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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT PRACTICES ON PHYSIOLOGICAL, MORPHOLOGICAL AND YIELD PARAMETERS OF CHILLI (*CAPSICUM ANNUM* L.)

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Abstract

A field trial in tunnel was executed at Student Research Farm, near Vermicompost Center, Department of Agronomy, University of Agriculture, Faisalabad during December 2019 to May 2020 to develop nutrient management practices for chilli crop. There were six treatments *viz.*, T_0: Soil test base recommended dose of chemical fertilizer, T_1: 100% cow dung, T_2: 100% cow dung vermicompost, $T_{3:}$ 100% vermi-tea, T_4: 33% cow dung + 33% vermicompost + 34% vermi-tea, T_5: 25% chemical fertilizers + 25%vermicompost + 25% cow dung + 25% vermi-tea. The concerned trial was carried out with the objective to study various morphological traits (such as plant height, stem diameter, number of leaves plant^{-1}, count of branches plant^{-1}, number of fruit plant^{-1}, fruit length, fruit fresh and dry weights), physiological attributes (chlorophyll *a* and *b*, total chlorophyll contents (*a*+*b*), chlorophyll contents of SPAD value, carotenoids, proteins, ascorbic acid, photosynthetic rate, stomatal conductance) and yield (yield plant^{-1}, plot^{-1} and hectare^{-1} was also calculated) of chilli variety Shandar. The obtained results indicated that treatment T_5 resulted in significantly higher ($p<0.05$) fruit yield (212.00g/plant, 17kg/plot and 6.20ton/ha) followed by treatment T_0 and T_1 produced significantly less fruit yield (160.0 g/plant, 11. 33 g/plot, 4.66 ton/ha and 148.67 g/plant, 10 kg/plot, and 4.25 ton/ha respectively) compared to all other treatments.

Key words: Cow dung, Chemical fertilizer, Chilli, Morphological, Nutrients, Physiological, Vermicompost, Vermi-tea, Yield.

Introduction

Capsicum annum L. produces green or red fruits, and is a member of the Solanaceae family. Chillies are indigenous to Mexico and Peru and in the 15th century, the Portuguese were the first to introduce them to India. Its cultivation became more common in the 17th century. Chilli cultivation covers 1.5 million hectares worldwide, with a cumulative production of about 7 million tonnes. India is world's largest chilli producer, it contributed almost 11.53 lac tonnes in 2005-2006; china stands at second in the production of chilli with total count of almost 4 lac tonnes; Mexico, stands with 3 lac tonnes; and Pakistan with three lakh tonnes (Anon., 2008). Chilli is high in vitamins A, C, E, and P. Some Studies by Anon., (2001) showed that almost 24 Kcal of energy is provided by almost 100 gm of edible portion of capsicum and also it gives 1.3 gm of protein, 4.3 gm of carbohydrates and almost 0.3 gm of fats (Anon., 2001).

In a nutshell, organic farming is crop production that uses natural-source inputs to decrease the use of environmentally degradable agrochemicals, such as pesticides and synthetic fertilizers. To maintain sustainability in world environmental efficiency, renewable products such as green leaf manures, cow dung, poultry waste and bio-digested slurry can be used in place of in-organic fertilizers (Diacono *et al.*, 2019). In the current times it is necessary to adopt alternative methods of collecting, processing, composting and using organic wastes and also the bio-fertilizerrs such as vermicompost and vermi-tea that all are environmentally sustainable and also commercially feasible which will also improve soil fertility (Canellas *et al*., 2002; Sinclair & Vadez, 2002). Vermicompost amendments in soil stabilize the soil via making low C:N ratios. Vermicompost supplies nutrients (N, P, K, Mg and Ca) in ready to use form in the rhizosphere of plants. Vermicompost particles has larger surface area that retains room for activities of microorganisms such as bacteria, fungi and actinomycetes, they also regulates nutrients in the soil and influences yield parameters very significantly (Nuss & Tanumihardjo, 2010; Chen & Aviad, 1990).

Vermitea, a by-product obtained from vermicomposting has abundance of nitrogen, phosphorus, and a variety of other micronutrients, hormones, and other substances. It also involves earthworm enzymes, which are helpful in enhancing plant growth and yield, though they also increase resistance to many diseases and pests in plants. Additionally, vermitea comprises dissolved nutrients, organic acids and earthworm mucus (Singh *et al*., 2011). It renders a positive impact on plant vigor and crop yield (Chen, 2006; Tara, 2003). Some of the studies in past showed a significant promotion in length of okra tap roots (Siddiqui *et al*., 2008; Keeling *et al.*, 2003). During early 1970s, chemical fertilizer such as N, P and K were widely used to improve crop productivity. However, in recent years it is observed that the un-ethically heavy use of chemical fertilizers results in many major problems like fertility loss, soil structure, permanent nutrition losses from soil and depletion of microbial activities which is ultimately a cause of yield deficiencies. With this ever increasing population we should urge us not only to maintain agricultural productivity but also to increase it in a sustainable way. The un-ethically excessive use of agro-chemicals like fertilizers and pesticides have badly damaged our soils and caused much loss in productivity of our soils.

Now it is necessary to maintain sustainability for better lifestyle of our next generations. Keeping these things in mind this study was planned involving different combinations of organic soil amendments and in-organic soil amendments to achieve sustainable yield of chilli. This study involved studying the effect of both organic and in-organic soil amendments on yield, growth parameters and bio-chemical parameters of chilli crop.

Materials and Methods

During the winter season of 2019-20, the current trial was executed at the Student Research Farm, Department of Agronomy, University of Agriculture Faisalabad at a height of 184 m above sea level, longitude 73.05° E, and latitude 31.30° N. The nursery of chilli variety Shandar was obtained from Institute of the Horticultural Sciences, University of Agriculture, Faisalabad. The Randomized Complete Block Design (RCBD) was used in this experiment. Four different fertilizers; Cow dung @ of 15 tons per hectare, earth worm's excreta based vermicompost @ 6 tons per hectare, vermitea @ 8% and chemical fertilizers (NP) @ 160-125 kilogram per hectare were introduced. Cow dung was used as precursor to make vermicompost. Vermi-tea was made by dissolving 500 grams of solid vermicompost in 2.0 liters of distilled water and storing it for two days. Vermi-tea was then extracted using sieve cloth and applied as a foliar application.

Soil analysis: The soil was clay loam used in the experiment. Before sowing and after harvesting of the chilli crop, soil analysis was performed at the soil and testing laboratory of the Ayub Agricultural Research Institute in Faisalabad, and the results are presented in the table below (Table 1).

Water analysis: The canal water was used for irrigating the chilli crop. Water was collected in plastic bottle, tagged and provided to soil and testing laboratory, Ayub Agricultural Research Institute, Faisalabad. The results are shown in below Table 2.

Organic fertilizers and raw material analysis: The organic fertilizers *i.e.* simple compost, vermicompost and vermi-tea chemical analysis for nutrients and heavy metals was done in plant and microbial ecology laboratory and hi-tech laboratory, University of Agriculture, Faisalabad. The results are showcased in below (Tables 3 and 4).

Meteorological data: Weather information was gathered during the crop's growing season from the Meteorological Observatory of the University of Agriculture's Department of Agronomy, Faisalabad. The weather conditions in 2019-20 are depicted in Fig. 1.

Table 1. Physio-chemical properties of soil pre-sowing and post harvesting of chilli crop.

Parameters	Before sowing soil results	After harvesting soil results					
		T_0	T_1	T_2	T_3	T_4	T_5
EC (mS/cm)	2.40	2.41	2.32	2.25	2.39	2.25	2.33
Soil pH	8.30	8.30	8.18	8.10	8.32	8.12	8.20
Organic matter (%)	1.45	1.43	1.61	1.60	1.40	1.57	1.54
Available nitrogen (%)	0.088	0.086	0.089	0.090	0.085	0.089	0.90
Available phosphorus (ppm)	4.45	4.44	5.10	5.20	4.42	448	449
Available potassium (ppm)	360	3.59	370	385	355	364	366
Saturation (%)	40	40	41	41	40	40	41

EC= Electrical conductivity, pH= Potential of hydrogen

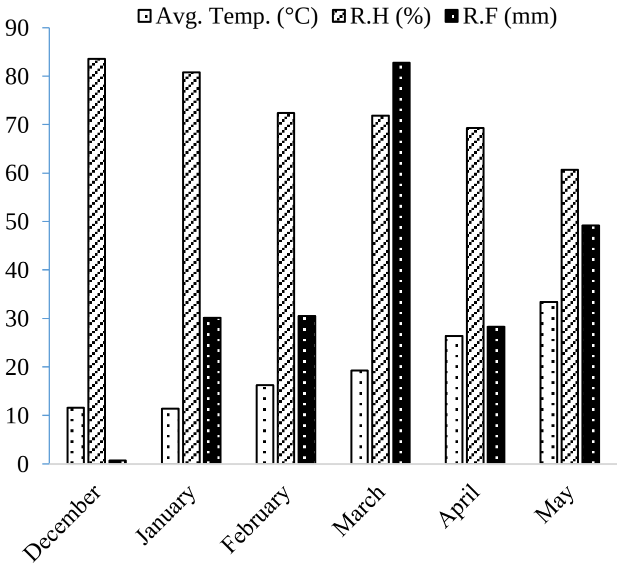

Fig. 1. Avg. Temp (Average temperature)[°C], R.H (Relative humidity)[%], R.F (Rainfall)[mm].

Treatments: The organic and inorganic fertilizers used in experiment are following; T_0: 100% recommended dose of chemical fertilizer on the base of soil test; T_1: 100% cow dung; T_2: 100% cow dung vermicompost; T_3: 100% vermi-tea; T_4: 33% cow dung + 33% vermicompost + 34% vermi-tea; T_5: 25% chemical fertilizers + 25% vermicompost + 25% cow dung + 25% vermi-tea.

The following parameters' data were recorded.

Table 2. Analysis of water used for irrigation.

Parameters	Values
Sulphate $(SO_4)^{-2}$	No
Electrical conductivity (ECx10)	800 m mol$_c$ L^{-1}
Extra Sodium Bicarbonate (RSC)	Nill
Carbonate $(Co)^{-2}$	Nil
Bicarbonate $(HCo)^{-2}$	6.96 m mol$_c$ L^{-1}
Chloride $(Cl)^{-1}$	0.79 m mol$_c$ L^{-1}
Sodium $(Na)^{+1}$	1.08 m mol$_c$ L^{-1}
Calcium+Magnesium $(Ca+Mg)^{+2}$	7.02 m mol$_c$ L^{-1}
Sodium Adsorption Ratio (SAR)	0.68 m mol$_c$ L^{-1}

Remarks: The water was fit for irrigation purpose

(i). Plant height (cm): Plant height of 3 randomly chosen plants from each plot was measured with a measuring rod and the average was calculated. **(ii). Number of leaves:** The number of leaves on three randomly chosen plants was manually counted, and the average was computed. **(iii). Stem diameter (cm):** Stem diameters of 3 plants were measured by using measuring tape and their mean was computed. **(iv). Number of branches per plant:** The number of branches on three randomly chosen plants were manually counted, and their mean was noted. **(v). Number of flowers per plant:** The number of flowers on three randomly chosen plants were manually counted, and their mean was computed. **(vi). Number of fruits per plant:** The number of fruits from three random plants were manually selected and their average was calculated. **(vii). Fruit length (cm)**: It was measured from three random plants using a tape meter and averaged. **(viii). Fresh weight of fruits (g)**: An automated meter was used to measure the weight of three fruits from randomly selected plants, and their mean was computed. **(ix). Dry weight of fruit (g)**: Fruit component was put in oven and heated at 70°C for 72 hours to achieve a steady dry weight, during which the dry weight (g) of the fruit was measured using an electrical balance. **(x). Chlorophyll contents (mg g^{-1}fwt):** The Arnon, (1949) method was used to assess the chlorophylls *a* and *b* contents. First of all, excised 0.2 gm fresh leaves were extracted for a night at 0-4°C with 80% acetone and then extracts were centrifuged for 5 minutes at 10,000 x g. Supernatant's absorbance peaks at 645 and 663nm were read on a spectrophotometer (Hitachi-U2001, Tokyo, Japan).

The formulae for calculating chlorophylls a and b contents is as follows:

Chl *a* = [12.7 (OD 663) -2.69 (OD 645)] x V/1000 x W
Chl *b* = [22.9 (OD 645) -4.68 (OD 663)] x V/1000 x W
V = extract's volume (mL)
W = fresh leaf tissue weight (g)

Table 3. Chemical properties of cow manures and it's simple compost, vermicompost and vermi-tea.

Treatments	pH	EC (dS/m)	OM (%)	N (%)	P_2O_5 (%)	K_2O (%)	Ca (%)	Mg (%)	Fe (%)	S (%)
Cow manure	8.22	4.32	71.00	1.00	0.71	0.90	1.20	0.61	0.39	0.18
Cow manure compost	7.10	4.00	52.00	1.50	1.15	1.00	1.80	0.75	0.62	0.50
Cow manure vermicompost	7.50	2.67	48.00	2.05	1.80	1.50	3.30	1.00	0.78	0.45
Cow manure vermi-tea	6.50	1.10	2.50	2.40	2.00	1.98	4.50	1.20	1.00	0.81

pH= Potential of hydrogen; EC= Electrical conductivity; OM= Organic matter; N= Nitrogen; P_2O_5= Phosphorus; K_2O= Potassium; Ca= Calcium; Mg= Magnesium, Fe= Iron; S= Sulphur

Table 4. Chemical properties of heavy metals in cow manures and it's simple compost, vermicompost and vermi-tea.

Treatments	Cd (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	Hg (mg/kg)	Cr (mg/kg)	Sn (mg/kg)
Cow manure	1.00	10.60	68.00	3.61	14.72	0.29
Cow manure compost	0.71	5.20	32.30	2.00	8.00	0.10
Cow manure vermicompost	0.39	3.40	25.22	1.20	6.50	0.05
Cow manure vermi-tea	0.29	3.00	18.41	0.90	3.00	0.01

Cd= Cadmium; Ni= Nickel; Pb= Lead; Hg= Mercury; Cr= Chromium; Sn= Stannum

(xi). Total Chlorophyll contents (*a*+*b*) [mg g^{-1}fwt]: Total chlorophyll contents= chlorophyll *a* content + chlorophyll *b* content. **(xii). Chlorophyll contents (SPAD value):** Leaves chlorophyll contents were computed by the SPAD instrument (model SPAD-502; Minolta Corp., Ramsey, N.J.). **(xiii). Total carotenoids (mg g^{-1}fwt):** Yang *et al.*, (1998) method was used to estimate total carotenoids but the method for extract preparation was the same as for chlorophyll assessment. The following equations were used to determine total carotenoids content:

$$\text{Total Carotenoids} = \frac{A^{car}}{Em} \times 100$$

where, Em = 2500

$$A^{car} = O.D\ 480 + 0.114\ (O.D\ 663) - 0.638\ (O.D\ 645)$$

(xiv). Ascorbic acid content (90 days after transplanting): Anon, (2001) method was used to determine ascorbic acid content in the samples.

Reagents

1. The 4 % oxalic acid solution
2. Dye solution: Dissolve 42 ml sodium bicarbonate ($NaHCO_3$) in distilled water, afterwards introduce 52 mg 2,6-dichlorophenol indophenol, and make final volume to 200 ml using distilled water.
3. Standard ascorbic acid solution: Dissolve 100 ml of ascorbic acid in 4 % oxalic acid solution then prepare final volume in a volumetric flask up to 100 ml with oxalic acid. Then, to prepare working standard solution, 10 ml of stock solution was diluted to 100 ml with oxalic acid.

Procedure

First of all, 5 ml standard solution of ascorbic acid was pipetted out into a 100 ml conical flask and then introduced 5 ml of 4% oxalic acid. It was titrated against a solution of 2, 4-dichlorophenol indophenols dye before a pink color appeared which lasted a few minutes. Afterwards dye factor was estimated by equating the quantity of dye consumed equivalent to the quantity of ascorbic acid present. 2g pulp was extracted in 4% oxalic acid solution and sieved through muslin cloth to determine the ascorbic acid content. At the end, final volume up to 25 mL was prepared by using 4% oxalic acid. Out of this a 5ml aliquot of 4% oxalic acid was titrated against 2, 6 – dichlorophenol indophenols dye until a pink colour appeared. Following formula was used to determine the amount of ascorbic acid in mg/100 g of fresh weight.

$$\text{Ascorbic acid content} = \frac{\text{Volume made up} \times \text{Titrate value} \times \text{Dye factor}}{\text{Aliquot taken} \times \text{Weight of sample}} \times 100 \text{ eq. no. 3. } (\frac{\text{mg}}{100} \text{fresh weight})$$

(xiv). Determination of protein (%) in fruit of chilli: Lowry *et al.,* (1951) method was used to determine the fruit's protein content.

Reagent A: 2gm NaOH +500ml. double distilled water + 1gm Sodium carbonate.
Reagent B: 1gm potassium sodium tartrate + 50ml double distilled water +0.25gm $CuSO_4$
Reagent C: 50 ml of reagent A + 1ml of Reagent B
Reagent D: 1 ml of foline + 1ml double distilled water
Phosphate Buffer:
Solution A: 1.36gm potassium dihydrogen orthophosphate + 100ml double distilled water
Solution B: 1.74 gmdipotassium orthophosphate + 100ml double distilled water

Solution C: 39ml of solution of A + 61ml of solution B. Normal NaOH; 4gm NaOH+100ml double distilled water, 0.5 gm fruit sample, crushed in 5 mL Phosphate buffer, centrifuged for 5 minutes at 3000 rpm. 0.5 ml of supernatant was collected in test tube, then 0.5 ml of 1N NaOH, 2.5 ml reagent C and 0.5ml reagent D was added to it after adding the reagent D on the appearance of blue colour and absorbance was noted at 660 nanometers. The curve obtained from Bovin Serum Albumin (BSA) protein was used as standard curve to measure protein contents. **(xv). Photosynthetic rate (An) [µmol m^{-2} s^{-1}]:** IRGA (infrared gas analyzer) was used to measure it from a leaf attached to the plant. For this purpose, 5 measurements out of 5 different plants of each treatment were taken and their mean was computed (Singh *et al.*, 2018; Rosolem *et al.*, 2019). **(xvi). Stomatal Conductance (gs) [µmol m^{-2} s^{-1}]**: The portable and open system LCA-4 ADC model infrared gas analyzer was used to measure stomatal conductance. The following settings were adjusted for taking measurement: atmospheric CO_2 concentration (Cref) 371 µmol mol^{-1}, leaf chamber volume gas flow rate (v) 296 mL min^{-1}, surface area of leaf 6.25 cm^2, leaf chamber temperature (Tch) ranging from 25-28 ^{0}C, leaf chamber molar gas flow rate (U) 400 µmol s^{-1}, an ambient pressure (P) of 97.95 kPa, and PAR (Qleaf) at leaf surface maximum up to 770 µmol m^{-2} s^{-1} (Analytical Development Company, Hoddeson, England). The fully emerged usually third from top and youngest leaf was used to measure stomatal conductance (gs) of each plant. **(xvii). Yield per plant (g)**: Three plants from each plot were randomly chosen to pick fruits and weighed on electrical balance then averaged to compute yield per plant. **(xviii). Yield per plot (kg):** From each plot, an area of one m^2 was selected and fruits were picked and weighed on electrical balance and converted it in to kg $plot^{-1}$. **(xix). Yield per hectare (ton):** From each sub plot, an area of one m^2 was selected and fruits were picked and weighed on electrical balance and converted it in to ton per hectare.

Statistical analysis

Fisher's analysis of variance (ANOVA) technique was employed for the statistical analysis of data. While comparison among treatment means was computed by Least Significant Difference (LSD) test by using a Statistix software version 8.1 (Analytical Software ©, 1985-2005) at 0.05 level of significance (Steel *et al*., 1997).

Results

The findings of analysis of variance revealed that integrated nutrient management practices had highly significant impact on chilies physiological, morphological and yield traits.

Plant height (cm): Data depicted in table 5 showed that integrated application of 25% C.F, 25% V.C, 25% C.D and 25% V.T resulted in longest plant height 46.33cm compared to 44.00cm in 33% VC, 33% CD and 33% VT and 34.66cm in 100% CD application. There was no significant difference between T_0 (100% C.F) and T_2 treatments (100% V.C).

Number of leaves per plant: Introduction of T_5 treatment produced highest number of leaves $plant^{-1}$ (85.33) followed by T_4 treatment (79.00). The lowest number of leaves $plant^{-1}$ were produced in T_1 (56.33) and T_0 (control) treatments (Table 5).

Stem diameter (cm): Stem diameter was also affected by nutrient management practices. As T_5 and T_4 treatments resulted in maximum stem diameter (1.72 and 1.51) while the lowest was observed in T_1 (1.05) as depicted in Table 5.

Number of branches per plant: The results showed that T_5 and T_4 treatments produced maximum number of branches $plant^{-1}$ (14.66 and 13.00). While lowest number of branches $plant^{-1}$ (6.00 and 7.33) were obtained from T_1 and T_0 (control) treatments respectively. T_1 and T_0 (control) treatments were statistically similar with each other (Table 5).

Number of flowers per plant: T_5 treatment had the highest number of flowers $plant^{-1}$ (24.00), followed by T_4 treatment (22.00). While on the contrary, the lowest number of flowers $plant^{-1}$ (13.33) was obtained using 100% C.D. (Table 5). There was no statistically significant difference between T_0 (control) and T_1 treatments.

Number of fruits per plant: Higher the number of fruits plant^{-1}, the more would be the yield. T_5 treatment gave rise to highest number of fruits plant^{-1} (19.33) followed by T_4 treatment. While sole cow dung application produced minimum number of fruits plant^{-1} (10.00) (Table 5).

Fruit length (cm): The maximum fruit length (10.00) was observed when T_5 treatment was applied. Whereas minimum fruit length (5.83) was obtained from T_1 followed by T_0 (control) as displayed in Table 5.

Fresh weight of fruit (g): Comparison of treatment showed that maximum fruit fresh weight (30.33) was noted in T_5 followed by T_4 treatments (27.33). While T_2 and T_3 were statistically at par with each other (Table 6).

Dry weight of fruit (g): The highest fruit dry weight was observed in T_5 and T_4 treatments (8.41 and 8.00). T_1 treatment produced lowest dry weight of fruit (5.16). Whereas T_5 and T_4 treatments were statistically at par with each other as mentioned in Table 6.

Chlorophyll *a* (mg g^{-1}fwt): Chlorophyll a/b content was increased due to addition of VC, VT and CD in chemical fertilizers. Maximum chlorophyll a content was observed in T_5, T_4 and T_3 treatments (3.00. 2.66 and 2,33) respectively. The lowest chlorophyll a content (1.55) was found in T_1 treatment. Whereas, T_0 (control) and T_2 treatments were statistically equal to each other (Table 6).

Chlorophyll *b* (mg g^{-1}fwt): T_5 treatment produced maximum chlorophyll *b* content (1.24) preceded by T_4 treatment (1.13). While T_1 treatment produced minimum chlorophyll *b* content (0.88). The treatments T_2 and T_3 were statistically same (Table 6).

Total chlorophyll contents (*a*+*b*) [mg g^{-1}fwt]: The highest value of total chlorophyll contents was noted in T_5 and T_4 treatments (4.24 and 3.80) respectively. Whereas the lowest value of total chlorophyll contents (2.43) was found in T_1 treatment (Table 6).

Chlorophyll contents (SPAD value): The highest value of chlorophyll contents (SPAD value) was observed in T_5 and T_4 treatments (49.00 and 46.66) respectively. While the lowest value of chlorophyll contents (SPAD value) (35.33) was recorded in T_1 treatment (Table 6).

Total carotenoids (mg g^{-1}fwt): Likewise, maximum carotenoid content was noted in T_5 and T_4 (3.06 and 2.73). While lowest carotenoid content (1.96) was found in T_1. There was no significant difference between T_0 (control) and T_1 treatments (Table 6).

Proteins (%): The highest (0.26) and lowest protein content (0.15) was found in T_5 and T_1 treatments respectively. While T_0 (control) and T_2 treatments were statistically at par with each other (Table 7).

Ascorbic acid: Ascorbic acid content positively influenced integrated nutrient management practices (Table 7). Maximum ascorbic acid content (1.69) was noted in T_5 treatment while the lowest ascorbic acid content (1.17) was found in T_1 treatment. There was no significant difference between T_5 and T_4 treatments (Table 7).

Table 5. Effect of inorganic and organic fertilizers on the morphological parameters of chilli crop.

Treatments	Plant height (cm)	Number of leaves per plant	Stem diameter (cm)	Number of branches per plant	Number of flowers per plant	Number of fruits per plant	Fruit length (cm)
T_0	37.00 d	62.33 e	1.15 e	7.33 e	15.33 d	12.00 e	6.66 e
T_1	34.66 e	56.33 f	1.05 f	6.00 e	13.33 e	10.00 f	5.83 f
T_2	39.00 d	68.66 d	1.25 d	9.00 d	16.66 d	13.66 d	7.33 d
T_3	41.33 c	74.33 c	1.37 c	11.00 c	18.33 c	15.33 c	8.00 c
T_4	44.00 b	79.00 b	1.51 b	13.00 b	22.00 b	17.66 b	8.83 b
T_5	46.33 a	85.33 a	1.72 a	14.66 a	24.00 a	19.33 a	10.00 a
MS for treatment	57.25**	345.73**	0.18**	33.43**	49.38**	36.66**	6.78**
LSD @ 0.05	2.14	3.06	0.07	1.52	1.43	1.44	0.56

** Significant at 0.05 level of significance, **=Highly significant, ns= Non-significant, MS= Mean sum of square, LSD= Least significant difference test, Means not sharing the common letter differ significantly

Table 6. Effect of inorganic and organic fertilizers on the morphological and physiological parameters of chilli crop.

Treatments	Fresh weight of fruit (g)	Dry weight of fruit (g)	Chlorophyll *a* (mg g^{-1}fwt)	Chlorophyll *b* (mg g^{-1}fwt)	Total chlorophyll contents (*a*+*b*) [mg g^{-1}fwt]	Chlorophyll contents (SPAD value)	Total carotenoids (mg g^{-1}fwt)
T_0	22.00 d	6.16 d	1.78 d	0.96 d	2.75 e	38.33 e	2.10 e
T_1	19.00 e	5.16 e	1.55 e	0.88 e	2.43 f	35.33 f	1.96 e
T_2	24.33 c	5.91 c	1.97 d	1.04 c	3.01 d	41.33 d	2.26 cd
T_3	25.66 c	7.50 bc	2.23 c	1.08 c	3.31 c	43.66 c	2.45 c
T_4	27.33 b	8.00 ab	2.66 b	1.13 b	3.80 b	46.66 b	2.73 b
T_5	30.33 a	8.41 a	3.00 a	1.24 a	4.24 a	49.00 a	3.06 a
MS for treatment	47.68**	4.38**	0.90**	0.04**	1.36**	78.58**	0.50**
LSD @ 0.05	1.51	0.65	0.22	0.05	0.25	1.51	0.20

** Significant at 0.05 level of significance, **= Highly significant, ns= Non-significant, MS= Mean sum of square, LSD= Least significant difference test, Means not sharing the common letter differ significantly

Table 7. Influence of organic and inorganic fertilizers on the biochemical and yield parameters of chilli crop.

Treatments	Proteins (%)	Ascorbic acid	Photosynthetic rate (µmol m^{-2} s^{-1})	Stomatal conductance (mmol m^{-2} s^{-1})	Yield/plant (g)	Yield/plot (kg)	Yield/ha (ton)
T_0	0.18 d	1.25 cd	13.33 e	66.00 d	160.00 e	11.33 e	4.66 e
T_1	0.15 e	1.17 d	12.00 f	63.66 e	148.67 f	10.00 f	4.25 f
T_2	0.19 d	1.33 bc	15.00 d	68.00 c	169.67 d	12.66 d	5.00 d
T_3	0.21 c	1.42 b	16.33 c	69.33 c	183.33 c	14.00 c	5.25 c
T_4	0.24 b	1.59 a	18.33 b	72.66 b	197.67 b	15.33 b	5.58 b
T_5	0.26 a	1.69 a	20.00 a	76.00 a	212.00 a	17.00 a	6.20 a
MS for treatment	0.00**	0.11**	27.30**	60.32**	1693.96**	20.05**	1.42**
LSD @ 0.05	0.01	0.05	1.10	1.68	8.18	0.91	0.22

** Significant at 0.05 level of significance, **= Highly significant, ns= Non-significant, MS= Mean sum of square, LSD= Least significant difference test, Means not sharing the common letter differ significantly

Photosynthetic rate (µmol m^{-2} s^{-1}): The results indicated that photosynthetic rate was increased on moving from sole nutrient application to integrated nutrient application. The T_5 treatment showed maximum photosynthetic rate (20.00) followed by T_4 (18.33). Whereas T_1 treatment exhibited minimum photosynthetic rate (12.00) (Table 7).

Stomatal conductance (mmol m^{-2} s^{-1}): Maximum stomatal conductance (76.00) was noted in T_5 treatment preceded by T_4 treatment (72.66). While the lowest stomatal conductance (63.66) was noted in T_1 treatment. The treatments T_2 and T_3 were statistically alike (Table 7).

Yield/plant (g): Yield was significantly affected by integrated application of balanced ratio of CF, CD. VC and VT. Maximum yield/plant (212.00) was obtained in T_5 treatment followed by T_5 (197.67). Whereas minimum yield/ plant (148.67) was obtained from T_1 treatment (Table 7).

Yield/plot (kg): Maximum yield/plot (17.00) was obtained in T_5 treatment followed by T_4 treatment (17.00). Whereas minimum yield/plot (10.00) was obtained from T_1 treatment (Table 7).

Yield/ha (ton): Maximum yield/ha (6.20) was obtained in T_5 treatment followed by T_4 treatment (6.20). Whereas minimum yield/ha (4.25) was obtained from T_1 treatment (Table 7).

Discussion

Chilli or pepper requires essential macroelements like N, P, K and many microelements including Mg, Ca, S, B, Fe, Mn, Mo, Cu, Zn, Cl, and Ni for normal growth and development. Plants generally obtain these elements from the soil. The crop productivity is usually affected by the deficiency or excessive availability of these elements in the root zone, on the other hand, toxic mineral elements including As (Arsenic), Hg (Mercury), Cd (Cadmium), and Pb (Lead) trigger an adverse effect for plant survival (Abayomi *et al.*, 2012).

Integrated nutrient management practices had a statistically significant impact on chili's growth characteristics like plant height, stem diameter, number of branches plant^{-1}, number of leaves plant^{-1}, fruit length, number of fruits plant^{-1}, fruit fresh and dry weights etc. Many researchers' findings corroborated the current findings and speculated that role of NPK in crops and concluded that integrated nutrients application improved morpho-physiological attributes of chilli (Baloch *et al.*, 2010; Cherif *et al.*, 2009). Organic fertilizers release nutrients slowly and may not meet plant demands; however, nitrogen via inorganic fertilizers is immediately obtainable to plants at the early growth stages, resulting in better vegetative growth (Heeb *et al.*, 2005). Nitrogen supplementation induces higher photosynthetic activity, branching, robust growth, and leaf development (Aslam *et al.*, 2020). Phosphorus, on the other hand, is a necessary component of nucleoproteins, plays a key function in cell division, its deficiency can limit crop growth and might subdue productivity of crop (Aslam & Ahmad, 2020; Ahmad *et al.*, 2021). Similarly, several studies have found that combined application of organic with inorganic manures enhanced plant vegetative characteristics statistically (Aslam *et al.*, 2020; Bellitürk *et al.*, 2020; Rehman *et al.*, 2020; Ahmad *et al.*, 2021). The admixture of NPK and humic acids increased the efficacy of NPK. The inclusion of HA in soils was shown to improve root growth attributes (origination and branching of root hairs) and root efficiency in nutrient grasping, resulting in increased nutrient contents of plants (Aslam *et al.*, 2020). Likewise, Khattak & Muhammad (2010) reported increment in nutrient uptake and crop growth resulting in increased plant growth characteristics obtained by combined application of humic acid with chemical fertilizers. It could be attributed to HA's ability to create a favorable media for soil biological activities by promoting microbial growth and enzymatic activities, and water holding capability, all of which resulted in increased nutrient uptake and crop growth. The combination of NP and FYM, vermicompost, and vermi-tea increased growth characteristics even more. These results were consistent to those of Bandyopadhyay *et al.*, (2003), who found out that soybean had a higher efficacy. The long-term survival of soil productivity and organic matter is not feasible with sole application of organic or inorganic fertilizers (Prasad, 1996).

The proline content of plant parts was regulated by using a combined application of chemical fertilizer, cow dung, vermicompost, and vermi-tea. When these organic and inorganic amendments were given to the plants, they showed higher Ca^{2+} /Na^+ and K^+/Na^+ ratios in their aerial sections. As a result of their combined application, the protein content of the roots and other plant parts increased (Xu *et al*., 2016). Physiological traits such as chlorophyll contents (Spade value), chlorophyll *a* and chlorophyll *b* contents, total chlorophyll (*a*+*b*) contents, total carotenoids, fruit ascorbic contents, protein contents in fruit, photosynthetic rate, stomatal conductance, and yield traits such as yield plant^{-1}, yield plot^{-1}, and yield ha^{-1} were all improved when organics and chemical fertilizers were applied together. Many other studies have found that combining synthetic fertilizers with vermicompost, vermi-tea and cattle manure improved the quality and quantity of vegetable crops such as, basil, and onions (Aslam *et al*., 2020; Yassen & Khalid, 2009; Biasi *et al*., 2009). Even some studies claimed boosting of peppermint's (*Mentha piperita* L.) essential oil contents especially in Kosi variety by adopting of integrated nutrient management practices (Rahman *et al.*, 2015).

The use of FYM, vermicompost, verm-tea, and NP chemical fertilizers increased nutrient availability, which improved plant vegetative growth and floral development, resulting in the highest yield (Hercencia *et al*., 2011). When compared to unfertilized plots, integrated nutrient management increased chilli's floral yield by a large amount. In addition, by using the right fertilizer at the right time, strawberry growth characteristics and yield were statistically increased (Ogendo *et al.,* 2008).

Conclusion

The findings of 6 treatments in current experiment showed that T_5 performed better than other treatments in all respects while T_1 and T_0 treatments were inferior. However, overall impact of integrated nutrient management practices on growth and yield characteristics was encouraging but T_5 treatment in which 25% chemical fertilizers +25% vermicompost +25% cow dung +25% vermi-tea were applied to chilli (*Capsicum annum* L.) variety produced better results than the other treatments in Faisalabad conditions. So, if we adopt T_5 treatment in Pakistan, we will undoubtedly achieve our goal of higher production.

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