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Effect of seed inoculation of chickpea (*Cicer arietinum* L.) with rhizobium, Iron and Zinc solubilizers on growth and yield in Central zone of UP

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Abstract
An experiment comprising 9 treatments *viz*., Control (T_1), Rhizobium inoculated + RDF (T_2), Fe-Zn solubilizers (inoculated) + RDF (T_3), Fe-Zn solubilizers inoculated and Rhizobium + RDF (T_4), $FeSO_4$ (uninoculated) + + RDF (T_5), $FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF (T_6), RDF+ $ZnSO_4$ (uninoculated) + RDF (T_7), $ZnSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF (T_8), $FeSO_4$ + $ZnSO_4$ (uninoculated) + RDF (T_9) were subjected in randomized block design with 3 replications at Research Farm of the University in Chickpea cv. Sadabahar, during *Rabi* 2022-23. $FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF (T_6) was found to be the most effective treatment on growth parameters *viz.*, initial plant population (10.76), plant height 27.64, 54.69, 66.39 and 68.09 cm, number of branches per plant 11.55, 16.22 and 17.66, number of leaves 682.50, 911.24 and 1,075.63, dry matter accumulation 1.97, 7.24, 10.14 at 30, 60, 90 DAS respectively and yield attributes i.e., pod length (3.70 cm), number seeds per pod (1.72), number of pods per plant (89.60) and seed index (19.30 g). maximum biological yield (59.48 q ha^{-1}), grain yield (24.39 q ha^{-1}) and straw yield (35.09 q ha^{-1}) are also recorded with $FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF (T_6) and maximum harvest index (44.96) with treatment Rhizobium inoculated + RDF (T_2). In the case of the B: C ratio, treatment $FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF (T_6) recorded the highest B: C ratio (1.82).

Keywords: Chickpea, rhizobium, zinc sulphate, ferrous sulphate, Zn solubilizers and Fe Zn solubilizers

Introduction
In India, pulses consistently supply food for people and animals, as well as supporting the nation's economy and ecology. Pulses are essential components of industrial systems that can withstand climate change. Asia and Africa produce 78% of the output for global consumption. Due to the low cost of growing pulses in poor countries, India is the world's top producer and consumer of pulses. Chickpea yield is still extremely low, even though chickpea output as a share of global pulse production increased to 35.22 percent in 2021–22. By importing products through 2017, the government aimed to address the supply-demand mismatch brought on by India's steadily rising pulse consumption. The cost of producing chickpeas has increased over time. (Anonymous, 2022) [11].

Due to their status as a legume, chickpeas (*Cicer criterium* L.) have the ability to fix nitrogen via the Rhizobium bacterium. Only when the plant is sufficiently supplied with all the mineral elements necessary for active growth can nodule rhizobia fix nitrogen actively (Russell, 1977)? Elements like P, Mo, Fe, Zn, and Co may be significant in this context. Micronutrients are essential substances that plants must have in little amounts to grow normally. If these components are not readily available, the plant will experience physiological stressors brought on by a number of enzyme systems that are not operating as effectively as they could and other related metabolic processes. Different reactions to a lack of trace elements were seen in crop species and cultivars in terms of growth and yield.

Iron is necessary for the synthesis of chlorophyll, iron chlorosis in crops that are sensitive to iron and are grown on calcareous soil can be easily identified. In addition, iron is a component of numerous enzymes involved in the transmission of energy, nitrogen reduction and fixation, and the creation of lignin. In plants, iron and sulphur combine to generate molecules that accelerate further processes. Yellow leaves are the principal sign of iron deficiency because they have low chlorophyll levels.

The younger top leaves in interveinal tissues are the first to yellow. Leaves that are severely iron deficient turn entirely yellow or practically white before dying and turning brown. Iron deficiency is more common in soils with high pH values, while it can also occur in acidic, sandy, low-organic matter soil.

One of the most crucial micronutrients is zinc. It plays a crucial function in the transformation of carbohydrates, controlling sugar consumption, and increasing the source of energy for chlorophyll synthesis.

Numerous bacteria and fungi that can dissolve iron and zinc have been identified. The fixed iron and zinc phosphates in the soil are known to be solubilized by them, making them available for plant uptake. When injected into the seed fixed, the culture of these organisms multiplies in the soil and aids in the solubilization of the soil's Fe and Zn components. Numerous bacteria and fungi that dissolve Fe-Zn also solubilize P, assisting plants in their P nutrition.

Material and Methods

The present experiment comprises 9 treatments viz., Control (T_1), Rhizobium inoculated + RDF (T_2), Fe-Zn solubilizers (inoculated) + RDF (T_3), Fe-Zn solubilizers inoculated and Rhizobium + RDF (T_4), $FeSO_4$ (uninoculated) + + RDF (T_5), $FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF (T_6), RDF+ $ZnSO_4$ (uninoculated) + RDF (T_7), $ZnSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF (T_8), $FeSO_4$ + $ZnSO_4$ (uninoculated) + RDF (T_9) were subjected in randomized block design with 3 replications at Research Farm of the University in Chickpea cv. Sadabahar, during *Rabi* 2022-23 following spacing of 30 cm x 10 cm in plot size of 3.50 m x 3.00 m. The experimental site is located at a latitude of about 26.57º North, a longitude of approximately 80.21 º East and an elevation of 126 m above mean sea level. The experimental soil was sandy loam in nature having 7.4 pH, 0.46 dSm^{-1} EC, 0.53% Organic Carbon, 133.5 kg ha^{-1} Available N, 15.5 kg ha^{-1} Available P_2O_5 and 215.3 kg ha^{-1} Available K_2O. The experimental field was prepared well for good germination. Fertilizers @ 20 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} were applied before sowing. Quality seed of variety Sadabahar was sown @100 kg ha^{-1} on Oct 20, 2022. Pre-emergence herbicides were administered by a Knapsack sprayer equipped with a flat fan nozzle and 500 litres of water per hectare. Other agronomical and plant protection measures were taken from time to time to raise an ideal crop.

Five plants selected randomly from each plot were tagged. The height (cm), number of branches per plant and number of leaves per plant were measured at 30, 60, and 90 DAS and at maturity. Mean values were computed. Days to 50% flowering of chickpea plants were recorded from the sowing of the seed of each treatment. The days were counted and average days were expressed as days to 50% flowering.

Grain yield was measured by adjusting to a moisture content of 12% in q/ha from the net plot area of each treatment replication-wise. The harvest index was determined by using Donald's (1962) [12] as Economic yield/ Biological yield x 100. The net return was computed by taking the cultivation expenses out of the specific treatment's gross return. Further, the Benefit: Cost ratio was calculated by dividing the net return by the cost of cultivating each particular treatment. Data were finally analysed following standard statistical methods.

Results and Discussion

The seed inoculation with rhizobium, iron and zinc have made remarkable effects on growth parameters initial plant population, plant height, number of branches per plant, number of leaves and dry matter accumulation. Seed inoculation with rhizobium increases the nitrogen availability to plants and inoculation with iron and zinc completes the recommendation of zinc and iron to plants.

Initial plant population

The experimental data on IPP is shown in Table-1. The remarkable effect on IPP was shown with the use of rhizobium, iron and zinc solubilizers. The maximum IPP i.e., 10.76 was recorded in the treatment T_6 {$FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} followed by 10.67 in T_8 {$ZnSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF}. The minimum IPP (10.37) was observed in the T_1 (control) treatment.

Plant height (cm)

The plant height of the chickpea was recorded at 30, 60, and 90 DAS and harvest stages. Data have been presented in Table-1. The plant increases in height between 30 to 90 days of sowing. The plants showed negligible growth at maturity or reaching maturity. The rhizobium, iron and zinc solubilizers increase the availability of nitrogen, iron and zinc to plants. Significant maximum plant height of 27.64, 54.69, 66.93 and 68.09 cm was recorded in the treatment T_6 {$FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} and a minimum height of plant 25.74, 45.68, 56.58 and 61.54 cm was recorded in the control treatment. The result of plant height was following the result of Zhou *et al*., 2012 [13].

Number of branches per plant

The data on a number of branches $plant^{-1}$ of chickpea were recorded at 30, 60 and 90 DAS and data have been depicted in Table-1. The data collected during the chickpea's growth period revealed that the growth was at its highest between 30 and 90 DAS. When plants reached maturity, the number of branches barely increased. The maximum branches in chickpea 11.55, 16.22 and 17.66 was recorded in the treatment T_6 {$FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} followed by 10.36, 15.36 and 17.33 which were observed in the treatment T_8 {$ZnSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF}. Minimum branches were observed at about 5.41, 9.74 and 11.96 recorded in the control treatment. The result of a number of branches $plant^{-1}$ was also revealed by Kumar *et al*., (2018) [3].

Number of leaves per plant

The leaves per plant on chickpea were recorded at 90 DAS and data have been depicted in Table-1. The data recorded during the growth phase of the chickpea showed that the growth was maximum during 30 DAS to 90 DAS. The plants reaching maturity were showed about zero growth in the number of leaves per plant. At 90 DAS, the maximum leaves in chickpea 1075.63 were recorded in the treatment T_6 $FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} followed by 1048.36 and 1015.25 which were observed in the treatment T_8 $ZnSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} and T_4 {Fe-Zn solubilizers inoculated and Rhizobium + RDF} respectively. Minimum leaves per plant were about 820.66 recorded in the control treatment. The

result on leaves per plant was also revealed by Tagore, G.S. and Namdeo SL (2013) [13].

Dry matter accumulation per plant

The data on dry matter accumulation per plant of chickpea was recorded at 30, 60 and 90 DAS. The data have been presented in Table-1. The data of dry matter accumulation of the growth phase of chickpea showed that accumulation was maximum between 30 DAS to 90 DAS. The highest dry matter accumulation of 1.97, 7.24 and 10.14 g per plant was recorded in the treatment T_6 {$FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} followed by 1.93 6.92 and 9.65 g per plant with treatment T_8 {$ZnSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} and minimum accumulation of dry matter per plant about 1.71, 3.32 and 7.89 g was in treatment control. The result of dry matter accumulation per plant was also observed by Pirdadesh *et al.*, (2013) [9].

Table-1: Effect of rhizobium, iron and zinc solubilizer on growth parameter of chickpea

Treatment	Initial Plant Population	Plant height cm				No. of branches per plant			No. of leaves per plant	Dry matter accumulation g per plant		
		30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS		30 DAS	60 DAS	90 DAS
T1	10.37	25.74	45.68	56.58	61.54	5.41	9.74	11.96	820.06	1.71	5.63	7.31
T2	10.54	26.11	47.64	58.54	63.25	7.20	12.14	13.66	857.67	1.73	6.32	7.89
T3	10.64	25.85	48.15	59.65	64.41	8.18	12.51	14.33	890.47	1.75	6.38	8.00
T4	10.65	27.13	52.53	63.40	67.33	10.17	14.75	16.66	1,015.25	1.90	7.15	9.30
T5	10.40	25.99	49.45	60.95	65.28	8.85	13.18	15.06	922.55	1.79	6.20	8.31
T6	10.76	27.64	54.69	66.39	68.09	11.55	16.22	17.66	1,075.63	1.97	7.24	10.14
T7	10.58	26.60	50.38	62.48	66.10	9.84	14.21	15.66	957.94	1.82	6.83	9.05
T8	10.67	26.82	51.33	64.33	67.38	10.36	15.36	17.33	1,048.36	1.93	6.92	9.65
T9	10.55	26.69	51.55	63.35	66.85	10.01	14.95	16.00	982.54	1.87	6.87	9.09
SE(m)	0.145	0.789	0.390	0.380	0.321	0.212	0.268	0.254	14.377	0.027	0.163	0.194
C.D.	NS	NS	1.179	1.148	0.971	0.642	0.810	0.767	43.474	0.083	0.493	0.588

Number of pods per plant

The table-2 clearly depicted that the experimental data of pods per plant. The number of pods per plant was significantly affected due to rhizobium, iron and zinc solubilizers. The maximum number of pods were i.e. 89.60 were recorded in the treatment T_6 {$FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} followed by 85.60 in T8 {$ZnSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF}. The lowest number of pods per plant i.e. 58.40 was observed in T1 (control) followed by 63.30 pods in treatment T2 (Rhizobium inoculated + RDF). The result of pods per plant was also found by Kumar *et al.*, (2016) [6].

Number of grains per pod

The experimental data of the number of grains per pod have been shown in Table-2. The number of seeds per pod was significantly affected due to various combinations of rhizobium, iron and zinc solubilizers. The highest number of seeds in pod were i.e., 1.72 were recorded in the treatment T_6 {$FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} followed by 1.65 in T8 {$ZnSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} and 1.60 seeds in treatment T4 {Fe-Zn solubilizers inoculated and Rhizobium + RDF}. The lowest number of seeds per pod i.e., 1.00 seed were found in T_1 (control). The result of grains per pod was also found by Kumar *et al.*, (2016) [6].

Pod length (cm)

The experimental data of pod length have been depicted in Table-2. The rhizobium, iron and zinc solubilizers provide nitrogen and micronutrient i.e. iron and zinc which increases seeds per pod. The maximum length of pod i.e. 3.70 cm was recorded in the treatment T_6 {$FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} followed by 3.50 cm in T_8 $ZnSO_4$ {(Rhizobium and Fe-Zn solubilizers inoculated) + RDF}. The minimum length of the chickpea pod i.e. 2.40 cm was found in control. The result of pod length was also found by Kumar *et al.*, (2016) [6].

Seed index (g)

The data of the seed index have been presented in Table-2. The seed index in the present investigation was found from 15.01 g to 19.30 g. The nutrient supply by RDF, rhizobium, iron and zinc produces healthy and bold seeds. The maximum seed index of 19.30 g was recorded in the treatment T_6 {$FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} which was at par with 19.00 g in T8 {$ZnSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF}. The minimum seed index of 15.01 g was found in control. The result of seed index was also found by Kumar *et al.*, (2018) [3].

Grain yield (q/ ha)

The data of grain yield per hectare have been presented in Table-2. The grain yield per hectare in this investigation was recorded between 11.78 q to 24.39 q. The nutrients NPK, zinc and iron complete the recommendation of plants for their growth and production and increase the yield also. The maximum grain yield of chickpea 24.39 q was recorded in the treatment T_6 {$FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} followed by 22.03 q in T_8 {$ZnSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF}. The minimum grain yield of 11.78 q was found in the control. The result of grain yield was also found by Kumar *et al.*, (2018) [3].

Harvest index (%)

The experimental data of the harvest index have been shown in Table-2. The highest harvest index of 44.96% was in the treatment T_2 (Rhizobium inoculated + RDF followed by T_1 control. The lowest harvest index of 40.89 was found in T_6 {$FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF)}. The result of the harvest index was also found by Kumar *et al.*, (2018) [3].

Table 2: Effect of rhizobium, iron and zinc solubilizer on yield and yield attributes of chickpea

Treatments	No. of pods per plant	No. of grains per pod	Pod length (cm)	Seed index (g)	Grain yield Q per ha.	Harvest index (%)	Net return Rs. per ha.	B: C ratio
T_1	58.40	1.00	2.40	15.01	11.78	44.73	23,855.43	1.49
T_2	63.30	1.34	2.50	15.60	14.44	44.96	30,331.05	1.52
T_3	68.50	1.40	2.60	16.10	16.05	44.11	36,465.47	1.57
T_4	83.50	1.60	3.30	18.50	20.50	41.07	56,164.70	1.70
T_5	72.40	1.46	2.70	16.70	17.35	42.63	40,687.50	1.60
T_6	89.60	1.72	3.70	19.30	24.39	40.89	68,438.46	1.82
T_7	75.80	1.52	2.90	17.20	19.38	42.28	46,009.32	1.63
T_8	85.60	1.65	3.50	19.00	22.03	41.66	60,848.57	1.75
T_9	80.40	1.58	3.10	17.80	20.55	41.81	51,696.19	1.68
SE(m)	1.288	0.017	0.048	0.288	0.442	0.241	-	-
C.D.	3.896	0.051	0.146	0.870	1.337	0.648	-	-

Net return Rs per hectare

The maximum net return of 68,438 Rs was recorded in the treatment T_6 {$FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} followed by 60,848 Rs in the treatment T_8 {$ZnSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF}. The minimum net return of 23,855 Rs was recorded in the treatment control.

B: C ratio

The treatment T_6 {$FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} recorded the highest benefit: Cost ratio (1.82) followed by T_8 {$ZnSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF} (1.75). The minimum benefit: Cost ratio (1.49) was recorded in the treatment control. The result of the B: C ratio was also found by Khaitov *et al.*, (2020) [4].

Conclusion

Keeping the above findings in view, it is concluded that the application of $FeSO_4$ (Rhizobium and Fe-Zn solubilizers inoculated) + RDF could be exploited in order to harvest the maximum grain yield 24.39 q ha^{-1}, revenue generation (net return Rs. 68438.462 ha^{-1}) and (1.82) B: C ratio in Chickpea cultivation during *Rabi* season 2022-23.

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