



Effect of Phosphorus, Zinc and *Rhizobium* on Productivity and Profitability of Chickpea (*Cicer arietinum* L.) under Central Plain Zone of Uttar Pardesh

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Field experiments were conducted to study the Effect of phosphorus, zinc and *rhizobium* on yield and profitability of chickpea (*Cicer arietinum* L.) during rabi season of 2020-21 and 2021-22 at students instructional farm, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur. The treatment consists of three levels of phosphorus (0, 30 and 60 kg ha⁻¹), three levels of zinc (0, 2.5, 5.0 kg ha⁻¹) and two levels of rhizobium inoculation (with and without rhizobium) totally eighteen treatment combinations. The experiment was laid out in Factorial randomized block design with three replications. N @ 20 kg ha⁻¹ and K @ 20 kg ha⁻¹ applied uniformly through urea and murate of potash respectively. The experiment was laid out in Factorial randomized block design with three replications. Chickpea variety RVG-202 was grown with the recommended agronomic practices. Results of the experiment reflected that yield of chickpea crop increased with the use of phosphorus, zinc and *rhizobium* inoculation. Maximum grain yield 20.89 kg ha⁻¹, stover yield 25.26

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kg ha⁻¹, biological yield 46.15 kg ha⁻¹ and harvest index 45.27% were recorded under T₁₈ (60 kg P+5 kg Zn ha⁻¹ *rhizobium* inoculation) over control during second year. But, significantly increased T₁₇ (60 kg P+2.5 kg Zn ha⁻¹ *rhizobium* inoculation) during both years (2020-21 and 2021-22). The maximum cost of cultivation (₹ 36615.23), gross return (₹ 115380), net return (₹ 78764.77) and B:C ratio (2.15) were recorded under T₁₈ (60 kg P+5 kg Zn ha⁻¹ *rhizobium* inoculation). The present study showed that combined application of phosphorus and zinc with *rhizobium* inoculation along with recommended nitrogen and potassium could be an effective option for enhancing chickpea yield component, yield and economic return.

Keywords: Chickpea; economics; phosphorous; rhizobium; yield and zinc.

1. INTRODUCTION

Pulses crop is pre-dominant role in maintain natural resources with high quality. It is grown in large scale in world but highest cultivated area and producer in India. "After cereal crop, pulses is the most important grown in every part of India. It is easily available in rural for protein. India is a highly populated country under the category of developing nations. The protein requirement of most of the people is fulfilling through pulses. In India, protein is major source of pulses crop especially vegetarians and provide staple cereals with completely diets likes, protein, essential amino acids, vitamins" and [1].

"In pulses crop, chickpea (*Cicer arietinum* L.) is one of the pre-dominant *rabi* crop in India. It is largest produced food legume in South Asia. Chickpea (*Cicer arietinum* L.) originated in south eastern turkey" [2]. It is a major legume crop cultivated for its edible seeds and belongs to the family *Fabaceae* (*leguminaceae*), and subfamily *Papilionaceae*. Chickpea is a good source of carbohydrates and important vitamins such as riboflavin, niacin, thiamin, folate and the vitamin A precursor β -carotene. Sulphur containing amino acids, Ca, Mg, Zn. Fe, P and, especially, K are also present in chickpea grains. "Chickpea has several potential health benefits, and, in combination with other pulses and cereals, it could have beneficial effects on some of the important human diseases such as CVD, type 2 diabetes, digestive diseases and some cancers. Overall, chickpea is an important pulse crop with a diverse array of potential nutritional and health benefits. Chickpea plays a significant role in improving soil fertility by fixing the atmospheric nitrogen" [3].

Phosphorus is an important nutrient especially for pulses crop to increase their productivity and fertility of soil. Legumes are heavy feeder of phosphorus and less responsive to nitrogen because of their capacity to meet their own

nitrogen requirement through symbiotic nitrogen fixation [4]. "Phosphorus plays an important role in nodulation, nitrogen fixation, growth and yield of chickpea" [5]. "It is essential for cell division, seed and fruit development and directly involvement of nucleic acids, that is, phospholipids, chromosomes and the coenzymes nicotinamide adenine dineucleotide (NAD), adenosine triphosphate (ATP) and nicotinamide adenine dineucleotide phosphate (NADP). Phosphorus is used in numerous molecular and biochemical plant processes, particularly in energy acquisition, storage and utilization" [6]. "It also improves the crop quality and resistance against plant diseases. Phosphorus application to legumes not only benefits the current crop but also favourably affects the succeeding non-legume crop. Phosphorus deficiency is a critical nutrient-deficiency problem in the Indian soils and may cause up to 29-45% yield losses in chickpea" [7]. "Symbiotic nitrogen fixation has a high P demand because the process consumes large amounts of energy" [8] and "energy generating metabolism strongly depends upon the availability of P" [9].

Similarly, zinc is also an important micro nutrient element which increases resistance to disease in plant. However, Khan et al. [10] reported that applying Zn increased yield and quality of chickpea. "Zinc deficiency in agricultural soils is also a wide-spread constraint for chickpea production in India. P and Zn facilitate the availability of each other for crop plants" [11]. Similarly zinc is also an important micro nutrient element which increases resistance to disease in plant. Sharma et al. [12] reported "antagonistic effect of P levels on Zn nutrition by the crops. The information on Zn and P relationship in an important crop like chickpea is not adequate, especially in situations where both the interacting nutrients (P and Zn) are deficient in soil. Most of the soils of Uttar Pradesh have been rated as deficient in available zinc". "A favourable balance between phosphorus and zinc should be

maintained for optimum growth of plant. It also promotes nodulation and nitrogen fixation in leguminous crops” [23].

“Biofertilizers may colonizes the rhizosphere and promotes growth by increasing the availability and supply of nutrients and/or growth stimulus to crop. Nitrogen fixer microorganisms play an important role in supplementing nitrogen to the plant, allowing a sustainable use of nitrogenous fertilizers” [14]. “Nitrogen fixation in agriculture can be improved by inoculation of legume crops with suitable *Rhizobium*. *Rhizobium* are symbiotic bacteria that facilitate formation of nodules on the roots of legume hosts, within which the bacteria fix atmospheric nitrogen into ammonia. Symbiotic nitrogen fixation is the main route for sustainable input of nitrogen into ecosystems. Adaptability of indigenous *Rhizobium* to their environment results in high levels of saprophytic competence” [15]. “Sometimes indigenous *Rhizobium* may be found in greater numbers than those of the inoculated strains which are also limited in mobility. Using high yielding varieties of chick-pea along with use of effective rhizobial strains can enhance the yield” [16].

2. RESOURCES AND METHODS

2.1 Experimental Site

The experiment was conducted during *rabi* season of 2020-21 and 2021-22 at student's Instructional farm, C.S.A. University of Agriculture and Technology, Kanpur Nagar (U.P.). The field was well leveled and irrigated by tube well. The farm is situated at main campus of

the university, in the west northern part of Kanpur city under sub-tropical zone in vth agro climatic zone (central plain zone).

2.2 Edaphic Condition

The soil was moist, well drained with uniform plane topography. The soil of the experimental field was alluvial in origin, sandy loam in texture and slightly alkaline in reaction and low organic carbon in soil. The soil samples were estimated for pH and Electrical conductivity (1:2.5 soil: water suspension method given by Jackson, 1967), Organic carbon percentage in soil (Walkley and Black's rapid titration method given by Walkley and Black, 1934), with available nitrogen in kg ha⁻¹ (Alkaline permanganate method given by Subbiah and Asija, 1956), available phosphorus as sodium bicarbonate-extractable P in kg ha⁻¹ (Olsen's calorimetrically method, Olsen et al., 1954) available potassium in kg ha⁻¹ (Flame photometer method given by Hanwey and Heidel, 1952) Available sulphur in kg ha⁻¹ (Turbidimetric method given by Chesnin and Yien, 1950) and Available zinc in mg ha⁻¹ was determined by (DTPA extraction Lindsay and Norvell, 1978). The nutrient status of initial soil prior to fertilization is presented in Table 1.

2.3 Detail of Treatments and Design

The experiment was consisted of 18 treatments combination of nutrient management having three factors: Factor A: Phosphorus (3 levels); P₀: 0 kg (Control), P₁: 30 kg, and P₂: 60 kg P₂O₅; Factor B: Zinc (3 levels): Zn₀: 0 kg (Control), Zn₁: 2.5 kg and Zn₂: 5 kg Zn ha⁻¹ and Factor C: *Rhizobium* (2 level): Rh₀: without *rhizobium*

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

S. No.	Soil characters	Value	
		2020-21	2021-22
1.	Texture	Sandy loam	Sandy loam
2.	pH (1:2.5 soil water suspension)	8.00	7.98
3.	EC (dsm ⁻¹) (1:2.5 soil water suspension)	0.47	0.46
4.	Organic carbon (%)	0.31	0.32
5.	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

Table 2. Detail of the treatment combinations

S. N.	Treatment combination	Symbol
1.	0 kg P+0 kg Zn without <i>rhizobium</i>	P ₀ Zn ₀ Rh ₀
2.	0 kg P+2.5 kg Zn without <i>rhizobium</i>	P ₀ Zn _{2.5} Rh ₀
3.	0 kg P+5 kg Zn without <i>rhizobium</i>	P ₀ Zn ₅ Rh ₀
4.	30 kg P+0 kg Zn without <i>rhizobium</i>	P ₃₀ Zn ₀ Rh ₀
5.	30 kg P+2.5 kg Zn without <i>rhizobium</i>	P ₃₀ Zn _{2.5} Rh ₀
6.	30 kg P+5 kg Zn without <i>rhizobium</i>	P ₃₀ Zn ₅ Rh ₀
7.	60 kg P+0 kg Zn without <i>rhizobium</i>	P ₆₀ Zn ₀ Rh ₀
8.	60 kg P+2.5 kg Zn without <i>rhizobium</i>	P ₆₀ Zn _{2.5} Rh ₀
9.	60 kg P+5 kg Zn without <i>rhizobium</i>	P ₆₀ Zn ₅ Rh ₀
10.	0 kg P+0 kg Zn with <i>rhizobium</i>	P ₀ Zn ₀ Rh ₁
11.	0 kg P+2.5 kg Zn with <i>rhizobium</i>	P ₀ Zn _{2.5} Rh ₁
12.	0 kg P+5 kg Zn with <i>rhizobium</i>	P ₀ Zn ₅ Rh ₁
13.	30 kg P+0 kg Zn with <i>rhizobium</i>	P ₃₀ Zn ₀ Rh ₁
14.	30 kg P+2.5 kg Zn with <i>rhizobium</i>	P ₃₀ Zn _{2.5} Rh ₁
15.	30 kg P+5 kg Zn with <i>rhizobium</i>	P ₃₀ Zn ₅ Rh ₁
16.	60 kg P+0 kg Zn with <i>rhizobium</i>	P ₆₀ Zn ₀ Rh ₁
17.	60 kg P+2.5 kg Zn with <i>rhizobium</i>	P ₆₀ Zn _{2.5} Rh ₁
18.	60 kg P+5 kg Zn with <i>rhizobium</i>	P ₆₀ Zn ₅ Rh ₁

(Control) and Rh₁: with *rhizobium*. The experiment was laid out in Factorial Randomized Complete Block Design (FRBD) with three replications. Nitrogen @ 20 kg ha⁻¹ and potash @ 40 kg ha⁻¹ applied uniformly through urea and murate of potash respectively 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 mid fortnight of March in both the years and growth attributes and economics were recorded at harvest.

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.

Seed yield (q ha⁻¹): After threshing produce of grain was weighed in kg per plot, which was converted into q ha⁻¹ on the basis of net plot area to record the yield in q ha⁻¹ under different treatments. Finally grain yield per plot was converted in to q ha⁻¹ by conversion factor.

Straw 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): The biological yield was calculated with the following formula:

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

Harvest index (%): The recovery of grains in total dry matter was considered as harvest index, expressed in percentage.

It has been calculated by following formula:

$$\text{Harvest Index (\%)} = [\text{Seed Yield (q ha}^{-1}\text{)} / \text{Biological Yield (q ha}^{-1}\text{)}] \times 100$$

2.4 Economics

The economics of different treatments was worked out on the basis of average yield (seed and stover) of 2020-21 and 2021-22. Treatments was calculated separately. The calculating economics of different treatments and expressed as cost of cultivation, gross return, net returns and benefit : cost ratio (B:C).

(i) Cost of cultivation

The cost of cultivation was worked out on the basis of input rates at the farm. Treatments cost was calculated separately. The common cost of cultivation (₹ ha⁻¹) was worked out by considering all the expenses incurred in the cultivation and added variable cost due to treatments (including interest of working capital) in order to get total cost of cultivation.

(ii) Gross return (₹ ha⁻¹)

It was calculated by taking the income from the grain and straw produced on the basis of market rates. The yield of chickpea crop was converted into gross return in rupees per hectare on the basis of current price of the produce.

$$\begin{aligned} \text{Gross return (₹ ha}^{-1}\text{)} \\ = \text{Total income from grain and stover yield} \end{aligned}$$

(iii) Net return (₹ ha⁻¹)

Net profit is the outcome received by subtracting the cost of cultivation from gross income (₹ ha⁻¹). The net return was worked out by using following formula-

$$\text{Net return (₹ ha}^{-1}\text{)} = \text{Gross return (₹ ha}^{-1}\text{)} - \text{Cost of cultivation (₹ ha}^{-1}\text{)}$$

(iv) Benefit Cost ratio (B:C)

Net income of each treatment was divided by cultivation cost of respective treatment and cost benefit ratio was recorded. There was calculated with the help of following formula.

$$\text{Benefit: cost ratio} = \frac{\text{Net Return (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

2.5 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.

3. RESULTS AND DISCUSSION**3.1 Productivity Parameters**

At a glance over the data given in the Table 3 and depicted in Fig. 1 clearly showed that among the productivity parameters viz. grain yield (q ha⁻¹), stover yield (q ha⁻¹) and biological yield (q ha⁻¹) except harvest index (%) significantly increase due to the application of phosphorous, zinc and *rhizobium* inoculation over control. Grain yield varied from 12.39 to 20.74 q ha⁻¹, stover yield varied from 17.48 to 25.11 q ha⁻¹, biological yield varied from 29.87 to 45.84 q ha⁻¹ and harvest index varied from 41.49 to 45.24% on pooled basis.

The maximum grain yield (20.89 q ha⁻¹), stover yield (25.26 q ha⁻¹), biological yield (46.15 q ha⁻¹) and harvest index (45.27%) was associated with the treatment T₁₈ [60.00 kg P+ 5.00 kg ha⁻¹ Zn with *Rhizobium*] during the second year (2021-22) of experimentation. The minimum grain yield (12.26 q ha⁻¹), stover yield (17.16 q ha⁻¹) and biological yield (29.42 q ha⁻¹) associated with the treatment T₁ [0 kg P+ 0kg ha⁻¹ Zn without *Rhizobium*] during the first year (2020-21) of experimentation and minimum harvest index (41.31%) associated with the treatment T₁ [0 kg P+ 0 kg ha⁻¹ Zn with *Rhizobium*] during the second year (2021-22) of experimentation.

The enhanced grain yield and stover yield might to be due to adequate amount of nutrients supply of chickpea plants because Symbiotic nitrogen fixation has more phosphorus demand like phosphorus zinc is essential micronutrient and essential for cell wall integrity, cell division, release of enzyme and nitrogen fixation. *Rhizobium* is symbiotic bacteria which facilitate nodules formation on the root of legume crop. On the whole all three factors increased yield attributes of chickpea. Grain, stover and biological yield of chickpea significantly increased due to phosphorus (60 kg P₂O₅ ha⁻¹) and zinc (2.5 kg Zn kg⁻¹) with *rhizobium* inoculation over their controls. Combine use of phosphorus 60 kg P₂O₅ ha⁻¹ and 2.5 kg Zn ha⁻¹ alone with *rhizobium* significantly increased grain 20.11 q ha⁻¹, stover 25.26 q ha⁻¹ and biological yield 44.7 q ha⁻¹ of chickpea recorded under T₁₇ [60 kg P+2.5 kg Zn ha⁻¹ with *Rhizobium* inoculation] over other treatments during second year. It may due to *rhizobium* which fix atmospheric nitrogen and increased the supply of other nutrients to plants and ultimately increased grain and stover yield of chickpea. These results also confirms the findings of Sinha et al. [17], Vimala and Natarajan [18], Tiwari et al. [19], Yadav et al. [20], Bicer [21], Badini et al. [22], Pegoraro et al. [23], Mali et al. [24], Yadav et al. [25], Valenciano et al. [26], Singh et al. [27], Krishna et al. [28], Ullah et al. [29], Kumari et al. [30], Raj et al. (2019).

3.2 Profitability

It is visualized from the data given in Table 4 and Table 5 clearly indicate that among the economics parameters viz. cost of cultivation

Table 3. Effect of different treatment combinations on productivity parameters of chickpea

Treatments	Grain yield (q ha ⁻¹)			Stover yield (q ha ⁻¹)			Biological yield(q ha ⁻¹)			Harvest Index (%)		
	2020-21	2021-22	pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T ₁	12.26	12.52	12.39	17.16	17.79	17.48	29.42	30.31	29.87	41.67	41.31	41.49
T ₂	13.79	14.02	13.91	18.72	18.86	18.79	32.51	32.88	32.70	42.42	42.64	42.53
T ₃	14.68	14.86	14.77	19.68	19.94	19.81	34.36	34.8	34.58	42.72	42.7	42.71
T ₄	14.51	14.61	14.56	19.16	19.36	19.26	33.67	33.97	33.82	43.09	43.09	43.09
T ₅	17.19	17.42	17.31	21.59	21.84	21.72	38.78	39.26	39.02	44.33	44.37	44.35
T ₆	18.05	18.47	18.26	22.05	22.37	22.21	40.1	40.84	40.47	45.01	45.23	45.12
T ₇	17.36	17.68	17.52	21.87	22.03	21.95	39.23	39.71	39.47	44.25	44.52	44.39
T ₈	18.93	19.03	18.98	23.79	23.99	23.89	42.72	43.02	42.87	44.31	44.24	44.28
T ₉	19.25	19.51	19.38	24.08	24.27	24.18	43.33	43.78	43.56	44.43	44.56	44.50
T ₁₀	13.65	13.87	13.76	18.02	18.28	18.15	31.67	32.15	31.91	43.1	43.14	43.12
T ₁₁	14.8	15.1	14.95	20.11	20.61	20.36	34.91	35.71	35.31	42.39	42.29	42.34
T ₁₂	16.39	16.82	16.61	20.79	21.07	20.93	37.18	37.89	37.54	44.08	44.39	44.24
T ₁₃	16.84	17.04	16.94	21.02	21.58	21.30	37.86	38.62	38.24	44.48	44.12	44.30
T ₁₄	18.25	18.63	18.44	22.89	23.1	23.00	41.14	41.73	41.44	44.36	44.64	44.50
T ₁₅	19.12	19.38	19.25	23.97	24.13	24.05	43.09	43.51	43.30	44.37	44.54	44.46
T ₁₆	18.75	18.86	18.81	23.24	23.68	23.46	41.99	42.54	42.27	44.65	44.33	44.49
T ₁₇	19.86	20.11	19.99	24.32	24.59	24.46	44.18	44.7	44.44	44.95	44.99	44.97
T ₁₈	20.58	20.89	20.74	24.95	25.26	25.11	45.53	46.15	45.84	45.2	45.27	45.24
Overall mean	16.90	17.16	17.03	21.52	21.82	21.67	38.43	38.98	38.70	43.88	43.91	43.89
SEm±	P 0.34 Zn 0.34 Rh 0.27	P 0.39 Zn0.39 Rh0.32	P 0.26 Zn 0.26 Rh0.21	P0.41 Zn0.41 Rh0.33	P0.45 Zn0.45 Rh0.37	P 0.30 Zn 0.30 Rh 0.25	P0.51 Zn0.51 Rh0.41	P0.57 Zn0.57 Rh0.47	P 0.38 Zn 0.38 Rh 0.31	P0.40 Zn0.40 Rh0.33	P0.45 Zn0.45 Rh0.37	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 Zn1.12 Rh0.91	P 0.72 Zn0.72 Rh0.59	P1.17 Zn1.17 Rh0.95	P1.30 Zn1.31 Rh1.06	P 0.85 Zn 0.85 Rh 0.70	P1.46 Zn1.46 Rh1.19	P1.64 Zn1.64 Rh1.34	P 1.07 Zn 1.07 Rh 0.87	P1.14 Zn N.S. Rh N.S.	P1.30 Zn N.S. Rh N.S.	P0.84 Zn N.S. Rh N.S.

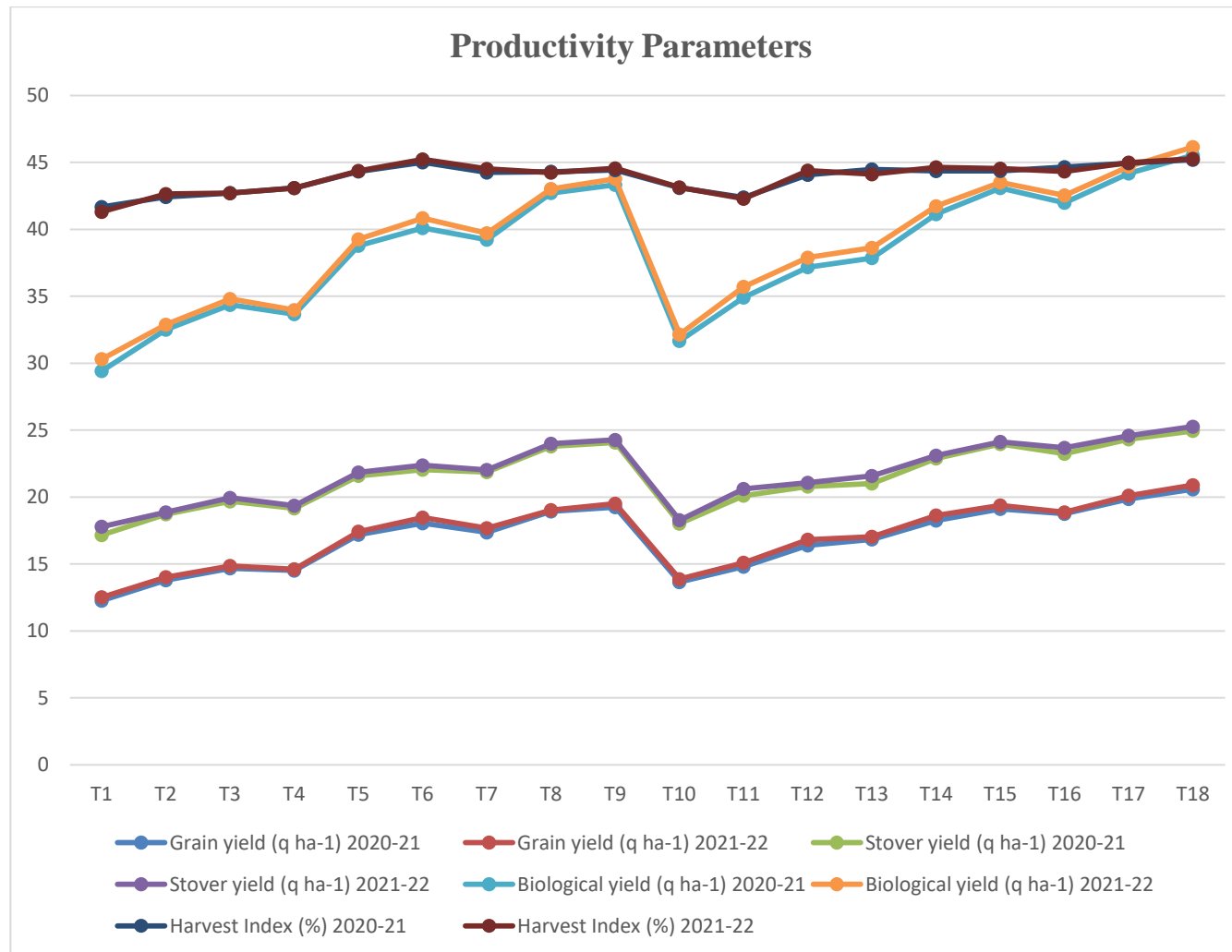


Fig. 1. Effect of different treatments treatments combinations on productivity parameters of chickpea

(₹ ha⁻¹), gross return (₹ ha⁻¹), net return (₹ ha⁻¹) and benefit cost ratio significantly increase due to the application of 60 kg phosphorous and 5.00 kg zinc with *rhizobium* inoculation. Cost of cultivation varied from 31524.5 to 36303.5 ₹ ha⁻¹, gross return varied from 67497 to 111596.3 ₹ ha⁻¹, net return varied from 35972.51 to 75292.76 ₹ ha⁻¹ and benefit cost ratio varied from 1.14 to 2.08 ₹ ha⁻¹ on the pooled basis. The application of phosphorus, zinc and rhizobium increased the cost of cultivation with the magnitude of 15.16 percent, gross return 65.34 percent, net return 109.31 percent and benefit cost ratio 82.46 percent. The maximum cost of cultivation ₹ 36615.23 gross

return ₹ 115380, net return ₹ 78764.77 and benefit cost ratio 2.15 was found with T₁₈ [60.00 kg P+ 5.00 kg ha⁻¹ Zn with *Rhizobium*] over the control during second year. The minimum cost of cultivation ₹ 31212.76, gross return ₹ 64915.5, net return ₹ 33702.74 and benefit cost ratio 1.08 recorded under T₁ [0 kg P+0 kg ha⁻¹ Zn with *Rhizobium*] during first year showed the table number 3. Similar finding of increased the crop yield and profitability with combined application of phosphorus and zinc with *rhizobium* inoculation has been reported by Singh et al. [31], Kedar et al. [32], Jain et al. [33], Yadav et al. (2013), Straw [34], Pal et al. [35].

Table 4. Effect of different treatment combinations on economics of chickpea

Treatments	Cost of cultivation (₹ ha ⁻¹)			Gross return (₹ ha ⁻¹)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T ₁	31212.76	31836.23	31524.50	64915.5	70078.5	67497
T ₂	32452.76	33076.23	32764.50	72842.25	78103	75472.63
T ₃	32831.76	33455.23	33143.50	77469	82765	80117
T ₄	33577.76	34201.23	33889.50	76484.25	81287	78885.63
T ₅	33956.76	34580.23	34268.50	90278.25	96486	93382.13
T ₆	34355.76	34959.23	34657.50	94608.75	102026.5	98317.63
T ₇	35073.76	35697.23	35385.50	91191	97878.5	94534.75
T ₈	35452.76	36076.23	35764.50	99420.75	105449.5	102435.1
T ₉	35831.76	36455.23	36143.50	101067.8	107995.5	104531.7
T ₁₀	32233.76	32857.23	32545.50	71949.75	77135	74542.38
T ₁₁	32612.76	33236.23	32924.50	78183	84223.5	81203.25
T ₁₂	32991.76	33615.23	33303.50	86138.25	93156.5	89647.38
T ₁₃	33777.76	34361.23	34069.50	88401	94457	91429
T ₁₄	34116.76	34740.23	34428.50	95835.75	103098	99466.88
T ₁₅	34495.76	35119.23	34807.50	100401	107283.5	103842.3
T ₁₆	35233.76	35857.23	35545.50	98378.25	104474	101426.1
T ₁₇	35612.76	36236.23	35924.50	104113.5	111167.5	107640.5
T ₁₈	35991.76	36615.23	36303.50	107812.5	115380	111596.3
Overall mean	33989.59	34609.73	34299.66	88860.59	95135.81	91998.2
SEM±	P 55.97 Zn 55.97 Rh 45.70	P 75.29 Zn 75.29 Rh 61.48	P 46.91 Zn 46.91 Rh 38.30	P 276.2 Zn 276.2 Rh 225.5	P 387.9 Zn 387.9 Rh 316.7	P 238.1 Zn 238.1 Rh 194.4
C.D. at 5%	P 161.04 Zn 161.04 Rh 131.49	P 216.65 Zn 216.65 Rh N.S.	P 131.33 Zn 131.33 Rh 107.23	P 794.7 Zn 794.7 Rh 648.9	P 1116.3 Zn 1116.3 Rh 911.4	P 666.6 Zn 666.6 Rh 544.3

Table 5. Effect of different treatment combinations on economics of chickpea.

Treatments	Net income (₹ ha ⁻¹)			B:C ratio		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T ₁	33702.74	38242.27	35972.51	1.08	1.2	1.14
T ₂	40389.49	45026.77	42708.13	1.24	1.36	1.30
T ₃	44637.24	49309.77	46973.51	1.36	1.47	1.42
T ₄	42906.49	47085.77	44996.13	1.28	1.38	1.33
T ₅	56321.49	61905.77	59113.63	1.66	1.79	1.73
T ₆	60252.99	67067.27	63660.13	1.75	1.92	1.84

Treatments	Net income (₹ ha ⁻¹)			B:C ratio		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T ₇	56117.24	62181.27	59149.26	1.6	1.74	1.67
T ₈	63967.99	69373.27	66670.63	1.8	1.92	1.86
T ₉	65235.99	71540.27	68388.13	1.82	1.96	1.89
T ₁₀	39715.99	44277.77	41996.88	1.23	1.35	1.29
T ₁₁	45570.24	50987.27	48278.76	1.4	1.53	1.47
T ₁₂	53146.49	59541.27	56343.88	1.61	1.77	1.69
T ₁₃	54623.24	60095.77	57359.51	1.62	1.75	1.69
T ₁₄	61718.99	68357.77	65038.38	1.81	1.97	1.89
T ₁₅	65905.24	72164.27	69034.76	1.91	2.05	1.98
T ₁₆	63144.49	68616.77	65880.63	1.79	1.91	1.85
T ₁₇	68500.74	74931.27	71716.01	1.92	2.07	2.00
T ₁₈	71820.74	78764.77	75292.76	2	2.15	2.08
Overall mean	54870.99	60526.08	57698.53	1.60	1.74	1.67
SEm±	P 689.1 Zn 689.1 Rh 562.6	P 849.6 Zn 849.6 Rh 693.7	P 546.9 Zn 546.9 Rh 446.6	P 0.022 Zn 0.022 Rh 0.018	P 0.033 Zn 0.033 Rh 0.027	P 0.020 Zn 0.020 Rh 0.017
C.D. at 5%	P 1982.8 Zn 1982.8 Rh 1618.9	P 2444.7 Zn 2444.7 Rh 1996.1	P 1531.3 Zn 1531.3 Rh 1250.3	P 0.064 Zn 0.064 Rh 0.053	P 0.096 Zn 0.096 Rh 0.078	P 0.057 Zn 0.057 Rh 0.047

4. CONCLUSIONS

The current study demonstrate the benefit of phosphorus, zinc and rhizobium alone with recommended N K for achieving higher productivity and profitability by chickpea crop. Application of phosphorus and zinc with *rhizobium* inoculation increased yield attributes, yield and economics of chickpea crop. The burgeoning human population in india needs higher pulses production for fulfilling the dietary protein and minerals requiremnts with maintain soil heath. Finally it can be concluded that the treatment T₁₇ (60 kg P+ 2.5 kg Zn with *rhizobium*) is a best option for improving productivity and profitability of chickpea crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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