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Root growth, crop productivity, nutrient uptake and economics of dwarf pea (*Pisum sativum*) as influenced by integrated nutrient management

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ABSTRACT

A field experiment was conducted during the two consecutive *rabi* seasons of 2007-08 and 2008-09 at Varanasi on sandy loam soil to study the effect of organic, inorganic and biofertilizers on dwarf pea (*Pisum sativum* L.). The experiment was conducted in a split-plot design and replicated thrice. All the fertility levels, viz. chemical fertilizers, vermicompost and control were allotted to main plot and combinations of biofertilizers (*Rizobium+Bacillus polymixa +Pseudomonas fluorescence*) and Zn along with control were subjected to sub-plot. Results showed superimposition of 50% $N_{organic}$ (recommended dose of N through vermicompost) to 100% NPK (recommended dose of NPK through chemical fertilizers) resulted in significant improvement of dry matter/plant, yield (grain and straw, harvest index), root growth (root dry weight, root N content and cation exchange capacity of root) and nutrient uptake (NPKS and Zn). However nodulation (root nodules/plant, dry weight of nodules/plant and nitrogenase activity at 30 and 60 DAS) was lesser with this fertility level but significantly higher than 100% NPK and control (no application).Gross and net returns (₹ 45 358 and 31 223/ha) were noted higher with 100% NPK + 50% $N_{organic}$ fertility level. Benefit: cost ratio (2.21) was also recorded higher with 100% NPK + 50% $N_{organic}$ level. The integrated application of biofertilizers and Zn was recorded significantly better than control as this treatment lucidly improved dry matter, yield, harvest index, root growth, nodulation and nutrient uptake. Benefit: cost ratio was also higher with combined application of PSB and Zn. Furthermore, integration of 100% NPK + 50% $N_{organic}$ and biofertilizers + Zn was conducive for getting significantly optimum yield (1873 kg/ha).

Key words: Biofertilizer, Dwarf pea, Micronutrient, NPK, Vermicompost

India is the largest producer and importer of the leguminous crop (Shakya *et al.* 2008). Pea is the major importer pulse, followed by pigeonpea, urdbean, chickpea and mungbean and is the premier pulses grown in the world. Advent of dwarf pea cultivars like HUDP 15 had marked its dent as high input pea crop responding to higher fertility and plant population for yield maximization.Since, fertilizer nutrients constitute a major costly production input, exploitation of yield potentiality of this crop depends on how efficiently and effectively this input is managed. Inorganic fertilizer alone can not sustain the soil productivity as well as the large scale use of only chemical fertilizers as a source of nutrients has less efficient (Kumar *et al.* 2003). In recent years biofertilizers, viz. Rhizobium, PSB and PGPR that are ecofriendly and low cost inputs, have emerged as an important and integral component of integrated plant nutrients supply system for pulse crop production. Hence, to combat this problem and to sustain food production the present investigation was carried out to find out appropriate integrated nutrient management including inorganic fertilizers, vermicompost and biofertilizers for field pea.

MATERIALS AND METHODS

The experiment was carried out during the *rabi* seasons of 2007-08 and 2008-09 at Pulse Block of Banaras Hindu University, Varanasi. Soil of experimental plot was sandy loam and neutral in reaction (pH 7.5) and low in organic carbon (0.44%), available nitrogen (197.02 kg/ha), sulphur (17.5 kg/ha), zinc (0.52 ppm) and moderate in phosphorus (19.07 kg/ha) and potassium (210.2 kg/ha). The experiment was laid out in a split-plot design with three replications.

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Table 1 Effect of fertility levels, biofertilizers and micronutrient on root growth and nodulation of dwarf pea (Mean of two years)

Treatment	Root dry weight/plant at maturity (g)	Root N content at maturity (%)	CEC at maturity (meq 100/g dry root)	Nodules/plant (No.) 30 DAS	Nodules/plant (No.) 60 DAS	Nodule dry weight/plant (mg) 30 DAS	Nodule dry weight/plant (mg) 60DAS	NA (µ moles C_2H_2) produced/hr/g nodule weight 30 DAS	NA (µ moles C_2H_2) produced/hr/g nodule weight 60 DAS
Fertility level									
Control	1.575	0.752	90.96	9.79	11.74	35.82	38.90	8.45	10.50
100% NPK	1.805	0.828	100.19	10.81	12.77	41.96	45.74	11.54	13.79
100% $N_{organic}$	1.708	0.811	98.11	18.87	20.34	75.80	79.65	18.04	21.44
100% NPK + 50% $N_{organic}$	1.912	0.849	102.70	17.30	19.07	71.89	76.94	15.58	18.05
100% $N_{organic}$ + 50% NPK	1.828	0.831	100.57	17.27	19.42	72.56	78.35	17.33	20.07
LSD (*P*=0.05)	0.029	0.007	1.17	1.08	2.06	2.23	2.16	0.52	0.41
Biofertilizers + Micronutrient									
Control	1.713	0.798	96.73	11.81	13.60	47.23	51.88	11.82	14.22
Biofertilizers	1.771	0.818	98.89	15.02	16.98	60.32	64.73	14.31	16.84
Zn @ 5 kg/ha	1.747	0.809	97.92	14.39	16.34	58.31	62.89	13.93	16.43
Biofertilizers + Zn	1.831	0.830	100.50	18.01	19.74	72.57	76.17	16.69	19.57
LSD (*P*=0.05)	0.012	0.007	0.66	0.88	1.26	1.49	1.26	0.44	0.33

NPK, Recommended dose of NPK through inorganic fertilizers; $N_{organic,}$ recommended dose of N through Vermicompost; Biofertilizers, seed inoculation with *Rhizobium leguminosarum* + *Bacillus polymixa* + *Pseudomonas fluorescence*.

Fertility levels, viz. control, 100% NPK, 100% $N_{organic,}$ 100% NPK + 50% $N_{organic}$, and 100% $N_{organic}$ + 50% NPK were allotted to main plot where NPK represents recommended dose of N, P, K, S (40-17-16-20 kg/ha) through inorganic fertilizers and $N_{organic}$ represents recommended dose of N (40 kg/ha) through vermicompost. The different treatments, viz. biofertilizers (*Rhizobium*+ *Bacillus*+ *Pseudomonas*), zinc, biofertilizers + zinc in addition to one control were allocated to sub plots. Thus total 20 (5 main plot × 4 sub plot) treatment combinations were replicated thrice. As per treatment, HUDP 15 dwarf pea was sown after proper seed inoculation with rhizobium (*Rhizobium leguminosarum*), PSB (*Bacillus polymixa*) and PGPR (*Pseudomonas fluorescence*) @ 200 g culture 10/kg seeds. The crop was sown @ 100 kg seed/ha in 30 cm rows to maintain the plants at 10 cm on November 7 and 16 during 2007 and 2008 respectively.The other crop management practices were performed as per standard recommendation of the region. Harvesting was done on 20 March in 2007 and 21 March in 2009.

RESULTS AND DISCUSSION

The beneficial effect of combined application of chemical fertilizers and vermicompost on root growth and development was manifested in this investigation. Root characters, viz. root dry weight (g)/plan, root N content (%) and CEC (meq 100/g dry root) at maturity increased significantly up to 100% NPK + 50% $N_{organic}$ level (Table 1). In superimposition of 50% $N_{organic}$ (vermicompost) to 100% NPK plot, extent of increase was by 0.337 g, 0.097% and 11.74 meq 100/g dry root as compared to control were recorded. The dry matter accumulation leading to more of photosynthate translocation towards root and also enhanced the nodulation of pea roots due to the favorable rhizosphere environment created by addition of vermicompost in addition to adequate supply of essential plant nutrients might be the factors responsible for higher root dry weight in 100% NPK + 50% $N_{organic}$ fertility level. The cation exchange capacity of the root has been taken as an indicator of the activity of root in term of response. The increase in cation exchange capacity of the roots in 100% NPK + 50% $N_{organic}$ fertility level might be due to favorable effect of vermicompost on root proliferation.Vermicompost along with fertilizer increased soil infiltration rate and density of root channels (Shukla *et al.* 2003).

Contrary to all the growth characters nodule number, nodule dry weight and acetylene reductase activity (ARA) decreased with increasing inorganic fertilizer levels (Table 1).The maximum numbers of nodule (18.8 and 20.3) associated with 100% $N_{organic}$ at 30 and 60 DAS but at 60 DAS, it was at par to 100% NPK + 50% $N_{organic}$ and 100% $N_{organic}$ + 50% NPK and at 30 DAS significantly superior to other treatments. However number of nodules increased significantly in 100% NPK + 50% $N_{organic}$ (60% and 49% at 30 and 60 DAS respectively) as compared to 100% NPK level. This may be due to direct addition from inorganic fertilizers and slow release of nutrient from vermicompost. Application of 100% $N_{organic}$ increased nodule dry weight and acetylene reductase activity over superimposition of 50% $N_{organic}$ to 100% NPK. This might be attributed to the beneficial effect of vermicompost in root proliferations with higher carbon content. Besides, vermicompost helped in increasing the bacterial populations by providing adequate food. The reduction in nodulation and their weight was also observed in the present study at 100% inorganic fertilizers (NPK). This could be attributed to decreased activity of

Table 2 Effect of fertility levels, biofertilizers and micronutrient on dry matter, yield and economics of dwarf pea (Pooled data of 2 years).

Treatment	Dry matter/plant at maturity (g)	Grain yield (kg/ha) 2007-08	2008-09	Pooled	Straw yield (kg/ha)	Harvest index (%)	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
Fertility level										
Control	25.11	919	859	889	1514	37.01	10593	23742.00	13149.00	1.25
100% NPK	30.61	1559	1461	1510	2231	40.36	12805	39977.50	27172.50	2.12
100% $N_{organic}$	27.14	1383	1297	1340	1999	40.13	13253	35505.63	22252.63	1.68
100% NPK + 50% $N_{organic}$	34.87	1773	1661	1717	2430	41.37	14135	45358.25	31223.25	2.21
100% $N_{organic}$ + 50% NPK	31.68	1590	1490	1541	2263	40.49	14359	40769.63	26410.63	1.84
LSD (*P*=0.05)	0.98	67	72	43	46	0.66				
Biofertilizers + Micronutrient										
Control	28.24	1346	1261	1304	1978	39.53	12529	34575.90	22046.90	1.73
Biofertilizers	30.22	1432	1342	1387	2081	39.75	12729	36756.10	24027.10	1.86
Zn @ 5 kg/ha	29.10	1454	1362	1408	2107	39.81	13329	37309.40	23980.40	1.78
Biofertilizers + Zn	32.00	1547	1450	1498	2184	40.38	13529	39641.00	26112.00	1.91
LSD (*P*=0.05)	0.32	28	27	18	26	0.40				

nitrogen fixing bacteria Rhizobium at higher mineral nitrogen. More ever its deleterious effect was inactivated in combination with vermicompost (Negi *et al.* 2007).

Root character, viz. root dry weight, N content, cation exchange capacity, no. of nodules/plant dry weight of nodules/plant and nitrogenase activity increased significantly at combined application of biofertilizer and zinc. The synergy between biofertilizer and micronutrients resulted in significantly maximum root dry weight, N content and CEC of the root. However, more number of nodules, nodule dry weight and nitrogenase activity were mainly due to contribution of Rhizobium and PSB (Singh *et al.* 2008). Combined application of biofertilizers and zinc was conducive for increasing the number, dry weight and nitrogenase activity of pea root nodules (Kasturikrishna and Ahlawat 2000).

Dry matter and yield

Beneficial effect of balanced fertilization on dry matter/plant, yield (grain and straw) and harvest index has been clearly brought. Dry matter/plant increased significantly up to 100% NPK + 50% $N_{organic}$ (Table 2). Significant variations created by addition of organic manure (vermicompost) with mineral fertilizers are attributed to higher availability and absorption of nutrients (Kachot *et al*. 2001). The grain and straw yield kept on significantly increasing up to 100% NPK + 50% $N_{organic}$ fertility level. In this treatment the extent of increase in yield was 13.7% in grain yield and 8.9% in straw yield as compared to 100% NPK level. Further, fertility level of 100% NPK + 50% $N_{organic}$ has facilitated greater economic sink capacity as yield has highly significant correlation with growth and yield attributes (Sen *et al*. 2005). Even though the total nitrogen was same in 100% NPK and 100% $N_{organic}$ applied plots, lower yield were recorded in100% $N_{organic}$ applied plots. Probably vermicompost alone does not provide all the necessary nutrient elements in adequate quantities for proper growth and yield in pea. Harvest index was found significant to control and 100% $N_{organic}$ and numerically increased for other fertility levels with maximum value of 41.3% at 100% NPK + 50% $N_{organic}$ fertility level.

Seed inoculation resulted in greater dry matter/plant, grain and straw yield. This may be attributed to increased nodulation and nitrogen fixation, more solubilization of native P and production of secondary metabolites by bacteria (Rajput and Kushwah 2005). Combined application of biofertilizers along with micronutrients resulted in significant improvement in dry matter/plant, yield and harvest index of the test crop (Table 2). Application of this micronutrient (Zn) along with inoculations might have a synergistic effect, which enhanced activity of nitrogenase, in turn supplied more nitrogen by fixation for better growth and finally increased yield and harvest index of the crop. These findings are in close conformity with the findings of Krouma and Abdelly (2005).

The interaction effect between treatments was found significant for dry matter production at maturity and grain yield of the test crop (Table 4). The dry matter/plant increased significantly up to 100% NPK + 50% $N_{organic}$ combined with biofertilizer + Zn. Increase uptake of nutrient may be the possible cause behind increased dry weight of plant. Application of 50% nitrogen through vermicompost integrated with recommended dose of inorganic fertilizer along with biofertilizers and zinc (100% NPK + 50% $N_{organic}$ x biofertilizers +Zn) increased the grain yield by 38.7% over the application of 100% NPK only (Table 3). The higher microbial population under vermicompost, in addition to role of rhizobium, phosphobacteria and pseudomonas could be reason for the favorable effect of integrated application of vermicompost, mineral fertilizers,

Table 3 Effect of fertility levels, biofertilizers and micronutrient on nutrient uptake (kg/ha) of dwarf pea (pooled data of 2 years)

Treatment	Nitrogen		Phosphorus		Potash		Sulphur		Zinc*	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Fertility level										
Control	29.00	16.79	7.86	6.01	5.06	14.61	3.67	1.91	25.02	23.61
100% NPK	60.09	27.67	19.24	12.58	11.16	27.94	6.76	3.24	44.58	37.73
100% $N_{organic}$	47.48	23.38	14.55	9.57	8.30	22.41	5.52	2.73	38.28	33.66
100% NPK + 50% $N_{organic}$	72.53	31.85	22.83	14.16	13.38	31.72	7.87	3.73	51.11	42.00
100% $N_{organic}$ + 50% NPK	58.33	27.91	19.81	12.68	11.35	28.29	6.71	3.28	45.86	38.80
LSD (P=0.05)	1.69	0.96	0.501	0.229	0.42	0.93	0.186	0.078	1.28	0.79
Biofertilizers + Micronutrient										
Control	46.43	23.45	14.63	9.90	8.73	22.74	5.54	2.78	37.16	32.66
Biofertilizers	53.16	25.41	17.02	11.06	9.67	24.91	6.03	2.95	39.14	34.74
Zn @ 5 kg/ha	53.62	25.66	16.49	10.90	9.99	25.36	6.13	2.99	41.30	35.57
Biofertilizers + Zn	60.74	27.55	19.28	12.13	11.01	26.96	6.71	3.19	45.28	37.67
LSD (P=0.05)	1.06	0.42	0.335	0.152	0.16	0.64	0.083	0.051	0.59	0.453

* Uptake in g/ha.

Table 4 Interaction effect of treatments on dry matter/plant at maturity and yield of dwarf pea (Pooled data of 2 years)

Treatment	Control	100% NPK	100% $N_{organic}$	100% NPK + 50% $N_{organic}$	100% $N_{organic}$ + 50% NPK
Dry matter/plant (g)					
Control	23.75	29.02	24.95	33.56	29.92
Biofertilizers	25.10	31.32	28.46	34.80	31.42
Zn @ 5 kg/ha	24.97	29.82	26.37	33.76	30.57
Biofertilizers + Zn	26.81	32.29	28.78	37.36	34.79
					LSD (P= 0.05)
Two sub plot means at the same main plot treatment					0.98
Two main plot means at same or different sub plot treatments					0.32
Grain yield (kg/ha)					
Control	858	1350	1243	1596	1473
Biofertilizers	878	1484	1326	1705	1544
Zn @ 5 kg/ha	882	1584	1362	1694	1519
Biofertilizers + Zn	939	1622	1431	1873	1627
					LSD (P=0.05)
Two sub plot means at the same main plot treatment					39
Two main plot means at same or different sub plot treatments					46

biofertilizers and zinc in grain yield of the pea crop.

Nutrient uptake

Nitrogen, phosphorus, potassium, sulphur and zinc uptake by grain and straw was also relatively higher with 100% NPK + 50% $N_{organic}$ (Table 3). This was mainly due to higher biological production under these fertility levels (Prasad 1999). Moreover, soil organic matter is store house of nitrogen, phosphorus and sulphur and there by contributed significantly to supply of these nutrients to the crop plants. Apart from nutrient supply soil organic matter also helps in release of nutrients from soil. All these are conducive for availability of nutrients and there by more uptake by crop.

Nutrient uptake increased significantly with biofertilizer +Zn treatment (Table 3). The increased uptake with application of biofertilizers and zinc might be due to enhanced effect of rhizobium in nitrogen supply, Bacillus help in phosphorus solubilization and pseudomonas in facilitating the availability of nutrients for quite longer period (Srivastava and Ahlawat 1995).

An increased uptake of nitrogen, phosphorus, potassium, sulphur and zinc was observed in integrated application of nutrients (100% NPK + 50% $N_{organic+}$ combined with biofertilizers + Zn) as consequence of better nutritional environment offered through cumulative effect of organic, inorganic sources of nutrients and biofertilizers (Jat and Ahlawat 2004). The greater mineralization of N increased its availability by vermicompost with the presence of rhizobium and pseudomonas, which increases root enzymatic activities and produces greater root vigour and density due to nitrogen fixation might have enhanced N uptake. The increased uptake of P by phosphobacteria (Bacillus) could be attributed to its greater P- solubilization potentiality in the presence of organic matter.

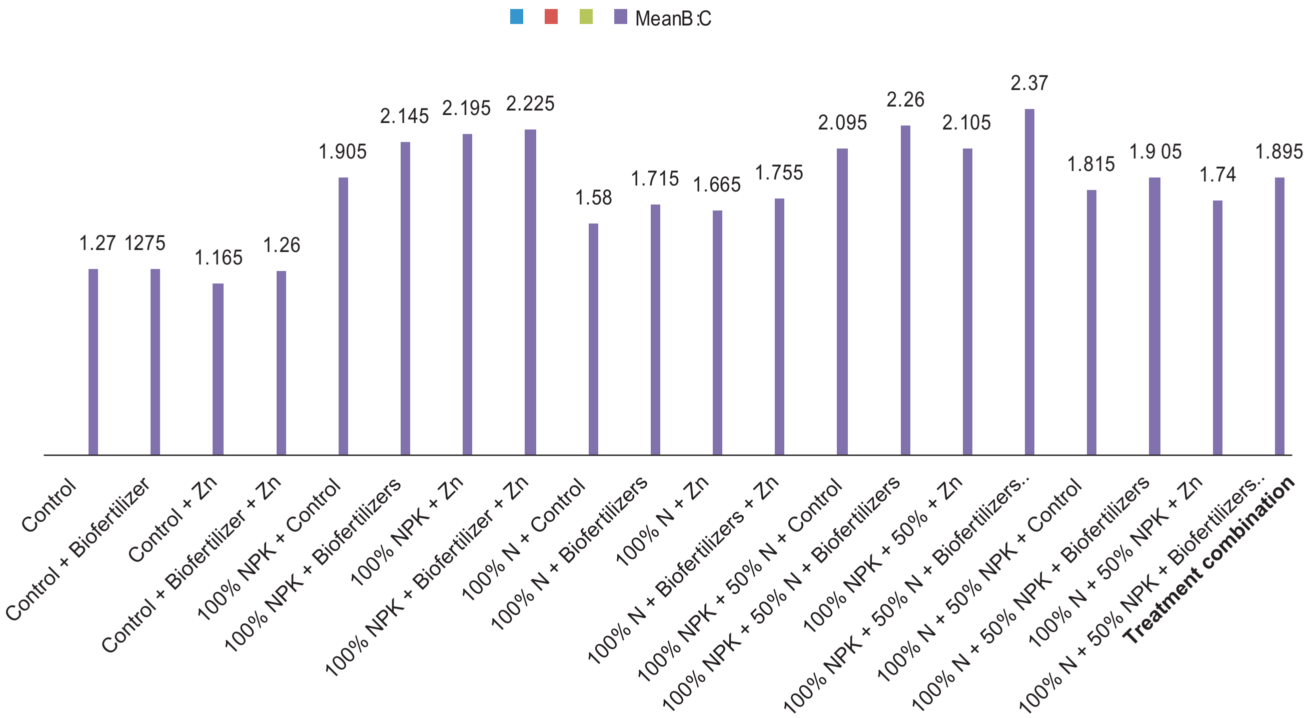

Fig 1 B: C ratio under different treatment combinations (Pooled data of two years)

Economics

The economics of fertility levels revealed that 100% NPK + 50% $N_{organic}$ level gave higher gross return, net return and B: C ratio than other fertility levels, during both the years (Table 2). Similarly, biofertilizers + micronutrient (Zinc) resulted in higher gross return and net return, and B: C ratio. The treatment of 100% NPK + 50% $N_{organic}$ combined with biofertilizers + Zn was economic optimum for the test crop (Fig 1).

On the basis of result drawn under the agro-climatic conditions of Varanasi, Eastern Uttar Pradesh it may be recommended that vermicompost @ 1.33 tonnes/ha should be superimposed to the recommended dose of fertilizer (40-17-16-20 kg NPKS/ha) along with 5 kg Zn/ha applied to the seeds inoculated with a biofertilizer consortia comprising of Rhizobium + PSB + PGPR for realizing economically optimum yield of field pea.

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