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Response of field pea [*Pisum sativum* var. *arvense* (L.)] to phosphorus and zinc fertilizers and their solubilizers on growth, yield and economics

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Abstract
A field experiment was conducted during *rabi* 2021-22 at Instructional farm, College of Agriculture, Kota to evaluate the response of field pea to P & Zn fertilizers and their solubilizers. Results revealed that maximum plant height, dry matter accumulation (g), number of branches/plant, number of pods/plant, number of seeds/pod, seed (2256 kg/ha), straw (4406 kg/ha), biological yield (6662 kg/ha), net returns (55864 ₹/ha) and B:C ratio (1.63) was obtained with application of 40 kg P_2O_5 + 25 kg $ZnSO_4$/ha and was found statistically at par to 30 kg P_2O_5 + 18.75 kg $ZnSO_4$/ha. Among P & Zn solubilizers application of biophos @ 5 ml/kg + biozinc @ 5 ml/kg resulted in maximum and significantly higher growth, yield attributes, seed (2129 kg/ha), straw (4187 kg/ha), biological yield (6316 kg/ha), net return (52059 ₹/ha) and B:C ratio (1.56) over rest of treatments. Thus all treatments significantly increased growth, yield and economics of field pea over control.

Keywords: Fertilizers, solubilizers, net return, B:C ratio

1. Introduction
Field pea [*Pisum sativum* var. *arvense* (L.)] is a principal winter season grain legume crop largely confined to cooler temperate zones. This crop serves as a source for food, feed and vegetable. It is the third most important pulse crop at global level and third most popular *rabi* pulse of India after chickpea and lentil. A proper and better nutrient management practice is important in field pea to achieve higher productivity and production. The favorable response to fertilizer application has been observed in field pea. However, continuous use of chemical fertilizers in the modern agricultural practices has led to an adverse effect on soil health and population of the native beneficial soil microorganisms. Biofertilizers are organic products of living cells of different types of microorganisms which could convert nutritionally important elements from unavailable to available form through biological processes (Itelima *et. al.*, 2018) [1]. Bio-fertilizers are natural fertilizers which contain micro-organism and helps in increasing the crop productivity by the processes of biological nitrogen fixation or solubilizing the insoluble phosphate or zinc and other growth regulators which are also required by plants for proper growth and development. In the context, nutrient management along with biofertilizers is emerging as an economically viable and ecologically sound means of fertilization (Kaur and Purewal, 2019) [2].

2. Material and Methods
A field experiment was conducted at Instructional Farm, College of Agriculture, Kota during *rabi* 2021-22 using field pea as test crop grown on clay loam soils having pH 7.45, organic carbon 0.43%, available soil N, P, K and Zn 241, 21.10, 328.4 kg/ha and 0.60 mg/kg, respectively. Sixteen treatments with four replications were used in split plot design. Main plot treatments *viz.* control, 20 kg P_2O_5 + 12.5 kg $ZnSO_4$/ha, 30 kg P_2O_5 + 18.75 kg $ZnSO_4$/ha and 40 kg P_2O_5 + 25 kg $ZnSO_4$/ha, while sub-plot treatments included control, biophos @ 5 ml/kg, biozinc @ 5 ml/kg and biophos @ 5 ml/kg + biozinc @ 5 ml/kg. One pre-sowing irrigation was given to the experimental field before field preparation. Field was prepared twice by disc harrowing with disc harrow followed by cultivator and planking. The experiment field was demarcated as per plan of layout with provision of irrigation channels. Phosphorus and zinc fertilizers were applied as basal dose as per treatments in the marked plots of the field experiment. 20 kg/ha nitrogen and 20 kg/ha potassium were applied through urea and MOP

respectively as basal dose uniformly to all the treatments. In total 20 kg/ha sulphur was applied *viz*. 5.63 kg/ha S through $ZnSO_4$ and remaining by sulphur dust. Biophos and biozinc were applied as seed inoculation as per treatments in the marked plots of the experiment. Seed of field pea was also inoculated with *Rhizobium leguminosarum*. Test crop variety Kota Matar-1 of field pea was used. Sowing was done by seed drill keeping inter row spacing of 30 cm and recommended seed rate of 80 kg/ha was used. One hand weeding was done manually at 30 DAS and application of pendimethalin 30 EC at 0.75 kg/ha as pre-emergence was used for controlling weeds. One irrigation was given to the crop at 75 DAS by check basin method. Plant height at 30, 60 DAS and at harvest was observed by measuring height of five tagged plant and plant height is indicated as average in cm. Dry matter accumulation of five plants was observed at harvest by oven drying them at 60 °C for 48 hours and by taking average it was expressed as g/plant. Number of branches/plant, pods/plant and seeds/pod were counted at harvested. 1000 seed weight was taken in g. Seed, straw and biological yield was observed in kg/ha and harvest index was computed. Net returns and B:C ratio were computed to evaluate the economics of the field experiment.

3. Results and Discussion

The application of P & Zn fertilizers and their solubilizers resulted in significant increase in plant height and dry matter accumulation (g/plant) over control. Maximum and significant increase in plant height at harvest was observed with application of 40 kg P_2O_5 + 25 kg $ZnSO_4$/ha (83.38) and Biophos @ 5 ml/kg + Biozinc @ 5 ml/kg (83.10). Application of 40 kg P_2O_5 + 25 kg $ZnSO_4$/ha (19.67) and Biophos @ 5 ml/kg + Biozinc @ 5 ml/kg (19.51) resulted in significantly higher dry matter accumulation (g/plant) in crop at harvest over rest of the treatments (Table 1). Data (Table 2) shows that application of P & Zn fertilizers and solubilizers significantly increased branches/plant, pods/plant and seeds/pod. Treatment 40 kg P_2O_5 + 25 kg $ZnSO_4$/ha and Biophos @ 5 ml/kg + Biozinc @ 5 ml/kg resulted in maximum branches/plant (2.40 and 2.08 respectively), pods/plant (16.61 and 16.02 respectively) and seeds/pod (6.19 and 5.92 respectively) over rest of the treatments. Results revealed that application of P & Zn fertilizers and solubilizers resulted in significantly higher seed, straw and biological yield over control. Maximum seed (2256 and 2129 kg/ha), straw (4406 and 4187 kg/ha) and biological (6662 and 6316 kg/ha) yield was recorded with application of 40 kg P_2O_5 + 25 kg $ZnSO_4$/ha and Biophos @ 5 ml/kg + Biozinc @ 5 ml/kg, respectively (Table 2). Treatment 40 kg P_2O_5 + 25 kg $ZnSO_4$/ha was statistically at par with 30 kg P_2O_5 + 18.75 kg $ZnSO_4$/ha. Increase in yield attributes and yield with increase in the level of phosphorus is due to one of the important function of phosphorus is to increase the number of pods in pulses. The increase in crop growth parameters might be due to the higher phosphatases activity in the rhizosphere and production of organic acids by PSB and ZSB might have solubilized the insoluble and native phosphate and zinc. PSB and ZSB strains released greater amounts of available phosphorus and zinc from the soil, which enabled the crop plants to absorb more P and Zn resulting in improved growth parameters. This resulted in increased P & Zn uptake by the crop. Phosphorus plays an important role in enzymatic reaction and metabolism which ultimately increase the total and effective pods. While on the other hand, zinc is the constituent of carbonic anhydrase and is involved in many enzymatic activities. It is also important for the synthesis of the growth hormone indole acetic acid (IAA), thus tends to increase the yield attributes and yield. This might have increased number of pods/plant, seeds/pod, seed, straw and biological yield. These results confirm with the earlier finding of Venkatrao *et al*. (2017) [8] and Kuniya *et al.* (2018) [4]. The beneficial effect of phosphorus solubilizing bacteria and zinc solubilizing bacteria on yield attributing characteristics have also been recorded by Kothyari *et al* (2017) [3] and Raut (2018) [5] respectively. Test weight was found non-significant with respect to various P & Zn fertilizers and their solubilizers levels. The economical perusal of data (Table 2) showed that among P & Zn fertilizer treatments 40 kg P_2O_5 + 25 kg $ZnSO_4$/ha resulted in highest and significant net return (55864 ₹/ha) and B:C ratio (1.63), while among P & Zn solubilizers maximum net return (52059 ₹/ha) and B:C ratio (1.56) was obtained with Biophos @ 5 ml/kg + Biozinc @ 5 ml/kg. Similar findings were also reported by Serawat *et al.* (2018) [6] and Singh *et al.* (2018) [7].

Table 1: Effect of P & Zn fertilizers and their solubilizers on growth and yield attributes (at harvest) of field pea

Treatments	Plant height (cm)	Dry matter accumulation (g/plant)	Branches/plant	Pods/plant	Seeds/pod	Test weight (g)
P & Zn fertilizers						
Control	68.92	15.92	1.04	9.98	4.53	176.70
20 kg P_2O_5/ha + 12.50 kg $ZnSO_4$/ha	75.22	17.88	1.70	12.79	5.23	179.82
30 kg P_2O_5/ha + 18.75 kg $ZnSO_4$/ha	80.75	19.32	2.36	15.66	5.84	184.10
40 kg P_2O_5/ha + 25 kg $ZnSO_4$/ha	83.38	19.67	2.40	16.61	6.19	189.52
S.Em ±	1.48	0.33	0.05	0.39	0.12	3.72
CD at 5%	4.73	1.06	0.17	1.23	0.37	NS
P & Zn solubilizers (seed inoculation)						
Control	71.78	16.98	1.67	11.73	4.98	177.29
Biophos @ 5 ml/kg	77.19	18.27	1.91	13.80	5.49	184.49
Biozinc @ 5 ml/kg	76.20	18.04	1.84	13.50	5.40	180.61
Biophos @ 5 ml/kg + biozinc @ 5 ml/kg	83.10	19.51	2.08	16.02	5.92	187.74
S.Em ±	1.18	0.32	0.04	0.22	0.12	3.14
CD at 5%	3.40	0.92	0.12	0.63	0.33	NS

Table 2: Effect of P & Zn fertilizers and solubilizers on seed, straw, biological yield, harvest index, net return and B:C ratio of field pea

Treatments	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)	Net return (₹/ha)	B:C ratio
P & Zn fertilizers						
Control	1323	2780	4104	32.28	21823	0.70
20 kg P_2O_5/ha + 12.50 kg $ZnSO_4$/ha	1758	3514	5272	33.33	37739	1.16
30 kg P_2O_5/ha + 18.75 kg $ZnSO_4$/ha	2187	4262	6449	33.91	53840	1.61
40 kg P_2O_5/ha + 25 kg $ZnSO_4$/ha	2256	4406	6662	33.88	55864	1.63
S.Em ±	42.4	83.2	108.2	0.52	1461.64	0.04
CD at 5%	135.7	266.0	346.1	NS	4676.05	0.14
P & Zn solubilizers (seed inoculation)						
Control	1657	3334	4992	33.06	33528	1.01
Biophos @ 5 ml/kg	1892	3769	5661	33.39	42789	1.29
Biozinc @ 5 ml/kg	1846	3673	5518	33.32	40890	1.23
Biophos @ 5 ml/kg + biozinc @ 5 ml/kg	2129	4187	6316	33.64	52059	1.56
S.Em ±	33.1	66.7	92.5	0.33	615.88	0.02
CD at 5%	94.8	191.3	265.2	NS	1766.43	0.05

4. Conclusion

Therefore, it can be concluded from the following experiment that compared to control various P & Zn fertilizer levels and their solubilizers resulted in significant increase in the growth parameters, yield attributes and yields of field pea crop and ultimately resulted in higher net return and B:C ratio. 40 kg P_2O_5 + 25 kg $ZnSO_4$/ha and Biophos @ 5 ml/kg + Biozinc @ 5 ml/kg recorded significantly higher growth, yields, net return and B:C ratio of field pea crop over rest of the treatments.

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