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Effect of phosphorus and zinc on nutrient content and uptake in chickpea (*Cicer aeritinum* L.)

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Abstract
A field experiment was conducted at Research farm, Vivekananda Global University, Jaipur (Rajasthan) during *Rabi season*¸ 2023 on loamy sand soil. The experiment comprises four levels of phosphorous (Control, 20, 40 and 60 kg ha^{-1}) and three treatments of zinc application (2.5, 5.0 and 7.5 kg ha^{-1}) thereby making 12 treatment combinations was laid out in factorial randomized block design and replicated thrice. Results showed that application of 60 kg phosphorous ha^{-1} and 7.5 kg Zn ha^{-1} significantly increased the content of P and Zn in seed and stover and their uptake.

Keywords: Phosphorus levels, zinc application, loamy sand soil

Introduction

Chickpea (*Cicer arietinum* L.) is one of the major Rabi pulse crop which has high digestible dietary protein (17-21 percent). Chickpea is also rich in calcium, iron, niacin, vitamin C and vitamin B. Its leaves contain malic acid which is very useful for stomach ailments and blood purification. Chickpea can be used for various kinds of food preparation which not only increase the taste but also the quality of food. Its feed and straw are highly rich in nutrients and are mostly used as productive ration. Chickpea plays a significant role in improving soil fertility by fixing the atmospheric nitrogen. Chickpea meets 80 percent of its nitrogen (N) requirement from symbiotic nitrogen fixation and can fix up to 140 kg N ha^{-1}. Its leaves have substantial amount of nitrogen for subsequent crops and adds plenty of organic matter to maintain and improve soil health and fertility and thus play a vital role in sustainable agriculture. In Rajasthan, chickpea crop grown in 2.05 million ha^{-1} hectares area and production is 2.66 million tones with a productivity of 1293 kg ha^{-1}. The productivity of chickpea in Rajasthan is deplorable low as compared to Madhya Pradesh. Chickpea being a high protein and energy crop and its productivity is often limited by the low availability of essential nutrients or imbalanced nutrition farming one of the important constraints to chickpea productivity in India. Hence, a balanced nutrients application is must to harness the productivity of the crops.

Phosphorus fertilization to legumes is more important than that of nitrogen because later is being fixed by symbiosis with Rhizobium bacteria. Phosphorus plays a significant role in the formation of energy rich phosphate bond like ADP and ATP, nuclear protein and phospholipids. It is also essential for growth of root system. Phosphorus fertilization also improves the quality of seeds and serves the dual purpose of increasing yield of main crop as well as succeeding crop. Phosphorus is deficient in most of soils of Rajasthan, particularly in light textured soils where most of the mothbean is grown and amongst the various factors limiting the plant growth, phosphorus deficiency has been recognized as major bottleneck in realizing the potential yield of mothbean (Patel *et al*., 2004) [6].

Zinc deficiency prevalent worldwide and more than 50 percent of world soils, deficient in zinc. Zinc is an essential micronutrient for plant and now it is fifth risks leading factor that limiting the crop growth and yield. Soil and foliar spray of zinc indicated a wide spread deficiency of zinc particularly in light textured soils, low in organic carbon and alkaline in reaction. Zinc is essential for several enzyme systems that regulate various metabolic activities in plants. Zinc plays an important role in the auxin metabolism like the tryptophan synthetase, tryptamine metabolism and hence, it affects the growth of plants. In many parts of the country, zinc as a plant nutrient now stands third in importance *i.e*. next to nitrogen and phosphorus. Zinc plays an outstanding role in systematic of chlorophyll, proteins and also regulators water absorption. It is also vital for the oxidation processes in plant cells and helps in the transformation of carbohydrates and regulates sugar in plant its deficiency retards photosynthesis and nitrogen metabolism. Protein synthesis in pulses is adversely affected due to zinc deficiency as zinc is involved in the maintenance of RNA levels in the plant. Further zinc plays a key role in flowering and seed setting in crops (Zaidi *et al*., 1997) [11].

Methodology

Nutrient content, uptake and quality attributes

Estimation of nitrogen content

Nitrogen was estimated by micro kjeldahl distillation method.

Digestion

Take 0.5 g seed and straw sample separately and digested with H_2SO_4 and H_2O_2 to obtain clear extract and make up the volume of 100 ml by adding distilled water.

Distillation

10 ml of the extract was taken and transferred in to micro Kjeldhal distillation tube while in conical flask, 25 ml of 4% boric acid solution to which the condenser outlet from where ammonia came was placed. After adding the aliquot, the funnel of the apparatus was washed with 2-3 ml of deionized water and 100 ml of 40% NaOH solution was added. Subsequently 100 ml aliquot was distilled to the flask containing 25 ml of boric acid. After distillation the distillate was titrated against 0.01 N H_2SO_4. Blank was also run without sample.

$$\text{Nitrogen (\%)} = \frac{(X\text{-}Y) \times 0.00028 \times 100}{\text{Weight of plant material}}$$

Weight of sample (g)

X = Amount of 0.01 N H_2So_4 used for neutralization of NH_3 in boric acid (ml)

Y = Amount of 0.01 N H_2So_4 used for blank reading (ml)

Estimation of phosphorus content

Phosphorus determination in the plant samples was done by Vanado-Molybdo-phosphoric acid, yellow colour method (Jackson, 1967) [4].

Digestion

Digestion of seed and straw sample was done by tri-acid mixture (minimum AR grade concentrate HNO_3, $HClO_4$ and H_2SO_4 in 9:4:1 ratio).

Development of colour

5 ml of aliquot from the colour less filtrate was taken in a 50 ml volumetric flask for determination, then 10 ml of ammonium molybdate-ammonium meta vanadate solution was added into each volumetric flask to develop yellow colour. The neck of the flask was washed with distilled water and diluted up to the required mark. The colour intensity was measured by spectrophotometer at 420 nm wavelength after mixing thoroughly and after setting the instruments to zero with blank as described (Jackson, 1967) [4].

$$\text{Phosphorous content (\%)} = \frac{A}{100\ V}$$

Where,

A = reading of sample on spectrophotometer

V = volume of aliquot taken (ml)

Estimation of Zinc concentration

Zinc: Zinc was estimated using wet digestion of plant with diacid (HNO_3 and $HCLO_4$ in ratio of 9:4) and was analysed with the help of AAS.

Nutrient uptake

The uptake of individual nutrient as nitrogen, phosphorus and potassium at harvest were estimated by using the following formula:

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient content in grain (\%)} \times \text{Grain yield (kg ha}^{-1}) + \text{Nutrient content in straw (\%)} \times \text{Stover yield (kg ha}^{-1})}{100}$$

Then nutrient uptake by crop was calculated by multiplying the percent nutrient content in seed and straw with their respective dry matter yield and expressed as kg/ha.

Statistical analysis

In order to test the significance of variation in experimental data obtained for various treatment effects, the data were statistically analyzed as described by Fisher (1950). The critical differences were calculated to assess the significance of treatment mean wherever the F' test was found significant at 5 percent level of probability. To elucidate the nature and magnitude of treatment effects, summary tables along with SEm± and CD (P=0.05) were prepared and are given in the text of the chapter. Experimental results and their analyses of variance are given in Appendices at the end.

The following formula were used for standard error, critical difference and coefficient of variance estimations.

SEm± = $\sqrt{EMS/r}$

C.D. = SEm± × $\sqrt{2}$ × t%

$$\text{C.V. (\%)} = \frac{\sqrt{EMS}}{\text{Grand mean}} \times 100$$

Where,

r = Number of replications

t = Number of treatments

D.F. = Degree of freedom

SEm± = Standard error of mean

EMS = Error mean squares

C.D. = Critical difference

C.V. = Coefficient of variance

Results and Discussion

A significant increase in phosphorous content in seed and stover was observed due to application of phosphorus up to 60 kg ha^{-1}. As stated earlier in preceding chapter that application of phosphorus might have improved the nutritional environment in rhizosphere as well as in plant system, leading to increased uptake and translocation of nutrients especially of phosphorous in reproductive structures which led to higher content and uptake. Further, the significant and positive correlation of seed yield with nutrients uptake also evidenced for higher content of nutrients. Since, uptake of N, P and K is the function of seed and stover yield and their content, the significant increase in content of these nutrients coupled with increased seed and stover yield enhanced the total uptake of N, P and K. Protein content is essentially the manifestation of N content in seed. Hence, increased N content might have increased the protein content. These results are in close conformity with the findings of Erman *et al*., (2009) [2] and Jain *et al*. (2007) [5] in greemgram.

Table 1: Effect of phosphorous and zinc on P content and uptake in chickpea seed and stover

Treatments	P content in seed (%)	P content in stover (%)	P uptake in seed (kg ha^{-1})	P uptake in stover (kg ha^{-1})
Phosphorous (kg ha^{-1})				
Control	0.474	0.171	7.09	4.16
20	0.480	0.185	8.39	5.16
40	0.483	0.188	9.25	5.62
60	0.486	0.190	9.82	5.93
SEm+	0.001	0.001	0.28	0.14
CD (P=0.05)	0.004	0.004	0.83	0.42
Zinc (kg ha^{-1})				
2.5	0.477	0.177	7.54	4.53
5.0	0.479	0.181	8.16	4.95
7.5	0.482	0.187	9.03	5.46
SEm+	0.001	0.001	0.24	0.12
CD (P=0.05)	0.004	0.003	0.72	0.36

Zinc fertilization as soil application (7.5 kg /ha) increased phosphorous and zinc content and their uptake by crop (Table 2). Significant increase in these characters with the application of zinc might be due to the fact that zinc is an essential component of enzyme responsible for assimilation of nitrogen. It also helps in the formation of chlorophyll and plays an important role in nitrogen metabolism. Similar findings were also reported by Sharma and Jain (2004) [8] in clusterbean, Choudhary (2006) [1] in clusterbean. The protein content in seed increased with the application of soil applied zinc 7.5 kg/ha (Table 2). It might be due to increased availability of zinc which improved the content and uptake of nitrogen in plants, resulting in higher protein concentration. These results are in line with those of Sunder *et al*. (2003) [9] in clusterbean, Jain (2007) [5] in mothbean and Sammauria (2007) [7] in fenugreek.

Table 2: Effect of phosphorous and zinc on Zn content and uptake in chickpea seed and stover

Treatments	Zn content in seed (ppm)	Zn content in stover (ppm)	Zn uptake in seed (g kg^{-1})	Zn uptake in stover (g kg^{-1})
Phosphorous (kg ha^{-1})				
Control	27.74	19.74	36.67	42.06
20	28.64	20.64	44.69	50.92
40	30.68	22.68	53.21	60.16
60	31.35	23.35	57.39	65.07
SEm+	0.74	0.74	2.28	2.60
CD (P=0.05)	2.16	2.14	6.68	7.63
Zinc (kg ha^{-1})				
2.5	27.16	19.16	37.91	42.83
5.0	29.66	21.66	45.23	52.26
7.5	30.25	22.25	51.42	58.05
SEm+	0.64	0.64	1.97	2.25
CD (P=0.05)	1.87	1.81	5.78	6.60

Conclusion

The study demonstrated that the application of 60 kg phosphorus ha^{-1} and 7.5 kg Zn ha^{-1} significantly enhanced the phosphorus and zinc content in chickpea seeds and stover, leading to higher nutrient uptake. Phosphorus improved the nutrient availability and translocation in the plant system, contributing to better nutrient uptake, while zinc, being a critical component of enzymatic processes, increased nitrogen metabolism, protein synthesis, and overall nutrient assimilation. These findings emphasize the importance of balanced phosphorus and zinc fertilization for optimizing chickpea nutrient content and improving crop productivity in loamy sand soils.

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