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EFFECT OF FERTILIZER DOSE, SEED INOCULATION AND FOLIAR NUTRITION ON GROWTH AND YIELD OF SUMMER COWPEA (*Vigna unguiculata* L. Walp.)

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ABSTRACT

An experiment was conducted at Rajasthan Agricultural Research Institute (RARI), Durgapura, Jaipur during summer 2024 to evaluate the effect of fertilizer dose, seed inoculation and foliar nutrition on growth, yield and economics of cowpea. The experiment consisted of two fertilizer doses [100% RDF and 75% RDF], three seed inoculation treatments [control, Rhizobium @ 50 g kg^{-1} seed + Biophos + Biozinc each @ 5 ml kg^{-1} seed and N P K Zn microbial consortia @ 50 g kg^{-1} seed] and four foliar nutrition treatments [N P K (19:19:19) @ 2%, Nano DAP @ 0.4%, Nano Urea @ 0.4% and water spray] laid out in a Factorial Randomized Block Design with three replications. The results revealed that application of 100% RDF recorded significantly higher plant height (65.66 cm), number of pods $plant^{-1}$ (12.30), pod length (11.98 cm), test weight (67.27 g), seed yield (524 kg ha^{-1}), straw yield (1312 kg ha^{-1}), biological yield (1837 kg ha^{-1}), gross returns (Rs. 49,818 ha^{-1}), net returns (Rs. 12,897 ha^{-1}) and B:C ratio (1.35) over 75% RDF. Among seed inoculation treatments, Rhizobium @ 50 g kg^{-1} seed + Biophos + Biozinc each @ 5 ml kg^{-1} seed recorded significantly higher seed yield (525 kg ha^{-1}), straw yield (1315 kg ha^{-1}) and biological yield (1840 kg ha^{-1}) over the control and remained statistically at par with NPKZn microbial consortia @ 50 g kg^{-1} seed. In case of foliar nutrition, application of NPK (19:19:19) @ 2% at pre-flowering and pod initiation stages recorded significantly higher plant height (68.12 cm), pods $plant^{-1}$ (12.12), test weight (70.49 g), seed yield (528 kg ha^{-1}), straw yield (1331 kg ha^{-1}), biological yield (1859 kg ha^{-1}), gross returns (Rs. 50,270 ha^{-1}), net returns (Rs. 13,826 ha^{-1}) and B:C ratio (1.38) over water spray, while remaining at par with Nano DAP and Nano Urea treatments. The study concluded that integrated nutrient management involving 100% RDF, seed inoculation with Rhizobium + Biophos + Biozinc and foliar application of NPK (19:19:19) at critical growth stages improved growth, productivity and profitability of summer cowpea under the agro-climatic conditions of Rajasthan.

***Keywords*:** Biofertilizers, economics, fertilizer dose, foliar nutrition, integrated nutrient management.

Introduction

Cowpea (*Vigna unguiculata* L. Walp.) is one of the most important pulse crops cultivated in tropical and subtropical regions of the world. It is widely grown for its grains, green pods, fodder and green manure purposes owing to its high nutritional value and adaptability to diverse agro-climatic conditions (Kombat *et al.,* 2026). Cowpea seeds are rich in protein (22-28%), carbohydrates, vitamins and minerals, making it an important component of human nutrition, particularly in developing countries. In India, cowpea is cultivated extensively in Rajasthan, Uttar Pradesh, Haryana, Punjab, Gujarat and several southern states under rainfed as well as irrigated conditions (Singh *et al.,* 2025). Besides serving as a nutritious food source, cowpea contributes to soil fertility through biological nitrogen fixation and fits well in various cropping systems. Despite its importance, the productivity of cowpea in many parts of India remains below its potential level due to inadequate and imbalanced nutrient management practices. Continuous cultivation and intensive cropping have resulted in depletion of essential plant nutrients from soils, thereby limiting crop growth and productivity. Application of recommended doses of fertilizers is essential for meeting crop nutrient requirements; however, indiscriminate use of chemical fertilizers alone may adversely affect soil health and increase production costs. Therefore, integrated nutrient management involving chemical fertilizers, biofertilizers and foliar nutrition has emerged as a sustainable approach for enhancing crop productivity while maintaining soil fertility (Singh *et al.,* 2025).

Biofertilizers play a vital role in improving nutrient availability and utilization by crops. Seed inoculation with efficient strains of *Rhizobium* enhances biological nitrogen fixation, resulting in improved plant growth and yield. Similarly, phosphate-solubilizing and zinc-solubilizing microorganisms increase the availability of phosphorus and zinc in the rhizosphere, thereby promoting root development and nutrient uptake (Bhardwaj *et al.,* 2014). The use of microbial consortia containing beneficial microorganisms has also gained importance owing to their synergistic effects on nutrient mobilization and crop productivity. Integration of biofertilizers with inorganic fertilizers not only improves nutrient use efficiency but also contributes to sustainable agricultural production. Foliar nutrition has been recognized as an effective strategy to supplement nutrient requirements during critical growth stages of crops. Application of water-soluble fertilizers and nano-fertilizers through foliar sprays ensures rapid nutrient absorption and utilization, particularly under conditions where nutrient availability from soil becomes limited. Foliar application of balanced fertilizers such as NPK (19:19:19), Nano DAP and Nano Urea at pre-flowering and pod initiation stages can improve photosynthetic activity, flowering, pod development and ultimately seed yield. Moreover, nano-fertilizers are reported to enhance nutrient use efficiency due to their targeted delivery and controlled release characteristics (Choudhary *et al.,* 2026 & Khan *et al.,* 2026). Considering the importance of balanced nutrient management and the potential benefits of integrating fertilizer dose, seed inoculation and foliar nutrition, the present investigation was undertaken to study the effect of fertilizer dose, seed inoculation and foliar nutrition on growth and yield of cowpea under summer season conditions of Rajasthan. The study was aimed at identifying an efficient nutrient management strategy for improving crop productivity and profitability while ensuring sustainable soil fertility management.

Materials and Methods

The field experiment was conducted during the summer season of 2024 at the Research Farm of Rajasthan Agricultural Research Institute (RARI), Durgapura, Jaipur, Rajasthan, India. The experimental site is situated at 26°51′ N latitude and 75°47′ E longitude with an altitude of about 390 m above mean sea level. The region falls under the semi-arid eastern plain agro-climatic zone of Rajasthan and is characterized by hot summers and low to moderate rainfall. The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction and low in available nitrogen, medium in available phosphorus and potassium. The experiment comprised twenty-four treatment combinations involving two fertilizer doses, three seed inoculation treatments and four foliar nutrition treatments. The treatments consisted of fertilizer dose [F_1: 100% recommended dose of fertilizer (RDF) and F_2: 75% RDF], seed inoculation [S_1: Control, S_2: Rhizobium @ 50 g kg^{-1} seed + Biophos + Biozinc each @ 5 ml kg^{-1} seed and S_3: NPKZn microbial consortia @ 50 g kg^{-1} seed] and foliar nutrition [N_1: NPK (19:19:19) @ 2% at pre-flowering and pod initiation stages, N_2: Nano DAP @ 0.4% at pre-flowering and pod initiation stages, N_3: Nano Urea @ 0.4% at pre-flowering and pod initiation stages and N_4: Water spray at pre-flowering and pod initiation stages].

The experiment was laid out in Factorial Randomized Block Design (FRBD) with three replications. Thus, a total of twenty-four treatment combinations were evaluated under field conditions. Recommended agronomic practices were followed uniformly for all the treatments throughout the crop growing period. The required quantity of fertilizers was applied as per treatment through inorganic sources. Full doses of phosphorus and other basal nutrients along with the prescribed quantity of nitrogen were applied at sowing. Seed inoculation treatments were carried out immediately before sowing using the respective biofertilizer formulations. Foliar sprays were applied twice, first at pre-flowering stage and subsequently at pod initiation stage using a knapsack sprayer during the morning hours to ensure uniform coverage. Observations on growth parameters such as plant height, number of branches per plant, dry matter accumulation and chlorophyll content were recorded at appropriate growth stages. Yield attributes including number of pods per plant, pod length, number of seeds per pod and test weight were recorded at harvest. Seed yield and straw yield were recorded on net plot basis and converted into kilogram per hectare. Protein content of seed was determined using standard analytical procedures. The data obtained from various observations were subjected to statistical analysis following the procedure of analysis of variance (ANOVA) appropriate for Factorial Randomized Block Design as described by Fisher (1956).

Results and Discussions

Effect on yield and harvest index

The yield and harvest index of summer cowpea were significantly influenced by fertilizer dose, seed inoculation and foliar nutrition treatments (Table 1). Application of 100% RDF (F_1) recorded significantly higher seed yield (524 kg ha^{-1}), straw yield (1312 kg ha^{-1}) and biological yield (1837 kg ha^{-1}) over 75% RDF (F_2), which produced 491, 1230 and 1721 kg ha^{-1} seed, straw and biological yield, respectively. The increase in yield under 100% RDF might be attributed to adequate and balanced nutrient supply throughout the crop growth period, resulting in enhanced photosynthetic activity, dry matter accumulation and translocation of assimilates towards reproductive organs. Harvest index remained unaffected by fertilizer levels. Among seed inoculation treatments, seed inoculation with Rhizobium @ 50 g kg^{-1} seed + Biophos + Biozinc each @ 5 ml kg^{-1} seed (S_2) recorded significantly higher seed yield (525 kg ha^{-1}), straw yield (1315 kg ha^{-1}) and biological yield (1840 kg ha^{-1}) over the control (S_1). However, it remained statistically at par with NPKZn microbial consortia @ 50 g kg^{-1} seed (S_3). The beneficial effect of biofertilizer inoculation may be attributed to enhanced biological nitrogen fixation, phosphorus solubilization and improved availability of micronutrients, which collectively promoted crop growth and productivity. Harvest index was not significantly influenced by seed inoculation treatments. Foliar nutrition significantly affected seed, straw and biological yields of summer cowpea. Application of NPK (19:19:19) @ 2% at pre-flowering and pod initiation stages (N_1) recorded the highest seed yield (528 kg ha^{-1}), straw yield (1331 kg ha^{-1}) and biological yield (1859 kg ha^{-1}), which were significantly superior to water spray (N_4). However, N_1 remained statistically at par with Nano DAP @ 0.4% (N_2) and Nano Urea @ 0.4% (N_3). The higher yield under foliar nutrient application may be due to rapid absorption and utilization of nutrients during critical growth stages, resulting in better flowering, pod development and seed filling (Pandey *et al.,* 2013; Singh *et al.,* 2026). Harvest index was not significantly influenced by foliar nutrition treatments. The results clearly indicated that integrated nutrient management through optimum fertilizer dose, seed inoculation and foliar nutrition enhanced crop productivity by improving nutrient availability and nutrient use efficiency, thereby resulting in higher seed and biological yields (Choudhary *et al*., 2006; Pathak *et al.,* 2025).

Effect on growth and yield attributes

Growth and yield attributes of summer cowpea were significantly influenced by various nutrient management practices (Table 2). Application of 100% RDF (F_1) produced significantly higher plant height (65.66 cm), number of pods $plant^{-1}$ (12.30), pod length (11.98 cm) and test weight (67.27 g) as compared to 75% RDF (F_2). Adequate nutrient supply under 100% RDF might have promoted vigorous vegetative growth, increased photosynthetic efficiency and improved assimilate partitioning towards reproductive structures. Among seed inoculation treatments, NPKZn microbial consortia @ 50 g kg^{-1} seed (S_3) recorded the highest number of pods $plant^{-1}$ (12.11) and pod length (12.00 cm), which were significantly superior to the control. The treatment S_2 (Rhizobium + Biophos + Biozinc) remained statistically at par with S_3 for these parameters. Plant height and test weight were not significantly influenced by seed inoculation treatments. The improvement in yield attributes due to microbial inoculation may be attributed to enhanced nutrient mobilization, better root growth and improved nutrient uptake throughout the crop growth period. Foliar nutrition exerted a significant influence on all growth and yield attributes. The treatment N_1 [NPK (19:19:19) @ 2%] recorded maximum plant height (68.12 cm), pods $plant^{-1}$ (12.12), pod length (11.92 cm) and test weight (70.49 g), followed by N_2 (Nano DAP @ 0.4%) and N_3 (Nano Urea @ 0.4%). The lowest values were observed under water spray (N_4). The beneficial response of foliar nutrition may be due to direct nutrient absorption through foliage during critical growth stages, which improved photosynthetic activity, flowering behaviour and seed development. The improvement in growth and yield attributes ultimately contributed to enhanced seed and biological yield of cowpea under integrated nutrient management practices (Singh *et al.,* 2013; Patil and Chetan, 2018 and Dangwal *et al.,* 2026).

Effect on economics

The economics of summer cowpea was markedly influenced by fertilizer dose, seed inoculation and foliar nutrition treatments (Table 3). Among fertilizer doses, application of 100% RDF (F_1) recorded significantly higher gross returns (Rs. 49,818 ha^{-1}), net returns (Rs. 12,897 ha^{-1}) and benefit ratio (1.35) over 75% RDF (F_2), which registered gross returns of Rs. 46,687 ha^{-1}, net returns of Rs. 9,922 ha^{-1} and B ratio of 1.27. The higher economic returns under F_1 were mainly due to increased seed and straw yield. With respect to seed inoculation, NPKZn microbial consortia @ 50 g kg^{-1} seed (S_3) produced the highest gross returns (Rs. 49,906 ha^{-1}), net returns (Rs. 12,906 ha^{-1}) and B ratio (1.36), which were significantly superior to the control. The treatment S_2 (Rhizobium + Biophos + Biozinc) remained statistically comparable and recorded gross returns of Rs.48,716 ha^{-1}, net returns of Rs.11,810 ha^{-1} and B ratio of 1.32. The increase in profitability under biofertilizer treatments was primarily due to enhanced crop productivity coupled with relatively lower additional input costs. aAmong foliar nutrition treatments, NPK (19:19:19) @ 2% (N_1) recorded the highest gross returns (Rs. 50,270 ha^{-1}), net returns (Rs. 13,826 ha^{-1}) and B ratio (1.38), followed by Nano DAP @ 0.4% (N_2) and Nano Urea @ 0.4% (N_3). Water spray (N_4) resulted in the lowest economic returns. The superior profitability under N_1 may be attributed to higher seed and straw yields obtained through balanced nutrient supply during pre-flowering and pod initiation stages (Aryan *et al.*, 2024).

Conclusion

The present investigation demonstrated that growth, yield and economics of summer cowpea were significantly influenced by fertilizer dose, seed inoculation and foliar nutrition. Application of 100% RDF recorded significantly higher growth parameters, yield attributes, seed yield (524 kg ha^{-1}), straw yield (1312 kg ha^{-1}), biological yield (1837 kg ha^{-1}) and economic returns compared to 75% RDF. Among seed inoculation treatments, Rhizobium @ 50 g kg^{-1} seed along with Biophos and Biozinc each @ 5 ml kg^{-1} seed proved most effective and recorded significantly higher productivity over the control, remaining statistically at par with NPKZn microbial consortia. Foliar application of NPK (19:19:19) @ 2% at pre-flowering and pod initiation stages resulted in maximum growth, yield attributes, seed yield (528 kg ha^{-1}), biological yield (1859 kg ha^{-1}), net returns (Rs. 13,826 ha^{-1}) and B ratio (1.38), although it remained statistically comparable with Nano DAP and Nano Urea treatments for several parameters. Therefore, application of 100% RDF along with seed inoculation using Rhizobium + Biophos + Biozinc and foliar spray of NPK (19:19:19) @ 2% at pre-flowering and pod initiation stages may be recommended for obtaining higher productivity and profitability of summer cowpea under semi-arid conditions of Rajasthan.

Table 1 : Effect of fertilizer dose, seed inoculation and foliar nutrition on yield and harvest index of summer cowpea

Treatment	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Fertilizer dose				
100% RDF	524	1312	1837	28.55
75%RDF	491	1230	1721	28.55
SEm±	7	15	26	0.41
CD at 5%	21	44	75	NS
Seed inoculation				
Control	486	1211	1697	28.65
Rhizobium @ 50g per kg + Biophos + Biozinc each @ 5 ml/kg	525	1315	1840	28.53
NPKZn microbial consortia @ 50g/kg	512	1287	1799	28.47
SEm±	9	19	32	0.51
CD at 5%	25	54	91	NS
Foliar Nutrition				
NPK (19:19:19) @ 2% at pre-flowering and pod initiation stages	528	1331	1859	28.40
Nano DAP @ 0.4% at pre-flowering and pod initiation stages	516	1298	1814	28.45
Nano Urea @0.4% at pre-flowering and pod initiation stages	509	1265	1774	28.69
Water spray at pre-flowering and pod initiation stages	478	1190	1668	28.66
SEm±	10.2	21.7	37.0	0.58
CD at 5%	29.1	61.8	105.4	NS
CV%	8.5	7.3	8.8	8.67

Table 2 : Effect of fertilizer dose, seed inoculation and foliar nutrition on growth parameters of summer cowpea

Treatment	Plant height (cm)	No of pods/ plant	Pod length (cm)	Test weight (g)
Fertilizer dose				
100% RDF	65.66	12.30	11.98	67.27
75%RDF	62.63	10.17	11.05	63.80
SEm±	0.99	0.20	0.22	1.00
CD at 5%	2.82	0.58	0.61	2.84
Seed inoculation				
Control	62.92	10.01	10.83	64.17
Rhizobium @ 50g per kg + Biophos + Biozinc each @ 5 ml/kg	64.62	11.59	11.70	65.82
NPKZn microbial consortia @ 50g/kg	64.89	12.11	12.00	66.62
SEm±	1.21	0.25	0.26	1.22
CD at 5%	NS	0.71	0.75	NS
Foliar Nutrition				
NPK (19:19:19) @ 2% at pre-flowering and pod initiation stages	68.12	12.12	11.92	70.49
Nano DAP @ 0.4% at pre-flowering and pod initiation stages	66.85	11.69	11.76	66.92
Nano Urea @0.4% at pre-flowering and pod initiation stages	64.15	11.12	11.65	64.82
Water spray at pre-flowering and pod initiation stages	57.45	10.01	10.72	59.92
SEm±	1.40	0.29	0.30	1.41
CD at 5%	3.98	0.82	0.87	4.01
CV%	9.26	10.81	11.21	9.12

Table 3 : Effect of fertilizer dose, seed inoculation and foliar nutrition on Economics of summer cowpea

Treatment	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C
Fertilizer dose				
100% RDF	36861	49818	12897	1.35
75% RDF	36716	46687	9922	1.27
SEm±	-	678	131	0.02
CD at 5%	-	1930	372	0.05
Seed inoculation				
Control	36291	46136	9513	1.26
Rhizobium @ 50g per kg + Biophos + Biozinc each @ 5 ml/kg	36495	48716	11810	1.32
NPKZn microbial consortia @ 50g/kg	36551	49906	12906	1.36
SEm±	-	830	160	0.02
CD at 5%	-	2364	455	0.06
Foliar Nutrition				
NPK (19:19:19) @ 2% at pre-flowering and pod initiation stages	36444	50270	13826	1.38
Nano DAP @ 0.4% at pre-flowering and pod initiation stages	36847	49100	12253	1.33
Nano Urea @0.4% at pre-flowering and pod initiation stages	37490	48280	10790	1.29
Water spray at pre-flowering and pod initiation stages	36591	45360	8769	1.24
SEm±	-	959	185	0.03
CD at 5%	-	2729	526	0.07
CV (%)	-	8.20	7.15	8.15

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