Impact of moisture conservation practices, seed inoculation and zinc level on growth and yield of chickpea (*Cicer arietinum* L.)

Abstract

A field experiment was conducted during the *Rabi* season of 2020-21 and 2021-22, to study the impact of moisture conservation practices, seed inoculation and zinc level on growth and yield of chickpea in central plain zone of U.P. the experiment was laid out in split-split plot design with 27 treatment combination comprising of three moisture conservation practices *viz.* flat bed with 2.5 t/ha crop residue, narrow bed and furrow with 2.5 t ha^{-1} crop residue and broad bed and furrow with 2.5 t ha^{-1} crop residue in main plot and three seed inoculation *viz.* control, rhizobium and PSB in sub plot with three zinc level *viz.* control, 2.5 kg Zn ha^{-1} and 5.0 kg Zn ha^{-1} in sub-sub plot. Result shows that the broad bed and furrow with 2.5 t ha^{-1} crop residue produced significantly all growth parameters and yields attributes as compare to flat bed with 2.5 t ha^{-1} crop residue and narrow bed and furrow with 2.5 t ha^{-1} crop residue, respectively. The all growth parameters and yields attributes were significantly recorded higher under seed inoculation with rhizobium over PSB and control. The application of different dose of zinc produced marked significant variation in growth parameter and yield attributes when it increased up to 5.0 kg Zn ha^{-1}. The highest yields were significantly receive in broad bed and furrow with 2.5 t ha^{-1} crop residue over narrow bed and furrow with 2.5 t ha^{-1} crop residue and flat bed with 2.5 t ha^{-1} crop residue, respectively with percent increment 16.33, 24.65, 11.47 and 7.16 in respect of biological yield, grain yield, stover yield and harvest index, respectively over control in pooled data. Seed inoculation with rhizobium produced significantly higher yields parameter over control and PSB with percent increment 5.37, 7.72, 3.84 and 2.34 in biological yield, grain yield, stover yield and harvest index, respectively over control. Application of 5.0 kg Zn ha^{-1} were produced significantly higher yields with percent increment 6.24, 7.25, 5.56 and 1.01 over control in respect of biological yield, grain yield, stover yield and harvest index, respectively. Therefore, broad bed and furrow with 2.5 t ha^{-1} crop residue and rhizobium inoculation with dose of 5.0 kg Zn ha^{-1} were significantly superior in respect to growth and yield attributes and yields of chickpea in present investigation.

Keywords: Chickpea, broad bed and furrow, flat bed, narrow bed and furrow, rhizobium, PSB, zinc, yield.

Introduction

Chickpea (*Cicer arietinum* L.) occupies prominent position among the various pulse crop grown in India. India ranks first in the world in respect of production as well as acreage and produces 11.23 million tons chickpea grains from 10.56 million hectare area with an average productivity of 1063 Kg ha^{-1} during 2017-18. India contributes 71 per cent of chickpea production of the world (Anonymous, 2020). It is commonly used for human consumption as well as for feeding animals. Chickpea is considered to have medicinal effects and it is used for blood purification. Chickpea mostly grown on stored or residual soil moisture after harvest of *kharif* crops faces moisture stress throughout the life cycle. In rainfed areas, not all the rainfall received is available for the crops, but a significant part is lost as runoff and evaporation. Hence, concentrated efforts are needed to develop soil and moisture conservation practices to mitigate the water stress to maximize food production with minimum environmental degradation. *In-situ* application of crop residues and division of field into beds and furrows could be used as low-cost input technology, which helps to conserve more rainwater in soil by minimizing runoff of water from soil surface under water scarcity situations (Singh *et al.,* 2012).Land configuration plays a major role in minimizing soil erosion and improving water and nutrient use efficiency of field crops. Most of the crops normally grow on poor, marginal soils with imbalanced nutrient application (Ramesh *et al.* 2020).

Seed inoculation with Rhizobium increase the nodulation through better root development and improves nutrient availability which is beneficial in improving the grain yield. Phosphorus solubilizing bacteria is a cheapest source of phosphorus availability particularity in legume crops, which increase the productivity. PSB possess the ability to bring sparingly insoluble organic and inorganic phosphate into soluble forms by secreting organic acid.

Zinc is essential for the synthesis of chlorophyll and carbohydrates. This element plays an important role in the metabolism of nitrogen, synthesis of amino acid tryptophan, metabolism of starch, plants flowering and fruit set, increasing plant resistance to fungal disease and expanding plant roots (Bahure *et al.,* 2016). It improves grain yield, grain quality regulate the photosynthesis and govern other physio- biochemical processes besides helping root enlargement it increasing nitrogen fixation. Thus, in the present investigation an efforts was made to evaluate the effect of seed inoculation on soil fertility with asses the suitable moisture conservation practices and zinc dose for achieving yield production of chickpea.

2. Material and methods

The experiment was conducted during the *Rabi* season of 2020-21 and 2021-22. The experiment was laid out in spit-split plot design with three replication. The experiment was conducted with 27 treatment combination comprising three moisture conservation practices namely, flat bed with 2.5 t/ha crop residue, narrow bed and furrow with 2.5 t/ha crop residue, broad bed and furrow with 2.5 t/ha crop residue in main plot and three seed inoculation (control, rhizobium and PSB) in sub-plots and three zinc level (control, 2.5 kg zinc/ha and 5.0 kg zinc/ha) in sub- sub plot. The chickpea variety RVG 202 was used for field experiment during both the year 2020-21 and 2021-22. The experimental field was prepared after pre-sowing irrigation at proper moisture condition. The crop was fertilized as per the treatment. The recommended dose of nitrogen, phosphorus and potassium @ Recommended dose of fertilizers were applied to the crops during both the years in all plots. 20 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha were applied in all the plots as basal dose at the time of sowing. Urea, DAP, murate of potash were used as the source of nitrogen, phosphorus and potassium. After field preparation and before sowing of crop, the narrow beds of 70 cm wide with furrows of 30 cm width and broad beds of 90 cm wide with furrow of 30 cm width were prepared manually in respective plots. Paddy straw residue was applied in chickpea crop as per treatments just after sowing as moisture management treatments during both the years of study. Zinc was applied as per treatments through zinc sulphate ($ZnSO_4.7H_2O$) containing 21% Zn and 10% S at the time of sowing as basal dose. seeds of chickpea are inoculated with Rhizobium and PSB as per treatments one day before sowing treated seeds are spread in shades for 8-10 hours then after used for sowing. The soil of the experimental field was alluvial in origin, sandy loam in texture and slightly alkaline in reaction having pH 7.65 and 7.64, electrical conductivity 0.25 and 0.27 dSm^{-1}, Organic carbon percentage in soil is 0.10 and 0.12 per cent with available nitrogen 183.50 and 184.81 kg ha^{-1}, available phosphorus as sodium bicarbonate-extractable P was 12.20 and 12.42 kg ha^{-1}, available potassium was 173.00 and 177.50 kg $ha^{-1}$and DTPA extractable zinc 0.66 and 0.67 $mgkg^{-1}$ crop was done in both the seasons. Data obtained on grain yield were analyzed statistically.

Result and discussion

A. Growth parameters

Plant height

It is visualized from the data given in Table-1 Significantly highest plant height (39.52, 40.50 and 40.02 cm) was observed with broad bed and furrow with 2.5 t/ha crop residue while, the minimum plant height (34.72, 35.69 and 35.21 cm) was obtained under flat bed method in 2020-21, 2021-22 and pooled data study. The data revealed that the broad bed and furrow with 2.5 t/ha crop residue while produced significantly maximum plant height with percent increment 13.82, 13.47 and 13.66 over flat bed with 2.5 t/ha crop residue. Similar result was reported by Mishra *et al.* (2012b), Lal *et al.* (2014), Kumar *et al.* (2015), Chavan *et al.* (2016) and Gupta *et al.* (2020).

The data extracted from the Table 1 it can be resulted that the tallest plant height (37.50, 38.48 cm) was recorded under rhizobium which was significantly superior over PSB and control, the lowest plant height (36.70, 37.66 and 37.19 cm) was obtained in control during 2020-21 and 2021-22 and pooled data, respectively. The percent improvement in rhizobium 2.22, 2.17 and 2.15 over control. The results of present investigation are also in agreement with the findings of Gyandev *et al.* (2015), Chauhan *et al.* (2017) and Singh *et al*. (2019).

Significantly highest plant height (37.51, 38.50 and 38.01cm) was observed with 5.0 kg zinc/ ha during both the year and pooled data, respectively. While, the minimum plant height (36.56, 37.53 and 37.04 cm) was obtained under control (Table-1). The percent improvement was 2.59, 2.58 and 2.61 with application of zinc level 5.0 kg/ha over control. The consequences of the current investigation are additionally in concurrence with the investigation of Yadav *et al.* (2012), Singh and Bhati (2013), Chaudhary *et al.* (2014), Yadav *et al.* (2022) and Yadav *et al.* (2022).

Number of branches

Broad bed and furrow with 2.5 t/ha crop residue planted chickpea show significantly superior to narrow bed and furrow with 2.5 t/ha crop residue and flat bed with 2.5 t/ha crop residue during both the year of experiment with percentage increment in primary branches and secondary branches over flat bed with 2.5 t/ha crop residue of 40.57, 30.98 and narrow bed and furrow of 17.02, 12.08 in pooled analyzed data of both the year of experimentation, respectively (Table-1). The results of present investigation are also in agreement with the findings of Mishra *et al.* (2012b), Chavan *et al.* (2016) and Gupta *et al.* (2020)

It is visualized from the data given in Table-1 the data clearly indicate that response of seed inoculation to number of branches (primary and secondary) was increased in rhizobium compare to PSB and control. Chickpea sown under rhizobium at harvest stage performed maximum (3.99, 6.18) number of primary and secondary branches over PSB and control. The minimum (3.50, 5.57) number of primary and secondary branches is found in control. The percentage increment in primary and secondary branches over control of 14.0, 10.95 and PSB of

5.0, 3.0 in pooled analyzed data of experimentation, respectively. The consequences of the current investigation are additionally in concurrence with the investigation of Gyandev *et al.* (2015), Chauhan *et al.* (2017), Singh *et al*. (2019), Katiyar *et al.* (2020), and Yadav *et al.* (2022).

The data extracted from the Table 1 it can be resulted that the level of zinc directly applied to chickpea also bring significant effect on number of primary and secondary branches per plant during both the years. Application of 5.0 kg Zn/ha significantly enhanced the number of primary branches and remained at par with 2.5 kg/ha zinc with percentage increment by 2.09 and 5.40 per cent over 2.5 kg/ha zinc and control. In case of secondary branches Application of 5.0 kg Zn/ha significantly increases the number of secondary branches by percentage increment by 1.52 and 3.44 per cent over 2.5 kg/ha zinc and control respectively. The similar result also confirms the findings of Yadav *et al.* (2010) and Singh *et al.* (2011b)

Dry matter accumulation

Dry matter accumulation per plant during both the years of experimentation varied significantly with different moisture management practices. Chickpea sown under broad bed and furrow with 2.5 t/ha crop residue performed maximum (20.35, 21.20 and 20.77g) dry matter accumulation over narrow bed and furrow 2.5 t/ha crop residue and flat bed with 2.5 t/ha crop residue during both the year and pooled analysis (Table-1). The minimum (16.64, 17.49 and 17.06g) dry matter accumulation in flatbed 2.5 t/ha method. The result revealed that the dry matter accumulation significantly increased with the age of crop in broad bed and furrow with 2.5 t/ha crop residue which was more than flat bed with 2.5 t/ha crop residue and narrow bed and furrow with 2.5 t/ha crop residue. with percentage increment over flat bed with 2.5 t/ha crop residue 21.74 and narrow bed and furrow with 2.5 t/ha crop residue of 14.62 in pooled analyzed data of experimentation, respectively. The results of present investigation are also in agreement with the findings of Lal *et al.* (2014), Chavan *et al.* (2016) and Gupta *et al.* (2020)**.**

The data extracted from the Table 1 it can be resulted that the response of seed inoculation to dry matter accumulation was increased in rhizobium compare to control and PSB. Chickpea sown under rhizobium performed maximum (19.18g) dry matter accumulation over PSB and control. The minimum (18.20g) dry matter accumulation is found in control. The percentage increment over control of 5.38 and PSB of 3.22 in pooled analyzed data of experimentation, respectively. These results also confirms of the findings of Singh *et al.* (2019), Katiyar *et al.* (2020) and Benjelloun *et al.* (2021).

It is visualized from the data given in Table-1, Zinc application exerted a positive effect on grain yield where the significantly response noted up to 5.0 kg Zinc/ha in both the years of study, the maximum (18.83g) dry matter accumulation in 5.0 kg Zinc/ha which was at par with 2.5kg/ha Zn and the minimum (18.39) in control. The percentage increment over control of 2.33% and 2.5kg/ha Zn of 0.53 % in pooled analyzed data of experimentation, respectively. Similar result was reported by Singh and Bhati (2013), Chaudhary *et al.* (2014) Thenua *et al.* (2014) and Yadav *et al* (2022)

B. Yield attributes

Significantly higher number of pods per plant (35.54, 36.00 and 35.77) were observed under broad bed and furrow with 2.5 t/ha crop residue and proved significantly superior over narrow bed and furrow with 2.5 t/ha crop residue and flat bed with 2.5 t/ha crop residue during both the years and pooled analysis with percent improvement 33.81 over control on pooled basis. The results of present investigation are also in agreement with the findings of Paliwal *et al.* (2011), Mishra *et al.* (2012a). The result revealed that number of grains per pod of chickpea did not influence significantly due to different moisture conservation practices during both the years and also in pooled. Maximum number of grain per pod (1.41, 1.44 and 1.43) are obtained with broad bed and furrow with 2.5 t/ha crop residue and minimum (1.38, 1.39 and 1.39) with flat bed with 2.5 t/ha crop residue in 2020-21 and 2021-22 and pooled data (Table-2), respectively. The consequences of the current investigation are additionally in concurrence with the investigation of Kumar *et al.* (2015). Data revealed that the 1,000 grain weight of chickpea are significantly influenced by moisture conservation practices. broad bed and furrow with 2.5t/ha crop residue show significantly higher grain weight (192.29, 194.50 and 193.40 g) which were 8.45 per cent higher over flat bed with 2.5 t/ha crop residue in pooled data. Similar result was reported by Chavan *et al.* (2016) and Gupta *et al.* (2020).

Seed inoculated with rhizobium produced significantly higher no. of pod per plant (32.20, 32.59 and 32.39) which were (6.65, 3.00, 6.61 and 6.57, 2.61, 2.79) per cent higher over control and PSB, respectively, during both the years of study and pooled data (Table-2). Result clearly show that number of grains per pod of chickpea also found not significant due to different seed inoculation during both the years of experimentation. Maximum number of grain per pod (1.44 and 1.46) are obtained with rhizobium and minimum (1.35 and 1.38) with control during both the years of investigation. The percent improvement in rhizobium 6.61 over control in pooled analysis. 1000 seed weight of chickpea significantly influenced by seed inoculation. Seed inoculated with rhizobium produced significantly higher 1000 grain weight (187.06 and 189.53) in 2020-21 and 2021-22, rhizobium show 2.45 per cent increment over control on pooled basis. The consequences of the current investigation are additionally in concurrence with the investigation of Singh and Singh (2018), Singh *et al.* (2018), Singh *et al.* (2019), Katiyar *et al.* (2020) and Benjelloun *et al.* (2021).

Number of pods per plant were also influenced significantly with zinc level treatments. Significantly higher number of pods per plant of chickpea 31.82 and 32.34 were recorded with direct application of 5.0 kg Zn/ha as compared to lower levels during both the years of investigation. The per cent improvement in number of pods per plant with 5.0 kg Zn/ha was 4.19 and 1.72 during 2020-21 and 4.72 and 2.01 during 2021-22, respectively, over control and 2.5 kg Zn/ha. However, the effect of direct applied zinc to chickpea was found non-significant on number of grains per pod during both the years and in pooled analysis. The maximum number of grain per pod (1.41 and 1.44) are obtained with 5.0 kg zinc/ha and minimum (1.38 and 1.39) with 2.5 kg/ha zinc in 2020-21 and 2021-22, respectively (Table-2). Application zinc in chickpea with increasing levels of zinc up to 2.5 kg/ha significantly improved the 1,000 grain weight, further increase in levels of zinc to 5.0 kg/ha increased the 1,000 grain weight but the response was not to the level of significance. Wherein, application of 5.0 kg Zn/ha resulted in maximum weight of 1,000 grain (187.12 and 189.80 g) during 2020-21 and 2021-22. The results of present investigation are also in agreement with the findings of Shivay *et al.* (2014), Pal *et al.* (2019), Parmar *et al.* (2021) and Yadav *et al.* (2022).

C. Yields

Biological yield

Planting of chickpea under broad bed and furrow with 2.5 t/ha crop residue produced significantly higher biological yield (42.23 and 43.93 q/ha) as compared to flat bed with 2.5 t/ha crop residue and narrow bed and furrow with 2.5 t/ha crop residue during both the years of experimentation (Table-3). This treatment registered an improvement in biological yield by 15.38 and 7.10 per cent during 2020-21 and 17.30 and 7.67 per cent during 2021-22 over flat bed with 2.5 t/ha crop residue and narrow bed and furrow with 2.5 t/ha crop residue, respectively. The consequences of the current investigation are additionally in concurrence with the investigation of Kumar *et al.* (2015), Chavan *et al.* (2016) and Gupta *et al.* (2020).

Result clearly show that biological yield of chickpea inoculated with rhizobium produced significantly higher biological yield (40.46 and 41.87 q/ha) as compared to control and PSB during both the years of study (Table-3). This treatment registered an improvement in biological yield by 5.20 and 2.82 per cent during 2020-21 and 5.51 and 3.05 per cent during 2021-22 over control and PSB, respectively. These results also confirms of the findings of Chauhan *et al.* (2017), Singh *et al.* (2017), Singh and Singh (2018),Singh *et al.* (2018), Katiyar *et al.* (2020) and Benjelloun *et al.* (2021).

Increasing levels of zinc significantly increased biological yield of chickpea during both the years of study. Application of 5.0 kg Zn/ha to chickpea resulted into significantly higher biological yield (40.50 and 41.87 q/ha) over lower levels during both the years (Table-3). This treatment of direct applied zinc level increased the biological yield by 6.18 and 2.19 per cent during 2020-21 and 6.26 and 2.32 per cent during 2021-22 over control and 2.5 kg Zn/ha, respectively. The results of present investigation are also in agreement with the findings of Singh and Bhati (2013), Shivay *et al.* (2014), Parmar *et al.* (2021) and Yadav *et al* (2022).

Grain yield

The result revealed that grain yield was significantly increased at broad bed and furrow with 2.5 t/ha crop residue which was more than flat bed with 2.5 t/ha crop residue and narrow bed and furrow with 2.5 t/ha crop residue in first year and second year with percentage increment over flat bed with 2.5 t/ha crop residue of 24.65% and narrow bed and furrow with 2.5 t/ha crop residue of 11.15% in pooled analyzed data of experimentation, respectively (Table-3). The consequences of the current investigation are additionally in concurrence with the investigation of Kumar *et al.* (2015), Chavan *et al.* (2016) and Gupta *et al.* (2020).

The data clearly indicate that response of grain yield to used seed inoculation was increased in rhizobium compared to control and PSB during both year of study. The percentage increment over control of 7.72% and PSB of 4.29% in pooled analyzed data of experimentation, respectively (Table-3). The results of present investigation are also in agreement with the findings of Chauhan *et al.* (2017), Singh *et al.* (2017), Singh and Singh (2018), Singh *et al.* (2018), Katiyar *et al.* (2020) and Benjelloun *et al.* (2021).

It is clear from the result that zinc application exerted a positive effect on grain yield where the significantly response noted up to 5.0 kg Zinc/ha in both the years with percentage increment over control of 7.25% in pooled analyzed data (Table-3). These results also confirms of the findings of Singh *et al.* (2013), Shivay *et al.* (2014), Parmar *et al.* (2021) and Yadav *et al* (2022).

Stover yield

The result revealed that stover yield was significantly increased at broad bed and furrow with 2.5 t/ha crop residue which was more than flat bed with 2.5 t/ha crop residue and narrow bed and furrow with 2.5 t/ha crop residue in first year and second year with percentage increment over flat bed with 2.5 t/ha crop residue of 11.47% and narrow bed and furrow with 2.5 t/ha crop residue of 5.02% In pooled analyzed data of experimentation, respectively (Table-3). The consequences of the current investigation are additionally in concurrence with the investigation of Kumar *et al.* (2015), Chavan *et al.* (2016) and Gupta *et al.* (2020)**.**

The data clearly indicate that response of stover yield to used seed inoculation was increased in rhizobium compare to control and PSB during both year of study (Table-3). The percentage increment over control of 3.84% and PSB of 2.07% in pooled analyzed data of experimentation, respectively. These results also confirms of the findings of Singh and Singh (2018), Singh *et al.* (2018), Katiyar *et al.* (2020) and Benjelloun *et al.* (2021)**.**

It is clear from the result that zinc application exerted a positive effect on stover yield where the significantly response noted up to 5.0 kg Zinc/ha in both the years with percentage increment over control of 5.56% and 2.5 kg/ha zinc of 1.57% in pooled analyzed data(Table-3). The results of present investigation are also in agreement with the findings of Jyothi *et al.* (2013), Shivay *et al.* (2014), Parmar *et al.* (2021) and Yadav *et al* (2022).

Harvest index

Sowing of chickpea under broad bed and furrow with 2.5 t/ha crop residue produced significantly higher harvest index (39.64 and 39.90%) as compared to flat bed with 2.5 t/ha crop residue and narrow bed and furrow with 2.5 t/ha crop residue during both the years of experimentation. This treatment registered an increment in harvest index by 6.64 and 3.39 per cent during 2020-21 and 7.60 and 3.63 per cent during 2021-22 over flat bed with 2.5 t/ha crop residue and narrow bed and furrow with 2.5 t/ha crop residue, respectively (Table-3). The results of present investigation are also in agreement with the findings of Kumar *et al.* (2015), Chavan *et al.* (2016) and Gupta *et al.* (2020).

Seed inoculated with rhizobium produced significantly higher harvest index (38.86 and 38.95%) as compared to control and PSB during both the years of study (Table-3). This treatment registered an increment in harvest index by 2.39 and 1.35 per cent during 2020-21 over control and PSB and 2.25 per cent during 2021-22 over control, respectively. Where as in second year PSB show similar result with rhizobium. The consequences of the current investigation are additionally in concurrence with the investigation of Chauhan *et al.* (2017), Katiyar *et al.* (2020) and Benjelloun *et al.* (2021).

Zinc level was remained non-significant on harvest index of chickpea during both the years of experimentation. Maximum harvest index (38.64 and 38.68) obtained with 5.0 kg zinc/ha during both the years of study (Table-3). These results also confirms of the findings of Jyothi *et al.* (2013), Parmar *et al.* (2021) and Yadav *et al.* (2022).

Conclusion

Based on the above result, it can be concluded that the broad bed and furrow with 2.5 t/ha crop residue is superior over the remaining moisture conservation practices with use of seed inoculation of rhizobium and dose of 5.0 kg zinc/ha in respect to growth parameter, yield attributing characters and yields. Thus broad bed and furrow with 2.5 t/ha crop residue and rhizobium with 5.0 kg zinc/ha may be recommended to realize higher yields of chickpea for farmers.

References

Anonymuos, 2020. *DES, Ministry of Agri. &FW (DAC&FW) Govt. of India.*

Bahure, G.K., Mirza, I.A.B., Bankar, A.N., Puri, A.N., Sirsath, M.K. 2016. Effect of foliar application of zinc, iron and magnesium on growth, yield and quality of soyabean (*Glycine max* L.) Merill. *Asian Journal of Multidisciplinary studies*, 4(3): 19-22.

Benjelloun, I.; Thami Alami, I.; El Khadir, M.; Douira, A.; Udupa, S.M. 2021. Co-Inoculation of *Mesorhizobium ciceri* with Either *Bacillus* sp. or *Enterobacter aerogenes* on Chickpea Improves Growth and Productivity in Phosphate-Deficient Soils in Dry Areas of a Mediterranean Region. *Plants*, ***10,*** 571.

Chaudhary, Seema, Singh, H., Singh, S. and Singh, V. 2014. Zinc requirement of green gram (*Vigna radiata*)-wheat (*Triticum aestivum*) crop sequence in alluvial soil. *Indian Journal of Agronomy* **59**(1): 48-52.

Chauhan, S.V.S. and Singh, R. B. 2017. Effect of phosphorus and phosphate solubilizing bacteria on growth, yield and quality of chickpea (*Cicer arietinum* L.). *Annals of Plant and Soil Research*, **19**(3): 303-306.

Chavan, S., Mansur, C.P. and Shantveerayya 2016. Soil moisture storage and productivity of chickpea as influenced by *in situ* moisture conservation practices in model watershed area *Advances in Life Sciences* **5**(3):1068-1073.

Fisher, R A., and Yates, F., 1975, Statistical tables for biological, agricultural and medical research. 6. Aufl. Oliver & Boyd, London 1963. 146 S. Preis 30 s 7(2): 124-125.

Gupta, R., Chundawat, G.S., Aswani, R.C. and Sarathe, A. 2020. Performance Evaluation of Tractor Operated Furrow Irrigated Raised Bed Seed Drill for Chickpea Production. *Advances in. Bioreasearch* **11** (2) 2020: 141-144.

Gyandev, Kurdikeri, B. M. B. and Salimath, P. M. 2015. Effect of seed treatment on plant growth, seed yield and Quality of chickpea varieties. *International Journal of Agricultural Science and Research*, **5**(6):61-66.

Jackson, M.L. 1973. Soil chemical analysis, Prentice Hall of India, Pvt. Ltd., New Delhi, pp. 111-204.

Jyothi, C.N., Ravichandra, K. and Babu, K.S. 2013. Effect of foliar supplementation of nitrogen and zinc on soybean (*Glycine max* L.) yield, quality and nutrient uptake. *Indian Journal of Dryland Agricultural Research and Development* **28**(2): 46-48.

Katiyar, D., Kumar, S. and Singh, N. 2020. Effect of Rhizobium and PSB inoculation on growth, yield attributes and yield of chickpea (*Cicer arietinum* L.). *International Journal of Chemical Studies* **8**(4): 3729-3734.

Kumar, D.; Arvadiya, L.K.; Desai, K.L.; Usadadiya, V.P. and Patel, A.M. 2015. Growth and yield of chickpea (*Cicer arietinum* L.) as influenced by graded levels of fertilizers and bio fertilizers. *The Bioscan*, **10**(1): 335-338.

Kumar, N., Singh, M.K., Praharaj, C.S., Singh, U. and Singh, S.S. 2015. Performance of chickpea under different planting method, seed rate and irrigation level in Indo-Gangetic Plains of India. *Journal of Food Legumes* **28**(1): 40-44.

Lal, B., Rana, K.S., Rana, D.S., Gautam, Priyanka, Shivay, Y.S., Ansari, M.A., Meena, B.P. and Kumar, K. 2014. Influence of intercropping, moisture conservation practice and P and S levels on growth, nodulation and yield of chickpea (*Cicer arietinum* L.) under rainfed condition. *Legume Research* **37**(3): 300-305.

Lindsay, W.I. and Norvell, W.A. 1978. Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal* **42**: 421-448.

Mishra, J.P., Praharaj, C.S. and Singh, K.K. 2012b. Enhancing water use efficiency and production potential of chickpea and fieldpea through seed bed configurations and irrigation regimes in North Indian plains. *Journal of Food Legumes* **25**(4): 310-313.

Mishra, J.P., Praharaj, C.S., Singh, K.K. and Kumar, N. 2012a. Impact of conservation practices on crop water use and productivity in chickpea under middle Indo-Gangetic plains. *Journal of Food Legumes* **25**(1): 41-44.

Olsen, S.R., Cole, C.L., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circular No. 939, Washington, pp. 72-75.

Paliwal, D.K., Kushwaha, H.S. and Thakur, H.S. 2011. Performance of soybean (*Glycine max*)-wheat (*Triticum aestivum*) cropping system under land configuration, mulching and nutrient management. *Indian Journal of Agronomy* **56**(4): 334-339.

Pal, V., Singh, G. and Dhaliwal, S.S. 2019. Agronomic biofortification of chickpea with zinc and iron through application of zinc and urea. *Communication in soil science and plant analysis* **50**(15):1864-1877.

Parmar, P.M., Poonia, T.C. and Raiyani, V.N. 2021. Agronomic Biofortification of Zinc in Chickpea Varieties in Calcareous Soil. *Legume Research*.:10.18805/LR-4677.

Ramesh, T., Rathika, S., Nagarajan, G., & Shanmugapriya, P. 2020. Land configuration and nitrogen management for enhancing the crop productivity: A review.

Ram, H., Singh, Y., Saini, K. S., Kler, D. S., Timsina, J., & Humphreys, E. J. 2012. Agronomic and economic evaluation of permanent raised beds, no tillage and straw mulching for an irrigated maize-wheat system in northwest India. *Experimental Agriculture*, 48(1), 21-38.

Richards, L.A. 1954. Diagnosis and improvement of saline alkaline soils. In USDA Handbook No. 60, Washington, pp. 111-112.

Singh, A.; Sachan, A.K.; Pathak, R.K. and Srivastava, S. 2018. Study on the Effects of PSB and *Rhizobium* with their combinations on nutrient concentration and uptake of chickpea (*Cicer arietinum* L.). *Journal of Pharmacognosy and Phytochemistry,* **7**(1): 1591-1593.

Singh, A.K. and Bhati, B.P. 2013. Effect of foliar application of zinc on growth and seed yield of late-sown lentil (*Lens culinaris*). *Indian Journal of Agricultural Sciences* **83**(6): 622-626.

Singh, A. K.; Chovatia, P. K.; Kathiria, R.K. and Savaliya, N. V. 2019. Effect of integrated nutrient management on growth, yield and economics of chickpea (*Cicer arietinum* L.). *International Journal of Chemical Science.* **7**(3): 3048-3050.

Singh, A.K., Meena, M.K., Bharati, R.C. and Gade R.M. 2013. Effect of sulphur and zinc management on yield, nutrient uptake, changes in soil fertility and economics in rice (*Oryza sativa*)-lentil (*Lens culinaris*) cropping system. *Indian Journal of Agricultural Sciences* **83**(3): 344-348.

Singh, G., Sekhon, H.S. and Kaur, H. 2012. Effect of farmyard manure, vermicompost and chemical nutrients on growth and yield of chickpea (*Cicer arietinum* L.). *International Journal of Agricultural Research* **7**(2): 93-99.

Singh, Y.; Singh, B. and Kumar, A. 2017. Response of Phosphorus Levels and Seed Inoculation with PSB and *Rhizobium* on Economic and Response Studies of Chickpea (*Cicer arietinum* L.) under Rainfed Condition. *International Journal of Current Microbiology and Applied Sciences*, **6**(11): 801-805.

Shivay, Y.S., Prasad, R. and Madan Pal. 2014. Effect of variety and zinc application on yield, profitability, protein content and zinc and nitrogen uptake by chickpea (*Cicer arietinum*). *Indian Journal of Agronomy* **59**(2): 317-321.

Subbaih, B. V. and Asija, C. L. 1954. Soil microbiology. Fourth Edition of Soil Microorganisms and Plant Growth. *Oxford and IBH Publishing*, New Delhi.

Thenua, O.V.S., Singh, K., Vivek Raj and Singh, J. 2014. Effect of sulphur and zinc application on growth and productivity of soybean [*Glycine max* (L.) Merrill] in northern plain zone of India. *Annals of Agricultural Research* **35**(2): 183-187.

Walkley, A. J. and Black, I. A. 1934. Estimation of soil organic carbon by the chromic acid titration method. *Soil Sci.* **37**:29-38.

Yadav, L.R., Choudhary, P., Santosh, Sharma, O.P. and Choudhary, M. 2012. Effect of phosphorus and zinc on yield and economics of mothbean under semi-arid conditions. *Journal of Food Legumes* **25**(4): 361-363.

Yadav, A., Singh, D., Kumar, R., Sachan, R., Kumar, K., Singh, A., & Singh, K. K 2022. Response of Different Level of Phosphorus, Zinc and Rhizobium Inoculation on Growth Yield Attributes and Yield of Chickpea (*Cicer aretinum* L.). *International Journal of Environment and Climate Change* 12(11): 1954-1964.

Yadav, A., Singh, D., Kumar, R., Sachan, R., Kumar, K., Singh, A., ... & Singh, K. K. Response of Different Level of Phosphorus, Zinc and Rhizobium Inoculation on Growth Yield Attributes and Yield of Chickpea (Cicer aretinum L.). *International Journal of*

Environment and Climate Change 12(11): 1954-1964, 2022; Article no.IJECC.91154
ISSN: 2581-8627

Table 1. Plant height, primary and secondary branches and dry matter accumulation as influenced by moisture conservation practices, seed inoculation and zinc level

Treatment	Plant height (cm)			Primary branches			Secondary branches			Dry matter accumulation g/plant		
	2020-21	2021-22	pooled	2020-21	2021-22	pooled	2020-21	2021-22	pooled	2020-21	2021-22	pooled
A. Moisture conservation practices												
Flat bed + 2.5 t/ha crop residue	34.72	35.69	35.21	3.08	3.18	3.13	4.93	5.27	5.10	16.64	17.49	17.06
NBF + 2.5 t/ha crop residue	37.12	38.11	37.62	3.71	3.80	3.76	5.80	6.13	5.96	17.69	18.54	18.12
BBF + 2.5 t/ha crop residue	39.52	40.50	40.02	4.35	4.44	4.40	6.51	6.85	6.68	20.35	21.20	20.77
S.Em. ±	0.157	0.093	0.097	0.014	0.009	0.013	0.018	0.006	0.012	0.070	0.116	0.101
CD at 5%	0.612	0.362	0.378	0.056	0.034	0.051	0.070	0.025	0.047	0.274	0.455	0.392
B. Seed inoculation												
Control	36.70	37.66	37.19	3.45	3.54	3.50	5.40	5.73	5.57	17.77	18.62	18.20
Rhizobium	37.50	38.48	37.99	3.94	4.02	3.99	6.01	6.36	6.18	18.75	19.60	19.18
PSB	37.16	38.16	37.66	3.75	3.85	3.80	5.83	6.16	6.00	18.15	19.00	18.58
S.Em. ±	0.191	0.128	0.121	0.012	0.007	0.012	0.022	0.017	0.026	0.086	0.104	0.085
CD at 5%	0.587	0.394	0.373	0.037	0.020	0.036	0.067	0.053	0.079	0.263	0.321	0.260
C. Zinc level												
Control	36.56	37.53	37.04	3.62	3.70	3.66	5.67	5.95	5.81	17.96	18.81	18.39
2.5 kg Zn/ha	37.30	38.28	37.79	3.73	3.82	3.78	5.77	6.11	5.92	18.31	19.16	18.73
5.0 kg Zn/ha	37.51	38.50	38.01	3.79	3.90	3.84	5.80	6.19	6.01	18.40	19.25	18.83
S.Em. ±	0.186	0.155	0.142	0.021	0.019	0.024	0.033	0.032	0.026	0.061	0.089	0.097
CD at 5%	0.535	0.444	0.407	0.061	0.056	0.069	0.093	0.091	0.075	0.174	0.254	0.278

Table 2. Yield attributes as influenced by moisture conservation practices, seed inoculation and zinc level

Treatments	No. of pod/plant			No. of grain/pod			1000 seed weight		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
A. Moisture conservation practices									
Flat bed + 2.5 t/ha crop residue	26.56	26.91	26.73	1.38	1.39	1.39	177.08	179.58	178.33
NBF + 2.5 t/ha crop residue	31.54	32.01	31.78	1.39	1.41	1.40	185.15	187.48	186.32
BBF + 2.5 t/ha crop residue	35.54	36.00	35.77	1.41	1.44	1.43	192.29	194.50	193.40
S.Em. ±	0.079	0.057	0.108	0.014	0.015	0.014	0.520	0.729	0.638
CD at 5%	0.307	0.224	0.423	NS	NS	NS	2.030	2.848	2.493
B. Seed inoculation									
Control	30.19	30.58	30.38	1.35	1.38	1.36	182.63	184.94	183.79
Rhizobium	32.20	32.59	32.39	1.44	1.46	1.45	187.06	189.53	188.30
PSB	31.26	31.76	31.51	1.39	1.42	1.40	184.83	187.09	185.96
S.Em. ±	0.052	0.069	0.150	0.017	0.012	0.012	0.493	0.608	0.547
CD at 5%	0.160	0.212	0.462	NS	NS	NS	1.520	1.872	1.685
C. Zinc level									
Control	30.54	30.88	30.71	1.38	1.39	1.38	181.99	184.00	183.00
2.5 kg Zn/ha	31.28	31.70	31.52	1.40	1.42	1.41	185.40	187.75	186.58
5.0 kg Zn/ha	31.82	32.34	32.06	1.41	1.44	1.42	187.12	189.80	188.46
S.Em. ±	0.108	0.110	0.133	0.013	0.014	0.014	0.676	0.705	0.591
CD at 5%	0.310	0.317	0.382	NS	NS	NS	1.939	2.023	1.695

Table 3. Yields as influenced by moisture conservation practices, seed inoculation and zinc level

Treatments	Biological yield(q/ha)			Grain yield (q/ha)			Stover yield(q/ha)			HI (%)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
A. Moisture conservation practices												
Flat bed + 2.5 t/ha crop residue	36.60	37.45	37.03	13.61	13.89	13.75	22.99	23.56	23.27	37.17	37.08	37.12
NBF + 2.5 t/ha crop residue	39.43	40.80	40.12	15.12	15.71	15.42	24.31	25.09	24.70	38.34	38.50	38.42
BBF + 2.5 t/ha crop residue	42.23	43.93	43.08	16.75	17.53	17.14	25.49	26.40	25.94	39.64	39.90	39.78
S.Em. ±	0.156	0.247	0.210	0.087	0.047	0.075	0.100	0.063	0.065	0.141	0.159	0.073
CD at 5%	0.608	0.965	0.819	0.338	0.184	0.291	0.389	0.248	0.255	0.551	0.619	0.285
B. Seed inoculation												
Control	38.46	39.68	39.07	14.62	15.15	14.89	23.84	24.53	24.19	37.95	38.09	38.02
Rhizobium	40.46	41.87	41.17	15.74	16.34	16.04	24.72	25.53	25.12	38.86	38.95	38.91
PSB	39.35	40.63	39.99	15.11	15.65	15.38	24.24	24.98	24.61	38.34	38.44	38.39
S.Em. ±	0.188	0.225	0.179	0.064	0.059	0.047	0.123	0.084	0.080	0.139	0.175	0.094
CD at 5%	0.580	0.693	0.551	0.198	0.181	0.146	0.380	0.260	0.246	0.428	0.538	0.291
C. Zinc level												
Control	38.14	39.40	38.77	14.63	15.15	14.89	23.51	24.25	23.88	38.28	38.36	38.32
2.5 kg Zn/ha	39.63	40.92	40.28	15.18	15.73	15.45	24.45	25.19	24.82	38.23	38.35	38.29
5.0 kg Zn/ha	40.50	41.87	41.19	15.68	16.27	15.97	24.83	25.60	25.21	38.64	38.78	38.71
S.Em. ±	0.132	0.189	0.208	0.070	0.082	0.074	0.121	0.102	0.093	0.212	0.206	0.154
CD at 5%	0.379	0.541	0.597	0.200	0.234	0.212	0.347	0.292	0.266	NS	NS	NS