

Response of different level of phosphorus, zinc and rhizobium inoculation on growth yield attributes and yield of chickpea(*Cicer arretinum*L.)

Abstract:

The present field experiment was conducted during Rabi season of 2020-21 and 2021-22 at the Student's Instructional Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh. **The objective of this research was to evaluate the Response of different level of phosphorus, zinc and rhizobium inoculation on growth and yield attributes of chickpea(*Cicer arretinum*L.).** The experiment comprised of 18 treatment combinations in Factorial randomized block design with three replications. Result showed that among the growth parameters such as maximum plant height (48.56 cm) at 90 DAS, number of nodules (31.27) at 60 DAS, dry weight of nodules (185.77 mg) at 60 DAS and number of branches (18.12), similarly among yield attributes and yield viz. number of pod plant⁻¹(69.54), number of grains pod⁻¹(1.78), 100 grain weight(20.19 gm), grain yield (20.89 q ha⁻¹) and stover yield (25.26 q ha⁻¹) were recorded under T₁₈ (P₆₀+Zn_{2.5}+ *rhizobium*) during second year (2021-22) of experimentation. Application of phosphorous, zinc and rhizobium inoculation significantly increase growth, yield and yield attributes of chickpea during the both year of experimentation. The present study showed that application of phosphorus, zinc and rhizobium inoculation along with recommended nitrogen and potassium could be effective option for enhancing chickpea growth parameters, yield attributes and yield of chickpea.

Key Words: Chickpea, Phosphorous, Rhizobium, Yield and Zinc

Introduction

Pulses are the most predominated crop after cereal crop in India. It is an easily available source of dietary protein in the rural heart of India and the best crop for sustainable and restoring soil fertility of soil. Pulses provide significant nutritional and health benefits and are known to reduce several non-communicable diseases such as colon cancer and cardiovascular diseases (**Jukantiet al. 2012**). India is the largest producer and consumer of pulses in the world. Major pulses grown in India include chickpea, pigeonpea, lentil, urd bean, mung bean, pea, lablab bean, moth bean, and horse bean. Among the pulses, chickpea is the most important growing in every part of India. Chickpea (*Cicer arretinum* L.) is one of the

pre-dominant *Rabi* crop in pulse-growing areas in India. It is originated in south eastern turkey (**Redden *et al.* 2007**). Chickpea is mainly cultivated in the cool, dry season of the semi-arid tropical region. The plant is well adapted to tropical climates with moderate temperatures and is successfully cultivated under irrigation in the cool season of many tropical countries (**Bejiga and Van der Maesen, 2006**). It is a major legume crop cultivated for its edible seeds legume of the family *Fabaceae*(*leguminaceae*), and subfamily *Papilionaceae*. It provides protein rich diet to the vegetarian of the Indian and complements the staple cereals in the diet with proteins, essential amino acids, vitamins and minerals (**Pingoliya *et al.* 2013**). Many attractive dishes viz – sweets, snacks and namkeen are also prepared from its flour called besan. Also eaten as whole fried or boiled and salted. Fresh green leaves (sag) are used as vegetables and green grains as hare chhole or chholia. The straw of gram is an excellent fodder while both husk and bits of ‘Dal’ are valuable cattle feed. Leaves consist of mallic and citric acid and are very useful for stomach ailments and bloodpurifiers. Nutritive value Chickpea grain contains Protein – 18-22%, Calcium – 280 mg/100 g, Carbohydrate – 61-62%, Iron–12.3 mg/100 g, Fat – 4.5 %, Phosphorus–301 mg/100 g Calorific value –396 kcal/100gm (**The Nutritive value of Indian Foods & the planning satisfactory Diets, ICMR**).

India is the largest producer (25% of global production), consumer (27% of world consumption) and importer (14%) of pulses in the world. India ranks first in the world in terms of pulse production (25% of total world's production) (FAOSTAT 2017). In India chickpea occupies 10.17 million ha area, with a production of 11.35 million tonnes registering the productivity of 1116 kg/ha. In Uttar Pradesh, chickpea crop occupied 0.62 million hectares area, 0.85 million tonnes production and 1371 kg/ha productivity (**Anonymous, 2021**).

Include a brief introduction for link the information between the two paragraphs

Phosphorus also plays an important role in the build-up and maintenance of soil productivity by legumes through its effect on host plant growth and through its specific effect on Rhizobium growth, survival, and nodulation capability. Phosphorus is one of the essential nutrients for legume growth and BNF (**Mhango *et al.*, 2008**). Symbiotic nitrogen fixation has a high P demand because the process consumes large amounts of energy (**Schulze *et al.*, 2006**) and energy generating metabolism strongly depends upon the availability of P (**Plaxton, 2004**). It plays a key role in various physiological processes some particular plant growth factors that are root development, vigorous stem, enhanced flower formation and seed

production, earlier and more uniform crop maturity, increase nitrogen fixing capacity of legumes, improvement in crop quality and resistance to plant diseases (**Rehanet et al. 2018**). Nodules themselves are strong sinks for P and nodulation and Nitrogen fixation are strongly influenced by P availability.

Zinc is also involved directly in the biosynthesis of plant hormones including indole acetic acid and in maintaining normal auxine concentration in tissues. It plays a vital role in the synthesis of protein and nucleic acid and helps in the utilization of nitrogen and phosphorus in plants. It also promotes nitrogen fixation through nodulation in leguminous crops. Zn solubility decreases markedly above pH 6.065 and thus Zn deficiencies can be encountered in neutral to alkaline soils. Phosphorus and Zinc application improved the fertility status of soil and produce higher grain yield of chickpea. In agriculture can be improved by inoculation of legume crops with suitable *Rhizobium*. Knowledge of the biodiversity of *Rhizobia* and of local populations is important for the design of successful inoculation strategies (**Lindström et al., 2010**). Formation of an effective symbiosis requires the existence of specific rhizobia in the soil that can nodulate host legume or inoculation of with effective rhizobia, and suitable environmental factors. The major abiotic factors that affect effective symbiosis are; nutrient, pH, temperature, water holding capacity, water stress, salinity and nitrogen level are the major factors affecting BNF (**Panchali, 2011**). The *Rhizobium* legume symbiotic relationship is highly specific and most legume plants form association with only a limited number of the *Rhizobium* strain (**Subba Rao. 1999**). There is a good possibility to increase its production by exploiting better colonization of the roots and rhizospheres through application of effective nitrogen fixing bacteria to the seed or to the soil. Microbial inoculants are cost-effective, eco-friendly, and renewable sources of plant nutrients (**Khan et al. 2007**).

Therefore, the objective of this research was to evaluate.....

Methods & Materials

The experiment was laid out in at the SIF Farm of CSAUA&T, Kanpur, Uttar Pradesh. It is located on 25°18' N latitude, 83° 03' E longitude and at an altitude of 80.71 meters above mean sea level. Experimental site area, Kanpur is situated in the central part of U.P. and have sub-tropical climate, characterized by hot summer and cool winters. Total rainfall received during the crop growing period was 15.90 mm during the period from 2020-21 and 2021-22 to study the effect of phosphorus, zinc and rhizobium on growth and yield

attributes of chickpea and the improvement of soil health of the research area. The experiment was consisted of three factors: Factor A: Phosphorus (3 levels); P₀: 0 kg (Control), P₁: 30 kg, and P₂: 60 kg P₂O₅; Factor Zn: (3 levels): Zn₀: 0 kg (Control), Zn₁ : 2.5 kg and Zn₂: 5 kg Zn ha⁻¹. The experiment was laid out in Factorial Randomized Complete Block Design (FRBD) with three replications. Full dose of nitrogen and potash were applied at the time of sowing homogeneously. Phosphorus, zinc and *rhizobium* were applied as per treatments. N, P, K and Zinc were applied through urea, SSP, Murate of potash and zinc sulphate respectively. The crop received two uniform irrigations (pre sowing and pre flowering).The crop was grown by adopting standard agronomic practices. The crop was harvested in the last week of March in both the years and growth and growth attributes were recorded at harvest.The nutrient status of initial soil prior to fertilization is presented in table-1

Table 1: Analytical data of the experimental soils (pre-sowing)

| S. No. | Soil characters | Value | |
|--------|--|------------|------------|
| | | 2020-21 | 2021-22 |
| | Texture | Sandy loam | Sandy loam |
| 1. | pH (1:2.5 soil water suspension) | 8.00 | 7.98 |
| 2. | EC (dsm ⁻¹) (1:2.5 soil water suspension) | 0.47 | 0.46 |
| 3. | Organic carbon (%) | 0.31 | 0.32 |
| 4. | Available N (kg ha ⁻¹) | 201.12 | 202.59 |
| 5. | Available P (kg ha ⁻¹) | 11.78 | 12.09 |
| 6. | Available K (kg ha ⁻¹) | 153.15 | 154.31 |
| 7. | Available S (kg ha ⁻¹) | 0.43 | 0.45 |
| 8. | Available Zinc (mg kg ⁻¹) | 11.84 | 12.49 |

The soil samples was analysed for pH, EC by (Jackson 1967) and organic carbon by the method described by (Walkley and Black, 1934). Available N was determining by alkaline

per magnate method as described by Subbiah and Asija (1956). Available phosphorus was extracted with 0.5 M NaHCO₃ (Olsen *et al.* 1954). The available K was determined by flame photo meter (Troth and Prince 1969). Available sulphur was determined by Turbidimetric method (Chesnin and Yien 1950), Available zinc was determined by DTPA extraction (Lindsay and Norvell 1978).

Table -2: detail of the treatment combinations:

| S. N. | Treatment combination | Symbol |
|-------|--|---|
| 1. | 0 kg P+0 kg Zn without <i>rhizobium</i> | P₀ Zn₀ Rh₀ |
| 2. | 0 kg P+2.5 kg Zn without <i>rhizobium</i> | P₀ Zn_{2.5} Rh₀ |
| 3. | 0 kg P+5 kg Zn without <i>rhizobium</i> | P₀ Zn₅ Rh₀ |
| 4. | 30 kg P+0 kg Zn without <i>rhizobium</i> | P₃₀ Zn₀ Rh₀ |
| 5. | 30 kg P+2.5 kg Zn without <i>rhizobium</i> | P₃₀ Zn_{2.5} Rh₀ |
| 6. | 30 kg P+5 kg Zn without <i>rhizobium</i> | P₃₀ Zn₅ h₀ |
| 7. | 60 kg P+0 kg Zn without <i>rhizobium</i> | P₆₀ Zn₀ Rh₀ |
| 8. | 60 kg P+2.5 kg Zn without <i>rhizobium</i> | P₆₀ Zn_{2.5} Rh₀ |
| 9. | 60 kg P+5 kg Zn without <i>rhizobium</i> | P₆₀ Zn₅ Rh₀ |
| 10. | 0 kg P+0 kg Zn with <i>rhizobium</i> | P₀ Zn₀ Rh₁ |
| 11. | 0 kg P+2.5 kg Zn with <i>rhizobium</i> | P₀ Zn_{2.5} Rh₁ |
| 12. | 0 kg P+5 kg Zn with <i>rhizobium</i> | P₀ Zn₅ Rh₁ |
| 13. | 30 kg P+0 kg Zn with <i>rhizobium</i> | P₃₀ Zn₀ Rh₁ |
| 14. | 30 kg P+2.5 kg Zn with <i>rhizobium</i> | P₃₀ Zn_{2.5} Rh₁ |
| 15. | 30 kg P+5 kg Zn with <i>rhizobium</i> | P₃₀ Zn₅ Rh₁ |
| 16. | 60 kg P+0 kg Zn with <i>rhizobium</i> | P₆₀ Zn₀ Rh₁ |
| 17. | 60 kg P+2.5 kg Zn with <i>rhizobium</i> | P₆₀ Zn_{2.5} Rh₁ |
| 18. | 60 kg P+5 kg Zn with <i>rhizobium</i> | P₆₀ Zn₅ Rh₁ |

Observation Recorded

The observations for evaluation of the treatment effects were recorded on various plant characters during the course of investigation. In the present investigation, the plants were selected randomly in each plot and tagged with a level for recording various observations on growth and yield parameters. The Plant height, number of nodules plant⁻¹, dry wt. of nodules plant⁻¹, grain, straw and biological yield were recorded following standard procedures.

Harvesting and threshing: the crop was harvested at maturity and was allowed to dry in sun. Separate bundles were made for each plot and weighted. The after drying harvest was threshed manually.

Grain yield (q ha⁻¹)

After threshing the grain yield from each plot was separately weighed and recorded after converting into quintals per hectare.

Stover yield (q ha⁻¹)

After subtracting the grain yield per plot from the total biological yield. After converting the yields into quintals per hectare, yields were recorded.

Biological yield (q ha⁻¹)

Seed yield and Stover yield together were regarded as biological yield. The biological yield was calculated with the following formula

$$\text{Biological yield} = \text{Seed yield} + \text{Stover yield}$$

Statistical analysis: The growth parameters and yields were recorded and analyzed as per Gomez and Gomez (1984) the tested at 5% level of significance to interpret the significant differences.

Result and discussion

Growth Parameters

Generally, Growth is a genetically controlled character. But several studies found that the growth can be increased by use of appropriate doses of fertilization. Significantly increased growth characteristics viz. plant height, number of branch plant⁻¹, number of nodules plants⁻¹ and dry weight of nodule plant⁻¹ use of different level (0, 30 And 60 kg ha⁻¹). The number increasing level of various doses of phosphorus with *rhizobium* inoculation significantly enhanced plant height, number of branch plant⁻¹, number of nodules plants⁻¹ and dry wt. of nodule plant⁻¹ except plant population during both of the years. The maximum level of these growth parameters due to supply essential plant nutrients in use of appropriate amount of fertilizer which result was preferential growth and development of chickpea plants while minimum growth parameter recorded with control. Application phosphorus may be due to increasing photosynthetic activity, efficient translocation and utilization of photosynthesis causing rapid cell elongation and cell division at entire period of chickpea crop. By use of *rhizobium* was fond enhanced formation of number of root nodules which fixed the free nitrogen of the atmosphere, which has better effect on the growth parameters of chickpea plants. These results are in accordance to the findings of **Kumar et al. (2000), Sharma et al. (2002), Tiwari et al. (2000), Ram and Dixit (2001), Rao and Shaktawat (2001), Thenuaet al. (2010), Zaman et al. (2011), Singh et al. (2014), Singh et al. (2018).**

Application of zinc also enhanced growth parameters viz. plant height, number of branch plant⁻¹, number of nodules plants⁻¹ and dry weight of nodule plant⁻¹. Significantly increased in growth characters was recorded upto 2.5 kg Zn ha⁻¹ while plant population effect was found to be non-significant in all level of Zinc during both years. Zinc plays pivotal role in regulating the auxin concentration in plant and nitrogen metabolism and might have

improved above stated growth characters. All interaction effect was found non-significant. These results are in close conformity with those of **Pathak *et al.* (2003)**, **Karwasra and Kumar (2007)**, **Khan *et al.* (2007)**, **Das *et al.* (2012)**, **Straw (2014)**, **Surendra R. (2018)**, **Woldearegayet *et al.* (2020)** and **Pal *et al.* (2021)**.

Table-3: Effect of treatment combinations on growth parameters of chickpea.

| Treatments | Plant height at 90 DAS | | | No. of Nodules plant ⁻¹ | | | Wt. of root nodules | | | No. of branch | | |
|-----------------|------------------------------|----------------------------|--------------------------------|------------------------------------|---------------------------|------------------------------|---------------------------|---------------------------|------------------------------|---------------------------|---------------------------|-----------------------------|
| | 2020-21 | 2021-22 | pooled | 2020-21 | 2021-22 | Pooled | 2020-21 | 2021-22 | Pooled | 2020-21 | 2021-22 | Pooled |
| T ₁ | 31.45 | 32.45 | 31.95 | 17.69 | 18.05 | 17.87 | 118.9 | 120.35 | 119.63 | 13.30 | 13.47 | 13.38 |
| T ₂ | 32.87 | 33.84 | 33.36 | 19.72 | 20.38 | 20.05 | 132.57 | 142.05 | 137.31 | 13.94 | 14.21 | 14.08 |
| T ₃ | 35.12 | 35.76 | 35.44 | 21.87 | 22.53 | 22.20 | 140.25 | 142.55 | 141.4 | 14.36 | 14.52 | 14.44 |
| T ₄ | 34.86 | 35.12 | 34.99 | 21.78 | 22.21 | 22.00 | 139.78 | 140.98 | 140.38 | 14.08 | 14.59 | 14.34 |
| T ₅ | 39.07 | 39.75 | 39.41 | 25.46 | 26.39 | 25.93 | 158.34 | 159.71 | 159.03 | 15.21 | 15.75 | 15.48 |
| T ₆ | 41.94 | 42.59 | 42.27 | 26.35 | 27.11 | 26.73 | 167.45 | 169.11 | 168.28 | 16.1 | 16.56 | 16.33 |
| T ₇ | 39.16 | 40.06 | 39.61 | 25.72 | 26.47 | 26.10 | 160.48 | 162.63 | 161.56 | 15.72 | 15.86 | 15.79 |
| T ₈ | 44.05 | 45.16 | 44.61 | 28.34 | 28.86 | 28.60 | 174.65 | 175.98 | 175.32 | 16.81 | 16.92 | 16.87 |
| T ₉ | 45.35 | 46.10 | 45.73 | 29.03 | 29.56 | 30.00 | 178.51 | 180.22 | 179.37 | 17.12 | 17.23 | 17.18 |
| T ₁₀ | 32.21 | 33.17 | 32.69 | 19.25 | 20.23 | 19.74 | 126.18 | 127.98 | 127.08 | 13.65 | 13.95 | 13.8 |
| T ₁₁ | 35.98 | 36.84 | 36.41 | 22.13 | 22.87 | 22.5 | 144.29 | 146.74 | 145.52 | 14.67 | 14.72 | 14.7 |
| T ₁₂ | 36.85 | 37.15 | 37 | 22.58 | 23.16 | 22.87 | 149.78 | 151.75 | 150.77 | 14.98 | 15.06 | 15.02 |
| T ₁₃ | 38.02 | 38.69 | 38.36 | 23.25 | 24.08 | 23.67 | 155.79 | 157.32 | 156.56 | 14.89 | 15.06 | 14.98 |
| T ₁₄ | 42.21 | 43.65 | 42.93 | 26.47 | 27.57 | 27.02 | 169.54 | 171.88 | 170.71 | 16.54 | 16.77 | 16.66 |
| T ₁₅ | 44.98 | 46.18 | 45.58 | 28.89 | 29.33 | 29.11 | 176.64 | 178.22 | 177.43 | 16.99 | 17.1 | 17.05 |
| T ₁₆ | 43.32 | 44.75 | 44.04 | 27.99 | 28.15 | 28.07 | 172.25 | 173.44 | 172.85 | 16.68 | 16.81 | 16.74 |
| T ₁₇ | 45.98 | 47.24 | 46.61 | 29.46 | 30.12 | 29.79 | 181.48 | 183.05 | 182.27 | 17.39 | 17.51 | 17.45 |
| T ₁₈ | 46.72 | 48.56 | 47.64 | 30.89 | 31.27 | 31.08 | 184.29 | 185.77 | 185.03 | 17.85 | 18.12 | 17.99 |
| Overall mean | 39.45 | 40.39 | 39.92 | 24.83 | 25.46 | 25.14 | 157.29 | 159.43 | 158.36 | 15.57 | 15.79 | 15.68 |
| SEM± | P 0.67 Zn 0.67 Rh 0.55 | P 0.73 Zn0.73 Rh0.60 | P 0.50 Zn 0.50 Rh0.40 | P0.40 Zn0.40 Rh0.33 | P0.45 Zn0.45 Rh0.36 | P 0.30 Zn 0.30 Rh 0.24 | P1.94 Zn1.94 Rh1.59 | P2.06 Zn2.06 Rh1.68 | P 1.42 Zn 1.42 Rh 1.16 | P0.18 Zn0.18 Rh0.15 | P0.22 Zn0.22 Rh0.18 | P 0.14 Zn 0.14 Rh0.12 |
| C.D. at 5% | P 1.92 Zn 1.92 Rh 1.57 | P 2.09 Zn2.09 Rh1.71 | P 1.36 Zn1.39 Rh1.13 | P1.14 Zn1.14 Rh0.93 | P1.28 Zn1.28 Rh1.04 | P 0.84 Zn 0.84 Rh 0.68 | P5.59 Zn5.59 Rh4.46 | P5.91 Zn5.91 Rh4.83 | P4.07 Zn4.07 Rh3.32 | P0.53 Zn0.53 Rh0.43 | P0.64 Zn0.64 Rh0.52 | P0.40 Zn0.40 Rh0.33 |

Yield and Yield attributes

Application of phosphorus enhanced all yield and yield attributes *viz.* number of pods plant⁻¹, number of grains pod⁻¹, test weight of 100 grains grain yield, stover yield, biological yield and harvest index. Significantly increased all level phosphorus with rhizobium yield parameters like, number of pods plant⁻¹, number of grains pod⁻¹, test weight of 100 grains grain yield, stover yield and biological yield during both of the years except harvest index during second years. The enhancement in yield attributes due to phosphorus may be due to

enriched nutritional conditions of the plants. It may be due to the all metabolic processes like photosynthesis, glycolysis and respiration are based on action of co-enzymes like NAD and NADP which are dependent on phosphorus. Similar observations were also reported by **Sinha *et al.* (2000), Vimla and Natarajan (2000), Tiwari *et al.* (2001), Yadav *et al.* (2002), Bicer (2014), Badiniet *al.* (2015), Pegoraroet *al.* (2018), Singh *et al.* (2021) and Pal *et al.* (2021)**

Application of different level of zinc considerably enhanced all characters of yield attributes viz. number of pods plant⁻¹, number of grains pod⁻¹, test weight of 100 grains grain yield, stover yield, biological yield and harvest index while significantly increased yield characters viz. number of pods plant⁻¹, number of grains pod⁻¹, test weight of 100 grains grain yield, stover yield and biological yield except harvest index during of the both years of chickpea crop. Similar findings were also reported by **Mali *et al.* (2003), Yadav *et al.* (2010), Valencianoet *al.* (2011), Kumari *et al.* (2019), Raj *et al.* (2019), Singh *et al.* (2022)Patel *et al.* (2022) and Yadav *et al.* (2022)**

Table-4: Effect of treatment combinations on yield attributes of chickpea.

| Treatments | No. of pod plant ⁻¹ | | | No. of grain pod ⁻¹ | | | 100 grain weight (gm) | | |
|-----------------|--------------------------------|---------|--------|--------------------------------|---------|--------|-----------------------|---------|--------|
| | 2020-21 | 2021-22 | Pooled | 2020-21 | 2020-22 | Pooled | 2020-21 | 2021-22 | Pooled |
| T ₁ | 47.36 | 48.02 | 47.49 | 1.23 | 1.25 | 1.24 | 17.02 | 17.05 | 17.04 |
| T ₂ | 51.53 | 51.64 | 51.59 | 1.41 | 1.43 | 1.42 | 17.24 | 17.26 | 17.25 |
| T ₃ | 52.47 | 52.75 | 52.61 | 1.48 | 1.49 | 1.49 | 17.43 | 17.45 | 17.44 |
| T ₄ | 51.84 | 52.12 | 51.98 | 1.45 | 1.46 | 1.46 | 17.41 | 17.43 | 17.42 |
| T ₅ | 58.89 | 60.45 | 59.67 | 1.57 | 1.59 | 1.58 | 18.3 | 18.4 | 18.35 |
| T ₆ | 63.05 | 65.15 | 64.1 | 1.62 | 1.65 | 1.64 | 18.96 | 19.07 | 19.02 |
| T ₇ | 59.24 | 61.05 | 60.15 | 1.58 | 1.59 | 1.59 | 18.32 | 18.35 | 18.34 |
| T ₈ | 64.13 | 65.52 | 64.83 | 1.68 | 1.69 | 1.69 | 19.06 | 19.21 | 19.14 |
| T ₉ | 65.57 | 66.09 | 65.83 | 1.71 | 1.73 | 1.72 | 19.34 | 19.48 | 19.41 |
| T ₁₀ | 50.62 | 51.47 | 51.05 | 1.39 | 1.4 | 1.4 | 17.13 | 17.15 | 17.14 |
| T ₁₁ | 55.68 | 56.42 | 56.05 | 1.5 | 1.52 | 1.51 | 17.64 | 17.68 | 17.66 |
| T ₁₂ | 56.96 | 57.78 | 57.37 | 1.51 | 1.53 | 1.52 | 17.96 | 18.07 | 18.02 |
| T ₁₃ | 58.67 | 59.87 | 59.27 | 1.54 | 1.56 | 1.55 | 18.09 | 18.11 | 18.1 |
| T ₁₄ | 63.84 | 65.28 | 64.56 | 1.65 | 1.67 | 1.66 | 18.98 | 19.12 | 19.05 |
| T ₁₅ | 65.03 | 65.95 | 65.49 | 1.7 | 1.71 | 1.71 | 19.32 | 19.45 | 19.39 |
| T ₁₆ | 63.97 | 65.39 | 64.68 | 1.67 | 1.68 | 1.68 | 19.03 | 19.16 | 19.1 |
| T ₁₇ | 67.94 | 68.11 | 68.03 | 1.73 | 1.74 | 1.74 | 19.58 | 19.64 | 19.61 |
| T ₁₈ | 68.64 | 69.54 | 17.04 | 1.76 | 1.78 | 17.04 | 19.94 | 20.19 | 17.04 |
| Overall mean | 59.19 | 60.14 | 17.25 | 1.57 | 1.58 | 17.25 | 18.38 | 18.46 | 17.25 |

| | | | | | | | | | |
|-------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
| SEm± | P 0.58 Zn 0.58 Rh 0.47 | P 0.62 Zn 0.62 Rh 0.50 | P 0.42 Zn 0.42 Rh 0.35 | P 0.03 Zn 0.03 Rh 0.02 | P 0.03 Zn 0.03 Rh 0.02 | P 0.02 Zn 0.02 Rh 0.02 | P 0.17 Zn 0.17 Rh 0.14 | P 0.18 Zn 0.18 Rh 0.15 | P 0.13 Zn 0.13 Rh 0.10 |
| C.D. at 5% | P 1.67 Zn 1.67 Rh 1.36 | P 1.78 Zn 1.78 Rh 1.45 | P 1.19 Zn 1.19 Rh 0.97 | P 0.08 Zn 0.08 Rh 0.07 | P 0.09 Zn 0.09 Rh 0.07 | P 0.06 Zn 0.06 Rh 0.05 | P 0.50 Zn 0.50 Rh 0.41 | P 0.52 Zn 0.20 Rh 0.42 | P 0.36 Zn 0.36 Rh 0.29 |

Table-5: Effect of treatment combinations on Productivity parameters

| Treatments | Grain Yield (q ha ⁻¹) | | | Stover Yield (q ha ⁻¹) | | |
|-----------------------|-----------------------------------|------------------------------|------------------------------|------------------------------------|------------------------------|------------------------------|
| | 2020-21 | 2021-22 | Pooled | 2020-21 | 2021-22 | Pooled |
| T₁ | 12.26 | 12.52 | 12.39 | 17.16 | 17.79 | 17.48 |
| T₁₀ | 13.65 | 13.87 | 13.76 | 18.02 | 18.28 | 18.15 |
| T₂ | 13.79 | 14.02 | 13.91 | 18.72 | 18.86 | 18.79 |
| T₄ | 14.51 | 14.61 | 14.46 | 19.16 | 19.36 | 19.26 |
| T₃ | 14.68 | 14.86 | 14.77 | 19.68 | 19.94 | 19.81 |
| T₁₁ | 14.8 | 15.1 | 14.95 | 20.11 | 20.61 | 20.36 |
| T₁₂ | 16.39 | 16.82 | 16.61 | 20.79 | 21.07 | 20.93 |
| T₁₃ | 16.84 | 17.04 | 16.94 | 21.02 | 21.58 | 21.30 |
| T₅ | 17.19 | 17.42 | 17.31 | 21.59 | 21.84 | 21.72 |
| T₇ | 17.36 | 17.68 | 17.52 | 21.87 | 22.03 | 21.95 |
| T₆ | 18.05 | 18.47 | 18.26 | 22.05 | 22.37 | 22.21 |
| T₁₄ | 18.25 | 18.63 | 18.44 | 22.89 | 23.10 | 23.00 |
| T₁₆ | 18.75 | 18.86 | 18.81 | 23.24 | 23.68 | 23.46 |
| T₈ | 18.93 | 19.03 | 18.98 | 23.79 | 23.99 | 23.89 |
| T₁₅ | 19.12 | 19.38 | 19.25 | 23.97 | 24.13 | 24.05 |
| T₉ | 19.25 | 19.51 | 19.38 | 24.08 | 24.27 | 24.18 |
| T₁₇ | 19.86 | 20.11 | 19.99 | 24.32 | 24.59 | 24.46 |
| T₁₈ | 20.58 | 20.89 | 20.74 | 24.95 | 25.26 | 25.11 |
| Overall mean | 16.90 | 17.16 | 17.03 | 21.52 | 21.82 | 21.67 |
| SEm± | P 0.34 Zn 0.34 Rh 0.27 | P 0.39 Zn 0.39 Rh 0.32 | P 0.26 Zn 0.26 Rh 0.21 | P 0.41 Zn 0.41 Rh 0.33 | P 0.47 Zn 0.47 Rh 0.31 | P 0.30 Zn 0.30 Rh 0.25 |
| C.D. at 5% | P 0.96 Zn 0.96 Rh 0.79 | P 1.12 Zn 1.12 Rh 0.91 | P 0.72 Zn 0.72 Rh 0.59 | P 1.17 Zn 1.17 Rh 0.95 | P 1.30 Zn 1.31 Rh 1.06 | P 0.85 Zn 0.85 Rh 0.70 |

Conclusion

The current study demonstrate the benefit of phosphorus, zinc and *rhizobium* alone with recommended N, K for achieving higher growth parameters and productivity by chickpea crop. Application of phosphorus, zinc and rhizobium inoculation increased yield attributes and yield of chickpea crop. Finally it can be concluded that the treatment T₁₈ [60 kg P+ 5.0 kg ha⁻¹ Zn with *Rhizobium*] is a best option for improving productivity of chickpea crop.

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