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# Effect of phosphorus levels on zinc, iron, copper and manganese removal by chickpea genotypes in Typic Ustochrept

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## ABSTRACT

**A pot trial was conducted to examine Zn, Fe, Cu and Mn uptake of 20 chickpea genotypes at different P levels on multi-nutrient deficient sandy loam soil. Increasing P up to 13.5 mg/kg soil increased Zn concentration while further increase led to decrease. Genotypes, KPG 59, BG 256, RSG 888 and JG 315 showed Zn concentration below the critical limit of 20 mg Zn per g DW at high level of P application (27.0 mg/kg). Fe concentration in plants decreased with increasing P levels. Up to 13.5 mg/kg P application, Cu concentration increased and thereafter it decreased. Mn concentration gradually increased with increasing P levels. Among genotypes, HK 94-134 maintained higher Zn concentration, Radhey in case of Fe, GCP 101 in Cu and RSG 888 in Mn at high level of P application (27.0 mg/kg).**

**Key words:** Chickpea genotypes, Interaction, Micronutrients, Phosphorus

Chickpea (*Cicer arietinum* L.) cultivation in India is largely concentrated on marginal and sub-marginal lands which are deficient for several micro-nutrients (Srinivasrao *et al.* 2002). In these regions, deficiency of P and Zn are more predominant. Among 3.6 million soil samples analyzed in India, 42% samples were found low, 38% medium and 20% samples high in P (Motsara 2002). Therefore, P deficiency is the key constraint in improving chickpea grain yield and management of P becomes an obvious strategy to increase the productivity. Among micronutrients, Zn deficiency is extensive in Indian soils ranging from 24 to 78% followed by Fe (2 - 39%), Mn (2-19%) and Cu (1-5%) deficiency (Takkar 1996). Phosphorus recommendations are available for most of the regions in India though its field adoption is variable (Srinivasrao *et al.* 2003). Some regions receive adequate P application (80 kg $P_2O_5$/ha) whereas others receive either sub-optimal P or no P application. High levels of available P in soil or high application rates of phosphate were reported to induce zinc deficiency in plants grown on soils characterized by low concentrations of available Zn (Singh *et al.* 1988). The interaction of P and Zn, called P-induced Zn deficiency, has been observed in many crops such as bean, wheat, tomato, cotton, flax, soybean, grape and citrus (Singh *et al.* 1988). In beans, phosphate supply increased shoot growth sufficiently which induced Zn deficiency (Singh *et al.* 1988). This effect becomes more pronounced if soils are already Zn deficient and adequate Zn is not supplied. However, effect of P application on Zn nutrition of chickpea has not been studied so far particularly under the conditions of deficiency of both the nutrients in soil (Subbarao and Rupa 2003). Similarly, information on effects of higher P application on Fe, Cu and Mn nutrition is not available for chickpea. Present study examines the effects of optimum and sub-optimum levels of P application on Zn, Fe, Cu and Mn nutrition of 20 chickpea cultivars on sandy loam soil deficient in P and Zn.

## MATERIALS AND METHODS

A pot culture experiment was conducted in green house conditions during *kharif*, 2003. Bulk soil sample was collected from New Research Farm of Indian Institute of Pulses Research, Kanpur (26° 28'N and 80° 24'E), processed to pass through 2 mm sieve and analyzed for various physico-chemical properties (Table 1). Particle size analysis was done by the hydrometer method following soil dispersion with Calgon (Day 1965), organic carbon by modified Walkley-Black procedure (Sefrioul *et al.* 1970), mineralizable nitrogen (N) was estimated by alkaline permanganate method (Subbaiah and Asija 1956). Phosphorus was extracted with sodium bicarbonate (Oslen *et al.* 1954), potassium with 1M neutral ammonium acetate (Hanway and Heidel 1952). Sulphur with 0.01 M $CaCl_2$ (Williams and Steinbergs 1959) and Zn with DTPA (Lindsay and Norvell

**Table 1. Physico-chemical properties and available nutrients status of experimental soil**

| Soil property | Value |
|---|---|
| Soil Taxonomy | Typic Ustochrept |
| pH (1:2.5) | 7.7 |
| Organic carbon (g/kg) | 2.1 |
| $CaCO_3$ (g/kg) | 2.1 |
| Clay (%) | 5.5 |
| Silt (%) | 30.0 |
| Sand (%) | 64.5 |
| Available N (mg/kg) | 62.50 |
| Available P (mg/kg) | 1.43 |
| Available K (mg/kg) | 40.2 |
| Available S (mg/kg) | 3.04 |
| Available Zn (mg/kg) | 0.4 |

1978). Twenty chickpea genotypes widely grown in different regions of India, *viz.*, Phule G 5, KPG 59, Pusa 209, BG 413, BG 256, K 850, Pant G 114, SAKI 9516, GPF 2, Vikash, Radhey, GCP 101, DCP 92-3, HK 94-134, RSG 888, GCP 105, JG 315, Vijay, GNG 663 and Sadabahar were grown in 4 kg pots filled with processed soil of 4 kg with 3 levels of added P (control, sub-optimum *i.e.,* 13.5 mg P/kg soil and optimum *i.e.,* 27 mg P/kg soil) in triplicates. Six healthy seeds were sown in each pot and after germination, four uniform plants were retained. Moisture content was maintained at optimum level (12%) by weighing method throughout the experiment with deionized water. Recommended doses of N, K, S and Zn were applied on soil weight basis in order to get 25 kg N, 30 kg K, 20 kg S and 5 kg Zn/ha. Phosphorus was added as diammonium phosphate. Crop was harvested after 90 days. After harvest, roots were thoroughly washed to remove soil particles and plants were divided into roots and shoots. All the plant parts were oven dried at 70°C for 48 hours and dry weights were recorded. Shoot samples were then ground and analyzed for P. Plant were wet digested in a mixture of nitric acid, perchloric acid and sulphuric acid (3:1:1) and diluted with water to a constant volume. The concentration of P in the extracted solution was determined by using the vanadomolybdate yellow colour method (Jackson 1973). Concentration of Zn, Fe, Cu and Mn were determined by atomic absorption spectrophotometer. Uptake of nutrients by chickpea genotypes were computed by multiplying the concentration of the respective elements with dry matter yield. Correlation analysis was done between P concentration and yield parameters and P uptake parameters. The LSD at P= 0.05 was used to separate the means of each treatment.

## RESULTS AND DISCUSSION

### *Effects of P on biomass and P uptake*

Significant differences were observed in different growth parameters of chickpea genotypes due to P application (Table 2). Both root and shoot dry matter increased with increase in the level of applied P from 0 to 27.0 mg P/kg. Root/shoot ratio decreased from 0.65±0.15 to 0.49±0.10 at 27 mg P/kg. Phosphorus concentration in shoot and P uptake increased significantly at 13.5 and 27 mg P/kg.

**Table 2. Effect of different P levels on dry matter, yield and P uptake in chickpea (Mean of 20 genotypes)**

| Parameter | P added (mg/kg soil) | | | LSD |
|---|---|---|---|---|
| | 0 | 13.5 | 27.0 | (P-0.05) |
| Root dry wt (g/pot) | 1.01± | 1.16± | 1.76± | 0.74 |
| Shoot dry wt (g/pot) | 1.57± | 2.04± | 3.69± | 1.52 |
| Root /shoot ratio | 0.65± | 0.59± | 0.49± | 0.18 |
| P concentration (g/kg) shoot DW) | 1 | 2. | 2.73± | 0.66 |
| P uptake (mg/pot) | 1.75± | 4.13± | 10.16 | 4.30 |

### *Zn concentration and uptake*

Zinc concentration varied widely among the genotypes (Table 3). Application of P at 13.5 mg/kg improved Zn concentration and further increase to 27.0 mg/kg resulted in significant decrease (P<0.05) in most of the genotypes. The mean Zn concentration increased from 22.1±0.72 at control to 25.3±0.53 mg/g at 13.5 mg P/kg which decreased to 20.8±0.36 mg at 27.0 mg P/kg. In all the three treatments, genotype HK 94-134 maintained higher shoot Zn concentration. Among genotypes KPG 59, BG 256, RSG 888 and JG 315 showed Zn concentration below critical limit of 20 mg Zn/g DW at 27.0 mg P/kg (Singh *et al.* 1988). However, across the genotypes, zinc uptake increased with increasing P levels with mean Zn uptake increasing from 34.8±12.5 in control to 76.4±32.6 mg/pot at 27.0 mg P/kg.

**Table 3. Effect of P application (mg/kg) on Zn and Fe concentrations in chickpea genotypes (mg/g shoot)**

| Genotype | Zn concentration | | | Fe Concentration | | |
|---|---|---|---|---|---|---|
| | 0 | 13.5 | 27 | 0 | 13.5 | 27 |
| Phule G5 | 22.0± 0.45 | 26.6± 0.60 | 20.5±0.30 | 515±4.2 | 486±4.5 | 452±11.1 |
| KPG 59 | 20.8±0.71 | 26.3±0.80 | 19.3±0.35 | 392±6.7 | 390±5.0 | 388±5.3 |
| Pusa 209 | 21.3±0.95 | 27.3±0.96 | 20.0±0.55 | 538±4.7 | 495±4.5 | 491±4.6 |
| BG 413 | 21.6±0.70 | 28.4±1.21 | 20.1±0.45 | 609±6.6 | 516±6.0 | 502±9.3 |
| BG 256 | 21.3±1.05 | 29.5±0.40 | 19.8±0.45 | 360±9.6 | 351±7.8 | 350±1.5 |
| K 850 | 21.4±0.76 | 25.5±0.40 | 21.1±0.32 | 594±6.4 | 510±10.0 | 507±14.5 |
| Pant G114 | 21.5±1.25 | 24.3±0.23 | 20.2±0.55 | 477±7.5 | 478±7.5 | 478±10.4 |
| SAKI 9516 | 20.8±1.05 | 22.8±0.75 | 21.5±0.30 | 577±12.7 | 482±17.8 | 463±10.6 |
| GPF 2 | 20.7±0.91 | 23.3±0.31 | 20.8±0.85 | 415±5.0 | 416±5.9 | 415±4.2 |
| Vikash | 20.1±0.55 | 24.2±0.70 | 20.6±0.15 | 530±5.5 | 520±10.0 | 503±7.0 |
| Radhey | 20.5±0.56 | 24.4±0.50 | 20.8±0.06 | 622±10.8 | 561±5.0 | 528±7.6 |
| GCP101 | 21.6±0.35 | 25.3±0.60 | 23.1±0.65 | 596±4.6 | 515±9.9 | 505±11.0 |
| DCP 92-3 | 25. ±0.55 | 29.5±0.40 | 22.3±0.25 | 567±7.0 | 515±99 | 494±8.5 |
| HK 94-134 | 26.1±0.91 | 30.0±0.40 | 23.5±0.55 | 436±7.0 | 421±9.0 | 412±3.8 |
| RSG 888 | 22.8±0.50 | 24.5±0.20 | 18.2±0.15 | 376±6.1 | 375±5.0 | 375±2.6 |
| GCP 105 | 22.5±0.55 | 21.3±0.35 | 20.7±0.25 | 504±10.0 | 481±8.2 | 457±6.2 |
| JG 315 | 21.8±0.56 | 23.9±0.0 | 19.1±0.35 | 392±2.9 | 380±4.5 | 370±4.7 |
| Vijay | 23.1±0.70 | 21.3±0.30 | 20.6±0.35 | 581±9.0 | 505±10.0 | 481±14.0 |
| GNG 663 | 21.6±0.60 | 22.5±0.26 | 21.8±0.21 | 492±8.7 | 441±7.1 | 428±6.8 |
| Sadabahar | 24.2±0.75 | 25.4±0.36 | 22.5±0.12 | 462±7.5 | 451±1.2 | 447±5.3 |
| **Mean** | **22.1±0.72** | **25.3±0.53** | **20.8±0.36** | **502±7.1** | **465±7.9** | **452±7.5** |
| **LSD(0.05)** | **1.22** | | | **42.3** | | |

The antagonistic effect of P and Zn has been well established (Singh *et al.* 1988). Our results indicated that at lower levels (13.5 mg/kg) of P application, Zn concentration increased in 18 out of 20 genotypes tested (Table 3). As the experimental soil was deficient in both available P (1.43 mg/kg) and Zn (0.4 mg/kg), positive interaction was observed between these elements at lower P application. However at higher P levels, there was an antagonistic interaction between P and Zn concentration. This was confirmed by the positive correlation between P and Zn concentration in no P control. Subbarao and Rupa (2003) stated that antagonism between P and Zn is observed when both elements in soil are deficient, but only one of them is applied. Through balanced application of P and Zn, the antagonism can be neutralized and converted into a synergistic effect. The relationship between P uptake and Zn concentration was significantly negative (Fig.1).

Inverse relationship between shoot P accumulation and Zn concentration was related to P translocation from roots to shoots. Therefore, reduction in Zn concentration can mainly be explained by a dilution effect caused by increased biomass. Lambert *et al.* (1979) reported that reduction in Zn concentration in maize was the result of a dilution and could be attributed to increased plant size.

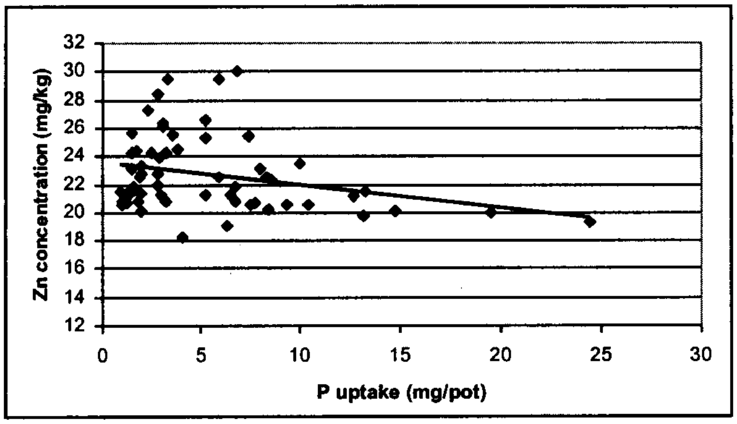


**Fig 1. Relationship between P uptake and Zn concentration in shoot of chickpea (R=-0.29 $P<0.05$; n=60)**

### *Fe concentration and uptake*

Concentration of Fe differed significantly among genotypes at all three level of P application (Table 3). In general, increasing level of P application decreased Fe concentration. Fe concentration in shoot ranged from 360±9.6 to 622±10.8 mg/g in control, from 351±7.8 to 561±15.0 mg/g at 13.5 mg P/kg, from 350±1.5 to 528±7.6 mg/g at 27.0 mg P/kg. Among genotypes, Radhey and BG 413 showed higher Fe concentration at all the levels of P application. The mean Fe concentration in shoot decreased from 502±7.1 mg/g in control to 452 ±7.5 mg/g at 27.0 mg P/kg. The mean Fe uptake increased from 773 mg/pot in control to 1655 mg/pot at 27.0 mg P/kg (Table 5). Fe concentration was significantly reduced at 13.5 mg P/kg except for two genotypes *i.e.*, Pant G 114 and GPF 2, which were not affected by P fertilization. The relationships of P concentration and uptake with concentration of Fe, being negative ($P<0.05$), Fe nutrition could be yield limiting factor under adequate P fertilization.

### *Cu concentration and uptake*

With increasing P levels, Cu concentration increased up to 13.5 mg P/kg and decreased significantly ($P<0.05$) with further increase in P up to 27.0 mg/kg (Table 4). Cu concentration ranged from 2.4±0.3 to 7.7±0.2 mg/g in control, from 1.8±0.3 to 7.5±0.6 mg/g at 13.5 mg P/kg, from 1.6±0.2 to 7.7±0.5 mg/g at 27.0 mg P/kg. Among genotypes, GCP101 maintained highest Cu concentration followed by JG 315 while BG 256 showed the lowest. At 27.0 mg P/kg, GCP 101 maintained the highest concentration of above 7 mg/g where as BG 413, BG 256 and K 850 recorded below 2 mg/g. Wide variation of 80, 53 and 54% was observed for Cu uptake in 20 genotypes in control, 13.5 and 27.0 mg P/kg treatments, respectively. A positive relationship was observed between P and Cu concentration at lower level of P whereas it was negative at higher P. At 27.0 mg P/kg, genotypes DCP 92-3 and GCP 101 maintained higher Cu concentration. Buerkert *et al.* (1998) also reported that increase in P application reduced Cu concentration in millet.

### *Mn concentration and uptake*

Increasing P levels increased the Mn concentration gradually (Table 4). However, mean increase was statistically significant only at 27 mg P/kg application. The mean Mn concentration increased from 256±3.2 mg/g (control) to 285±4.2 mg/g at 27 mg P/kg. Among genotypes, RSG 888 showed the highest whereas KPG 59 showed the lowest concentration at all the three levels of P application. Unlike other micronutrients, Mn concentration increased with increasing P levels (Table 4). The relationship between P and Mn concentration was significantly positive ($P<0.05$). However, the mean increase in Mn concentration was statistically significant at 27.0 mg P/kg only. Among genotypes, RSG 888 was found to be highly Mn efficient and KPG 59 Mn-inefficient at all the P levels.

**Table 4. Effect of P application (mg/kg) on Cu and Mn concentration in chickpea genotypes (mg/g shoot)**

| Genotype | Cu concentration at P levels of | | | Mn Concentration at P levels of | | |
|---|---|---|---|---|---|---|
| | 0 | 13.5 | 27 | 0 | 13.5 | 27 |
| Phule G5 | 3.2± 0.1 | 3.7± 0.2 | 2.7± 0.3 | 241± 1.2 | 249±3.2 | 250±6.5 |
| KPG 59 | 5.9± 0.3 | 4.6± 0.5 | 3.6± 0.2 | 166± 6.0 | 219±5.6 | 234±4.0 |
| Pusa 209 | 4.1± 0.2 | 4.9± 0.5 | 3.3± 0.5 | 247± 3.1 | 259±4.0 | 265±5.5 |
| BG 413 | 2.8± 0.3 | 1.8± 0.3 | 1.7± 0.3 | 251± 2.6 | 269±3.0 | 272±5.5 |
| BG 256 | 2.4± 0.3 | 1.9± 0.2 | 1.9± 0.2 | 269± 3.6 | 271±6.0 | 287±3.8 |
| K 850 | 2.5± 0.4 | 3.1± 0.6 | 1.6± 0.2 | 269± 5.5 | 278±3.8 | 295±4.2 |
| Pant G114 | 4.9± 0.5 | 6.6± 0.6 | 2.5± 0.1 | 249± 4.0 | 265±5.0 | 281±5.1 |
| SAKI 9516 | 2.7± 0.5 | 5.6± 0.2 | 2.2± 0.3 | 235± 5.0 | 255±1.5 | 292±3.5 |
| GPF 2 | 3.8± 0.5 | 6.1± 0.6 | 3.1± 0.3 | 231± 2.6 | 246±2.1 | 271±1.5 |
| Vikash | 4.2± 0.4 | 5.2± 0.6 | 2.9± 0.2 | 239± 4.2 | 256±1.3 | 267±2.6 |
| Radhey | 3.0± 0.3 | 5.1± 0.6 | 3.5± 0.4 | 257± 4.4 | 269±3.0 | 280±2.1 |
| GCP101 | 7.7± 0.2 | 6.9± 0.0 | 7.7± 0.8 | 269± 5.5 | 278±3.8 | 295±3.0 |
| DCP 92-3 | 4.7± 0.5 | 4.8± 0.5 | 5.2± 0.5 | 273± 6.7 | 288±1.4 | 300±5.0 |
| HK 94-134 | 5.7± 0.5 | 7.5± 0.3 | 5.1± 0.4 | 266± 4.0 | 267±6.5 | 278±2.5 |
| RSG 888 | 3.6± 0.4 | 4.4± 0.3 | 5.5± 0.5 | 324± 16.4 | 331±7.1 | 368±4.9 |
| GCP 105 | 4.2± 0.8 | 6.8± 0.4 | 2.8± 0.2 | 299± 3.6 | 311±2.6 | 323±4.9 |
| JG 315 | 7.1± 0.3 | 7.5± 0.6 | 3.3± 0.4 | 246± 4.0 | 258±3.1 | 266±8.1 |
| Vijay | 2.9± 0.8 | 5.7± 0.5 | 5.7± 0.1 | 270± 1.5 | 279±1.8 | 286±4.0 |
| GNG 663 | 5.3± 0.8 | 6.4± 0.3 | 3.5± 0.5 | 284± 7.5 | 305±4.4 | 321±2.6 |
| Sadabahar | 6.1± 0.3 | 5.5± 0.2 | 3.5± 0.2 | 235± 4.5 | 257±1.7 | 264±3.5 |
| **Mean** | **4.3±0.4** | **5.2±0.2** | **3.6±0.2** | **256±3.2** | **270±3.5** | **285±4.2** |
| **LSD (0.05)** | **1.10** | | | **17.6** | | |

Present study demonstrated the interaction effects of P and four important micronutrients in 20 chickpea genotypes. These interactions bear greater implication in nutrient management as most chickpea growing regions of India are deficient in P as well as in micronutrients and farmers apply only P. Results also demonstrated wide variations in Zn, Fe,

**Table 5. Uptake (mg/pot) of micronutrients in chickpea genotypes as influenced by P levels**

| Micro-nutrient | P level (mg/kg) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | | 13.5 | | 27 | |
| | Mean | CV (%) | Mean | CV (%) | Mean | CV (%) |
| Zn | 34.8±12.5 | 36 | 52.6±21.8 | 41 | 76.4±32.6 | 43 |
| Fe | 773±215 | 28 | 941±298 | 32 | 1655±687 | 42 |
| Cu | 8.2±6.6 | 80 | 10.8±5.7 | 53 | 11.9±6.4 | 54 |
| Mn | 405±150 | 37 | 554±196 | 35 | 999±430 | 43 |

Cu and Mn efficiency among genotypes. Results suggest that under conditions of deficiency of both P and Zn in soil, application of P alone at higher doses negatively effects the Zn nutrition and inclusion of Zn in the nutrient management of chickpea should be given due importance along with P fertilization. Another significant observation was the marked differences among genotypes for Zn nutrition. Genotypes HK 94-134 and GCP 101 were found Zn efficient whereas KPG 59, BG 256, RSG 888 and JG 315 showed Zn concentration below critical limit at 27.0 mg P/kg. Similarly, considerable variations were also observed in the interaction effects among genotypes. Depending on soil test and genotypes, inclusion of micronutrients is essential to realize full yield potential of chickpea cultivars. With further field studies, efficient genotypes could also be used in breeding programme aimed at evolving genotypes suitable for a given soil condition.

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