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Effect of Nitrogen and Phosphorus on Nutrient Use Efficiency of Irrigated Chickpea (*Cicer arietinum* L.) under Scarce Rainfall Zone of Andhra Pradesh, India

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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

A field experiment was carried out on sandy loam soils at Agricultural College, Mahanandi during *rabi* season of 2021-22 in order to study the yield, nutrient uptake and nutrient use efficiency of chickpea under varied levels of fertilizer application. The experimental field was laid out in a randomized block design with 10 treatments, each replicated three times. Nitrogen was applied through urea in two halves, one at sowing and one at 30 days after sowing (DAS). Complete dose of single super phosphate was applied through single super phosphate as a basal in all the 3 levels

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@ 50, 60 and 70 kg P_2O_5 ha^{-1}. The treatment with application of 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal (T_9) resulted in significantly higher values of seed yield (1346 kg ha^{-1}), harvest index (49.2), nutrient uptake (N, P and K uptake) and phosphorus use efficiency (22.4%). Significantly higher nitrogen use efficiency with 10 kg N basal + 10 kg N split + 70 kg P_2O_5 basal (T_4) and with application of 20 kg N basal + 20 kg N split + 70 kg P_2O_5 basal (T_{10}) resulted higher haulm yield (1352 kg ha^{-1}). Harvest index and post-harvest soil nutrient status (available N, P_2O_5 and K_2O) were not significantly affected by levels of fertilizer application. The present investigation concluded that 20 kg N basal + 20 kg N split + 60 kg P2O5 basal (T_9) was the optimum dose of fertilizer for better performance of chickpea in scarce rainfall zone of Andhra Pradesh.

Keywords: Chickpea; nitrogen; phosphorus; nutrient uptake and yield.

1. INTRODUCTION

"India is the world's largest producer, and consumer of pulses. Therefore, pulses are important for Indian economy. The nitrogen-fixing property of pulses improves soil fertility, increasing and extending the productivity of farmland and also reduces the need of synthetic nitrogen fertilizers. Pulses also produce a smaller carbon footprint, indirectly reducing greenhouse gas emissions. Pulses provide protein and fiber, as well as a significant source of vitamins and minerals such as iron, zinc, folate and magnesium. Chickpea (*Cicer arietinum* L.) is self-pollinated, *rabi* season legume crop that belongs to family Fabaceae, subfamily Faboideae. Chickpea normally referred as king of pulses. In India, chickpea is cultivated in 10.19 M ha with a production of 11.57 Mt, and with a productivity of 1172 kgha^{-1}" [1]. "In Andhra Pradesh, it is cultivated in 0.302 M ha with a production of 0.30 Mt and with a productivity of 994 kg ha^{-1}" [2]. "Chickpea contains 62% carbohydrates, 21% protein and 2.2% fat and also a food of high nutritive value having considerable amount of vitamins A, B and C along with iron, phosphorus and calcium. Among the pulses, chickpea has relatively lower protein content but of higher biological value and protein digestibility" [3]. "Proper nutrient management is a key factor among many, that influence grain yield, significantly contributing to higher productivity. Though chickpea being a grain legume is capable of fixing atmospheric nitrogen, but a starter dose of nitrogen is required for proper growth and development. Different measures have been suggested to increase crop nitrogen use efficiency, such as using the optimal rate, time and method of application to coordinate nitrogen supply with crop demand. Nitrogen fertilizer rates and application timing are decisive factors in obtaining more yields. Compared to single nitrogen application, split application of nitrogen fertilizer results in higher recovery efficiency, and higher grain yields" [4]. "Commonly, legumes demand excessive amount of phosphorus as the process of symbiotic nitrogen fixation consumes a lot of energy" [5]. "Apart from being a constituent of certain malic acids, phosphorus stimulates root, seed and pod development as well as aids in vital metabolic functions" [6].

Farmers are usually unaware of optimum dose of fertilizers when grown under irrigated conditions. The excessive, and imbalance application of fertilizers increase cost of production. This may in turn lead to the depletion of soil nutrient status or soil salinization. So proper nutrient management is mandatory for obtaining higher yield in chickpea. But such scientific work has not yet been conducted till now about the optimum level of fertilizers under irrigated conditions, but farmers are using more quantity of fertilizers in split doses where crop is cultivated with one irrigation at 30-35 days after sowing. By considering above points in view, the present field investigation was proposed to quantify the optimum dose of fertilizers under irrigated conditions.

2. MATERIALS AND METHODS

The study was carried out at the College Farm within the Mahanandi campus of Acharya N.G. Ranga Agricultural University during the *rabi* season of 2021-22. This location is positioned at 15.51^0 N latitude, 78.61^0 E longitude, and has an elevation of 233.48 meters above sea level. It falls within the Scarce Rainfall Zone of Andhra Pradesh and according to Troll's classification, is categorized as Semi-Arid Tropics (SAT).

The experimental field was arranged in a randomized block design, featuring ten treatments and was replicated three times.

Table 1. Treatment details

T_1:	20 kg N basal + 50 kg P_2O_5 (RDF)
T_2:	10 kg N basal + 10 kg N split + 50 kg P_2O_5 basal
T_3:	10 kg N basal + 10 kg N split + 60 kg P_2O_5 basal
T_4:	10 kg N basal + 10 kg N split + 70 kg P_2O_5 basal
T_5:	15 kg N basal + 15 kg N split + 50 kg P_2O_5 basal
T_6:	15 kg N basal + 15 kg N split + 60 kg P_2O_5 basal
T_7:	15 kg N basal + 15 kg N split + 70 kg P_2O_5 basal
T_8:	20 kg N basal + 20 kg N split + 50 kg P_2O_5 basal
T_9:	20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal
T_{10}:	20 kg N basal + 20 kg N split + 70 kg P_2O_5 basal

The experimental field's soil was sandy loam texture, being neutral in pH (7.33). It had low levels of organic carbon (0.49%), and available nitrogen (258 kg ha^{-1}), medium availability of phosphorus (49 $kgha^{-1}$), and high levels of available potassium (584 $kgha^{-1}$). The chickpea variety used was NBeG-3, with a growth duration of 90-100 days, sown at a spacing of 30 cm × 10 cm. Nitrogen, and phosphorus were applied to all plots using urea and single superphosphate, respectively. The nitrogen, allocated according to the treatments, was applied in two equal splits. Half of the nitrogen was used as a basal fertilizer at sowing, while the other half was side-dressed near the crop rows using furrows 30 days after sowing. The entire dose of single superphosphate was applied as a basal fertilizer at three levels (50, 60, and 70 kg P_2O_5 ha^{-1}).

"Seed and haulm yields were measured from the net plot. The harvest index is defined by the ratio of grain yield to total biological yield, as reported by Donald in 1962. NPK uptake was calculated by multiplying the NPK content by the corresponding dry matter production, and expressed in kg ha^{-1}. Nutrient use efficiency is defined as seed yield produced per unit of total nutrients supply" (Sowers et al.,1994).

The critical difference was correlated at 5 per cent level of significance to compare different treatment means as suggested by Panse and Sukhatme [7]. "The data were analyzed statically using the analysis of variance (ANOVA) technique with the MSTAT-C computer software. Duncan's Multiple Range Test (DMRT) was employed for mean comparison" [8].

3. RESULTS AND DISCUSSION

3.1 Yield Attributes

3.1.1 Seed Yield (kg ha^{-1})

The application of 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal (T_9) resulted in a significantly higher seed yield (1346.1 kg ha^{-1}) of chickpea and was at par with T_{10} (1308.9 kg ha^{-1}). Lower seed yield (783.5 kg ha^{-1}) was recorded with 10 kg N basal + 10 kg N split + 50 kg P_2O_5 basal (T_2) followed by T_3 (841.0 kg ha^{-1}).

Higher fertilizer doses increased nutrient availability, boosting chickpea yield through improved growth, more pods and seeds per plant, and higher seed weight, ultimately enhancing overall grain yield significantly. Similar kind of results were obtained Das et al. [9], Kumar et al., [10], Singh [11], Yadav et al., [12] and Kumawat et al., [13].

3.1.2 Haulm yield (kg ha^{-1})

Significantly higher haulm yield (1352.7 kg ha^{-1}) of chickpea was recorded with 20 kg N basal + 20 kg N split + 70 kg P_2O_5 basal (T_{10}) and was at par with T_9 (1351.3 kg ha^{-1}). Lower haulm yield (950.7 kg ha^{-1}) was recorded with 10 kg N basal + 10 kg N split + 50 kg P_2O_5 basal (T_2) followed by T_3 (963.9 kg ha^{-1}), and T_1 (971.2 kg ha^{-1}).

The application of higher fertilizer doses, which resulted in increased haulm yield, may be attributed to the sufficient supply of nitrogen and phosphorus, leading to enhanced vegetative growth with taller plants, and greater dry matter accumulation. Similar kind of results were obtained by Kumar et al., [10], Yadav et al., [12], Nawange et al. [14] and Singh et al., [15].

3.1.3 Harvest index

The harvest index in chickpea was not significantly affected by the different levels of fertilizer application. Higher harvest index (49.9%) of chickpea was recorded in the treatment 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal (T_9), and lower harvest index (45.2%) was recorded in 10 kg N basal + 10 kg N split + 50 kg P_2O_5 basal (T_2). Similar kinds of results were obtained by Neenu et al., [16], Singh [11] and Yadav et al., [12].

Table 2. Seed yield, haulm yield and harvest index as influenced by levels of fertilizers

Treatments	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index (%)
T_1: 20 kg N basal + 50 kg P_2O_5 (RDF)	883.6	971.2	47.6
T_2: 10 kg N basal + 10 kg N split + 50 kg P_2O_5 basal	783.5	950.7	45.2
T_3: 10 kg N basal + 10 kg N split + 60 kg P_2O_5 basal	841.0	963.9	46.6
T_4: 10 kg N basal + 10 kg N split + 70 kg P_2O_5 basal	1052.1	1092.5	49.0
T_5: 15 kg N basal + 15 kg N split + 50 kg P_2O_5 basal	1059.8	1185.0	47.0
T_6: 15 kg N basal + 15 kg N split + 60 kg P_2O_5 basal	1120.3	1218.7	47.8
T_7: 15 kg N basal + 15 kg N split + 70 kg P_2O_5 basal	1119.3	1203.6	48.2
T_8: 20 kg N basal + 20 kg N split + 50 kg P_2O_5 basal	1066.4	1201.5	47.0
T_9: 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal	1346.1	1351.3	49.9
T_{10}: 20 kg N basal + 20 kg N split + 70 kg P_2O_5 basal	1308.9	1352.7	49.2
S.Em±	**52.44**	**39.89**	**1.85**
CD (P=0.05)	**157.01**	**119.43**	**NS**

3.2 Nutrient Uptake

3.2.1 N Uptake (kg ha^{-1})

In seed, significantly higher uptake of nitrogen (43.91 kg ha^{-1}) was recorded with 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal (T_9), and was at par with 20 kg N basal + 20 kg N split + 70 kg P_2O_5 basal (T_{10}) (42.66 kg ha^{-1}), and lowest nitrogen uptake was recorded with 10 kg N basal + 10 kg N split + 50 kg P_2O_5 basal (T_2) (23.24 kg ha^{-1}).

In haulm, significantly higher uptake of nitrogen (30.01 kg ha^{-1}) was recorded with 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal (T_9), and was at par with 20 kg N basal + 20 kg N split + 70 kg P_2O_5 basal (T_{10}) (29.82 kg ha^{-1}), and lowest nitrogen uptake was recorded with 20 kg N basal + 50 kg P_2O_5 basal (T_1) (18.66 kg ha^{-1}).

3.2.2 P Uptake (kg ha^{-1})

In seed, significantly higher uptake of phosphorus (16.59 kg ha^{-1}) was recorded with 20 kg N basal + 20 kg N split + 70 kg P_2O_5 basal (T_{10}), and was at par with 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal (T_9) (16.44 kg ha^{-1}). The lowest phosphorus uptake was recorded with 10 kg N basal + 10 kg N split + 50 kg P_2O_5 basal (T_2) (9.13 kg ha^{-1}), and was on par with T_3 (10.05 kg ha^{-1}) and T_1 (10.38 kg ha^{-1}).

In haulm, significantly higher uptake of phosphorus (2.89 kg ha^{-1}) was recorded with 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal (T_9), and was at par with T_{10}(2.74 kgha^{-1}), T_8 (2.58 kg ha^{-1}), T_7 (2.56 kg ha^{-1}), and T_6 (2.40 kg ha^{-1}). The lowest phosphorus uptake was recorded with 10 kg N basal + 50 kg P_2O_5 basal (T_1) (1.97 kg ha^{-1}).

3.2.3 K Uptake (kg ha^{-1})

In seed, significantly higher uptake of potassium (15.63 kg ha^{-1}) was recorded with 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal (T_9), and was at par with 20 kg N basal + 20 kg N split + 70 kg P_2O_5 basal (T_{10}) (15.44 kg ha^{-1}), and lowest potassium uptake was recorded with 10 kg N basal + 10 kg N split + 50 kg P_2O_5 basal (T_2) (9.44 kg ha^{-1}).

In haulm, significantly higher uptake of potassium (6.06 kg ha^{-1}) was recorded with 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal (T_9), and was at par with T_7(5.83 kg ha^{-1}), T_6(5.36 kg ha^{-1}), and T_8(5.35 kg ha^{-1}). The lowest potassium uptake was recorded with 20 kg N basal + 50 kg P_2O_5 basal (T_1) (3.98 kg ha^{-1}).

Higher doses of fertilizers resulted in increased nutrient uptake in both the seed, and haulm of chickpea. This may be attributed to improved root proliferation and nodulation, which enhance the availability of nitrogen, phosphorus, and potassium.Similar kind of results were obtained by Das et al., [9], Rani and Krishna [17], Balai et al., [18], Yadav et al. [12], Singh et al. [15], and Kumawat et al., [13].

3.3 Nutrient Use Efficiency

Significantly higher nitrogen use efficiency (52.6%) was recorded with 10 kg N basal + 10 kg N split + 70 kg P_2O_5 basal (T_4), and lower was recorded with T_6 (26.7). Significantly higher phosphorus use efficiency (22.4%) was recorded with 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal (T_9), and was at par with T_8 (21.3%), and T_5 (21.2%) lower was recorded with T_6 (26.7), and significantly lower was recorded with T_3 (14.0%) followed by T_4 (15.0%).

Table 3. Nutrient uptake (N, P and K uptake) as influenced by levels of fertilizers

Treatments	Nitrogen uptake (kg ha^{-1})		Phosphorus uptake (kg ha^{-1})		Potassium uptake (kg ha^{-1})	
	Seed	**Haulm**	**Seed**	**Haulm**	**Seed**	**Haulm**
T_1: 20 kg N basal + 50 kg P_2O_5 (RDF)	26.83	18.66	10.38	1.97	10.30	3.98
T_2: 10 kg N basal + 10 kg N split + 50 kg P_2O_5 basal	23.24	19.33	9.13	2.12	9.44	4.40
T_3: 10 kg N basal + 10 kg N split + 60 kg P_2O_5 basal	25.77	20.34	10.05	2.12	10.38	4.01
T_4: 10 kg N basal + 10 kg N split + 70 kg P_2O_5 basal	32.52	22.19	12.18	2.08	14.41	4.69
T_5: 15 kg N basal + 15 kg N split + 50 kg P_2O_5 basal	32.81	24.56	12.65	2.11	13.80	4.99
T_6: 15 kg N basal + 15 kg N split + 60 kg P_2O_5 basal	35.19	25.53	13.55	2.40	12.42	5.36
T_7: 15 kg N basal + 15 kg N split + 70 kg P_2O_5 basal	35.65	25.10	13.76	2.56	13.93	5.83
T_8: 20 kg N basal + 20 kg N split + 50 kg P_2O_5 basal	34.75	25.75	13.70	2.58	13.38	5.35
T_9: 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal	43.91	30.01	16.44	2.89	15.63	6.06
T_{10}: 20 kg N basal + 20 kg N split + 70 kg P_2O_5 basal	42.66	29.82	16.59	2.74	15.44	4.86
S.Em±	**1.87**	**1.31**	**0.86**	**0.18**	**1.08**	**0.34**
CD (P=0.05)	**5.61**	**3.90**	**2.56**	**0.55**	**3.22**	**1.03**

Table 4. Nutrient use efficiency as influenced by levels of fertilizers

Treatments	NUE (kg/kg N)	PUE (kg/kg P)
T_1: 20 kg N basal + 50 kg P_2O_5 basal (RDF)	44.2	17.7
T_2: 10 kg N basal + 10 kg N split + 50 kg P_2O_5 basal	39.2	15.7
T_3: 10 kg N basal + 10 kg N split + 60 kg P_2O_5 basal	42.1	14.0
T_4: 10 kg N basal + 10 kg N split + 70 kg P_2O_5 basal	52.6	15.0
T_5: 15 kg N basal + 15 kg N split + 50 kg P_2O_5 basal	35.3	21.2
T_6: 15 kg N basal + 15 kg N split + 60 kg P_2O_5 basal	37.3	18.7
T_7: 15 kg N basal + 15 kg N split + 70 kg P_2O_5 basal	37.3	16.0
T_8: 20 kg N basal + 20 kg N split + 50 kg P_2O_5 basal	26.7	21.3
T_9: 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal	33.7	22.4
T_{10}: 20 kg N basal + 20 kg N split + 70 kg P_2O_5 basal	32.7	18.7
S.Em±	1.9	1.0
CD (P=0.05)	5.6	2.8

These results are similar with the findings of Kumar et al., [19], who also observed reduction in efficiency of nutrients with increase in their application rate.

3.4 Post-harvest Soil Nutrient Status

3.4.1 Available N (kg ha^{-1})

Soil available nitrogen after harvest of the crop was not significantly affected by the levels of fertilizer application. However slight increase (264.3 kg ha^{-1}) in available N was observed with application of 20 kg N basal + 20 kg N split + 70 kg P_2O_5 basal (T_{10}), and minimum soil available N was observed with 10 kg N basal + 10 kg N split + 70 kg P_2O_5 basal (T_4) (251.0 kg ha^{-1}). Similar kind of results were obtained by Rani and Krishna [17].

3.4.2 Available P_2O_5(kg ha^{-1})

Soil available P_2O_5 after harvest of the crop was not significantly affected by the levels of fertilizer application. However slight increase (54.3 kg ha^{-1}) in available P_2O_5 was recorded with application of 20 kg N basal + 20 kg N split + 70 kg P_2O_5 basal (T_{10}), and minimum soil available P_2O_5 was recorded with 10 kg N basal + 10 kg N split + 50 kg P_2O_5 basal (T_2) (47.7 kg ha^{-1}). Similar kind of results were obtained by Rani and Krishna [17].

3.4.3 Available K_2O (kg ha^{-1})

Soil available K_2O after harvest of the crop was not significantly affected by the various levels of fertilizer application. However, slight increase (578.0 kg ha^{-1}) in available K_2O was recorded with application of 20 kg N basal + 20 kg N split + 50 kg P_2O_5 basal (T_8), and minimum soil available $K_2O$was recorded with 20 kg N basal + 50 kg P_2O_5 basal (T_1) (566.7 kg ha^{-1}). Similar kind of results were obtained by Rani and Krishna [17].

Table 5. Post-harvest soil nutrient status (available N, P_2O_5 and K_2O) as influenced by levels of fertilizers

Treatments	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
T_1: 20 kg N basal + 50 kg P_2O_5 basal (RDF)	254.0	48.9	567
T_2: 10 kg N basal + 10 kg N split + 50 kg P_2O_5 basal	253.0	47.7	577
T_3: 10 kg N basal + 10 kg N split + 60 kg P_2O_5 basal	252.0	48.2	578
T_4: 10 kg N basal + 10 kg N split + 70 kg P_2O_5 basal	251.0	51.4	576
T_5: 15 kg N basal + 15 kg N split + 50 kg P_2O_5 basal	255.7	50.2	569
T_6: 15 kg N basal + 15 kg N split + 60 kg P_2O_5 basal	254.7	53.3	574
T_7: 15 kg N basal + 15 kg N split + 70 kg P_2O_5 basal	259.0	53.3	573
T_8: 20 kg N basal + 20 kg N split + 50 kg P_2O_5 basal	258.3	52.2	578
T_9: 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal	263.4	53.0	576
T_{10}: 20 kg N basal + 20 kg N split + 70 kg P_2O_5 basal	264.2	54.3	571
S.Em±	**4.85**	**2.01**	**5.08**
CD (P=0.05)	**NS**	**NS**	**NS**

4. CONCLUSION

Based on the above investigation, it is concluded that application of 20 kg N basal + 20 kg N split + 60 kg P_2O_5 basal is the optimal fertilizer level to obtain higher yield, and higher nutrient uptake in scarce rainfall zone of Andhra Pradesh. The split application of nitrogen minimized losses, thereby enhancing chickpea growth, and yield. Additionally, this practice promoted long-term improvements in soil fertility and overall soil health.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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