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Effect of phosphorus, biofertilizers and zinc application on growth and quality-attributing characteristics of garden pea (*Pisum sativum*)

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Abstract

A field experiment was conducted during November 2021 to February 2022 and November 2022 to February 2023, comprising 32 treatment combinations replicated three times, at Rajasthan Agricultural Research Institute, Durgapura, Jaipur, Rajasthan. It followed a split plot design with main plots assigned to four phosphorus levels (P_2O_5 @ 0, 20, 40 and 60 kg/ha) and two biofertilizer conditions (without inoculation and with inoculation of Rhizobium + PSB). Sub-plots were dedicated to four zinc levels (control, 2.5, 5.0 and 7.5 kg Zn/ha). There was significantly maximum plant height (65.17, 63.47 and 64.32 cm), number of primary branches (2.57, 2.45 and 2.51), minimum days to 50 % flowering (41.90, 41.51 and 41.70), nitrogen content (3.74, 3.52 and 3.63 %) and protein content (23.40, 21.97 and 22.69 %) were recorded with application up to P_2O_5 40 kg/ha, In biofertilizer, maximum plant height (64.42, 63.03 and 63.72 cm), number of primary branches (2.61, 2.52 and 2.57), minimum days to 50 % flowering (42.30, 42.82 and 42.56) nitrogen content (3.66, 3.39 and 3.53 %) and protein content (22.90, 21.20 and 22.05 %) were recorded with inoculation (Rhizobium+PSB) and In zinc treatments the maximum plant height (65.05, 64.06 and 64.56 cm) number of primary branches (2.58, 2.50 and 2.54) minimum days to 50 % flowering (42.09, 41.25 and 41.67) nitrogen content (3.57, 3.39 and 3.48 %) and protein content (22.31, 21.19 and 21.75 %) were recorded with 5.0 kg Zn/ha, respectively.

Key Words : Biofertilizer, Protein, Phosphorus, Zinc levels, Growth Flowering

Garden pea (*Pisum sativum* var. *hortense* L.), Leguminosae family, is highly valued for its protein content and its supply of various minerals and vitamins. (Gopalan *et al.*, 2007). Adequate phosphorus application improved growth, yield, quality, and nodule formation in legumes. More than 30% of the world's arable land used for pea production is limited by phosphorus availability (Tesfaye *et al.*, 2007). Phosphorus is especially critical for legumes in nutrient-poor environments due to its significant role in nitrogen fixation process (Tsvetkova and Georgiev, 2007). Sharma and Chandra (2004), reported that supplying plants with phosphorus is the development of deeper and more extensive root systems. Similarly use of biofertilizers plays an important role in improving fertilizers use efficiency. These days biofertilizers have emerged as an important component to improve an overall crop performance (Yadav and Kavita, 2016). The most crucial micronutrient zinc is required for cell division and the metabolism of nitrogen and carbohydrates and the relationship between water and plant growth (Brady, 1990). Zinc is necessary for metabolism and helps to create nodules that fix nitrogen (Patel *et al.*, 2011). Zinc is requires in auxin metabolism like tryptophan synthesis and tryptamine metabolism (Kuldeep *et al.,* 2018). Phosphorus and zinc interaction affects the availability and utilization of both nutrients and dynamics are impacted by an imbalance in soil matrix (Singh *et al.,* 2017).

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MATERIALS AND METHODS

The experiment was conducted at Rajasthan Agricultural Research Institute, Durgapura, Jaipur, during November 2021 to February 2022 and November 2022 to February 2023. There was 32 treatment combinations replicated three times, following a split plot design with the main plots assigned to four phosphorus levels (P_2O_5 @ 0, 20, 40 and 60 kg/ha) and two biofertilizer conditions (without inoculation and with inoculation of Rhizobium + PSB). Sub-plots were dedicated to four zinc levels (control, 2.5, 5.0 and 7.5 kg Zn/ha).

The pea variety Azad P-3 was sown on November, 2021 and November, 2022, maintaining a row-to-row spacing of 30 cm and a plant-to-plant spacing of 10 cm. The geographical location of this place is 75^0 47' east (longitude), $26^0$51' North (latitude) and 393 m above MSL. The experimental field with loamy sand texture, had slightly alkaline, and low levels of organic carbon. The soil was deficient in available nitrogen but had medium levels of available phosphorus and potassium. The pH was 8.2-8.4 with electrical conductivity of 0.19-0.25 dS/m throughout the growing period, the recommended cultural practices were followed. The soil analysis was performed as per AOAC (2005) guidelines. Phosphorus and zinc were applied at sowing through diammonium phosphate (DAP) and zinc sulphate (21%), respectively.

Nitrogen was applied at sowing in the form of urea and a biofertilizer was introduced through seed inoculation.

The plant height was studied 60 days after sowing (DAS) by meter scale, number of primary branches 50 DAS, and days to 50 % flowering. The nitrogen (%), protein (%) and total soluble solids (TSS), which were used to judge the quality of peas. Protein content was estimated by multiplying the nitrogen content (determined by digesting samples with concentrated H_2SO_4 and using a digestion mixture, by colorimetric method of Snell and Snell, 1949) by a factor of 6.25. TSS content was determined using a Zeiss Pocket refractometer (0 to 32.0 Brix), where a drop of extracted juice from fresh pea grains was placed on the prism and the reading was taken (AOAC, 1975). The data were statistically analysed as per Panse and Sukhatme (1985). The critical differences were calculated to assess the significance of treatment means wherever 'F' test was found significant at a 5 % level of probability. Mention the parameters used for data recordings to decide performance of the plants.All the standard cultural practices were followed during the crop growth.

RESULTS AND DISCUSSION

Growth attributes

The plant height was significantly influenced by the application of phosphorus biofertilizer and zinc fertilizers 60 days after sowing. The plant height 60 DAS increased notably with the application of phosphorus up to 40 kg/ha compared to the control and 20 kg/ha application. This increase was also statistically at par to P_2O_5 @ 60 kg/ha during 2021-22 and 2022-23, pooled basis. The use of phosphorus can enhance plant development due to its role in synthesis of proteins, vitamins and chlorophyll. These findings are consistent with those of Kumar and Puri (2002), Kumar *et al.* (2009), and Sonet *et al.* (2020). In biofertilizer, highest plant height was recorded with B_1 (Rhizobium + PSB) treatment (64.42, 63.03 and 63.72 cm, respectively.) while lowest plant height was found in B_0 (without inoculation) treatment (56.86, 55.66 and 56.26 cm, respectively.). Rhizobium increased fixation of atmospheric nitrogen in the soil, making it available for plant use and promoting vigorous plant growth. Similar results were also reported by Sibbal *et al.* (2002) and Tyagi *et al.* (2003). The PSB facilitated increased nutrient absorption, elevated photosynthesis and enhanced assimilate production (Table 1).

Applying 2.5 kg Zn/ha resulted in a significant increase in plant height compared to plants that did not receive any zinc treatment. Plant height increased further with a treatment of 5 kg Zn/ha compared to 2.5 kg Zn/ha. However, increasing zinc application rate from 5 kg Zn/ha to 7.5 kg Zn/ha led to a decrease in plant height, likely due to antagonistic effect of phosphorus at higher zinc levels. Thus, application of 5 kg Zn/ha resulted in tallest plants (Table 1). This effect can be attributed to zinc's role as a catalyst or stimulant in numerous physiological and metabolic processes, as well as its enzyme-activating properties, which enhanced plant growth and development. Comparable findings were reported by Ullah *et al.* (2018).

The number of primary branches/plant (2.57, 2.45 and 2.51, respectively.) was observed up to the application of P_2O_5 @ 40 kg/ha (P_2). This level of phosphorus application was significantly higher than the control (P_0) (2.24, 2.12 and 2.18, respectively) and the application of P_2O_5 @ 20 kg/ha (P_1) (2.32, 2.24 and 2.28, respectively.). Moreover, it remained at par with the application of P_2O_5 @ 60 kg/ha (P_3). Kumar *et al.* (2009) and Sonet *et al.* (2020) reported similar results. In biofertilizer, highest number of branches/plant (2.61, 2.52 and 2.57, respectively.) was recorded with B_1 (Rhizobium + PSB) treatment while lowest number of branches/plant (2.28, 2.16 and 2.22, respectively.) was found in B_0 (without inoculation) treatment during 2021-22, 2022-23, polled basis.

Similar results were reported by Sibbal *et al.* (2002), Tyagi *et al.* (2003) and Gaind and Guar (1991). The number of primary branches/plant at 50 days after sowing (DAS) increased significantly with zinc application. The highest number of primary branches/plant was observed with the 7.5 kg Zn/ha treatment, followed by 5 kg Zn/ha treatment and the control. However, higher levels of zinc (5 and 7.5 kg Zn/ha) were statistically similar in terms of number of primary branches/plant. Similar results were reported by Ullah *et al.* (2018).

The number of days to 50 % flowering varied with different phosphorus levels. The shortest time to 50 % flowering was observed (41.21, 40.12 and 40.66) with application of P_2O_5 60 kg/ha which was significantly shorter than the control and P_2O_5 20 kg/ha treatments. However, it was statistically at par to the P_2O_5 40 kg/ha (41.90, 41.51 and 41.70) treatment during 2021-22 and 2022-23 seasons a pooled basis. The reduction in number of days to 50 % flowering may be attributed to the readily available applied phosphorus, promoting enhanced root and shoot growth. This, in turn, translated into improved vegetative growth and earlier flowering, aligning with findings from Magani and Kuchinda (2009). In biofertilizer, the shortest time to 50 % flowering was recorded with B_1 treatment (42.30, 42.82 and 42.56 days), while longest time was observed with B_0 treatment (45.27, 43.55 and 44.41 days) during 2021-22, 2022-23 seasons, pooled mean, respectively. The application of 5.0 kg Zn/ha resulted in shortest time to 50% flowering (42.09, 41.25

Table 1. Effect 0f fertilizer on plant height, number of primary branches and day to 50% flowering

Treatment	Plant height (cm)			No. of primary branches			Days to 50 % flowering		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Phosphorus									
P_0-Control	51.94	50.87	51.41	2.24	2.12	2.18	46.64	46.10	46.37
P_1-20 kg P_2O_5/ha	59.06	57.80	58.43	2.32	2.24	2.28	45.40	45.01	45.20
P_2-40 kg P_2O_5/ha	65.17	63.47	64.32	2.57	2.45	2.51	41.90	41.51	41.70
P_3-60 kg P_2O_5/ha	66.38	65.23	65.81	2.64	2.56	2.60	41.21	40.12	40.66
SEm±	1.37	1.29	0.94	0.06	0.05	0.04	0.98	0.92	0.67
CD (P=0.05)	4.09	3.83	2.73	0.18	0.16	0.12	2.91	2.75	1.95
Biofertilizer									
B_0-Without inoculation	56.86	55.66	56.26	2.28	2.16	2.22	45.27	43.55	44.41
B_1-With inocultion (Rhizobium+PSB*)	64.42	63.03	63.72	2.61	2.52	2.57	42.30	42.82	42.56
SEm±	0.97	0.91	0.67	0.04	0.04	0.03	0.69	0.65	0.48
CD (P=0.05)	2.89	2.71	1.93	0.13	0.11	0.08	2.06	1.94	1.38
Zinc									
Z_0-Control	55.81	53.65	54.73	2.29	2.17	2.23	44.69	44.16	44.43
Z_1-2.5 Kg Zn/ha	57.73	56.35	57.04	2.40	2.25	2.33	45.38	45.10	45.24
Z_2-5.0 Kg Zn/ha	65.05	64.06	64.56	2.51	2.44	2.48	42.09	41.25	41.67
Z_3-7.5 Kg Zn/ha	63.97	63.31	63.64	2.58	2.50	2.54	42.98	42.23	42.61
SEm±	0.74	0.72	0.52	0.05	0.05	0.03	0.72	0.70	0.50
CD (P=0.05)	2.10	2.05	1.45	0.15	0.13	0.10	2.04	1.97	1.41

and 41.67) outperforming the control and 2.5 kg Zn/ha treatments. However, this result was statistically at par to the 7.5 kg Zn/ha (42.98, 42.23 and 42.61) treatment across both individual years and on a pooled basis. These consequences are in agreement with Neenu *et al.,* (2014) who informed delay in flowering and physiological maturity in control plots.

Quality attributes

This increase was found to be statistically significant compared to the preceding levels of application, with highest nitrogen content (3.83, 3.64 and 3.73 %, respectively) observed at P_2O_5 @ 60 kg/ha (P_3) consistently during the 2021-22, 2022-23 and on a pooled basis. In biofertilizer highest nitrogen content in seeds was recorded as 3.66, 3.39 and 3.53 % was observed under treatment B_1 (Rhizobium + PSB). In contrast, lowest nitrogen content, measured at 3.05, 2.97 and 3.01 % was found in treatment B_0 (without inoculation) during 2021-22, 2022-23 pooled analysis, respectively. In zinc treatments highest increase in nitrogen content (3.57, 3.39 and 3.48 % during 2021-22 and 2022-23, respectively) observed with application of 5.0 kg Zn/ha, followed by 7.5 kg Zn/ha (3.51, 3.32 and 3.42 % during 2021-22 and 2022-23, respectively.). The application of phosphorus likely improved nutritional environment in rhizosphere and plant system, resulting in an enhanced uptake and translocation of nutrients, particularly nitrogen and phosphorus (Table 2).

The higher levels of phosphorus led to a significant increase in protein content, peaking at P_2O_5 @ 40 kg/ha. The application of P_2O_5 @ 40 kg/ha was statistically equivalent to P_2O_5 @ 60 kg/ha during 2021-22, 2022-23 and in the pooled analysis. The highest protein content (22.90, 21.20 and 22.05 %, respectively) was observed under treatment B_1 (Rhizobium + PSB) whereas lowest protein content (19.03, 18.58 and 18.81 %, respectively) was recorded in treatment B_0 (without inoculation) during 2021-22, 2022-23 and in pooled analysis. The protein content (21.94, 20.75 and 21.34 per cent, respectively) achieved with application of 5.0 kg Zn/ha (Z_2) was notably higher than the control and 2.5 kg Zn/ha (Z_1) but statistically on a par (21.94, 20.75 and 21.34 %, respectively) to that of 7.5 kg Zn/ha (Z_3) during both years and on a pooled basis. Similar findings were reported by Ahmed *et al.* (2003), Vikrant *et al.* (2005) and Tripathy *et al.*

Table 2. Effect of phosphorus, biofertilizers and zinc on nitrogen and protein content in garden pea seed (%)

Treatment	Nitrogen content (%)			Protein content (%)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Phosphorus						
P_0-Control	2.72	2.59	2.66	16.97	16.21	16.59
P_1-20 kg P_2O_5/ha	3.13	2.98	3.06	19.53	18.65	19.09
P_2-40 kg P_2O_5/ha	3.74	3.52	3.63	23.40	21.97	22.69
P_3-60 kg P_2O_5/ha	3.83	3.64	3.73	23.96	22.72	23.34
SEm±	0.05	0.05	0.04	0.38	0.37	0.27
CD (P=0.05)	0.16	0.15	0.11	1.14	1.10	0.77
Biofertilizer						
B_0-Without inoculation	3.05	2.97	3.01	19.03	18.58	18.81
B_1-With inocultion (Rhizobium+PSB*)	3.66	3.39	3.53	22.90	21.20	22.05
SEm±	0.04	0.04	0.03	0.27	0.26	0.19
CD (P=0.05)	0.11	0.10	0.07	0.81	0.78	0.55
Zinc						
Z_0-Control	3.04	2.87	2.96	19.00	17.94	18.47
Z_1-2.5 Kg Zn/ha	3.30	3.15	3.23	20.63	19.69	20.16
Z_2-5.0 Kg Zn/ha	3.57	3.39	3.48	22.31	21.19	21.75
Z_3-7.5 Kg Zn/ha	3.51	3.32	3.42	21.94	20.75	21.34
SEm±	0.04	0.04	0.03	0.22	0.21	0.15
CD (P=0.05)	0.11	0.11	0.08	0.63	0.58	0.42

(2020). Singh and Singh (2012) reported that application of increasing doses of Zn resulted in a significant increase in protein content of chickpea over control which might be attributed to its involvement in nitrogen metabolism of plants.

CONCLUSION

Thus applying 40 kg/ha of phosphorus (P_2O_5) and 5.0 kg/ha of zinc significantly enhanced plant height, number of branches/plant, reduced days to 50 % flowering, and enhanced nitrogen and protein quality. Therefore, it can be concluded that the optimal treatment for improving the growth and quality parameters of garden pea crops is the application of P_2O_5 40 kg/ha, biofertilizer (inoculated with Rhizobium and PSB) and 5.0 kg/ha of zinc.

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