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Effect of variable nitrogen sources on seed yield, seed quality and nutrient uptake of okra (*Abelmoschus esculentus*)

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ABSTRACT

During *kharif* season of 2012 and 2013, a field experiment was conducted at CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur to study the effect of variable nitrogen sources on seed yield, seed quality and nutrient uptake of okra [*Abelmoschus esculentus* (L.) Moench]. The experiment consisted of seven treatments, viz. 25% N through FYM + 75% N through inorganic fertilizer, 25% N through fortified vermicompost + 75% N through inorganic fertilizer, 25% N through vermicompost + 75% N through inorganic fertilizer, 50% N through FYM + 50% N through inorganic fertilizer, 50% N through fortified vermicompost + 50% N through inorganic fertilizer, 50% N through vermicompost + 50% N through inorganic fertilizer and recommended dose of fertilizers. The result of two years study revealed that the use of 50% N through fortified vermicompost + 50% N through inorganic fertilizer resulted in significantly highest seed yield of 694.4 kg/ha and 745.4 kg/ha during 2012 and 2013, respectively. Significantly higher number of capsules/plant, seeds/capsule and long capsules with the application of 50% N through fortified vermicompost + 50% N through inorganic fertilizer were recorded. Application of 50% N through fortified vermicompost + 50% N through inorganic fertilizer resulted in significantly higher net returns (180.2 $\times 10^3$ ₹/ ha/year) and net returns per rupee invested (₹ 4.91). Moreover, seed quality parameters were also enhanced with the application of 50% N through fortified vermicompost + 50% N through inorganic fertilizer over other treatments.

Key words: Economics, Farmyard manure, Fortified vermicompost, Nutrient uptake, Okra, Seed yield, Vermicompost

The mid hill zone of North-Western Himalayas offer large potential for vegetable production, especially okra [*Abelmoschus esculentus* (L.) Moench] and is one of the most important vegetable crops grown during summer and rainy season due to its high adaptability over a wide range of environmental conditions. In Himachal Pradesh, okra is being grown for table purpose in an area of about 2.9 thousand ha with an annual production of 38.8 thousand million tonnes (Anonymous 2016). The green vegetable fetches high premium to hill farmers but taking okra as seed crop can be more profitable. Despite of favourable climatic conditions offered by hilly terrain, the productivity of okra is low due to poor organic matter status of soil owing to imbalanced application of major nutrients in continuous cropping systems and hence limited availability of quality seed. By the use of chemical fertilizers the quantity of food production increases but nutritional quality and soil fertility over the years decreases, if used in imbalanced form.. Among organic manures apart from FYM, use of vermicompost and fortified vermicompost are vital for supplementing plant nutrients and maintenance of soil fertility. Application of fortified vermicompost (compost enriched with *Azotobacter* + PSB + *Trichoderma*) is of great significance as they play an important role in improving growth, yield and quality of vegetable crops by providing nutrition along with disease resistance. A good economic return can be obtained with the use of combination of organic and inorganic sources of nutrients by maintaining good soil health for the subsequent crop yield. Therefore, the present investigation was carried out with the objective of studying the effect of variable nitrogen sources on seed yield, seed quality and nutrient uptake in okra crop.

MATERIALS AND METHODS

During the rainy season (June to October) of 2012 and 2013, a field experiment was carried out at the Experimental Farm of Department of Seed Science and Technology, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur situated at 32°6 N latitude and 76°3 E longitude with an elevation of 1290.8 m above mean sea level. The experiment was

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Table 1 Detail of treatments

Treatment	Treatment detail
M_1	25% N through FYM + 75% N through inorganic fertilizer
M_2	25% N through fortified vermicompost + 75% N through inorganic fertilizer
M_3	25% N through vermicompost + 75% N through inorganic fertilizer
M_4	50% N through FYM + 50% N through inorganic fertilizer
M_5	50% N through fortified vermicompost + 50% N through inorganic fertilizer
M_6	50% N through vermicompost + 50% N through inorganic fertilizer
M_7	Recommended dose of fertilizers

conducted on silty clay loam soil having pH 5.2, organic C (0.78%), available N (234 kg/ha), available P (19 kg/ha) and available K (236 kg/ha).

The experiment, consisted of seven treatments are given in Table 1.

The experiment was laid out in randomized block design with three replications. The nutrient sources, viz. FYM, fortified vermicompost and vermicompost as well as required quantity of N, P and K in the form of urea, single super phosphate and muriate of potash, respectively were applied as per the treatments at the time of sowing. The composition of FYM, vermicompost and fortified vermicompost is presented in Table 2. Okra variety P-8 was sown by using seed rate of 10 kg/ha at an inter row spacing of 45 cm on 13 June 2012 and 7 June 2013, respectively at the same location. Two irrigations were given during *kharif* 2012, whereas there was enough rainfall during *kharif* 2013, so there was no need of irrigation (Fig 1). The figure depicts that rainfall during June to October 2013 was higher as compared to rainfall received during June to October 2012.The weedicide alachlor @ 3 litres/ha was sprayed as pre-emergence herbicide to keep the weeds under control. In addition to chemical weed control, two manual weedings were done at 30 and 45 DAS. Randomly five plants per plot were selected in the net plot area and tagged for recording growth and yield attributes. The crop was manually harvested, threshed and seed yield was recorded. After harvesting, soil samples were collected from each plot at 0-15 cm depth and analysed using standard procedures. The total N content of plants was analysed by Microkjeldahl method, P by vanadomolybdate method and K by flame photometer method. Shelling percentage was computed as

$$\text{Shelling percentage} = \frac{\text{weight of seeds}}{\text{weight of capsules}} \times 100$$

The net returns/ha and net returns/rupee invested were computed using the prevailing market rates and prices for inputs including seeds. After harvest of okra seeds, 150 seeds (three replications of 50 each) from each treatment were placed in moist germination paper at 30ºC in incubator. Per cent normal seedlings were recorded after four days and final count was recorded at 8th day of seeding. Germination test was conducted as per ISTA rules. The electrical conductivity of the seed leachate was measured in dS/m, whereas the vigour index (VI) values were computed as per the procedure given by Abdul- Baki and Anderson (1973) and expressed in number as seedling vigour index.

Seedling vigour index = Germination (%) × Seedling length (cm)

Since data followed the homogeneity test, pooling was done over the seasons and mean data are given.

RESULTS AND DISCUSSION

Growth parameters

With the use of 50% N through fortified vermicompost + 50% N through inorganic fertilizer (M_5) produced significantly taller plants and higher dry matter

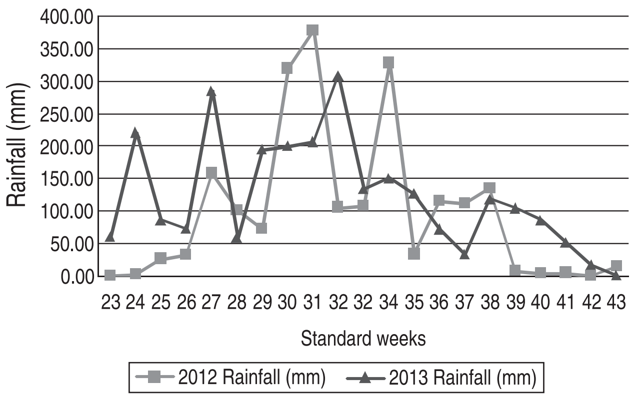

Fig 1 Rainfall data from June to October, 2012 and 2013 respectively.

Table 2 Composition of FYM, vermicompost and fortified vermicompost used in the experiment

Parameter	Okra 2012			Okra 2013		
	FYM	Vermicompost	Fortified vermicompost	FYM	Vermicompost	Fortified vermi-compost
Nitrogen (%)	0.9	1.6	2.2	0.9	1.7	2.1
Phosphorus (%)	0.3	0.9	0.9	0.3	0.8	0.9
Potassium (%)	0.7	1.2	1.1	0.6	1.1	1.3

Table 3 Effect of organic and inorganic sources of nitrogen on growth parameters, yield attributes and seed yield of okra (pooled mean data of 2 years)

Treatment	Plant height at harvest (cm)	Plant dry matter at harvest (g/m^2)	Number of capsules/ plant	Capsule length (cm)	Fruit thickness (cm)	Number of seeds/ capsule	1000 seed weight	Shelling per-centage	Seed yield (kg/ha)		
									2012	2013	Mean
FYM25N + $Fertilizer_{75}$ (M1)	72.7	377.4	7.1	13.8	1.4	45.1	65.3	58.8	503.7	523.1	513.4
FVC25N + $Fertilizer_{75}$ (M2)	77.9	434.1	7.6	14.7	1.4	48.5	66.1	61.0	541.7	611.1	576.4
VC25N + $Fertilizer_{75}$ (M3)	77.1	421.2	7.6	14.5	1.4	50.0	66.4	60.7	552.8	601.9	577.3
FYM50N + $Fertilizer_{50}$ (M4)	76.2	390.5	7.4	14.2	1.4	47.2	65.1	60.4	527.8	532.4	530.1
FVC50N + $Fertilizer_{50}$ (M5)	81.5	544.6	8.9	15.7	1.5	52.6	67.9	62.9	694.4	745.4	719.9
VC50N + $Fertilizer_{50}$ (M6)	79.6	519.6	8.7	15.0	1.5	51.3	67.6	63.1	680.6	722.2	701.4
RDF (M7)	70.2	358.2	6.6	13.2	1.4	42.4	64.3	55.8	480.6	476.9	478.7
SEm±	0.04	5.4	0.1	0.3	0.04	0.07	1.1	1.0	13.6	11.7	10.4
CD (P=0.05)	1.2	16.2	0.3	0.9	NS	2.2	NS	3.1	40.8	35.2	31.3

accumulation at harvest of okra crop and was closely followed by the use of 50% N through vermicompost + 50% N through inorganic fertilizer (M_6) but remained significantly different to each other. Significantly, shorter plants and lower dry matter accumulation was found with RDF (M_7). (Table 3). The effect of vermicompost and biofertilizers in combination was more pronounced with the advancement of crop growth indicating better effect on plant height of okra. It might be attributed to improved fertility status of the soil through microbial activities and better utilization of plant nutrients by okra. The slow release of nutrients associated with vermicompost might have resulted in higher concentration of nutrients in plant cells resulting in higher dry matter accumulation. Similar increase in growth parameters by combined application of nutrients was reported in okra.

Yield attributes

Significantly higher number of capsules/plant and seeds/capsule were found with the use of 50% N through fortified vermicompost + 50% N through inorganic fertilizer (M_5) followed by 50% N through vermicompost + 50% N through NPK (M_6), M_2, M_3 and M_4 treatments (Table 3). The treatments M_5 and M_6 were found statistically at par with each other. Similar trend in capsule length was recorded. Since, the plants were healthy under the treatment having combination of fortified vermicompost (*Azotobacter* + PSB +*Trichoderma*) and chemical fertilizers in 50:50 N ratio, they produced more dry matter which was then reflected in their different yield attributes and due to increased nutrient utilization resulted in enhanced fruit characteristics of okra. Similar findings of significantly higher number of fruits/plant by integrated application of chemical fertilizer, organic manures and biofertilizers were reported. The minimum number of capsules/plant, seeds / capsule and shorter capsules were recorded in control plots (RDF). Further examination of data shows that application of organic manures, fortified vermicompost and inorganic fertilizers in different combinations did not influence the 1000 seed weight and fruit thickness of okra significantly. Test weight of grains, generally a varietal character, is less sensitive to management levels. The use of 50% N through vermicompost + 50% N through fertilizer (M_6) resulted in significantly higher shelling percentage of okra followed by use of 50% N through fortified vermicompost + 50% N through fertilizer (M_5) , M_2, M_3, M_4 and these treatments were also found to be significantly at par with each other with regard to shelling percentage. Treatment applied with recommended dose of fertilizers (M_7) resulted in significantly lower shelling percentage of okra. Similar results were also reported with the application of enriched compost in rice .

Yield

The use of 50% N through fortified vermicompost + 50% N through fertilizer (M_5) remaining at par with 50% N through vermicompost + 50% N through fertilizer (M_6) resulted in significantly higher seed yield during both the years, 2012 and 2013. There was an increase of 213.8 kg and 268.5 kg/ha seed due to application of treatment M_5 (50% N through fortified vermicompost + 50% N through fertilizer) over control treatment during 2012 and 2013, respectively. The increase in seed yield due to this treatment was to the tune of 30.8% during 2012 and 36.1% during 2013. However, control treatment (M_7) (recommended dose of fertilizers) proved significantly inferior among all the treatments. Similar results were also reported by biofertilizers in okra. This might be due to rapid mineralization and steady supply of nitrogen from vermicompost and FYM, which might have met the N requirement of crop at critical stages of crop. The seed yield is the ultimate result of interaction of various factors, including climatic factors which remained by and large optimum during the crop season. Better growth in okra crop due to organic manures, fortified vermicompost and inorganic fertilizers in combination resulted in improvement in physical, chemical and biological properties and further leads to higher assimilation of nutrients due to better

Table 4 Effect of organic and inorganic sources of nitrogen on nutrient availability (kg/ha) and nutrient uptake (kg/ha) in okra (pooled mean data of 2 years)

Treatment	Nutrient uptake (kg/ha)			Organic carbon (%)	Available nutrients (kg/ha)			Available micronutrient cations (mg/kg)			
	N	P	K		N	P	K	Fe	Mn	Zn	Cu
FYM25N + $Fertilizer_{75}$ (M1)	25.95	7.90	11.34	1.04	222.30	20.27	264.69	11.30	0.84	0.94	0.43
FVC25N + $Fertilizer_{75}$ (M2)	31.46	9.93	15.03	1.09	242.06	21.83	281.49	12.00	0.92	1.07	0.51
VC25N + $Fertilizer_{75}$ (M3)	30.61	9.21	14.64	1.10	236.86	22.70	275.26	12.03	0.89	1.00	0.49
FYM50N + $Fertilizer_{50}$ (M4)	31.89	9.92	15.08	1.13	248.82	23.97	286.72	12.62	0.92	1.07	0.50
FVC50N + $Fertilizer_{50}$ (M5)	40.52	14.21	20.07	1.16	267.54	26.21	330.77	13.93	0.99	1.19	0.56
VC50N + $Fertilizer_{50}$ (M6)	39.79	13.19	18.96	1.15	261.04	24.94	309.49	13.88	0.96	1.14	0.56
RDF (M7)	23.55	6.03	10.00	0.93	206.70	19.00	224.52	10.50	0.80	0.85	0.41
SEm±	0.41	0.16	0.24	0.01	2.78	0.43	4.59	0.16	0.007	0.02	0.007
CD(P=0.05)	1.22	0.47	0.72	0.04	8.35	1.30	13.78	0.47	0.02	0.06	0.02

nutrient supply and better translocation of photosynthates to storage organs, might have improved the yield attributes and ultimately seed yield.

Economics

Significantly higher net returns (180.2×10^3 ₹ /ha/year and net returns/rupee invested (₹ 4.91) were obtained from the crop sown with the use of 50% N through fortified vermicompost + 50% N through inorganic fertilizer and this treatment resulted in similar yield with use of 50% N through vermicompost + 50% N through inorganic fertilizer (Table 5). The lowest net returns/ha and net returns/rupee invested were recorded in plots applied with RDF (M_7). Due to high cost of vermicompost, resulted in increased cost of cultivation without too much increase in net returns. Hence, this overall effect of vermicompost reflected in net returns/rupee invested.

Table 5 Effect of organic and inorganic sources of nitrogen on economics of okra (pooled data of 2 years)

Treatment	Cost of cultivation ($\times 10^3$ ₹/ha)	Gross returns ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Net returns/ rupee invested
FYM25N + $Fertilizer_{75}$ (M1)	33.9	154.8	120.9	3.56
FVC25N + $Fertilizer_{75}$ (M2)	34.5	173.7	139.2	4.04
VC25N + $Fertilizer_{75}$ (M3)	34.3	173.9	139.6	4.07
FYM50N + $Fertilizer_{50}$ (M4)	35.5	159.8	124.3	3.50
FVC50N + $Fertilizer_{50}$ (M5)	36.7	216.9	180.2	4.91
VC50N + $Fertilizer_{50}$ (M6)	36.4	211.3	174.9	4.80
RDF (M7)	32.3	144.3	112.1	3.47
SEm±		3.13	3.13	0.09
CD(P=0.05)		9.39	9.39	0.26

FYM- farmyard manure, FVC-fortified vermicompost, VC-vermicompost, Cost of seed- ₹ 300/kg, FYM-₹ 500/t, fortified vermicompost -₹ 2600/t, vermicompost-₹ 2000/t, urea- ₹ 5.7/kg, SSP- ₹ 9.9/kg, MOP- ₹ 16.8/kg.

Nutrient uptake

Significantly higher N, P and K uptake was recorded with the use of 50% N through fortified vermicompost + 50% N through inorganic fertilizer (M_5) followed by 50% N through vermicompost + 50% N through inorganic fertilizer (M_6) (Table 4). The treatments M_5 and M_6 were found significantly similar with each other with respect to nitrogen uptake while, the control plots recorded significantly minimum N, P and K uptake. This could be due to better availability of phosphorus in crop root zone resulting from its solubilization caused by the organic acids, produced from decaying organic matter and increased uptake by the okra roots. The net overall efficiency of NPK over a period of years is greater than 50% of that of chemical fertilizers due to release of organic nitrogen and other nutrients in compost at constant rate from the accumulated humus. Since the treatment 50% N through fortified vermicompost + 50% N through fertilizer increased all the growth characters which gave subsequently more dry matter yield therefore, more seed yield/straw yield, which was reflected in more uptake of N, P and K compared to rest of the treatments.

Soil fertility

Use of 50% N through fortified vermicompost + 50% N through inorganic fertilizer (M_5) recorded significantly highest organic carbon (1.16%) and was found statistically similar to 50% N through vermicompost + 50% N through inorganic fertilizer (M_6) and 50% N through FYM + 50% N through inorganic fertilizer (M_4) treatments. Significantly higher soil available N (267.5 kg/ha), available P (22.2 kg/ha) and available K (330.8 kg/ha) was found with 50% N through fortified vermicompost + 50% N (M_5) through inorganic fertilizer followed by application of 50% N through vermicompost + 50% N through inorganic fertilizer (M_6) (Table 4). Both the treatments M_5 and M_6 were found statistically similar in respect of N and P availability. RDF treatment recorded significantly low content of available N, P and K. It may be due to the fact that in manured plots, microbial population might have increased and as a result of soil aggregation and decomposition there was an increased organic carbon content in soil. It might be due to that the vermicompost fortified with biofertilizers resulted in higher nitrogen fixation and hence increased the nitrogen content of soil. The increase in available P might be due to the organic acids, which were released during microbial decomposition of organic matter which helped in the solubility of native phosphates as a result of which the availability of P content increased. The increase in available K contents due to the addition of organics may be ascribed to the direct contribution of K from these materials after their decomposition. Use of 50% N through fortified vermicompost + 50% N through inorganic fertilizer (M_5) recorded significantly higher micronutrient cations (Fe, Mn, Zn and Cu) over rest of the treatment combinations followed by 50% N through vermicompost + 50% N through inorganic fertilizer (M_6). Both the treatments M_5 and M_6 were found statistically similar in respect of Fe, Zn and Cu availability. Vermicompost might have contributed more to soil as it is rich in micronutrients. Well decomposed FYM and vermicompost might have involved in formation of chelates with organic ligands which have lowered susceptibility to adsorption, fixation and precipitation in the soil and also it was attributed to mineralization of organic manures and consequent release of micronutrients.

Seed quality

Use of 50% N through fortified vermicompost + 50% N through inorganic fertilizer (M_5) resulted in significantly highest germination percentage over rest of the treatments and was found significantly at par with 50% N through vermicompost + 50% N through inorganic fertilizer (M_6) (Table 6). Application of 50% N through fortified vermicompost + 50% N through inorganic fertilizer (M_5) resulted in significantly higher shoot and root length and seedling vigour index followed by application of 50% N through vermicompost + 50% N through inorganic fertilizer (M_6). Significantly lower germination percentage, shoot and root length and seedling vigour index was found in plots with RDF (M_7). Seedling dry weight depends upon root and shoot length of okra seed. It can be correlated with seed vigour index. Vigorous seeds resulted in longer root and shoot length. Use of 50% N through fortified vermicompost + 50% N through NPK (M_5) followed by 50% N through vermicompost + 50% N through NPK (M_6) resulted in lower electrical conductivity.

On the contrary, significantly highest electrical conductivity was found with the application of recommended dose of fertilizers (M_7) (Table 6). This may be due to the fact that increase in electrical conductance is roughly proportional to the percentage of dead tissues in the seed. Fundamental principle of the electrical conductivity test is that deteriorated seed loose more amino acid, electrolytes and soluble sugars due to the loss of membrane integrity. The inverse relationship between electrical conductivity and germinability and vigour in the seed of several crop species including grain legume is well established.

Table 6 Effect of organic and inorganic sources of nitrogen on seed quality parameters of okra (pooled mean data of 2 years)

Treatment	Germination (%)	Root length (cm)	Shoot length (cm)	Seedling vigour index	Eletrical conductivity (dS/m)
FYM25N + $Fertilizer_{75}$ (M1)	79.00	3.33	13.75	1349	0.470
FVC25N + $Fertilizer_{75}$ (M2)	79.83	3.59	14.23	1422	0.449
VC25N + $Fertilizer_{75}$ (M3)	80.17	3.75	14.58	1470	0.447
FYM50N + $Fertilizer_{50}$ (M4)	80.75	4.42	15.65	1620	0.434
FVC50N + $Fertilizer_{50}$ (M5)	84.33	5.76	18.60	2054	0.406
VC50N + $Fertilizer_{50}$ (M6)	82.50	5.18	17.38	1862	0.418
RDF (M7)	77.67	3.13	12.73	1231	0.499
SEm±	0.68	0.14	0.32	34	0.003
CD(P=0.05)	2.05	0.43	0.97	103	0.010

On the basis of two years study, it is concluded that application of 50% N through fortified vermicompost + 50% N through NPK proved to be helpful in increasing seed yield, available NPK, nutrient uptake, higher net returns and seed quality in okra crop.

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