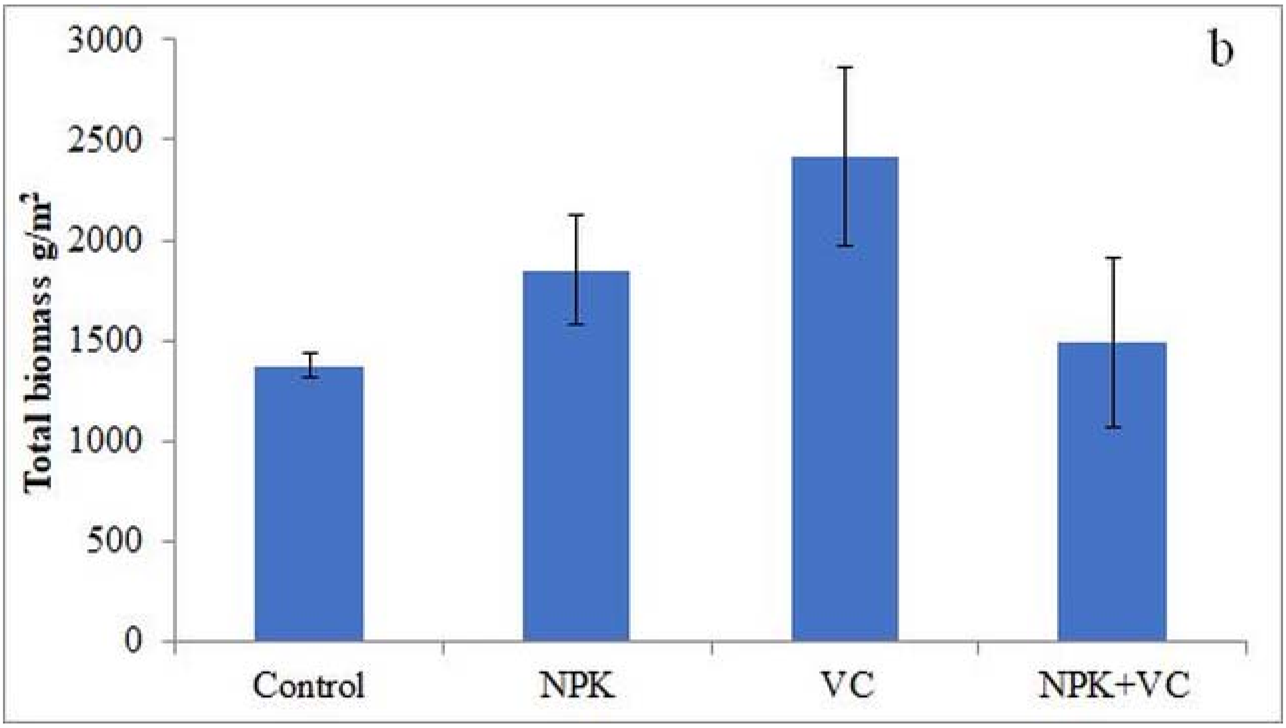
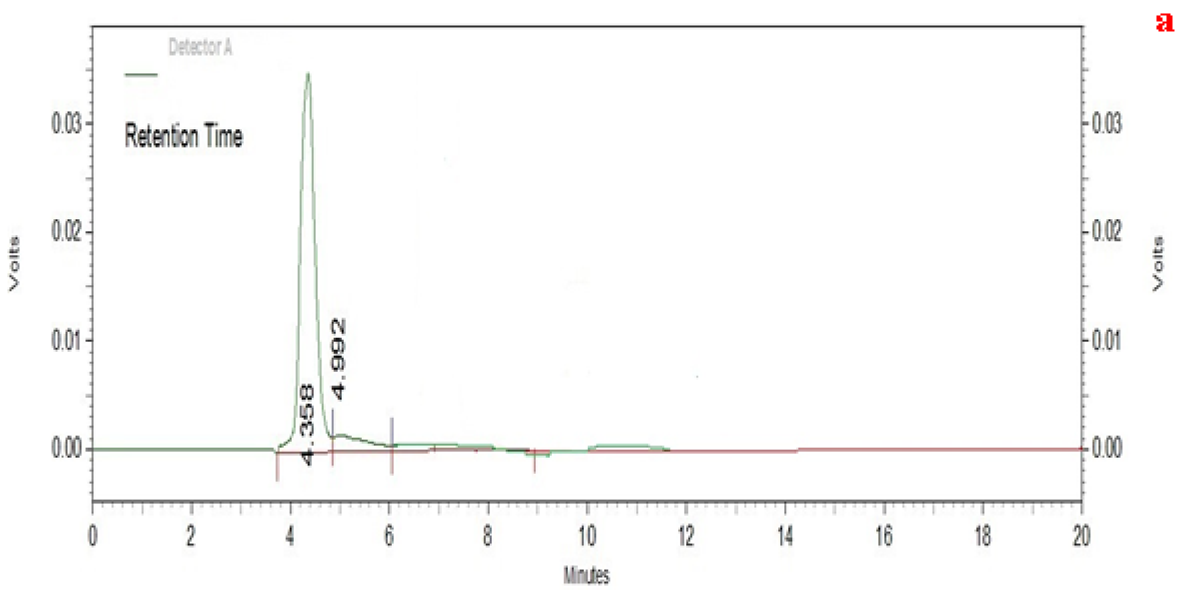


Figure 8. Effect of integrated use of vermicompost and inorganic fertilizer on (a) number of fruits produced/plant, (b) total biomass (g/m^2) of fruits

(Vermicompost + NPK 50:50) samples. Table 2 shows the capsaicin concentrations in the examined chilli samples, as well as the level of pungency represented in Scoville heat units (SHU). The mean concentration of capsaicin in control treatment was 4649.62 µg/g, in T1 4847.32 µg/g, in T2 5590.18 µg/g, and in T3 5207.30 µg/g. The highest pungency level evaluated in SHU was observed in T2 treatment. *Capsicum* in control and T1 treatment had the low capsaicin content, and our results fall within the range of very highly pungent (>80000 SHU) for all treatments (Figs.9a, b and 10 a, b, c).



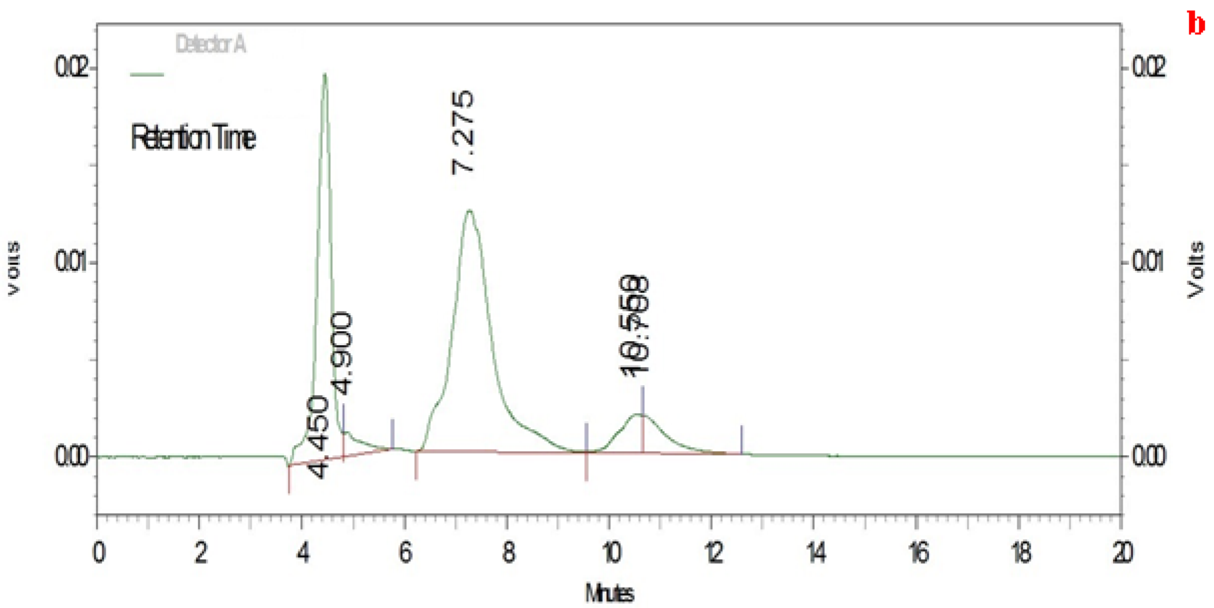


Figure 9. (a) Chromatogram of the Standard solution corresponding to 250 µg/g of capsaicin retention time corresponding to pure standard for Capsaicin was 4.358 minutes, (b) Control Graph (C), Retention time corresponding to pure capsaicin extracted from *C. annum* fruit obtained from C treatment was 4.450 minutes

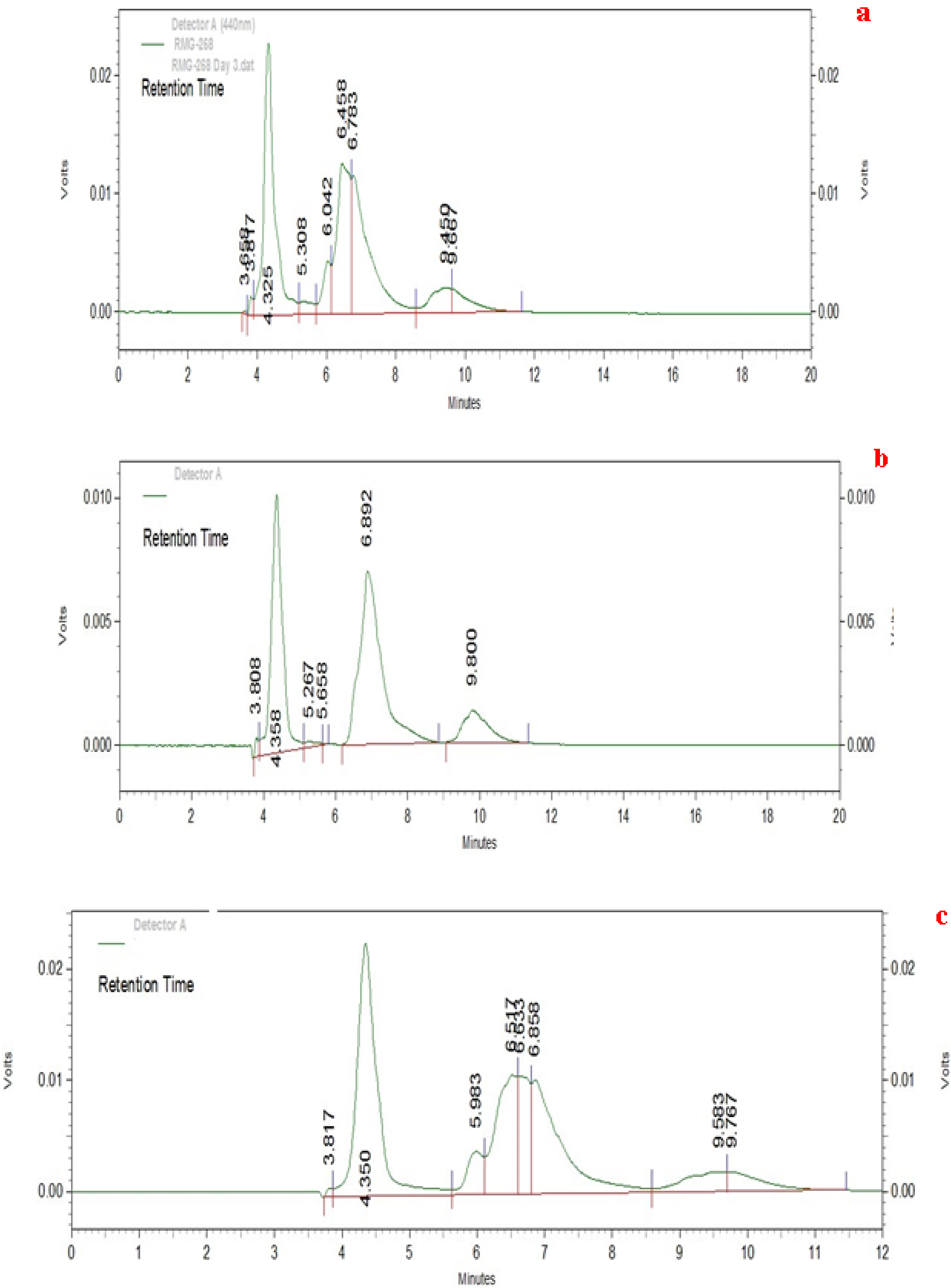


Figure 10. (a) Retentition time corresponding to pure capsaicin T1 treatment was 4.325 minutes; (b) T2 treatment was 4.358 minutes and (c) T3 treatment was 4.350 minutes

Table 2. Capsaicin concentrations as well as pungency level in Scoville heat units (SHU) in the chilli fruits under different treatments

Treatments	Capsaicin µg/g	Scoville heatunits (SHU)	Levels of pungency
Control(C)	4649.62	74393.92	Very high pungent
NPK(T1)	4847.32	77557.12	Very high pungent
Vermicompost(T2)	5590.18	89442.88	Very high pungent
Vermicompost+ NPK(T3)	5207.30	83316.30	Very high pungent

DISCUSSION

Environmental conditions must trigger the seed to grow. Generally, the depth of the seed, the availability of water, and the temperature all play a role in this. T2 had the highest germination rate because vermicompost had larger concentrations of vital elements like phosphorus and potassium, which encourage the development of plants (Perner et al.2006). The plant height is an important parameter finally influencing the total growth and output of the plant yield. Earthworm intestine has a wide range of microorganisms which aid in increase of several essential minerals, enzymes, and other components, as well as growth hormones like "auxins" and "cytokinins, that are transferred to vermicompost during the organic waste degradation process (Ferreira 2011, Umar 2022) thus resulted in was faster rate of shoot length and shoot diameter in T2 treated chilly plant as compared to T1, T3 and control (Ansari and Sukhraj 2010). Root is a plant organ that supports the absorption of soil nutrients and water. In fact, deeper roots seem to uptake more water from the soil and higher root length densities seem to absorb more nutrients. The vermicompost contains coelomic fluid produced by earthworms which increases phosphorus availability and allows plants to better utilise it. Furthermore, the coelomic fluid enhances microbial growth and activity, improves nutrient cycling as well as nutrient availability to the plants, boosting root formation and ultimately plant vegetative growth (Chattopadhyay 2015). This is also supported by the studies of Arisha et al. (2003), who noted that organic manures operate as substrates for microbe growth, which stimulates plant growth and nutrient absorption. According to Bachman and Metzger (2007) hormone-like activity of vermicompost leads to an increase in root bio-mass, root initiation, and better growth and development of plants. Vermicompost is a rich source of humic acids, and humic acid increases plant growth and root biomass (Joshi et al. 2014). However, after 100 and 140 days, the highest mean root length of plants growing in control and T2 treatments were not substantially different, which could be attributed to root development rates that continuously adapt to resource availability with photo assimilate (Prradhiepan et al. 2018). It is capable of initiating faster growth of the shoot carrying a bigger number of leaves and branches as compared to control, higher metabolic activity generated by optimal nitrogen supply through coelomic fluid treatment could explain the formation of more primary and secondary branches per plant (Farooqi and Bhadauria 2022). Phytohormones such as NAA and cytokinins may have hastened the formation of additional primary and secondary branches per plant by breaking apical dominance (Medhe et al. 2010). Chlorophyll was raised by applying Vermicompost treatment, while the lowest values were obtained by using vermicompost+ NPK (50:50) treatment during the seasons of study. Ganeshnauth et al. (2018) found the chlorophyll level increased by organic fertilizer in pepper plants. Vermicompost contains a combination of macro- and micro-nutrients and the uptake of the nutrients has a positive effect on plant nutrition, growth, photosynthesis and chlorophyll content of the leaves (Rekha et al. 2018). The enhanced availability of nitrogen, which is a key constituent of chlorophylls and proteins, can be linked to the largest number of leaves in the T2 treatment (Islam et al. 2019). Growth-promoting compounds in the coelomic fluid could have also favoured growth and differentiation of meristematic tissues producing leaves (Farooqi and Bhadauria 2022). The results obtained in this study may also be attributed to the presence of plant growth regulating substances (PGRS) in vermicompost, which act directly on the plants physiology, providing more significant growth and development. Microorganisms can produce PGRS such as auxins, gibberellins, cytokinins, abscisic acid and ethylene in significant amounts (Arshad and Frankenberger 1993, Karadeniz et al. 2006). These five classic hormones are known to modulate various stages of fruit development (Ozga and Reinecke 2003). Among PGRS, the gibberellins are involved in flowering regulations and are essential for the development of fertile flowers in tomato (van den Heuvel et al. 2002). Increased nitrogen levels due to microbial activity cause greater root expansion, which in turn leads to greater uptake of nutrients, water, and rate of photosynthesis, ultimately leading to better flowering, for this reason, T2 had an early flowering period (Taleshi et al. 2011). The presence of gibberellins, auxin and cytokinin activities were identified in *Eisenia fetida* earthworm feces (Aremu et al. 2015, Suthar 2010). Thus, it is probable that the presence of these hormones, especially gibberellins, could explain the anticipation of flowering and fruiting stages, as well as the greater production of fruits in treatments with the highest doses of vermicompost so in T2 treatment the biomass of chilli fruits was highest. Mineral nutrient applications could cause stimulation of vegetative growth during the period critical to fruit retention resulting in increased fruit drop and loss of yield (Lovatt 2015). Due to the application of vermicompost with significant microbiota, treatment T2 had greater capsaicin content (Gopal et al. 2010). They improve food accessibility or create growth hormones, including indole-3-acetic acid, minerals, and enzymes that are essential for the synthesis and deposition of capsaicin (Ghosh et al. 2015, Kumari et al. 2018). With an improvement in nutritional status, particularly nitrogen and potassium, which appear to be in charge of nutrient production and aggregation in fruits, capsaicin concentrations increased in the T2 treatment (Veermani 2010). The use of vermicompost for growing pepper plants had a greater effect on plant growth and productivity than other fertilizers. Chemical fertilizers (T1 and T3) did not have better effect for growing chilli plants. Chemical fertilizers not only do average effect on plant growth but also have negative impacts on pepper plants by causing pest and diseases on every plant grown in this treatment and premature dropping of fruits (Ganeshnauth et al. 2018)). This also proved that vermicompost has positive influence on chilli plant, which may be due to the fact that percentage of nitrogen content, phosphorous, potassium, electrical conductivity and moisture showed overall enhancement as compared with control and also with chemical fertilizers.

CONCLUSION

According to experimental research, vermicompost alone exhibited the strongest growth and yield characteristics in *C. annum* plants and also exhibited pesticidal properties. Thus, vermicompost can be suggested as a biofertilizer to increase the production of *C. annum* crops.

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Authors' contribution: TB conceptualized, designed, analysed and interpreted the data and prepared the first draft. GS involved in the collection literature, collection of data (sampling and analysis) interpretation of data and manuscript preparation.

Conflict of interest: The authors declare no conflict of interest.

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