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Research Paper

# Performance of chickpea (*Cicer arietinum*) as influenced by moisture management and zinc fortification in pearlmillet (*Pennisetum glaucum*)–chickpea cropping system under limited moisture conditions

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## ABSTRACT

A field experiment was conducted during the winter (*rabi*) season of 2012–13 and 2013–14 at research farm of Indian Agricultural Research Institute, New Delhi, to determine the effect of moisture management and direct as well as residual effect of zinc fortification on performance of chickpea (*Cicer arietinum* L.) in pearlmillet [*Pennisetum glaucum* (L.) R. Br.]–chickpea cropping system under limited moisture conditions. Different moisture-management practices resulted in significantly higher plant height, dry-matter accumulation, number and weight of root nodules, number of branches, pods/plant, grains/pod and 1,000-grain weight compared to flat planting. However, flat bed planting recorded significantly higher values of root parameters than crop residue-applied treatments. Significantly higher grain (2.48 t/ha) and stover (5.98 t/ha) yields with water productivity of 116.9 kg/$m^3$ were observed under flat bed with 5.0 t/ha crop residue over flat bed without residue and flat bed with 2.5 t/ha crop residue. Narrow bed and furrow with 2.5 t/ha crop residue cover fetched significantly higher production efficiency, whereas, flat bed with 5.0 t/ha crop residue recorded significantly higher Zn content in grain and stover of chickpea than rest of the moisture-management practices. Under direct-applied zinc fortification treatments increasing levels of zinc up to 5.0 kg/ha significantly enhanced the growth parameters, yield attributes, yield, water productivity, production efficiency and Zn content in both grain and stover of chickpea. Under residual effect of zinc fortification, plant height, number and dry weight of root nodules, root parameters, number of secondary branches, pods/plant, test weight, stover yield, water productivity and production efficiency of chickpea were increased significantly only up to 2.5 kg Zn/ha. However, application 5.0 kg Zn/ha to pearlmillet recorded significantly higher dry-matter accumulation, number of primary branches, grain yield (2.32 t/ha) and content of Zn in grain as well as in stover than lower levels.

***Key words* :** Chickpea, Crop residue, Grain yield, Moisture management, Narrow bed and furrow, Water productivity, Zinc fortification

Chickpea is the premier pulse crop of India, which is predominantly grown on marginal lands of rainfed areas. India ranks first in the world in respect of production as well as acreage and produces 8.88 million tonnes chickpea grains from 8.70 million ha with an average productivity of 896 kg/ha (GoI, 2013). Since 1950's in India considerable progress in irrigation development has been made, but 70% of chickpea is still grown under rainfed conditions. It is mostly grown under rainfed condition after the harvesting of rainy-season crops on conserved soil moisture. Because of this it faces moisture scarcity throughout the growth period but at terminal stages of crop growth it becomes conspicuous and more-frequent that results in low productivity/production despite the crop have a unique adaptive mechanism to moisture stress. Land-configuration practices, viz. ridge and furrow, broad bed and furrow and flat bed with *Gliricidia* leaves mulching, showed a remarkable improvement in performance of crop over flat bed planting (Paliwal *et al.,* 2011). *In-situ* application of crop residues and division of field into beds and furrows could be used as low-cost input technology, which helps conserve more rainwater in soil by minimizing runoff of water from soil surface during rainy season (Rathore *et al.,* 2006; Singh *et al.,* 2012a).

Besides, moisture conservation, other important factor for stepping up the yield of chickpea is micronutrient management especially zinc. Increased use of high-analysis

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fertilizer and less or no use of organic manure and continuous multiple cropping with fertilizer-responsive varieties of crops have accentuated the depletion of their reserves in the soil, often leading to significant responses to their application. Zinc deficiency reduces not only the grain yield, but also the nutritional quality of grain and ultimately nutritional quality of human diet. Zinc plays an important role in formation of chlorophyll and growth hormones and is associated with the uptake of water. Application of zinc to chickpea enhanced the chlorophyll a and b contents of leaf, number of flowers and grain yield (Singh *et al.,* 2011). So efforts should be required to enhance the productivity and quality of chickpea produce through adoption of suitable moisture-conservation techniques along with zinc fortification. Hence the present investigation was undertaken to improve the productivity of chickpea by moisture management and zinc fortification under limited moisture conditions.

## MATERIALS AND METHODS

A field experiment was conducted during the winter (*rabi*) seasons of 2012–13 and 2013–14 at the research farm of the Indian Agricultural Research Institute, New Delhi, to find out the effect of moisture management and zinc fortification on performance of chickpea under limited moisture conditions. The maximum and minimum temperature during the crop-growing season was 34.6 and 0.6°C during 2012–13 and 34.8 and 1.0°C during 2013–14 respectively. The total rainfall received during the cropping season of 2012–13 and 2013–14 was 164.4 and 152.4 mm respectively, out of which 138.5 (84.3%) and 139.6 mm (91.6%) was measured as effective. The experimental soil was sandy loam in texture (61.48% sand, 12.66% silt and 25.86% clay) and slightly alkaline in reaction (pH 7.7). The soil was low in organic carbon (0.40%) and available nitrogen (135.4 kg N/ha), medium in available phosphorus (12.8 kg P/ha), potassium (178.8 kg K/ha) and DTPA-extractable Zn (0.63 mg/kg of soil).

The experiment comprised 4 moisture-management practices (flat bed, flat bed with 2.5 t/ha crop residue, flat bed with 5.0 t/ha crop residue and narrow bed and furrow with 2.5 t/ha crop residue) in main plots and 3 treatments of zinc fortification (control, 2.5 kg Zn/ha and 5.0 kg Zn/ha) in sub-plots to pearlmillet and in sub-subplots to chickpea grown after pearlmillet in the winter (*rabi*) season. The experiment was laid out in double split-plot design and replicated thrice. After field preparation and before sowing of crop, the narrow beds of 70 cm wide with furrows of 30 cm width were prepared manually in respective plots. The chickpea variety 'Pusa 1103' was taken for experiment and sown at 30 cm × 10 cm spacing. For sowing of chickpea during the first year, pre-sowing irrigation was applied to get optimum germination and after this crop was grown on stored soil moisture; however, during the second year no pre-sowing irrigation was required because of good rainfall after harvesting of pearlmillet. A common dose of 20 kg N, 40 kg $P_2O_5$ and 40 kg $K_2O$/ha was applied basal at the time of sowing. Pearlmillet residue was applied in main plots as per treatment just after sowing as moisture management treatments during both the years. Zinc fortification treatments were applied to sub-sub plots as per treatment through zinc sulphate ($ZnSO_4.7H_2O$) containing 21% Zn and 10% S at the time of sowing as basal dose. The amount of sulphur was adjusted through single superphosphate in all the plots. The crop was grown with recommended package of practices. The crop was sown on 2 November and 23 October and harvested on 1 and 5 April during 2012–13 and 2013–14 respectively.

Five random plants from each plot were tagged permanently and used for measurement of plant height and yield attributes. Dry-matter accumulation was measured from the 5 random plants from each plot. The samples were first air-dried for some days and dried in oven at 65°C till constant weight. Root samples were taken from the sample row at 50% flowering stage with the help of root auger of 8.0 cm diameter and 15 cm height (core volume = 754.28 $cm^3$). The roots were separated by gradually loosening the soil. The remaining soil adhered to roots was washed properly by putting roots on container with sieves to prevent loss of fine roots during washing. The measured root parameters like root length and root volume were recorded through scanning and image analysis using WIN-RHIZO system. After scanning the root samples were dried at 65°C for 48 hr for recording root dry weight. For counting number of root nodules, 5 plants were uprooted carefully in wet soil at 50% flowering. The total root nodules obtained from the 5 plants from each plot were subjected to oven dry at 65°C till a constant weight to measure the dry weight. Ten pods from each plot were selected to count number of grains per pod. A random sample of grain was taken from the produce of the net plot to measure 1,000-grain weight. The weight of the thoroughly sun-dried harvested produce from net area of each plot was recorded separately before threshing for total biomass yield. After proper drying harvested produce were threshed separately and weighed for grain yield. Water productivity was worked out by dividing grain yield with seasonal crop consumptive use of water. Production efficiency (PE) was expressed as the ratio of the net returns to total duration of the crop in days. The content of Zn in grain and stover were analysed by using the standard procedure. Statistical analysis of the data was carried out using standard analysis of variance (Gomez and Gomez, 1984).

## RESULTS AND DISCUSSION

### *Effect of moisture management*

Two years pooled data revealed that growth parameters of chickpea, viz. plant height, dry-matter accumulation, nodulation and rooting characteristics, were influenced significantly by moisture-management practices (Table 1). Flat bed with 5.0 t/ha crop residue produced significantly taller plant and higher dry-matter accumulation than flat bed and flat bed with 2.5 t/ha crop residue, but remained on a par with narrow bed and furrow with 2.5 t/ha crop residue. There was 12.2 and 4.4% increase in plant height and 30.8 and 11.0% increase in dry-matter accumulation under flat bed with 5.0 t/ha crop residue over flat bed and flat bed with 2.5 t/ha crop residue respectively. The highest values of mean crop-growth rate (CGR) were observed under flat bed with 5.0 t/ha crop residue at all the growth stages (Fig. 1). Mean CGR was progressively increased from 0–30 days after sowing (DAS) to 90–120 DAS and then decreased at 120 DAS–harvest. Chickpea planted under flat bed with 5.0 t/ha crop residue recorded significantly higher number of root nodules/plant in comparison to flat bed planting. However, in terms of dry weight of root nodules flat bed with 5.0 t/ha crop residue remained at par with narrow bed and furrow with 2.5 t/ha crop residue and proved significantly superior to rest of the treatments. Contrary to these, higher values of root parameters, viz. root length, root volume and root dry weight, were observed with flat bed planting. The roots of flat bed-planted chickpea grows to deeper soil layers in search of moisture under moisture-stress conditions and recorded significantly higher values of rooting parameters than crop residue applied treatments which had higher conserved moisture (Table 1). The improvement in growth parameters of chickpea ascribed to favourable soil-moisture condition maintained for relatively longer period under flat bed with 5.0 t/ha crop residue. The enhanced nutrient supply through decomposition of organic matter together with favourable moisture condition created conducive environment to plant growth and development (Meena *et al.,* 2006; Mishra *et al.,* 2012).

Flat bed with 5.0 t/ha crop residue remained at par with narrow bed and furrow with 2.5 t/ha crop residue and significantly enhanced the primary branches/plant by 22.4 and 9.1% and pods/plant by 25.7 and 8.9% over flat bed alone and flat bed with 2.5 t/ha crop residue respectively (Table 2). And planting of chickpea under flat bed with 5.0 t/ha crop residue recorded significantly higher number of secondary branches over all the other moisture-management practices (Table 2). However, in case of grains/pod and 1,000-grain weight all the treatments which received crop residue performed in statistically similar way and proved significantly better than flat bed without residue. The favourable improvement in yield attributes was owing to adequate supply of moisture, leading to greater nutrient

**Table 1.** Effect of moisture management and zinc fortification on growth of chickpea (pooled data of 2 years)

| Treatment | Plant height (cm) | Dry-matter accumulation (g/plant) | Root nodules | | Root parameters | | |
|---|---|---|---|---|---|---|---|
| | | | Nos./ plant | Dry weight (mg/plant) | Length (cm/plant) | Volume ($cm^3$/plant) | Dry weight (mg/plant) |
| *Moisture management* | | | | | | | |
| Flat bed | 58.8 | 20.1 | 20.0 | 241.3 | 344.3 | 3.59 | 976.5 |
| Flat bed + 2.5 t/ha crop residue | 63.2 | 23.7 | 21.9 | 270.3 | 301.2 | 3.09 | 810.3 |
| Flat bed + 5.0 t/ha crop residue | 66.0 | 26.3 | 22.5 | 283.4 | 273.7 | 2.91 | 736.3 |
| NBF + 2.5 t/ha crop residue | 65.5 | 25.4 | 22.3 | 279.0 | 284.1 | 3.00 | 752.6 |
| SEm± | 0.49 | 0.52 | 0.28 | 4.03 | 6.60 | 0.07 | 17.83 |
| CD (P=0.05) | 1.51 | 1.61 | 0.87 | 12.41 | 20.32 | 0.22 | 54.95 |
| *Zinc fortification to pearlmillet (kg/ha)* | | | | | | | |
| 0 | 62.2 | 22.4 | 21.1 | 259.1 | 279.6 | 2.89 | 754.8 |
| 2.5 | 63.6 | 24.2 | 21.8 | 269.8 | 304.9 | 3.22 | 840.0 |
| 5.0 | 64.3 | 25.2 | 22.1 | 276.4 | 317.9 | 3.34 | 862.0 |
| SEm± | 0.29 | 0.31 | 0.22 | 3.50 | 5.01 | 0.06 | 12.82 |
| CD (P=0.05) | 0.84 | 0.90 | 0.62 | 10.09 | 14.44 | 0.16 | 36.94 |
| *Zinc fortification to chickpea (kg/ha)* | | | | | | | |
| 0 | 61.3 | 21.1 | 20.6 | 255.3 | 273.7 | 2.81 | 725.4 |
| 2.5 | 63.7 | 24.5 | 21.9 | 270.8 | 305.8 | 3.24 | 843.7 |
| 5.0 | 65.0 | 26.1 | 22.6 | 279.3 | 322.9 | 3.40 | 887.6 |
| SEm± | 0.28 | 0.29 | 0.21 | 2.60 | 5.16 | 0.06 | 11.74 |
| CD (P=0.05) | 0.78 | 0.81 | 0.58 | 7.31 | 14.49 | 0.16 | 32.97 |

NBF, Narrow bed and furrow

uptake, efficient partitioning of metabolites and adequate accumulation and translocation of photosynthates (Ramesh and Devasenapathy, 2008; Paliwal *et al.*, 2011). Significantly higher grain and stover yields of chickpea were observed under flat bed with 5.0 t/ha crop residue over flat bed and flat bed with 2.5 t/ha crop residue but remained at par with narrow bed and furrow with 2.5 t/ha crop residue. This treatment enhanced the grain yield by 37.8 and 13.2% and stover yield by 33.2 and 11.8% over flat bed and flat bed with 2.5 t/ha crop residue, respectively. Harvest index was increased with moisture-management practices but failed to show any significant improvement. The improved growth parameters and yield attributes led to higher grain and stover yields under flat bed with 5.0 t/ha crop residue. Similar findings were also reported by Singh and Rana (2006) and Paliwal *et al.* (2011).

Moisture-management practices also significantly affected water productivity, production efficiency and Zn content in both grain and stover of chickpea (Table 3). Sowing of chickpea under flat bed with 5.0 t/ha crop residue, being statistically similar with narrow bed and furrow with 2.5 t/ha crop residue, recorded significantly higher water productivity than flat bed without residue and flat bed with 2.5 t/ha crop residue. The improvement in water productivity under flat bed with 5.0 t/ha crop residue sown chickpea might be owing to the lower consumptive use and higher grain yield than other practices (Mishra *et al.*, 2012). Chickpea sown on narrow bed and furrow with 2.5 t/ha crop residue remained on a par with flat bed with 5.0 t/ha crop residue, fetched significantly higher production efficiency than rest of the moisture-conservation practices. Paliwal *et al.* (2011) also reported similar results. Significantly higher content of Zn in grain and stover of chickpea was recorded under flat bed with 5.0 t/ha crop residue than the other moisture-management practices. Application of crop residue might have lowered down the soil pH through liberation of $CO_2$ and organic acids during decomposition and its decomposition products might gave rise natural complexing agents that solubilized the nutrients already present in soil and rendered zinc available to the plant (Kumari and Prasad, 2014).

### *Direct effect of zinc fortification*

Increasing levels of zinc to chickpea significantly enhanced the plant height and dry matter/plant (Table 1). Application of 5.0 kg Zn/ha significantly enhanced the plant height by 3.7 and 1.3 cm and dry matter by 23.7 and 6.5% respectively, over the control and 2.5 kg Zn/ha. The mean crop growth rate (CGR) of chickpea was progressively increased from 0–30 DAS to 90–120 DAS and then decreased at 120 DAS–harvest, and the highest values of mean CGR were observed with 5.0 kg Zn/ha at all the crop growth stages (Fig. 1). Nodulation of chickpea were also influenced significantly with zinc fortification, wherein application of 5.0 kg Zn/ha recorded significantly

**Table 2.** Effect of moisture management and zinc fortification on yield attributes of chickpea (pooled data of 2 years)

| Treatment | Branches/plant (no.) | | Pods/ plant | Grains/ pod | 1,000-grain weight (g) | Yield (t/ha) | | Harvest index (%) |
|---|---|---|---|---|---|---|---|---|
| | Primary | Secondary | | | | Grain | Stover | |
| *Moisture management* | | | | | | | | |
| Flat bed | 4.9 | 13.0 | 29.2 | 1.59 | 193.6 | 1.80 | 4.49 | 28.6 |
| Flat bed + 2.5 t/ha crop residue | 5.5 | 15.2 | 33.7 | 1.67 | 206.7 | 2.19 | 5.35 | 29.0 |
| Flat bed + 5.0 t/ha crop residue | 6.0 | 16.6 | 36.7 | 1.70 | 211.3 | 2.48 | 5.98 | 29.3 |
| NBF + 2.5 t/ha crop residue | 5.8 | 15.8 | 35.9 | 1.68 | 209.5 | 2.42 | 5.85 | 29.2 |
| SEm± | 0.08 | 0.26 | 0.59 | 0.02 | 1.82 | 0.04 | 0.10 | 0.31 |
| CD (P=0.05) | 0.23 | 0.79 | 1.81 | 0.06 | 5.61 | 0.13 | 0.30 | NS |
| *Zinc fortification to pearlmillet (kg/ha)* | | | | | | | | |
| 0 | 5.3 | 14.3 | 31.9 | 1.63 | 201.7 | 2.10 | 5.16 | 28.9 |
| 2.5 | 5.6 | 15.4 | 34.3 | 1.67 | 205.7 | 2.24 | 5.47 | 29.1 |
| 5.0 | 5.8 | 15.8 | 35.4 | 1.68 | 208.4 | 2.32 | 5.63 | 29.1 |
| SEm± | 0.06 | 0.18 | 0.46 | 0.02 | 1.33 | 0.03 | 0.06 | 0.24 |
| CD (P=0.05) | 0.18 | 0.52 | 1.31 | NS | 3.84 | 0.08 | 0.19 | NS |
| *Zinc fortification to chickpea (kg/ha)* | | | | | | | | |
| 0 | 5.2 | 13.9 | 31.1 | 1.63 | 198.9 | 2.04 | 5.03 | 28.8 |
| 2.5 | 5.6 | 15.4 | 34.4 | 1.66 | 206.7 | 2.26 | 5.49 | 29.1 |
| 5.0 | 5.9 | 16.1 | 36.1 | 1.69 | 210.1 | 2.36 | 5.73 | 29.1 |
| SEm± | 0.05 | 0.13 | 0.40 | 0.01 | 1.17 | 0.02 | 0.05 | 0.23 |
| CD (P=0.05) | 0.13 | 0.35 | 1.12 | NS | 3.29 | 0.07 | 0.13 | NS |

NBF, Narrow bed and furrow

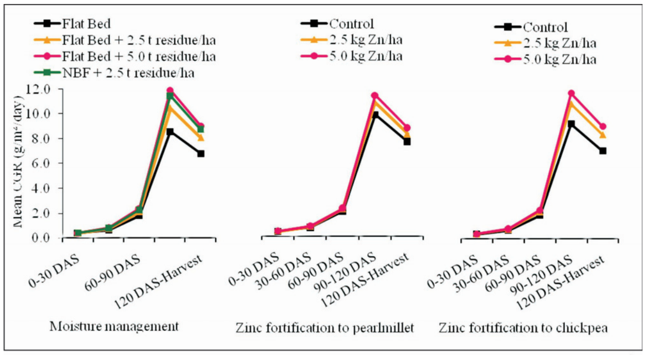


**Fig. 1.** Effect of moisture management and zinc fortification on mean crop-growth rate of chickpea (pooled data of 2 years)

higher number and dry-matter of root nodules than lower levels (Table 1). The effects of zinc fortification were also found to be significant on rooting characteristics of chickpea (Table 1). Application of 5.0 kg Zn/ha recorded significantly higher root length, root volume and root dry-weight of chickpea. The favourable influence of applied zinc on these characters might ascribed to its involvement in various metabolic activities, controlling auxin levels and nucleic acids. Zinc is also an essential component of enzymes responsible for assimilation of nitrogen which helps chlorophyll formation and plays an important role in nitrogen metabolism contributing towards increase in growth and development of plant (Gupta and Sahu, 2012; Singh and Bhati, 2013).

Number of primary and secondary branches, pods/plant and 1,000-grain weight of chickpea were increased significantly with gradual increase in zinc levels up to 5.0 kg Zn/ha (Table 2). This treatment registered an increase of 13.5 and 5.4% in primary branches, 15.8 and 4.5% in secondary branches, 16.1 and 4.9% in pods/plant and 5.6 and 1.6% in 1,000-grain weight over the control and 2.5 kg Zn/ha respectively. However, zinc fortification treatments failed to bring any significant effect on grains/pod. As already discussed that zinc plays an important role in nitrogen metabolism and formation of chlorophyll and carbohydrate, which leads to maintain photosynthetic activity for longer period and finally results in increasing the yield attributes of the crop (Jyothi *et al.*, 2013). Results further revealed that increasing levels of zinc were also significantly enhanced the grain and stover yields (Table 2). Application of 5.0 kg Zn/ha recorded significantly higher grain and stover yield of chickpea than lower levels. Zinc fortification treatments were failed to bring any significant effect on harvest index. The cumulative beneficial effect of growth and yield-attributing characters was finally reflected on yield of chickpea (Gupta and Sahu, 2012; Singh *et al.*, 2012b).

Direct applied zinc fortification treatments were also

**Table 3.** Effect of moisture management and zinc fortification on water productivity, production efficiency and Zn content of chickpea (pooled data of 2 years)

| Treatment | Water productivity (kg/m$^3$) | Production efficiency (₹/ha/day) | Zn content (mg/kg) | |
|---|---|---|---|---|
| | | | Grain | Stover |
| *Moisture management* | | | | |
| Flat bed | 0.81 | 261 | 43.3 | 37.4 |
| Flat bed + 2.5 t/ha crop residue | 01.1 | 308 | 46.3 | 40.3 |
| Flat bed + 5.0 t/ha crop residue | 1.17 | 338 | 48.2 | 42.0 |
| NBF + 2.5 t/ha crop residue | 1.13 | 355 | 47.0 | 40.9 |
| Sem± | 0.02 | 9.0 | 0.38 | 0.33 |
| CD (P=0.05) | 0.06 | 27.7 | 1.17 | 1.02 |
| *Zinc fortification to pearlmillet (kg/ha)* | | | | |
| 0 | 0.98 | 289 | 43.4 | 37.4 |
| 2.5 | 1.04 | 321 | 46.5 | 40.5 |
| 5.0 | 1.07 | 336 | 48.7 | 42.5 |
| SEm± | 0.012 | 5.8 | 0.29 | 0.27 |
| CD (P=0.05) | 0.036 | 16.6 | 0.84 | 0.78 |
| *Zinc fortification to chickpea (kg/ha)* | | | | |
| 0 | 0.96 | 279 | 41.3 | 36.2 |
| 2.5 | 1.05 | 323 | 46.9 | 40.7 |
| 5.0 | 1.08 | 344 | 50.4 | 43.6 |
| SEm± | 0.011 | 5.1 | 0.27 | 0.27 |
| CD (P=0.05) | 0.032 | 14.2 | 0.75 | 0.77 |

NBF, Narrow bed and furrow

brought significant response on water productivity, production efficiency and Zn content in grain and stover of chickpea (Table 3). Application of 5.0 kg Zn/ha to chickpea resulted in significantly higher water productivity and production efficiency with an improvement of 13.0 and 3.6% in water productivity and 23.3 and 6.5% in production efficiency over the control and 2.5 kg Zn/ha respectively. The enhancement in production efficiency of chickpea with the application of 5.0 kg Zn/ha might be owing to higher additional returns through higher grain yield under this treatment as compared to additional cost involved. Fortification of chickpea with 5.0 kg Zn/ha was also recorded significantly higher content of Zn in grain as well as in stover as compared to lower levels. The increased Zn content attributed to greater absorption of Zn by the crop owing to higher availability in soil due to direct addition of zinc; otherwise the soil was deficit in available Zn. Sharma and Abrol (2007) also reported similar findings with zinc fertilization.

### *Residual effect of zinc fortification*

The residual effect of zinc fortification treatments applied to preceding pearlmillet crop were examined during both years of study and results of pooled analysis showed significant improvement in growth parameters of chickpea (Table 1). Significant effect of zinc fortification on plant height, number and dry weight of root nodules and length, volume and dry weight of root was observed only up to 2.5 kg Zn/ha, though application of 5.0 kg Zn/ha recorded the highest values of these parameters. Application of 5.0 kg Zn/ha to pearlmillet significantly enhanced the dry-matter accumulation/plant by 12.5 and 4.1% over the control and 2.5 kg Zn/ha respectively. The same treatment also recorded highest mean crop growth rate (CGR) of chickpea (Fig. 1). The yield attributes and yield of chickpea were also influenced significantly with residual effect of zinc fortification (Table 2). Wherein, application of 5.0 kg Zn/ha was at par with 2.5 kg Zn/ha and produced significantly higher number of secondary branches, number of pods, 1,000-grain weight and stover yield over the control. However, number of primary branches and grain yield of chickpea were improved significantly up to 5.0 kg Zn/ha. This treatment improved the number of primary branches by 9.4 and 3.6% and grain yield by 10.5 and 3.6% over the control and 2.5 kg Zn/ha respectively. Number of grains/pod and harvest index of chickpea were not varied significantly under treatments of residual zinc. The improvement in above parameters might be owing to improved status of available zinc in soil, because application of zinc to pearlmillet left residual effect, which resulted in increased supply and uptake of zinc by the succeeding chickpea crop and finally improved the growth parameters and yield attributes. Thus, positive impact on these characters led to significant improvement in yield of succeeding chickpea. Sammauria and Yadav (2008) in pearlmillet and Singh *et al.* (2013) in lentil also reported similar results with regards to residual effect of zinc.

Residual effect of zinc fortification also brought considerable improvement in water productivity, production efficiency and content of Zn in grain as well as in stover of chickpea (Table 3). Residual effect of 5.0 kg Zn/ha being at par with 2.5 kg Zn/ha, recorded significantly higher water productivity and production efficiency of chickpea over the control. However, content of Zn in grain and stover of chickpea increased significantly with increasing levels of residual zinc fortification and each level differ significantly to others. Application of 5.0 kg Zn/ha enhanced the content of Zn in grain by 12.2 and 4.7% and in stover by 13.6 and 4.9% over the control and 2.5 kg Zn/ha respectively. Jain and Dahama (2005) also reported improvement in content of Zn in grain and stover with residual effect of zinc.

### *Correlation*

Regression analysis between yield and yield attributes of chickpea showed highly significant and positive correlation of chickpea grain yield with number of primary branches/plant, number of pods/plant, number of grains/pod and 1,000-grain weight (Fig. 2).

It can be concluded that under limited moisture conditions and in zinc-deficient soils of arid and semi-arid areas, for achieving higher productivity of chickpea, the crop should be planted either on flat bed with 5.0 t/ha crop residue or narrow bed and furrow with 2.5 t/ha crop residue and fertilized with 5.0 kg Zn/ha.

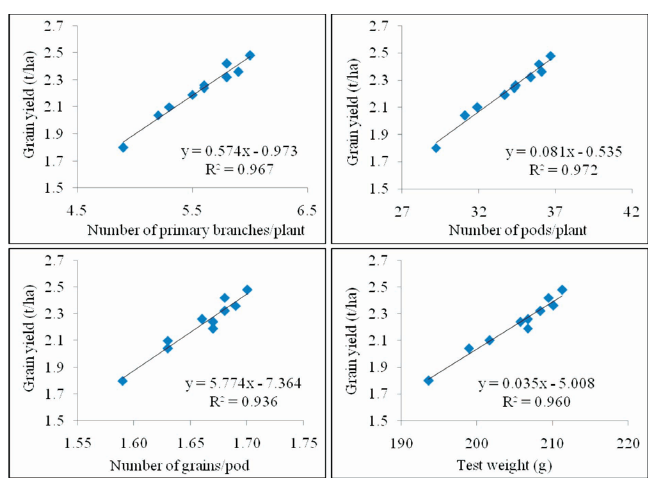


**Fig. 2.** Correlation and regression of chickpea grain yield with yield attributes (pooled data of 2 years)

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