

Effect of phosphorus, zinc and *rhizobium* on productivity and profitability of chickpea (*Cicer arietinum* L.)

Comment [WU1]: In what geo edaphic condition???

Comment [WU2]: Plagiarism report???

Comment [WU3]: Name of country???

Abstract

Field experiments were done 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 experiment consisted of 18 treatment combinations in factorial randomized block design with three replications. Three levels of phosphorus (0, 30 and 60 kg ha⁻¹), three levels of zinc (0, 2.5 and 5.0 kg ha⁻¹) and two levels of *rhizobium* inoculation (with *rhizobium* and without *rhizobium*). 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 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.

Comment [WU4]: Name of country???

Key Words: Chickpea, Economics, Phosphorus, *Rhizobium*, Yield.

Comment [WU5]: Concluding & recommendation sentence???

Comment [WU6]: Synergetic effect

Introduction:

Pulse crop is pre-dominant role in maintaining natural resources with high quality. It is grown in large scale in world but highest cultivated area and producer in India. After cereal

Comment [WU7]: Background of research???

Comment [WU8]: Problem statement???

Comment [WU9]: Hypothesis???

Comment [WU10]: Aims & objectives of research???

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 a major source of pulses crop especially vegetarians and provide staple cereals with completely diets like protein, essential amino acids, vitamins and (Pingoliya *et al.*, 2013).

In pulses crop, chickpea (*Cicer arietinum* L.) is one of the pre-dominant *rabic* crop in India. It is largest produced food legume in South Asia. Chickpea (*Cicer arietinum* L.) originated in south eastern turkey (Redden *et al.* 2007). It is a major legume crop cultivated for its edible seeds and family belong *Fabaceae* (*leguminaceae*), and subfamily *Papilionaceae*. Chickpea is known by various name in different countries like garbanzo (Spanish), pois chiche (French), kichar or chicher (German), chana (Hindi) and gram or Bengal gram (English). 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 (Balai *et al.* 2017)

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 (Kumar *et al.* 2016). Phosphorus plays an important role in nodulation, nitrogen fixation, growth and yield of chickpea (Meena *et al.*, 2005). It is essential for cell division, seed and fruit development and directly involvement of nucleic acids, that is, phospholipids, chromosomes and the coenzyme nicotinamide adenine dinucleotide (NAD), adenosine triphosphate (ATP) and nicotinamide adenine dinucleotide phosphate (NADP). Phosphorus is used in numerous molecular and biochemical plant processes, particularly in energy acquisition, storage and utilization (Epstein and Bloom, 2005). 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 (Ahlawat *et al.*, 2007). 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 on the availability of P (Plaxton, 2004).

Similarly, zinc is also an important micro nutrient element which increases resistance to disease in plant. However, Khan *et al.* (2004) reported that applying Zn increased yield and quality of chickpea. Zinc deficiency in agricultural soils is also a widespread constraint for chickpea production in India. P and Zn facilitate the availability of each other for crop plants (Ryan *et al.*, 2012). Similarly, zinc is also an important micro nutrient element which increases resistance to disease in plant. Sharma *et al.* (2000) reported an 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 (Demeterio *et al.*, 1972).

Biofertilizers may colonize the rhizosphere and promote growth by increasing the availability and supply of nutrients and/or growth stimuli to the crop. Nitrogen fixing microorganisms play an important role in supplementing nitrogen to the plant, allowing a sustainable use of nitrogenous fertilizers (Tambekar *et al.*, 2009). 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 (Zengen *et al.*, 2006). 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 chickpea along with use of effective rhizobial strains can enhance the yield (Bhuiyan *et al.*, 2008).

Resources and

Methods Experimental Si

te:

The experiment was conducted during *rab* 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 agroclimatic zone (central plain zone).

Edaphic Condition:

The soil was moist, well drained with uniform plain 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 Hand 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 $P\ mg\ kg^{-1}$ (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 $mg\ kg^{-1}$ was determined by (DTPA extraction Lindsay and Norvell, 1978). The nutrient status of initial soil prior to fertilization is presented in table no. 1

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 ($ds\ m^{-1}$) (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

Comment [WU11]: Name of country???

Comment [WU12]: Synergetic effect of applying zinc with phosphorus, formation of zinc phosphate & non available to plants in soil ????

Comment [WU13]: Old references???

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* (Control) and Rh₁: with *rhizobium*. The experiment was laid out in Factorial Randomized Complete Block Design (FRBD) with three replications. Full dose (recommended 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 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.

Comment [WU14]: Statistical & economic analysis???

Table-2: detail of the treatment combinations:

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

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.

Seedyield (q ha⁻¹)

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 into 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): Each net plot was harvested and bundles were weighed separately after drying in the sun. Biological yield was recorded in kg plot⁻¹ and finally expressed in q ha⁻¹. The biological yield was calculated with the following formula:

$$\text{Biological yield} = \text{Seedyield} + \text{Stover yield.}$$

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:

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

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. Treatment 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.

Gross return (₹ha^{-1}) = Total income from grain and stover yield

(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-

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

(iv) Benefit Co 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.

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

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:

Productivity Parameters:

At a glance over the data given in the Table-3 and depicted in Fig.-1 clearly show that among the productivity parameters viz. grain yield (qha^{-1}), stover yield (qha^{-1}) and biological yield (qha^{-1}) except harvest index (%) significantly increased due to the application of phosphorus, zinc and *Rhizobium* inoculation. Grain yield varied from 12.39 to 20.74 qha^{-1} , stover yield varied from 17.48 to 25.11 qha^{-1} , biological yield varied from 29.87 to 45.84 qha^{-1} and harvest index varied from 41.49 to 45.24 % on pooled basis. The application of phosphorus, zinc and *Rhizobium* increased the grain yield with the result that the 67.39 percent, stover yield 43.64 percent, biological yield 53.47 percent and harvest index 9.04 percent.

The maximum grain yield (20.89 qha^{-1}), stover yield (25.26 qha^{-1}), biological yield (46.15 qha^{-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 qha^{-1}), stover yield (17.16 qha^{-1}) and biological yield (29.42 qha^{-1}) associated with the treatment T₁ [0 kg P + 0 kg ha⁻¹ Zn without *Rhizobium*]

Comment [WU15]: Need more discussion with comparison with latest past study???

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 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 facilitates nodule 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 be 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 confirm the findings of **Sinha et al. (2000), Vimla and Natarajan (2000), Tiwari et al. (2001), Yadav et al. (2002), Bicer (2014), Badini et al. (2015), Pegoraro et al. (2018), Mali et al. (2003), Yadav et al. (2010), Valenciano et al. (2011), Singh et al. (2012), Krishna et al. (2017), Ullah et al. (2017), Kumari et al. (2019), Raj et al. (2019).**

Profitability:

It is visualized from the data given in Table-4 and Table-5 clearly indicate that among the economic parameters viz. cost of cultivation (₹ ha⁻¹), gross return (₹ ha⁻¹), net return (₹ ha⁻¹) and benefit cost ratio significantly increased due to the application of 60 kg phosphorus 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

etal. (2005), Kedaretal. (2006), Jainetal. (2006), Yadavetal. (2013), Straw (2014), Paletal. (2021).

conclusions:

The current study demonstrates 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 mineral requirements with maintains soil health. Finally it can be concluded that the treatment T₁₇ (60kgP+2.5kgZn with *rhizobium*) is a best option for improving productivity and profitability of chickpea crop.

Table No.03: Effect of different treatment combinations on productivity parameters of chick pea.

Treatments	Grain yield (qha ⁻¹)			Stover yield (qha ⁻¹)			Biological yield (qha ⁻¹)			Harvest Index (%)		
	2020-21	2021-22	poole d	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 0.39Zn 0.39Rh 0.32	P0.26 Zn0.26 Rh0.21	P0.41Z n0.41R h0.33	P0.45Z n0.45R h0.37	P 0.30 Zn0.30 Rh0.25	P0.51Z n0.51R h0.41	P0.57Z n0.57R h0.47	P0.38 Zn0.38 Rh0.31	P0.40Z n0.40R h0.33	P0.45Z n0.45R h0.37	P 0.30 Zn0.30 Rh0.25

C.D.	P 0.96	P	P	P1.17Z	P1.30Z	P 0.85	P1.46Z	P1.64Z	P1.07	P1.14Z	P1.30Z	P0.84Z
at5	Zn 0.96	1.12Zn	0.72Zn	n1.17	n1.31	Zn0.85	n1.46	n1.64	Zn	nN.S.	nN.S.	nN.S.
%	Rh0.79	1.12	0.72	Rh0.95	Rh1.06	Rh0.70	Rh1.19	Rh1.34	1.07Rh	RhN.S.	Rh N.S.	Rh N.S.
		Rh0.91	Rh0.59						0.87			

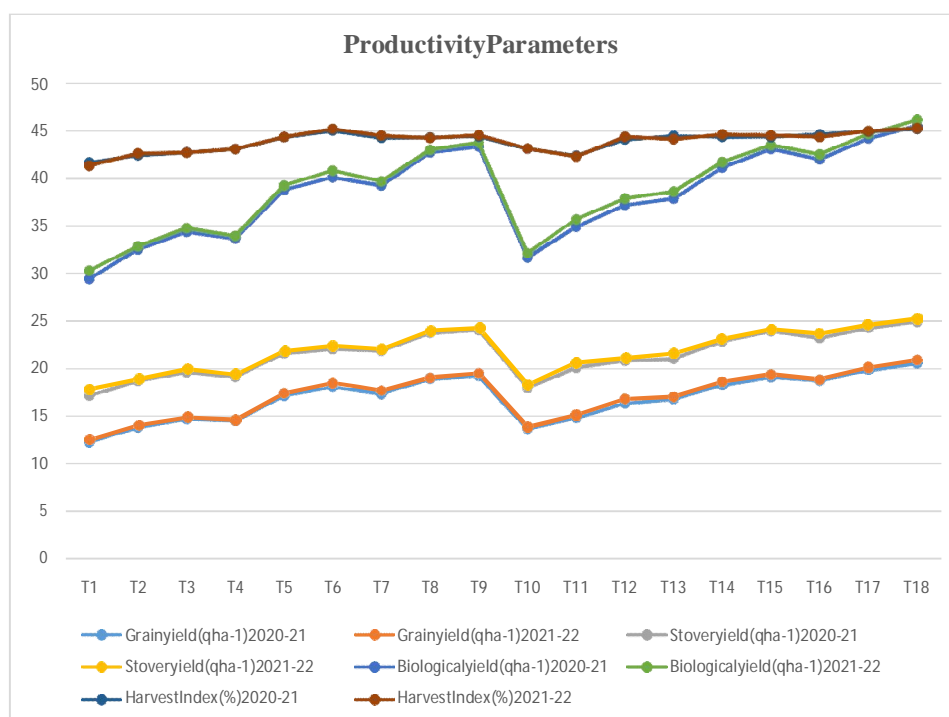


Fig.-
1: Effect of different treatment combinations on productivity parameters of chickpea.

Table No.: 04 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
Overallmean	33989.59	34609.73	34299.66	88860.59	95135.81	91998.2
SEM±	P55.97 Zn55.97 Rh45.70	P75.29 Zn75.29 Rh61.48	P46.91 Zn46.91 Rh38.30	P276.2 Zn276.2 Rh225.5	P387.9 Zn387.9 Rh316.7	P238.1 Zn238.1 Rh194.4
C.D.at5%	P161.04 Zn161.04 Rh131.49	P216.65 Zn 216.65R hN.S.	P131.33 Zn131.33 Rh107.23	P794.7 Zn794.7 Rh648.9	P1116.3 Zn1116.3 Rh911.4	P666.6 Zn666.6 Rh544.3

TableNo.:05Effectofdifferenttreatmentcombinationseconomics chickpea.

Treatments	Net income(₹ha ⁻¹)			B:Cratio		
	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
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
Overallmean	54870.99	60526.08	57698.53	1.60	1.74	1.67

SEm±	P689.1 Zn689.1 Rh562.6	P849.6 Zn849.6 Rh693.7	P546.9 Zn546.9 Rh446.6	P0.022 Zn0.022 Rh0.018	P0.033 Zn0.033 Rh0.027	P0.020 Zn0.020 Rh0.017
C.D.at5%	P1982.8 Zn1982.8 Rh1618.9	P2444.7 Zn2444.7 Rh1996.1	P1531.3 Zn1531.3 Rh1250.3	P0.064 Zn0.064 Rh0.053	P0.096 Zn0.096 Rh0.078	P0.057 Zn0.057 Rh0.047

Refrenaces:

Ahlawat, I.P.S., Gangaiah, B. and Zahid, M.A. (2007). Nutrient management in chickpea. In: Yadav SS, Redden R, Chen W and Sharma B (eds.) Chickpea Breeding and Management. CABI, Wallingford, UK, pp.213-232.

Balai, K., Jajoria, M., Verma, R., Deewan, P., & Bairwa, S. K. (2017). Nutrient content, uptake, quality of chickpea (*Cicer arietinum* L.) and fertility status of soil as influenced by fertilization of phosphorus and zinc. *Journal of Pharmacognosy and Phytochemistry*, 6(1), 392-398.

Bhuiyan, M.A.H., Khanam, D., Hossain, M.F., & Ahmed, M.S. (2008). Effect of Rhizobium inoculation on nodulation and yield of chickpea in calcareous soil. *Bangladesh Journal of Agricultural Research*, 33(4), 549-554.

Badini, S.A., Khan, M., Baloch, S.U., Baloch, S.K., Baloch, H.N., Bashir, W., Badini, A.R. Badini, M.A. (2015). Effect of Phosphorus Levels on Growth and Yield of Chickpea (*Cicer arietinum* L.) Varieties. *Journal of Natural Sciences Research*. 5 (3): ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online).

Bicer, B.T. (2014). The effect of phosphorus doses on chickpea cultivars under rain fall conditions. *Agron. Res. Moldov*, 47, 89-95.

Demeterio, J.L., Ellis Jr, R., and Paulsen, G.M. (1972). Nodulation and Nitrogen Fixation by Two Soybean Varieties as Affected by Phosphorus and Zinc Nutrition. *Agronomy Journal*, 64(5), 566-568.

Epstein, E., and Bloom, A.J. (2005). Sinauer Associates. *Mineral Nutrition of Plants: Principles and Perspectives*. 2nd edn. Sunderland MA, USA, 172.

Jain, L. K., Singh, P., and Balyan, J. K. (2006). Productivity and profitability of chickpea (*Cicer arietinum* L.) cultivation as influenced by biofertilizers and phosphorus fertilization. *Indian Journal of Dryland Agricultural Research and Development*, 21(2), 201-203.

Kedar, P.S., Kumar, R.P. and Rathi, J.P.S. (2006). Effect of FYM and biofertilizer in conjunction with inorganic fertilizer on growth, yield and profit of chickpea (*Cicer arietinum* L.). *Plant Achieves*, 5(2): 609-912.

Khan, H., McDonald, R. and Rengel, G.K. (2004). Zinc fertilization and water stress affects plant water relations, stomatal conductance and osmotic adjustment in chickpea (*Cicer arietinum* L.). *Plant Soil*, 267: 271-284.

Comment [WU16]: Match each reference with in text

Comment [WU17]: Reference format is according to journal???

Krishna, K. S. S. R., and George, P. J. (2017).Effect of levels of phosphorus and zinc on growth and yield of Kabuli chickpea (*Cicerkabulium* L.). *JPharmacognosyPhytochemistry*, 6, 013-1016.

Kumar, S., Tripathi, D.K., Bharose, R., Kumar, M. and Kumar, R. (2016).Effect of different fertility level and micronutrients on nodulation and nutrient uptake by chickpea. *An Asian Journal of Soil Sci.* 11(1):62-66.

Kumari, N., Mondal, S., Mahapatra, P., Meetei, T.T. and Devi, Y.B. (2019).Effect of Biofertilizer and Micronutrients on Yield of Chickpea, *International Journal of Current Microbiology and Applied Sciences* 8(1):2389-2397.

Mali, G. C., Sharma, N. N., Acharya, H. K., Gupta, S. K., and Gupta, P. K. (2003).Response of pigeonpea to S and Zn fertilization on vertisols in south-eastern plain of Rajasthan. *Advances in arid legumes research*, 267-271.

Meena, L. R., Singh, R. K., and Gautam, R. C. (2005).Effect of conserved soil moisture, phosphorus levels and bacterial inoculation on dry matter production and uptake pattern of phosphorus by chickpea. *Indian Journal of Pulses Research*, 18(1), 32.

Pal, S., Pandey, S. B., Singh, A., Singh, S., Sachan, R., and Yadav, A. (2021). Effect of Phosphorus, Boron and Rhizobium inoculation on productivity and profitability of chickpea. *The Pharma Innovation Journal*, 10(12):1810-1814.

Pegoraro, R.F., Almeida Neta, M.N.D., Costa, C.A.D., Sampaio, R.A., Fernandes, L.A., and Neves Rodrigues, M. (2018). Chickpea production and soil chemical attributes after phosphorus and molybdenum fertilization. *Ciência e Agrotecnologia*, 42, 474-483.

Pingoliya, K. K., Dotaniya, M. L., and Mathur, A. K. (2013). *Role of phosphorus and iron in chickpea (Cicerarietinum L.)*. LAP LAMBERT Academic Publishing.

Plaxton, W.C. (2004). Plant response to stress: biochemical adaptation to phosphate deficiency. *Encyclopedia of plant and crop science*. Marcel Dekker, New York, 976-980.

Redden R., Chen, W., Sharma, B., editors. Chickpea Breeding & Management. CABI, Wallingford, U.K. Pp 355-368.

Ryan, J., Sommer, R., and Ibrikci, H. A. Y. R. I. Y. E. (2012). Fertilizer best management practices: A perspective from the dryland West Asia–North Africa region. *Journal of Agronomy and Crop Science*, 198(1), 57-67.

Sharma, R. S., Prakash, O., and Singh, B. P. (2000). Response of mothbean genotypes to phosphorus and row spacing under semi-arid conditions. *Annals of Plant and Soil Research*, 2(2), 240-243.

Singh, A.K., Singh, B., & Singh, H.C. (2005). Response of chickpea (*Cicerarietinum* L.) to fertilizer phosphorus and zinc application under rainfed condition of eastern Uttar Pradesh. *Indian Journal of Dryland Agricultural Research and Development*, 20(2), 114-117.

Singh, D., & Singh, H. (2012). Effect of phosphorus and zinc nutrition on yield, nutrient uptake and quality of chickpea. *Ann. Pl. Soil Res.*, *14*(1), 71-74.

Schulze, J., Temple, G., Temple, S. J., Beschow, H., and Vance, C. P. (2006). Nitrogen fixation by white lupin under phosphorus deficiency. *Annals of Botany*, *98*(4), 731-740.

Sinha, B. N., Mehta, B. S., and Joydip, M. (2000). Quality and seed yield of garden pea (*Pisum sativum*) cultivars as influenced by date of planting and phosphorus levels. *Indian Journal of Agricultural Sciences*, *70*(4), 248-249.

Straw, S. (2014). Response of chickpea to levels of zinc and phosphorus. *Annals of Plant and Soil Research*, *16*(2), 172-173.

Tambekar, D. H., Gulhane, S. R., Somkuwar, D. O., Ingle, K. B. and Kanchalwar, S. P. (2009). Potential Rhizobium and phosphate solubilizers as biofertilizers from saline belt of Akola and Buldhana district, India. *Research Journal of Agriculture and Biological Sciences*, *5*(4):578-582.

Tiwari, V. N., Upadhyay, R. M., and Pandey, R. K. (2001). Associative effect of diazotrophs and phosphorus on chickpea. *Indian Journal of Pulses Research*, *14*(2), 129-132.

Ullah, S., Jan, A., Ali, M., Ahmad, A., Ullah, A., Ahmad, G., Afridi, K., Ishaq, M., Saeed, M. and Raiz, A. (2017). Effect of phosphorus under different application methods on yield attributes of chickpea (*Cicer arietinum* L.). *Int. J. Agri and Env. Res.*, *3*(1):79-85.

Valenciano, J. B., Boto, J. A. and Marcelo, V. (2011). Chickpea (*Cicer arietinum* L.) response to zinc, boron and molybdenum application under field conditions, *New Zealand Journal of Crop and Horticultural Science* Vol. *39*(4), 217-229.

Vimala, B., and Natarajan, S. (2000). Effect of nitrogen, phosphorus and biofertilizers on pod characters, yield and quality in pea (*Pisum sativum* L. spp. hortense). *South Indian Horticulture*, *48*(1/6), 60-63.

Yadav, M. K., Singh, B. H. A. G. W. A. N., Singh, A. K., Mahajan, G. A. U. R. A. V., Kumar, R. A. K. E. S. H., Singh, M. K., and Balai, S. R. (2010). Response of Chickpea (*Cicer arietinum* L.) to Sowing Methods and Zinc Sulphate Levels under Rainfed Condition of Eastern Uttar Pradesh. *Environment and Ecology*, *28*(3), 1652-1654.

Yadav, P. S., Kameria, P. R. and Rathore, S. (2002). Effect of phosphorus and iron fertilization on yield, protein content and nutrient uptake in gram (*Cicer arietinum* L.) on loam sand soil. *Journal of the Indian Society of Soil Science* *50*:225-226.

Zengeni, R., Mpeperekwi, S., and Giller, K. E. (2006). Manure and soil properties affect survival and persistence of soybean nodulating rhizobia in smallholder soils of Zimbabwe. *Applied Soil Ecology*, *32*(2), 232-242.

UNDER PEER REVIEW

