Eco. Env. & Cons. 29 (January Suppl. Issue) : 2023; pp. (S468-S478)
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ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i01s.072

Influence of Organic and Inorganic Nitrogen Amendments on Okra Growth, Yield, Quality and Economics

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(Received 17 July, 2022; Accepted 13 October, 2022)

ABSTRACT

To evaluate the influence of organic and inorganic nitrogen amendments on okra, field experimental trials were conducted during summer seasons of year 2016 and 2017 at Vegetable Research Centre, G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand with fourteen treatment combinations of nitrogen through organic (FYM and Vermicompost) and inorganic sources (Urea and Neem coated urea) along with one control treatment. The experiment was laid out in Completely Randomized Block Design with three replications and the observations on various growth, yield, quality and economic parameters were recorded. Among all other treatments, treatment T_4 (RDN- 100% through neem coated urea) proved to be economically best as per benefit: cost ratio, while treatments T_{10} (RDN- 100% through NCU + 2.5 t/ha Vermicompost) and T_6 (RDN- 75% through neem coated urea + 25% through Vermicompost) were found best with regards to increase in productivity of okra with optimum net returns, hence recommended for the present agro-climatic conditions.

Key words : *Okra, Neem coated urea, Vermicompost, Growth, Yield*

Introduction

Okra, belonging to Malvaceae family, is an economically important crop grown for its tender green fruits for vegetable purpose and widely grown as a commercial crop in various Asian, African, European and South American countries. Among all other growing countries, India is the leading producer with 6.1 million tonnes (61.9% of the total world production) of okra produced from 0.5 million hectare (ha) land (Ministry of Agriculture and Farmers Welfare, 2018). In Uttarakhand state, okra productivity is around 7.25 tonnes/ha which is very low as compared to that of national productivity (12.2 tonnes/ ha). This could be due to effect of imbalanced nutrient application especially nitrogen (N) which is the most critical nutrient required by the plants for adequate nutrition and high yield of okra (Sati *et al.*, 2018). Indian soils are generally deficient in nitrogen due to nitrification and leaching losses. To overcome this deficiency indiscriminate use of fertilizers like urea is done by the farmers which gives higher profits but in return causes decline in fertility level of soil as a result the production capacity of soil gets affected.

The development of neem coated urea has proved to be very effective in reducing the nitrification and leaching losses (Sati *et al.*, 2018). This could be very helpful in reducing the indiscriminate uses and also the negative effects of high urea applications on soil fertility. Organic manures, on the other hand, are also an effective alternative to inorganic fertilizers as their application increases the organic matter content as well as fertility of soil (Kumari *et al.*, 2011). These could also be combined with chemical fertilizers in order to get instant and residual effects both on the main crop and successive crops. This will also cut down the input of high amounts of inorganic fertilizers. Further, a new approach soil test-based crop response (STCR) is being used now a days for the estimation of fertilizer nutrient for targeted yields which could also minimize the over uses of chemical fertilizers, thereby maintaining the soil sustainability along with higher yields (Goswami, 2006).

Keeping all these valuable options in view, the present investigation was carried out to find out the effect of various organic and inorganic amendments on okra growth, yield, quality and economics at Uttarakhand lowland conditions.

Materials and Methods

During summer seasons of year 2016 and 2017, field trials were conducted at Vegetable Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, District- Udham Singh Nagar, Uttarakhand (India). The experimental site falls in the humid subtropical zone and comes under the lowland region of Uttarakhand at the foothills of *Shivalik* range of Himalayas. Geographically, it situates at 29ºN and 79.30ºE longitudes at an altitude of 243.84 meters above mean sea level. This place has humid and subtropical climate with the maximum temperature ranging from 32 ºC to 44 ºC in summer and minimum temperature 4.4 ºC in winter. The summers are dry and hot, winter too cold and frost expected from last week of December to end of the January. The onset of monsoon usually occurs from the last week of June and continues in appreciable amount up to the middle of September. During this period maximum rainfall occurs. The mean annual rainfall records approximately 1300 mm. A few or little showers also expected during the winter month.

The soil of the experimental plot was Mollisol having sandy loam soil with neutral pH (7.35 and 6.90) and low available nitrogen (151.8 and 165.12 kg/ha), phosphorus (28.5 and 29.91 kg/ha) and potash (168.35 and 181.72 kg/ha), respectively during both the years. The experiment laid out in Completely Randomized Block Design with three replications consisting following treatments *viz.,* T_1 (No application of Nitrogen), T_2 (RDN-Recommended dose of nitrogen 50% VC + 50% FYM), T_3 (RDN-100% Urea), T_4 (RDN- 100% NCU), T_5 (RDN- 75% Urea + 25% VC), T_6 (RDN- 75% NCU + 25% VC), T_7 (RDN- 75% Urea + 10 t/ha FYM), T_8 (RDN- 75% NCU + 10 t/ha FYM), T_9 (RDN- 100% Urea + 2.5 t/ha VC), T_{10} (RDN- 100% NCU + 2.5 t/ha VC), T_{11} (RDN- 100% Urea + 5 t/ha FYM), T_{12} (RDN- 100% through NCU + 5 t/ha FYM), T_{13} (STCR with organic) and T_{14} (STCR without organic). Organic sources *viz.,* FYM (0.57% N, 0.32% P_2O_5 and 0.52% K_2O) and vermi-compost (1.61% N, 1.17% P_2O_5 and 1.84% K_2O) were applied one week before sowing of seeds. The recommended dose of fertilizers was 100:40:40 kg NPK/ ha from which full dose of P_2O_5 and K_2O applied in all treatments (except T_2 and STCR treatments) as basal while, nitrogen doses were applied as per treatments in two equal splits *i.e.,* as basal and as top-dress at 30 DAS. Treatment T_2 applied fully as organic. The STCR treatments were applied with nitrogen (neem-coated urea), phosphorus (SSP) and potassium (MOP) while, 20 t/ha FYM was applied only in treatment STCR with organic, after working out the doses required as per the calculations made with the equations suggested for Mollisol soils by Rawat *et al.* (2015) and also used by Sati *et al.* (2018).

Five random plants from each plot were selected and tagged for recording data on various parameters. Observations were recorded on various plant growth characters *viz.*, number of primary branches and number of nodes per plant at 30, 60 and 90 days after sowing (DAS), fresh and dry weight of plants at final picking; yield characters *viz.,* number of green pods and yield of green pods per plot; and quality characters *viz.,* dry matter, protein and moisture and ascorbic acid content in green pods. Economics of the treatments was also worked out for both the trials. The methods and formulas used for estimation or determination or calculations of quality and economic parameters are discussed here as follows:

Dry matter content of green pods was determined by collecting ten green pod samples each from tagged plants of each treatment. These samples were weighed and cut into thin pieces with the help of a sharp knife, packed in paper bags and then dried in hot air oven at about 70 ^{0}C for 8-10 hours per day for 2-3 days to achieve complete drying. After this, samples were weighed again and dry matter content expressed in per cent calculated by using following formula as used by Sati *et al.* (2017):

$$\text{Dry matter content (\%)} = \frac{\text{Oven dried weight (g)}}{\text{Fresh weight (g)}} \times 100$$

Protein content of green pods of okra was determined on dry weight basis by using micro-Kjeldhal method for total nitrogen determination as per procedure suggested by AOAC (1995) and calculations were made with the help of following conversion formula as used by Sati *et al.* (2017):

Protein content (%) = 6.25 × Total nitrogen (%)

Where, 6.25 is conversion factor for converting total nitrogen into protein content (%) based on the assumptions that nitrogen constitutes 16% of protein.

The moisture content of green pods expressed in per cent was calculated using following formula:

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight (g)} - \text{Oven dried weight (g)}}{\text{Fresh weight (g)}} \times 100$$

The estimation of ascorbic acid content of fresh green pods of okra was done as per the method suggested by Ranganna (1986) using fruits of 6th picking. The calculation was done with the following formula:

$$\text{Ascorbic acid content (mg/100 g)} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume made up} \times}{\text{Volume of aliquot taken} \times \text{Weight of sample taken}}$$

Economic components like cost of cultivation or total expenditure worked out by taking all considerations of expenditure incurred on basis of existing market rate of inputs, total output or gross income calculated by multiplying per hectare marketable yield of green pods under various treatments with prevailing selling rates of green pods in the local market, and the benefit: cost ratio computed by adopting following formula as used by Sati *et al.* (2017):

$$\text{Benefit: Cost ratio} = \frac{\text{Gross income (Rs/ha)}}{\text{Total expenditure (Rs./ha)}}$$

Statistical analysis was done by subjecting the collected data to analysis of variance (ANOVA) as per the methods suggested by Sukhatme and Panse (1995).

Results

Growth parameters

Number of primary branches per plant

Number of primary branches per plant as presented in Table 1 indicates significant effect of different nitrogen treatments. During final stages of crop growth the maximum number of primary branches per plant recorded under treatment T_{10} (RDN- 100% through NCU + 2.5 t/ha Vermicompost) while, the minimum number was recorded under treatment T_1 (No application of nitrogen).

At 30 DAS, as compared to other treatments, pooled mean showed that significantly maximum number of primary branches per plant (1.6) recorded under treatments T_5 (RDN- 75% through Urea + 25% through Vermicompost), T_6 (RDN- 75% through NCU + 25% through Vermicompost), T_9 (RDN- 100% through Urea + 2.5 t/ha Vermicompost) and T_{11} (RDN- 100% through Urea + 5 t/ha FYM) as compared to all other treatments whereas, treatments T_1 (No application of nitrogen) and T_2 (RDN- 50% through Vermicompost + 50% through FYM) were found to be *at par*, while it was significantly minimum (1.1) under treatments T_7 (RDN- 75% through Urea + 10 t/ha FYM), T_8 (RDN- 75% through NCU + 10 t/ha FYM) and T_{10} (RDN- 100% through NCU + 2.5 t/ha Vermicompost) over rest of the treatments.

The pooled mean data revealed that at 60 DAS, treatment T_{10} (RDN- 100% through NCU + 2.5 t/ha Vermicompost) recorded significantly maximum number of primary branches (3.2) among rest of the treatments while, treatment T_{12} (RDN- 100% through NCU + 5 t/ha FYM) recorded the minimum number (2.2) as compared to all other treatments however, treatments T_1 (No application of nitrogen), T_6 (RDN- 75% through NCU + 25% through Vermicompost), T_8 (RDN- 75% through NCU + 10 t/ha FYM) and T_9 (RDN- 100% through Urea + 2.5 t/ha Vermicompost) were found *at par*.

At 90 DAS, the pooled mean data showed that treatment T_{10} (RDN- 100% through NCU + 2.5 t/ha Vermicompost) recorded significantly maximum number of primary branches per plant (3.9) as compared to other treatments however, treatments T_3 (RDN- 100% through Urea) and T_7 (RDN- 75% through Urea + 10 t/ha FYM) were found *at par*, while treatment T_1 (No application of nitrogen) recorded the minimum number of primary branches (2.5).

Number of nodes per plant

It is evident from the data Table 2 that number of nodes per plant was significantly affected by various nitrogen treatments at all stages of crop growth. The number of nodes per plant was recorded significantly maximum under treatment T_{10} (RDN- 100% through NCU + 2.5 t/ha Vermicompost) during initial stages while under treatment T_6 (RDN- 75%

Table 1. Effect of different nitrogen treatments on number of primary branches per plant in okra

Treatments	Number of primary branches per plant								
	30 DAS			60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	1.3	1.7	1.5	2.1	2.4	2.3	2.5	2.5	2.5
T_2	1.2	1.7	1.5	2.4	2.5	2.5	3.1	3.1	3.1
T_3	1.2	1.2	1.2	2.5	3.3	2.9	3.7	3.7	3.7
T_4	1.3	1.3	1.3	2.5	2.9	2.7	3.3	3.3	3.3
T_5	1.4	1.8	1.6	2.5	2.4	2.5	3.1	3.1	3.1
T_6	1.3	1.8	1.6	2.7	2.2	2.4	3.5	3.1	3.3
T_7	1.2	1.0	1.1	2.5	3.3	2.9	3.7	3.7	3.7
T_8	1.3	1.0	1.1	2.3	2.2	2.3	3.2	2.9	3.1
T_9	1.4	1.8	1.6	2.5	2.4	2.4	3.2	3.0	3.1
T_{10}	1.3	1.0	1.1	2.6	3.8	3.2	3.9	3.8	3.9
T_{11}	1.2	1.9	1.6	2.4	2.7	2.5	3.3	3.0	3.2
T_{12}	1.5	1.0	1.2	2.2	2.2	2.2	3.2	2.9	3.0
T_{13}	1.3	1.4	1.4	2.4	3.1	2.8	3.5	3.4	3.4
T_{14}	1.3	1.3	1.3	2.3	2.9	2.6	3.3	3.5	3.4
SEm±	0.05	0.09	0.06	0.06	0.11	0.07	0.15	0.13	0.12
C.D. (0.05)	0.16	0.27	0.17	0.18	0.33	0.20	0.45	0.39	0.35

Table 2. Effect of different nitrogen treatments on number of nodes per plant in okra

Treatments	Number of nodes per plant								
	30 DAS			60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	5.1	6.0	5.6	15.7	16.0	15.8	25.4	26.5	25.9
T_2	5.8	6.0	5.9	16.9	16.7	16.8	31.8	35.5	33.7
T_3	8.0	8.6	8.3	19.5	19.3	19.4	34.2	40.1	37.2
T_4	10.4	10.0	10.2	22.6	21.2	21.9	37.4	41.3	39.3
T_5	9.7	9.8	9.8	20.2	19.9	20.0	35.6	40.0	37.8
T_6	13.9	10.9	12.4	25.2	24.9	25.1	40.1	48.0	44.1
T_7	10.4	10.1	10.2	22.1	21.6	21.8	35.8	41.7	38.8
T_8	12.2	11.8	12.0	24.2	23.5	23.8	37.3	43.5	40.4
T_9	10.8	10.1	10.5	22.6	21.8	22.2	33.9	41.5	37.7
T_{10}	14.4	12.5	13.4	26.2	26.9	26.6	39.7	44.4	42.1
T_{11}	9.2	9.7	9.4	20.3	19.3	19.8	34.0	40.7	37.3
T_{12}	11.0	11.0	11.0	22.9	23.0	23.0	36.3	42.9	39.6
T_{13}	10.1	10.3	10.2	21.9	22.1	22.0	35.4	41.9	38.6
T_{14}	9.1	8.5	8.8	20.7	21.5	21.1	33.5	40.5	37.0
SEm±	0.3	0.6	0.4	0.2	0.3	0.2	0.4	1.3	0.7
C.D. (0.05)	0.8	1.8	1.1	0.7	0.9	0.7	1.3	4.0	2.0

through NCU + 25% through Vermicompost) at later stages of crop growth.

At 30 DAS, the pooled mean showed that treatment T_{10} (RDN- 100% through NCU + 2.5 t/ha Vermicompost) recorded the maximum number of nodes per plant (13.4) which was followed by treatment T_6 (RDN- 75% through NCU + 25% through Vermicompost). On the other hand, the minimum number of nodes per plant (5.6) recorded under treatment T_1 (No application of nitrogen) however, treatment T_2 (RDN- 50% through Vermicompost + 50% through FYM) was found to be statistically *at par*.

According to pooled mean data, treatment T_{10} (RDN- 100% through NCU + 2.5 t/ha Vermicompost) recorded the maximum number of nodes per plant (26.6) at 60 DAS as compared to all other treatments, while treatment T_1 (No application of nitrogen) recorded the minimum number of nodes per plant (15.8) as compared to all other treatments.

At 90 DAS, treatment T_6 (RDN- 75% through NCU + 25% through Vermicompost) followed by treatment T_{10} (RDN- 100% through NCU + 2.5 t/ha Vermicompost) recorded the maximum number of nodes per plant (44.1) as per the pooled mean data as compared to all other treatments, while treatment T_1 (No application of nitrogen) recorded the minimum number of nodes per plant (25.9).

Fresh weight of plants

The data pertaining to fresh weight of plants (Table 3) was found significantly affected by various nitrogen treatments. In comparison to other treatments, treatment T_6 (RDN- 75% through NCU + 25% through Vermicompost) recorded significantly maximum fresh weight of plants (21.7 kg/ plot) as per pooled mean, while it was recorded minimum (8.9 kg/ plot) under treatment T_1 (No application of nitrogen) which was found statistically *at par* with treatments T_3 (RDN- 100% through Urea), T_{10} (RDN- 100% through NCU + 2.5 t/ha Vermicompost) and T_{13} (STCR with organic).

Dry weight of plants

Pooled mean (Table 3) indicated that the maximum values for dry weight of plants (3.0 kg/ plot) was recorded under treatment T_6 (RDN- 75% through NCU + 25% through Vermicompost) which was statistically highest among all other treatments whereas, the minimum values for dry weight of plants (1.9 kg/ plot) was recorded under treatment T_1 (No application of nitrogen).

Yield parameters

Number of green pods per plot

The pooled mean data (Table 4) indicated that the treatment T_6 (RDN- 75% through NCU + 25% through Vermicompost) recorded most number of green pods per plot (1025.4) as compared to all other treatments. While, least number of green pods per plot (484.9) was recorded under treatment T_1 (No application of nitrogen) whereas, treatments T_9

Table 3. Effect of different nitrogen treatments on fresh and dry weight of plants of okra

Treatments	Fresh weight of plants(kg/ plot)			Dry weight of plants(kg/ plot)		
	2016	2017	Pooled	2016	2017	Pooled
T_1	11.5	6.4	8.9	1.5	1.2	1.3
T_2	12.4	8.7	10.6	1.6	1.5	1.6
T_3	14.8	9.3	12.0	1.9	1.6	1.8
T_4	16.2	9.4	12.8	2.1	1.7	1.9
T_5	15.6	15.4	15.5	2.0	2.5	2.2
T_6	24.5	19.0	21.7	3.2	2.9	3.0
T_7	15.2	14.4	14.8	2.0	2.3	2.1
T_8	17.1	10.3	13.7	2.2	1.8	2.0
T_9	10.4	8.3	9.4	1.4	1.5	1.4
T_{10}	15.3	9.4	12.4	2.0	1.6	1.8
T_{11}	12.6	13.7	13.2	1.6	2.2	1.9
T_{12}	17.6	13.2	15.4	2.3	2.1	2.2
T_{13}	11.5	11.2	11.4	1.5	1.9	1.7
T_{14}	12.3	13.7	13.0	1.6	2.2	1.9
SEm±	1.14	1.80	1.22	0.14	0.26	0.17
C.D. (0.05)	3.31	5.23	3.56	0.43	0.77	0.51

(RDN- 100% through Urea + 2.5 t/ha Vermicompost), T_2 (RDN- 50% through Vermicompost + 50% through FYM) and T_{11} (RDN- 100% Urea + 5 t/ha FYM) were found to be *at par*.

Green pod yield

It is evident from data (Table 4) that the green pod yield was significantly affected by various nitrogen treatments. Pooled mean data over the years showed significantly maximum green pod yield (11.9 kg/ plot) recorded under treatment T_6 (RDN- 75% through NCU + 25% through Vermicompost) as compared to all other treatments whereas, treatments T_{10} (RDN- 100% through NCU + 2.5 t/ha Vermicompost) and T_8 (RDN- 75% through NCU + 10 t/ha FYM) were found *at par*, while green pod yield was found statistically minimum (6.6 kg/ plot) under treatment T_1 (No application of nitrogen).

Quality parameters

Dry matter content

Pooled mean data (Table 5) showed that treatment T_4 (RDN- 100% through NCU) recorded the maximum dry matter content (11.7%), while treatments T_5 (RDN- 75% through Urea + 25% through Vermicompost), T_6 (RDN- 75% through NCU + 25% through Vermicompost), T_8 (RDN- 75% through NCU + 10 t/ha FYM), T_{11} (RDN- 100% through Urea + 5 t/ha FYM) and T_{12} (RDN- 100% through NCU + 5 t/ha FYM) were found to be statistically *at par*. However, the minimum dry matter content (7.8%) was recorded under treatment T_1 (No application of nitrogen).

Protein content

The data for protein content (Table 5) was found significantly affected by various nitrogen treatments. The highest protein content (15.8%) was recorded under treatment T_{12} (RDN- 100% through NCU + 5 t/ha FYM) which was found to be highly superior to treatments T_1 (No application of nitrogen), T_2 (RDN- 50% through Vermicompost + 50% through FYM), T_9 (RDN- 100% through Urea + 2.5 t/ha Vermicompost) and T_{14} (STCR without organic). On the other hand, the lowest protein content (11.4%) was recorded under treatment T_1 (No application of nitrogen).

Moisture content

The maximum values of moisture content in green pods (92.2%) was recorded under treatment T_1 (No application of nitrogen) whereas, the minimum moisture content (88.3%) was recorded under treatment T_4 (RDN- 100% through NCU), while treatments T_5 (RDN- 75% through Urea + 25% through Vermicompost), T_6 (RDN- 75% through NCU + 25% through Vermicompost), T_8 (RDN- 75% through NCU + 10 t/ha FYM), T_{11} (RDN- 100% through Urea + 5 t/ha FYM) and T_{12} (RDN- 100% through NCU + 5 t/ha FYM) were found statistically *at par* as per the pooled mean (Table 5).

Table 4. Effect of different nitrogen treatments on number of green pods and green pod yield of okra

Treatments	Number of green pods/ plot			Green pod yield (kg/ plot)		
	2016	2017	Pooled	2016	2017	Pooled
T_1	558.2	403.0	484.9	6.5	6.7	6.6
T_2	721.7	477.7	598.5	8.8	8.4	8.6
T_3	743.7	576.3	670.8	9.1	9.1	9.1
T_4	816.5	692.7	765.4	10.9	9.5	10.2
T_5	743.0	772.6	759.6	9.4	10.7	10.0
T_6	1158.6	880.0	1025.4	12.0	11.7	11.9
T_7	743.3	688.3	720.7	9.2	9.8	9.5
T_8	822.6	817.2	835.5	10.4	11.4	10.9
T_9	634.0	513.9	571.0	8.9	9.2	9.1
T_{10}	778.7	663.1	722.8	11.2	12.3	11.8
T_{11}	744.0	509.0	621.1	9.1	9.7	9.4
T_{12}	768.6	643.7	715.1	9.5	9.8	9.7
T_{13}	624.2	732.2	675.3	9.1	10.0	9.5
T_{14}	685.2	635.2	660.0	9.0	9.5	9.2
SEm±	88.1	81.1	60.0	0.3	0.5	0.3
C.D. (0.05)	256.3	236.0	174.6	1.1	1.5	1.0

Ascorbic acid content

Pooled mean (Table 5) indicated the maximum ascorbic acid content (19.20 mg/ 100 g) recorded under treatment T_{11} (RDN- 100% through Urea + 5 t/ha FYM) as compared to all other treatments. On the other hand, the minimum ascorbic acid content (15.35 mg/ 100 g) was recorded under treatment T_1 (No application of nitrogen).

Economic parameters

Cost of cultivation

It is evident from the data (Table 6 and 7) that with general cost of cultivation of Rs. 58386.0 per hectare, the highest total expenditure (Rs. 143056.0 and Rs. 127641.0, respectively) was incurred with treatment T_2 (RDN- 50% through Vermicompost + 50% through FYM) both in first year and second year,

Table 5. Effect of different nitrogen treatments on quality parameters of green pods of okra

Treatments	Dry matter content (%)			Protein content (%)			Moisture content (%)			Ascorbic acid (fresh) content (mg/ 100 g)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_1	8.5	7.2	7.8	11.3	11.5	11.4	91.5	92.8	92.2	15.34	15.36	15.35
T_2	10.8	8.0	9.4	13.1	14.3	13.7	89.2	92.0	90.6	17.45	17.41	17.43
T_3	11.7	8.3	10.0	14.4	14.6	14.5	88.3	91.7	90.0	16.21	16.65	16.43
T_4	13.4	9.9	11.7	14.6	14.9	14.8	86.6	90.1	88.3	16.25	16.71	16.48
T_5	12.4	9.3	10.9	15.0	15.1	15.0	87.6	90.7	89.1	18.15	19.04	18.59
T_6	12.4	10.5	11.5	15.6	15.4	15.5	87.6	89.5	88.5	18.42	18.26	18.34
T_7	10.0	9.1	9.6	15.5	14.5	15.0	90.0	90.9	90.4	17.18	16.87	17.03
T_8	11.5	9.8	10.7	15.4	15.0	15.2	88.5	90.2	89.3	17.53	17.99	17.76
T_9	10.6	7.8	9.2	12.9	12.6	12.8	89.4	92.2	90.8	17.68	17.47	17.57
T_{10}	10.1	9.2	9.6	14.6	15.2	14.9	89.9	90.8	90.4	18.17	18.27	18.22
T_{11}	11.4	9.3	10.4	15.3	14.2	14.8	88.6	90.7	89.6	18.93	19.47	19.20
T_{12}	11.0	9.7	10.4	16.1	15.5	15.8	89.0	90.3	89.6	17.73	18.33	18.03
T_{13}	10.4	8.2	9.3	15.3	14.6	14.9	89.6	91.8	90.7	17.81	17.42	17.62
T_{14}	10.9	9.1	10.0	13.8	14.0	13.9	89.1	90.9	90.0	17.34	17.72	17.53
SEm±	0.7	0.3	0.3	0.6	0.6	0.3	0.7	0.3	0.3	0.24	0.30	0.18
C.D. (0.01)	2.7	1.5	1.5	2.7	2.3	1.5	2.7	1.5	1.5	0.97	1.17	0.54

Table 6. Effect of different nitrogen treatments on economics of okra in 2016

Treatments	General Cost of Cultivation (Rs./ha)	Additional Cost (Rs./ ha)	Total Expenditure (Rs./ ha)	Marketable Yield (t/ ha)	Gross Income (Rs./ ha)	Net Income (Rs./ ha)	B: C Ratio
T_1	58386.0	6008.0	64394.0	8.1	81338.0	22952.0	1.26
T_2	58386.0	84670.0	143056.0	10.5	104834.0	46447.0	0.73
T_3	58386.0	8934.0	67321.0	10.8	107856.0	49469.0	1.60
T_4	58386.0	9666.0	68052.0	14.0	139761.0	81374.0	2.05
T_5	58386.0	54149.0	112536.0	11.5	115102.0	56715.0	1.02
T_6	58386.0	55051.0	113437.0	15.6	155554.0	97168.0	1.37
T_7	58386.0	49753.0	108140.0	10.8	108412.0	50026.0	1.00
T_8	58386.0	50371.0	108757.0	13.6	135554.0	77168.0	1.25
T_9	58386.0	35226.0	93613.0	11.6	115691.0	57305.0	1.24
T_{10}	58386.0	35906.0	94293.0	14.5	145329.0	86942.0	1.54
T_{11}	58386.0	30166.0	88553.0	11.3	112995.0	54609.0	1.28
T_{12}	58386.0	30244.0	88631.0	11.5	114537.0	56151.0	1.29
T_{13}	58386.0	54398.0	112785.0	11.3	112460.0	54073.0	1.00
T_{14}	58386.0	17574.0	75960.0	10.7	107173.0	48787.0	1.41

*Selling price of okra was Rs. 10,000/ tonne (t).

respectively, while the lowest total expenditure (Rs. 64394.0 and Rs. 64317.0) was incurred with treatment T_1 (No application of nitrogen) both in first year and second year, respectively.

Total output

The highest total output or gross income per hectare of Rs. 155554.0 and Rs. 146919.0, respectively recorded with the treatment T_6 (RDN- 75% through NCU + 25% through Vermicompost) in the first year and treatment T_{10} (RDN- 100% through NCU + 2.5 t/ha Vermicompost) in the second year, while lowest gross income of Rs. 81338.0 and Rs. 77852.0 was recorded with the treatment T_1 (No application of nitrogen) in both the years, respectively.

Benefit: cost ratio

The production efficiency of different treatments as indicated by its benefit: cost ratio was recorded highest (2.05 and 1.63, respectively) with treatment T_4 (RDN- 100% through NCU) both in first year and second year while, the lowest benefit: cost ratio (0.73 and 0.72, respectively) was procured with treatment T_2 (RDN- 50% through Vermicompost + 50% through FYM) during both the years.

Discussion

Growth parameters

It is evident from the data (Table 1-3) that application of neem coated urea along with vermicompost had some significant positive effect on growth parameters of okra crop. Treatments T_6 and T_{10} proved to be equally best which could be attributed to the role of vermicompost from which nutrients are released gradually through the process of mineralization maintaining optimal soil levels over prolonged periods of time thus leading to increased growth parameters (Bationo *et al.*, 2004). The improvements in plant growth could be partially due to large increases in soil microbial biomass after vermicompost applications, leading to production of hormones or humic acids in the vermicompost acting as plant growth regulators independent of nutrient supply (Arancon *et al.*, 2003). Kashyap *et al.* (2014) in brinjal, Shahbaz *et al.* (2014) and Garhwal *et al.* (2010) in okra also reported increase in growth parameters with the combined application of inorganic and organic fertilizers. Results are in agreement with the findings of Meenakumari and Shehkar (2012) and Papathanasiou *et al.* (2012) who reported increase in fresh weight of leaves and plants, and Patel (2006) who reported increase in dry weight of plants.

Yield parameters

A significant increase was found in number and yield of green pods (Table 4) with the combined application of recommended dose of nitrogen through neem coated urea and vermicompost. Nitrogen is the major constituent of chlorophyll, proteins and amino acids, the synthesis of which is accelerated by

Table 7. Effect of different nitrogen treatments on economics of okra in 2017

Treatments	General Cost of Cultivation (Rs./ha)	Additional Cost (Rs./ ha)	Total Expenditure (Rs./ ha)	Marketable Yield (t/ ha)	Gross Income (Rs./ ha)	Net Income (Rs./ ha)	B: C Ratio
T_1	58386.0	5930.0	64317.0	7.8	77852.0	19466.0	1.21
T_2	58386.0	69255.0	127641.0	9.2	92192.0	33805.0	0.72
T_3	58386.0	8771.0	67157.0	10.0	100284.0	41897.0	1.49
T_4	58386.0	9030.0	67416.0	11.0	110085.0	51699.0	1.63
T_5	58386.0	41157.0	99544.0	12.4	124121.0	65735.0	1.25
T_6	58386.0	41680.0	100066.0	14.7	146919.0	88533.0	1.47
T_7	58386.0	49762.0	108148.0	10.9	108819.0	50433.0	1.01
T_8	58386.0	50457.0	108843.0	13.9	139375.0	80989.0	1.28
T_9	58386.0	35140.0	93527.0	11.2	111896.0	53509.0	1.20
T_{10}	58386.0	36010.0	94396.0	15.0	150285.0	91899.0	1.59
T_{11}	58386.0	30175.0	88561.0	11.4	113500.0	55113.0	1.28
T_{12}	58386.0	30141.0	88527.0	11.0	109765.0	51378.0	1.24
T_{13}	58386.0	53961.0	112348.0	11.7	116731.0	58345.0	1.04
T_{14}	58386.0	16462.0	74849.0	10.6	105884.0	47498.0	1.41

*Selling price of okra was Rs. 10,000/ tonne (t).

the increased supply of nitrogen in soil (Arnon, 2003) and since, nutrients in the vermicompost are released gradually over prolonged periods of time through the process of mineralization maintaining optimal soil levels thus leading to increased growth parameters (Bationo *et al.*, 2004) which could have improved the number and yield of green pods. This could also be attributed to the presence of several plant growth hormones like cytokinins and auxins in casts of earthworms which have positive beneficial effect on yield parameters (Krishnamoorthy and Vajranabaiah, 1986). Shalini *et al.* (2002) in knol-khol and Shahbaz *et al.* (2014) in okra also observed same response with combined application of nitrogen through organic and inorganic fertilizers. Kashyap *et al.* (2014) in brinjal, and Garhwal *et al.* (2010) in okra also reported higher number of fruits attributed to some positive effects of vermicompost on performance of crop.

Quality parameters

A critical analysis of the data (Table 5) revealed that green pod dry matter content was higher in plots inorganically treated with neem coated urea and those with combination of inorganic and organic sources as compared to control which might be due to improved light interception, dry matter production, accumulation and partitioning due to increased photosynthetic activity of plants as a result of availability of nutrients in right proportion (Akanbi *et al.*, 2010). Similar results were also reported by Chattoo *et al.* (2011) with the application of inorganic and organic sources of nutrients.

The protein content of green pods (Table 5) increased with the application of organic manures along with inorganic fertilizers. This might be due to higher nitrogen and dry matter accumulation by pods with availability of nutrients for longer periods as a result of which increase in protein content was observed in pods produced under these treatments as compared to control. Our results are in agreement with the findings of Garhwal *et al.* (2010) and Chattoo *et al.* (2011) who reported higher protein content with combined application of inorganic fertilizers and organic manure than control. Sajjan *et al.* (2002) also reported increase in protein content with increase in nitrogen application rate.

The lowest moisture content in pods was observed under inorganically treated plots and a critical analysis of the data (Table 5) revealed that application of inorganic fertilizers and organic manures resulted in lower moisture content, while highest moisture content in pods was obtained under control treatment. This might be due to the effect of nitrogen released through inorganic sources in the initial period of crop growth and through organic manure during later stages which increased the vegetative growth of plants that resulted in adequate uptake of water and more accumulation of dry matter by green pods ultimately resulting in lower moisture content. Since, fertilization is generally less in organic agriculture and therefore, organic fruits and vegetables are smaller in size and thus, contain less water (Basker, 1992). Similar results were also reported by Kumar *et al.* (2017).

The perusal of the data (Table 5) revealed that ascorbic acid content of okra pods increased with the sole application of nitrogen either in the form of organic or inorganic or combined application of inorganic and organic sources as compared to control, however it was recorded highest with the application of urea and 5 t/ha FYM. Our findings are in agreement to the findings of Dhakal *et al.* (2016) in broccoli, Eggert and Kaharamann (1984) in tomato, Tripathy and Maity (2009) and Chattoo *et al.* (2011) in okra, who reported similar results with the combined application of inorganic fertilizers with organic manure.

Economic parameters

The higher total expenditure (Table 6 and 7) in treatment T_2 (RDN- 50% through Vermicompost + 50% through FYM) during both the years was due to much higher additional cost of organic manures (FYM and vermicompost), while the higher total output in T_6 (RDN- 75% through NCU + 25% through Vermicompost) and T_{10} (RDN- 100% through NCU + 2.5 t/ha Vermicompost) in the first and the second year, respectively was due to higher marketable yield of green pods under these treatments as compared to all other treatments. The higher benefit: cost ratio in both the years with treatment T_4 (RDN- 100% through NCU) was due to lower input and moderate yield under this treatment as compared to all other treatments. Treatments with combined organic and inorganic sources especially neem coated urea and vermicompost proved best in terms of higher productivity and moderate net returns. Similar results were reported by Ballal and Kadam (2016).

Conclusion

As per the results, STCR treatments did not performed well, while among organic and inorganic N sources, vermicompost and neem coated urea were found best for improving various growth, yield and quality parameters. Though, treatment T_4 (RDN-100% through NCU) was found best as per the economics is concerned but based on the results of the present investigation it can be concluded that application of T_{10} (RDN- 100% through NCU + 2.5 t/ha Vermicompost) and T_6 (RDN- 75% through NCU + 25% through Vermicompost) could be recommended to the farmers of Uttarakhand lowland region to increase the production and productivity of okra with optimum net returns.

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