International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
Maths 2023; SP-8(5): 668-670

https://www.mathsjournal.com
Received: 28-06-2023
Accepted: 01-08-2023

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Effect of bio-fertilizers on growth, yield and yield attributes of chickpea (*Cicer arietinum)*

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Abstract
The experiment utilized a Randomized Block Design (RBD) method with six treatments and three replications. The treatments included T_1: Control + 100% Recommended Dose of Fertilizer (RDF), T_2: 100% RDF + *Rhizobium*, T_3: 100% RDF + *Trichoderma*, T_4: 100% RDF + *Rhizobium* + Phosphate Solubilizing Bacteria (PSB), T_5: 100% RDF + *Trichoderma* + *Rhizobium*, T_6: 100% RDF + *Rhizobium* + *Trichoderma* + PSB. The application of a combination of chemical and biological fertilizers substantially induced the growth, production, and yield characteristics of gram (chickpea). Notably, the application of T_6 (100% RDF + *Rhizobium* + *Trichoderma* + PSB) had a highly positive impact on various plant growth parameters, including plant height (measuring 45.18 cm), branches per plant, leaves per plant (294.67), dry biomass per plant (40.83 g), and nodules per plant (50.67). Additionally, this treatment positively affected yield-related attributes, such as pods per plant (69.00), seed pods per plant (2.33), and test weight (171.67 g).

Keywords: Chickpea, RDF + Bio-fertilizers, growth, yield and yield attributes

Introduction
Pulse crops hold paramount importance as the primary protein source for the vegetarian community in our nation. However, the per capita availability of pulses is on a steady decline due to the combination of a burgeoning population and low pulse crop productivity. In contrast to the World Health Organization/Food and Agriculture Organization's recommended daily intake of 104 grams of pulses, only 47 grams of pulses are available per person. Chickpeas, scientifically known as *Cicer arietinum* L., belong to the Fabaceae or Leguminosae family and are commonly referred to as Bengal gram or black chana in both Hindi and English. Chickpeas are a fine source of protein, carbohydrates, fats, vitamins, and essential minerals such as calcium, phosphorus, and iron. They also possess significant forage value and can serve as animal feed. Chickpeas hold the distinction of being the most extensively cultivated food legume in South Asia and rank as the third most cultivated worldwide, trailing behind field peas and common beans. India takes the lead in chickpea production, contributing to 64% of the world's chickpea output, making it the largest global producer. India further dominates with a 76% share of the global chickpea cultivation area and a 67% share of global chickpea production. In India, approximately 9.18 million hectares of land are dedicated to chickpea cultivation, resulting in a total production of 8.22 million tons, with an average yield of 900 kg/ha.

Bio-fertilizers are specific strains of favorable soil microorganisms that are cultured in a laboratory and then packaged in an appropriate carrier. These bio-fertilizers can be applied to the soil or used as a treatment for seeds. By their activities in the soil or rhizosphere, they play a crucial role in enhancing the availability of essential nutrients like nitrogen and phosphorus to plants in a soluble form. One notable application involves the incorporation of selected *Rhizobium* bacteria strains into seeds. This helps enhance atmospheric nitrogen fixation, ultimately promoting plant growth and increasing agricultural productivity. Additionally, the assistance of phosphorus-solubilizing bacteria (PSB) in converting chemically fixed, insoluble phosphate into a readily accessible form contributes to achieving higher crop yields.

Materials and Methods

The study titled "Performance of bio-fertilizers on yield and economics of chickpea (*Cicer arietinum*)" was carried out at the Crop Research Cafeteria at the educational institution known as the G. H. Raisoni University's School of Agricultural Sciences is located in Chhindwara, a region within the state of Madhya Pradesh., hosted its Rabi season in 2022. This chapter provides detailed information about the materials used in the experiment, the methodologies employed throughout the research, field observations, and laboratory-based chemical analyses. Meteorological information, encompassing peak and nadir temperatures, mean relative humidity levels, precipitation amounts, and evaporation rates were collected at the G. H. Raisoni University meteorological observatory during the crop growth period spanning from November 6, 2022, to March 10, 2023. According to the data, there was a total of 59.00 mm of rainfall during the Rabi 2022 crop growth phase. The soil characteristics of the experimental field were also examined. The topography of the field was consistent, with a gentle slope, and adequate drainage facilities were available. Prior to planting the crop, a random soil sample was collected from a depth of 15 cm in the experimental field. These individual samples were then combined to create a composite soil sample for subsequent chemical analysis.

Plant height (cm)

The plant's vertical growth was assessed in centimeters, starting from the plant's root and extending to the tip of its primary stem. Throughout the entire growth cycle, measurements were taken at consistent 30-day intervals.

Dry matter plant^{-1}

Plants were harvested from each set of replications and treatments individually. The plant samples were subsequently rinsed using tap water to eliminate any soil or particles clinging to them. Afterward, they were exposed to dry air to allow the surface to aerate. The weight of the plant samples was quantified in grams per plant using an electronic scale.

Number of branches plant^{-1}

To ascertain the mean branch count of plant^{-1}, we recorded the number of branches on five specifically chosen plants and calculated their average.

Yield attributes and yield studies

Following the completion of the crop harvest, a thorough examination was conducted to analyze the key factors contributing to the yield.

Number of pods plant^{-1}

Five pods were chosen at random from a set of plants, and the collective count of pods was tallied. Approximations were utilized to estimate the mean quantity and weight of pods for plant^{-1}.

Seed pod^{-1}

The mean seed weight for plant^{-1} was determined following the individual threshing of pods from the selected observation plants.

Seed index

Representative samples from each net plot were used to count and independently weight 100 seeds. This 100-seed weight was calculated as a seed index.

Seed yield (kg ha^{-1})

After the produce was winnowed and sun dried with the aid of a double pan balance, the grain yield per net plot was calculated. The final step was multiplying the seed yield of each plot by the appropriate conversion factor to produce the seed yield kg/ha.

Stover yield (kg ha^{-1})

The calculation of stover yield involved subtracting the economic yield (seed yield) from the biological yield (bundle weight) for each plot. Afterward, this outcome was multiplied by the same conversion factor used for determining seed yield in kilograms per hectare, yielding the straw yield in kilograms per hectare.

Harvest index (%)

This concept pertains to the percentage representation that signifies the connection between the economic yield (specifically seed yield) and the combined biological yields (encompassing both seed and stover yields) within a given treatment. To calculate this metric for individual plots, the following formula, as proposed by Donald in 1962, was employed:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

Results and Discussion

The study's results and relevant discussions have been organized into the following categories:

Effect on growth parameters

The highest recorded plant height at harvest, measuring 45.18 cm, as well as the greatest number of leaves per plant (294.67), dry weight per plant (40.83 g), and nodules per plant were observed in treatment T_6. This treatment involved the application of 100% recommended dose of fertilizer (RDF) along with *Rhizobium*, *Trichoderma*, and PSB (Phosphate Solubilizing Bacteria). These results demonstrated significant superiority over treatments T_5 (RDF 100% + *Trichoderma* + *Rhizobium*), T_3 (RDF 100% + *Trichoderma*), and T_2 (RDF 100% + *Trichoderma*). Conversely, the lowest values for these parameters were recorded in the control treatment, T_1 (Control + RDF 100%). It is worth noting that the findings of this study align with previous research conducted by Rajput (2018) [8], Singh *et al.* (2019) [6], Boreddy *et al.* (2019) [1], and Shivran *et al.* (2017) [9].

Table 1: The impact of various nutrient sources on the height (in centimeters) of chickpea plants at different developmental stages.

T. No	Treatments	plant height (cm)	leaves plant^{-1}	Dry weight plant^{-1}	Nodules plant^{-1}
T_1	Control + RDF 100%	36.91	219.33	23.73	24.67
T_2	RDF 100% + *Rhizobium*	40.80	295.33	38.04	39.67
T_3	RDF 100% + *Trichoderma*	42.24	290.67	39.07	35.33
T_4	RDF 100% + *Rhizobium* + PSB	43.92	292.33	43.94	46.67
T_5	RDF 100% + *Trichoderma* + *Rhizobium*	42.10	273.00	39.8	44.00
T_6	RDF 100% + *Rhizobium* + *Trichoderma* +PSB	45.18	294.67	40.83	50.67
S.Em±		0.74	0.74	0.94	0.91
CD (P=0.05)		2.36	2.36	2.81	2.72

Effect on yields

Yield (Kg ha^{-1})

Treatment T_6, which consisted of RDF 100%, *Rhizobium*, *Trichoderma*, and PSB, demonstrated the highest seed yield (1693 kg ha-1), stover yield (2607 kg ha^{-1}), and harvest index (39.37%). In contrast, treatment T_1 (Control + RDF 100%) exhibited the lowest seed yield, stover yield, and harvest index. This difference in performance can be attributed to more efficient transportation of food materials from source to sink (tuber) and a well-balanced supply of essential nutrients to the crop plants. These findings align with previous research conducted by Gudadhe *et al.* (2011) [2], Khandelwal *et al.* (2012) [3], Kumar *et al.* (2018) [4], Boreddy *et al.* (2019) [1], and Singh *et al.* (2019) [6].

Table 2: Effect of integrated nutrient management on seed, stover yield ha^{-1}, harvest index of chickpea

T. No	Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest Index (%)
T_1	Control + RDF 100%	1,016	1,789	36.23
T_2	RDF 100% + *Rhizobium*	1,465	2,344	38.46
T_3	RDF 100% + *Trichoderma*	1,398	2,177	39.12
T_4	RDF 100% + *Rhizobium* + PSB	1,574	2,440	39.22
T_5	RDF 100% + *Trichoderma* + *Rhizobium*	1,555	2,441	38.92
T_6	RDF 100% + *Rhizobium* + *Trichoderma* +PSB	1,693	2,607	39.37
S.Em±		22.29	44.49	0.18
CD (P=0.05)		71.14	142.01	0.57

Effect on yield attributes

Table 3 presents a summary of the effects of different treatments on three key parameters: the number of pods per plant, the number of seeds per pod, and seed weight. The results indicate that several treatments had a significant impact on these parameters. Specifically, the treatment labeled T_6 (comprising RDF 100%, *Rhizobium*, *Trichoderma*, and PSB) resulted in the highest yield for these characteristics, including a seed weight of 125.67 grams, a substantial number of seeds per pod, and an increased number of pods per plant. These findings align with those reported by Verma *et al.* (2017) [7] and Boreddy *et al.* (2019) [1], demonstrating consistency in the observed effects of these treatments on crop yield.

Table 3: The impact of various nutrient sources on the quantity of pods per plant, the number of seeds per pod, and the test weight of chickpeas

T. No	Treatments	Pod plant^{-1}	Seed pod^{-1}	Test weight (g)
T_1	Control + RDF 100%	47.00	1.00	125.67
T_2	RDF 100% + *Rhizobium*	59.33	1.33	153.33
T_3	RDF 100% + *Trichoderma*	57.67	2.00	149.00
T_4	RDF 100% + *Rhizobium* + PSB	65.67	2.00	164.00
T_5	RDF 100% + *Trichoderma* + *Rhizobium*	63.33	1.33	154.67
T_6	RDF 100% + *Rhizobium* + *Trichoderma* +PSB	69.00	2.33	171.67
S.Em±		1.57	0.26	5.32
CD (P=0.05)		5.02	0.82	16.97

Conclusion

After conducting a year-long trial, it was concluded that employing a combination of RDF (Recommended Dose of Fertilizers) at full strength along with *Rhizobium*, *Trichoderma*, and PSB (Phosphate Solubilizing Bacteria) in the Chhindwara district of Madhya Pradesh would yield the greatest chickpea crop production and deliver the most favorable benefit-to-cost ratio.

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