RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume 59 Issue 7: 1119-1125 (July 2025)

Influence of Varied Nutrient Management Strategies on Yield, Nutrient Absorption and Grain Protein Content in Chickpea (*Cicer arietinum* L.)

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10.18805/IJARe.A-6255

ABSTRACT

Background: Chickpea is an important global legume crop, known for high protein content and ability to fix atmospheric N. Achieving optimal chickpea yields in Bundelkhand region is often limited by various biotic and abiotic factors, including nutrient deficiencies in the soil. Thus, proper nutrient management, through inorganics and organics, is a prerequisite for obtaining better yields and quality produce in chickpea.

Methods: A field experiment was conducted at Rani Lakshmi Bai Central Agricultural University, Jhansi during *rabi* season 2022-2023 on different nutrient managements in chickpea. The field experiment was done in a completely randomized block design with nine treatments replicated thrice *viz*, control (T1), 100% RDF (T2), 75% RDF (T3), 100% RDF + 5 t ha^{-1} FYM (T4), 75% RDF + 5 t ha^{-1} FYM (T5), 100% RDF + 5 t ha^{-1} vermicompost (T6), 75% RDF + 5 t ha^{-1} vermicompost (T7), 100% RDN through FYM (T8) and 100% RDN through vermicompost (T9).

Result: Yield and total uptake of N, P and K were significantly ($p<0.05$) higher in T6 followed by T4, whereas total S uptake was highest in T4. Grain protein content and protein yield were significantly ($p<0.05$) higher in T4 followed by T6. It was concluded that combined application of inorganic and organic inputs can lead to dual benefits: increased crop yield and improved protein content in harvested chickpea grains.

Key words: Agronomic efficiency, Grain protein content, Nutrient management, Pulse crop.

INTRODUCTION

Pulses have three times much high-quality-protein than cereals. Chickpea (*Cicer arietinum* L.) is one of the most significant pulses globally, contributing substantially to both human nutrition and agricultural sustainability (Madurapperumage *et al.,* 2021). Chickpea is comprised of carbohydrates (50-58%), proteins (15-22%), fats (4-10%) and micronutrients (<1%) (Madurapperumage *et al.,* 2021). In India, nearly 3.10 Mha area is under pulse cultivation with 27.69 Mt production and 892 kg ha^{-1} productivity, which makes India the largest pulse producing country of the world (MA and FW, 2023). Chickpea is grown since 7000 BC in many parcels of the world yet its cultivation is largely confined to semi-arid environment (Arriagada *et al.,* 2022). Optimum growth and yield are interlinked with various factors and one of those is the adequate nutrient availability in soil, which is essential for supporting the plant's physiological processes, including photosynthesis, root development and ultimately, yield and productivity (Prabaharan and Surendar, 2017; Sodavadiya *et al*., 2023). Chickpea plays a significant part in increasing soil fertility by absorbing atmospheric N, meeting 80% of the plant's N requirements through symbiotic nitrogen fixation up to 140 kg N ha^{-1} (Vaishnavi *et al.,* 2021). However, the efficiency of the nutrient uptake and utilization by chickpea can be influenced by various factors such as soil properties, water availability and management regimes.

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How to cite this article: Yadav, S.L., Debnath, S., Singh, Y., Singh, S.K., Devi, Y.B., Ghosh, A., Ram, A., Kumar, S. and Arunachalam, A. (2025). Influence of Varied Nutrient Management Strategies on Yield, Nutrient Absorption and Grain Protein Content in Chickpea (*Cicer arietinum* L.). *Indian Journal of Agricultural Research.* **59(7):** 1119-1125. doi: 10.18805/IJARe.A-6255.

Submitted: 11-05-2024 **Accepted:** 09-08-2024 **Online:** 06-12-2024

Both excessive and insufficient fertilizer application, coupled with inadequate resource management, not only degrade soil health but also raise environmental concerns. (Krasilnikov *et al.,* 2022). In order to boost and maintain crop yield and sustain productivity, effective and efficient methods to limit the rate of nutrient mining and returning the nutrients to the soil is highly warranted (Paramesh *et al.,* 2023). Chemical fertilizers without the addition of organic

manures have reduced the soil quality and decline the crop productivity (Meena *et al.,* 2019). Owing to wide range of environmental problems caused by the unscrupulous chemicals usage, use of organics became more popular among the scientists and farming community, which includes the use of bulky organic manures like vermicompost, farmyard manure (FYM) and green manures (Sen *et al*., 2021). When organic manures are combined with synthetic fertilizers, organic matter acts as a reservoir for nutrients, releasing them gradually over time as the plants require them in a slow-release form, which can improve the uptake of nutrients by chickpea plants (Stella *et al.,* 2019). This, in turn, reduces the risk of nutrient imbalances and leads to better nutrient utilization efficiency and minimizes the toxic effect associated with excessive fertilizer application (Shah *et al*., 2023). This balanced supply of nutrients throughout the growing season promotes healthy plant growth and higher yields.

The Bundelkhand region is characterized by water scarcity, high erosion, land degradation, poor soil fertility, low crop productivity (1-1.5 q ha^{-1}), low water use efficiency (35-45%), frequent droughts, poor irrigation facilities, less vegetation cover and frequent crop failure resulting in food scarcity (Singh *et al.,* 2022; Sah *et al.,* 2024). Soil organic carbon (SOC) is the primary source of nutrient cycling and manages the soil physical, chemical and biological properties. SOC is an important index of soil quality as it is related with the crop productivity (Gao *et al.,* 2024). Organic manures such as FYM and vermicompost can lead to better water retention, improved nutrient availability and overall healthier soils, which are crucial for sustaining agricultural productivity in the region. Nevertheless, there have been a lack of scientific understanding how combined application of organic and inorganic fertilizers may affect the nutrient uptake pattern and the yield of chickpea in this region. It was hypothesized that integrated use of inorganic and organic sources of nutrients would outperform chickpea growth and yield and nutrient uptake as compared to their individual applications. The objectives of this study was to examine the effect of combined use of organic and inorganic fertilizers on yield and its components, nutrient uptake and grain protein content in chickpea.

MATERIALS AND METHODS

The current study site was located at the Rani Lakshmi Bai Central Agricultural University, Jhansi (25°51′N; 78°56′E; 227.1 m above mean sea level) during the *rabi* season of 2022-23. The experimental site experiences semi-arid to sub-tropical climate with a mean annual precipitation ~900 mm. The average maximum and minimum temperature prevailed during the experimental period was 30.6 and 10.2°C, respectively. The total precipitation received during the experimental period (November, 2022-April, 2023) was 32.9 mm. The soil is clay loam in texture, non-saline with a pH 7.3, 3.8 g kg^{-1} SOC, 152.0 kg N ha^{-1}, 10.7 kg P ha^{-1}, 147.2 kg K ha^{-1} and 19.4 kg S ha^{-1}.

A field experiment was undertaken in a completely randomized block design (CRBD) with nine treatments replicated thrice *viz*, control (T1), 100% recommended dose of fertilizer RDF: 20:60:20:20 kg ha^{-1} N:P:K:S (T2), 75% RDF (T3), 100% RDF + 5 t ha^{-1} FYM (T4), 75% RDF + 5 t ha^{-1} FYM (T5), 100% RDF + 5 t ha^{-1} vermicompost (T6), 75% RDF + 5 t ha^{-1} vermicompost (T7), 100% recommended dose of N (RDN) through FYM (3.44 t ha^{-1}) (T8) and 100% RDN through vermicompost (1.31 t ha^{-1}) (T9). The required amounts of N,P,K and S were added basally through diammonium phosphate (DAP), single super phosphate (SSP), muriate of potash (MOP) and bentonite (S-90%) followed by sowing. Chickpea [*cv*. Pusa Parvati (BG 3062)] was sown at a seed rate of 80 kg ha^{-1} with a spacing of 30.0×10.0 cm with the help of a seed drill in plots sized 6×5 m.

At harvest, yield attributing traits like numbers of pods $plant^{-1}$, numbers of seeds pod^{-1} and test weight were recorded in tagged plants. The harvested produce was threshed to separate grain and stover and weighed and converted into q ha^{-1}. Plant sample were collected for elemental (N,P,K and S) analysis in grain and stover. For N analysis, the ground plant samples were digested with sulpho-salicylic acid in presence of a catalyst mixture ($CuSO_4$+K_2SO_4) and N concentration was estimated using a semiautomatic micro-Kjeldahl digester (Singh *et al.,* 2005). For other nutrients, the finely ground plant samples were digested in a microwave digestion unit (Titan MPS, Perkin Elmer, USA) and P,K and S concentration was estimated by the vanado-molybdo phosphoric acid yellow colour method, flame photometry and turbidity method, respectively (Singh *et al.,* 2005). Nutrient concentrations in the plant samples were expressed as percentage (%) of dry weight. The nutrient concentrations in grain and stover were transformed into their uptake by multiplying with grain and stover yield and expressed as g ha^{-1}.

Grain protein content (GPC) was computed by multiplying N content of seeds with a factor 6.25. Protein yield was calculated by multiplying protein content with seed yield as follows:

$$\text{Protein yield (kg ha}^{-1}\text{)} = \frac{\text{Protein content (\%)} \times \text{Seed yield (kg ha}^{-1}\text{)}}{100}$$

Nutrient use efficiency was quantified in terms of apparent nutrient recovery (ANR) and agronomic efficiency (AE) of the applied N,P,K and S fertilizers. The ANR and AE was computed using the following eq.:

$$\text{ANR (\%)} = \frac{\text{Nutrient uptake in fertilized plot (kg ha}^{-1}\text{)} - \text{Nutrient uptake in control plot (kg ha}^{-1}\text{)}}{\text{Nutrient applied (kg ha}^{-1}\text{)}} \times 100$$

$$\text{AE (kg kg}^{-1}\text{)} = \frac{\text{Yield in fertilized plot (q ha}^{-1}\text{)} - \text{Yield in control plot (q ha}^{-1}\text{)}}{\text{Nutrient applied (kg ha}^{-1}\text{)}}$$

The experimental data was analyzed using a completely randomised block design (CRBD) using an open access OPSTAT software (http://14.139.232.166/opstat/). The significance of treatment differences on the measured parameters was assessed using the critical difference (C.D.) at 5% level of significance.

RESULTS AND DISCUSSION

Yield and yield attributing traits

Yield and yield attributing traits were significantly ($p < 0.05$) affected by treatments, except test weight (Table 1). The highest numbers of pods plant^{-1}, numbers of seeds pod^{-1}, test weight and grain and stover yield were observed in T6 (51.46, 1.78, 127.41 g, 18.13 and 34.74 q ha^{-1}, respectively) followed by T4 (50.57, 1.70, 125.61 g, 17.96 and 32.74 q ha^{-1}, respectively). However, a varying trend was recorded in harvest index (HI) with highest in T7 followed by T5. Results, in majority, revealed that treatments T8 and T9 although increased yield attributing traits, yields and HI over the control but remained statistically at par with each other. Our results explicitly showed that integration of RDF with either FYM or vermicompost enhanced yield and yield attributing traits to the greatest extent. The synergistic effects of inorganic and organic fertilizers on improving overall yield and its contributing traits in chickpea were previously reported (Das *et al.,* 2016; Patel and Thanki, 2020) and, ultimately corroborates our findings. Organic amendments are known to improve soil fertility, water retention and beneficial microbial activity, which perhaps contributed to enhanced plant vigour and reproductive performance (Patel and Thanki, 2020). Nevertheless, the non-significant increase of yield and yield attributing traits in organically amended treatments (T8 and T9) over the control reveals that yield enhancement cannot be achieved with suboptimal nutrient supply. Thus, the findings depending exclusively on organic nutrients for sustainable food production would

Table 1: Effect of different nutrient management practices on yield attributing traits and yield.

Treatment	No of pods plant^{-1}	No of seeds pod^{-1}	Test weight (g)	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Harvest index (%)#
T1: Control	32.19	1.10	116.74	9.18	22.81	28.72
T2: 100% RDF	43.30	1.47	124.46	15.18	27.66	35.34
T3: 75% RDF	40.09	1.43	123.74	14.57	27.54	34.59
T4: 100% RDF + 5 t ha^{-1} FYM	50.57	1.70	125.61	17.96	32.74	35.42
T5: 75% RDF + 5 t ha^{-1} FYM	43.97	1.50	123.48	15.72	29.63	34.66
T6: 100% RDF + 5 t ha^{-1} vermicompost	51.46	1.78	127.41	18.13	34.74	34.32
T7: 75% RDF + 5 t ha^{-1} vermicompost	44.37	1.57	124.71	16.51	29.51	35.87
T8: 100% RDN through FYM	34.67	1.30	118.45	12.64	23.81	34.67
T9: 100% RDN through vermicompost	34.95	1.33	119.46	12.85	24.34	34.55
SEm±	1.68	0.06	4.91	0.50	1.12	0.46
CD at 5%	4.99	0.19	NS	1.48	3.34	1.38

#Harvest index = [economic yield/biological yield] ×100.

RDF- Recommended dose of fertilizer; FYM- Farm yard manure; RDN- Recommended dose of nitrogen.

Table 2: Effect of different nutrient management practices on nutrient concentration at harvesting.

Treatment	N	P	K	S	N	P	K	S
	Stover (%)				Grain (%)			
T1: Control	1.07	0.20	0.97	0.15	2.97	0.48	0.69	0.25
T2: 100% RDF	1.25	0.24	1.09	0.24	3.14	0.62	0.80	0.30
T3: 75% RDF	1.19	0.23	1.04	0.20	3.11	0.55	0.75	0.31
T4: 100% RDF + 5 t ha^{-1} FYM	1.36	0.26	1.19	0.32	3.57	0.75	0.85	0.39
T5: 75% RDF + 5 t ha^{-1} FYM	1.24	0.25	1.10	0.27	3.17	0.63	0.74	0.37
T6: 100% RDF + 5 t ha^{-1} vermicompost	1.42	0.27	1.23	0.29	3.48	0.76	0.88	0.38
T7: 75% RDF + 5 t ha^{-1} vermicompost	1.27	0.25	1.09	0.26	3.21	0.67	0.79	0.35
T8: 100% RDN through FYM	1.11	0.21	1.00	0.16	3.02	0.51	0.71	0.26
T9: 100% RDN through vermicompost	1.12	0.22	1.02	0.17	3.03	0.52	0.72	0.27
SEm±	0.04	0.01	0.04	0.009	0.09	0.07	0.02	0.01
CD at 5%	0.15	0.03	0.13	0.03	0.27	0.07	0.05	0.03

RDF- Recommended dose of fertilizer; FYM- Farm yard manure; RDN- Recommended dose of nitrogen.

Table 3: Effect of different nutrient management practices on total nutrient uptake at harvesting.

Treatment	N	P	K	S	N	P	K	S	N	P	K	S
	Stover (kg ha^{-1})				Grain (kg ha^{-1})				Total (kg ha^{-1})			
T1: Control	24.41	4.56	22.13	3.42	27.26	4.41	6.33	2.29	51.67	8.97	28.46	5.71
T2: 100% RDF	34.57	6.63	30.15	6.64	47.66	9.41	12.14	4.55	82.23	16.041	42.29	11.19
T3: 75% RDF	31.58	6.10	27.60	5.30	45.31	8.01	10.92	4.52	76.89	14.11	38.52	9.82
T4: 100% RDF + 5 t ha^{-1} FYM	44.53	8.51	38.96	10.48	64.11	13.47	15.26	7.00	108.64	21.98	54.22	17.48
T5: 75% RDF + 5 t ha^{-1} FYM	35.50	7.16	31.49	7.73	49.83	9.90	11.63	5.82	85.33	17.063	43.12	13.55
T6: 100% RDF + 5 t ha^{-1} vermicompost	49.33	9.38	42.73	10.07	63.09	13.78	15.95	6.89	112.42	23.16	58.68	16.96
T7: 75% RDF + 5 t ha^{-1} vermicompost	37.48	7.38	32.16	7.67	52.99	11.06	13.04	5.78	90.47	18.44	45.2	13.45
T8: 100% RDN through FYM	26.43	5.00	23.81	3.80	38.17	6.45	8.97	3.28	64.60	11.45	32.78	7.08
T9: 100% RDN through vermicompost	27.26	5.35	24.82	4.14	38.93	6.68	9.25	3.47	66.19	12.03	34.07	7.61
SEm ±	2.77	0.55	2.42	0.54	3.31	0.52	0.76	0.41	5.72	1.29	2.80	0.94
CD at 5%	8.23	1.64	7.19	1.61	9.84	1.08	2.27	1.21	16.99	3.86	8.32	2.81

RDF- Recommended dose of fertilizer; FYM- Farm yard manure; RDN- Recommended dose of nitrogen.

not produce sufficient grain to satisfy the food demand. (Wei *et al.,* 2016).

Nutrient concentration

Nutrient concentration in grain and stover were significantly ($p < 0.05$) affected by treatments (Table 2). Results revealed that highest concentration of P and K in grain was observed in T6 (0.76 and 0.88%) followed by T4 (0.75 and 0.85%). However, a reverse trend was recorded for N and S concentration between T4 (3.57 and 0.39%) and T6 (3.48 and 0.30%). Treatment T2 (100% RDF) significantly ($p<0.05$) increased N,P,K and S concentrations in grains to 3.14, 0.62, 0.80 and 0.30%, respectively. Again, T2 registered a significant ($p<0.05$) increase in N, P, K and S concentrations in stover to 1.25, 0.24, 1.09 and 0.24%, which were 16.8, 20.0, 12.3 and 60.0% higher over control (T1), respectively. On the other hand, treatments T8 and T9 although increased their concentration in grain and stover over the control but remained statistically at par with each other. The highest nutrient concentration in grain and stover in T4 and T6 can be attributed to many factors. Firstly, organic manures improved soil nutrient availability and enhanced nutrient uptake by chickpea plants (Thorhate *et al.,* 2019). Secondly, the balanced combination of inorganics and organics ensured a comprehensive nutrient supply, optimizing nutrient assimilation by the plants which, in turn, led to higher nutrient concentration in the grains and stover (Das *et al.,* 2016; Mukati *et al.,* 2021).

Nutrient uptake

Results showed that significantly ($p<0.05$) highest uptake of P and K in grain and N, P and K in stover was observed in T6 (13.78 and 15.95 and 49.33, 9.38 and 42.73 kg ha^{-1}, respectively) followed by T4 (13.47 and 15.26 and 44.53, 8.51 and 38.96 kg ha^{-1}, respectively) (Table 3). However, a reverse trend was noticed for N and S uptake in grain and S in stover between T4 (64.11 and 7.00 and 10.48 kg ha^{-1}, respectively) and T6 (63.09 and 6.89 and 10.06 kg ha^{-1}, respectively). The highest nutrient uptake in grain and stover was obtained with a combination of 100% RDF along with either 5 t ha^{-1} of FYM or vermicompost and corroborates the observations by Kemal *et al.* (2018). Our result is supported by the findings of Khan *et al.* (2023) who reported an enhanced nutrient uptake in chickpea following the application of organics. The increased nutrient uptake may result from the acidification process caused by the generation of CO_2 and various organic acids in manures, which influence soil reaction and enhance nutrient accessibility to plants. This result is also supported by Agegnehu *et al.* (2016). Plants generally rely upon the microbes like bacteria and fungi to access the nutrients, as they shape processes like mineralization of N, P and S that are bound to organic compounds. Organic manures generally improve the microbial activity of soil. The releases the inorganic forms of nutrients (NH_4^+, NO_3^-, PO_4^{3-}, SO_4^{2-}) into the soil increases their availability and subsequently uptake by plants.

Nutrient use efficiency

Our findings revealed that the highest ANR of N, P, K and S was observed in T3 (168.1%), T4 (17.6%), T2 (69.2%) and T9 (38.0%) followed by T2 (152.8%), T6 (15.6%), T3 (67.1%) and T4 (33.9%), respectively (Fig 1). The results also revealed that highest AE of N, P, K and S was observed in T3 (35.9 kg kg^{-1}), T9 (17.5 kg kg^{-1}), T3 (35.9 kg kg^{-1}), T9 (73.6 kg kg^{-1}) followed by T2 (30.0 kg kg^{-1}), T8 (17.3 kg kg^{-1}), T2 (30.0 kg kg^{-1}) and T2 (35.9 kg kg^{-1}), respectively (Fig 2). Nutrient use efficiencies (ANR and AE) of the applied nutrients were found to be high with inorganic fertilization, whether applied at 100% or 75% RDF alone or in combination with organic fertilizers like FYM or vermicompost. This might be due to, inorganic fertilizers provided readily available nutrients in precise amounts, resulting in higher nutrient recovery by the crop. The balanced application of inorganic and organic fertilizers in combination may enhance nutrient utilization, further contributing to increased agronomic efficiency. Organic fertilizers, while beneficial for soil health, may release nutrients slowly, leading to relatively lower nutrient recovery compared to inorganic fertilizers. However, the synergistic effects of both fertilizer types in the combination treatment could optimize nutrient uptake, ultimately improving the agronomic efficiency in chickpea cultivation (Debnath *et al*., 2015; Sahu *et al*., 2015).

Grain protein content and protein yield

The result showed that significantly ($p < 0.05$) highest grain protein content (GPC) was observed in T4 (22.3%) followed by T6 (21.8%) and similarly, highest protein yield (PY) was observed in T4 (400.5 kg ha^{-1}), followed by T6 (394.7 kg ha^{-1}) (Fig 3). Higher GPC and PY in chickpea with the combination of 100% RDF along with either of FYM or vermicompost could be due to many key factors. Organic manures improved soil N availability and enhanced its uptake

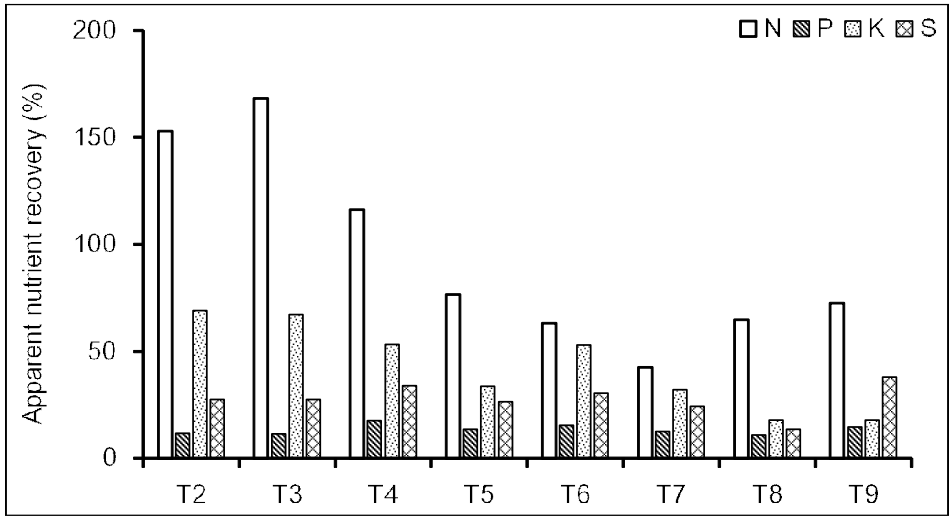


Fig 1: Effect of different nutrient management practices on apparent recovery of the applied N, P, K and S fertilizers in chickpea.

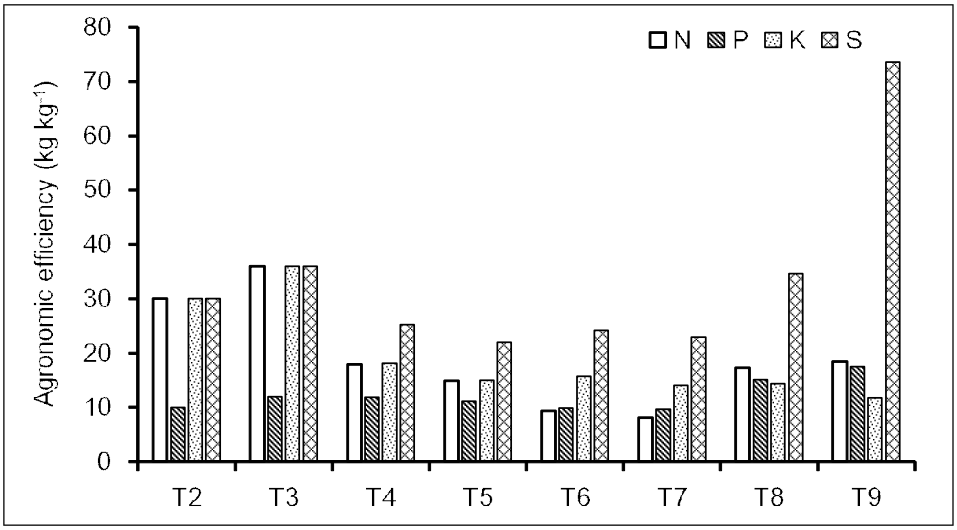


Fig 2: Effect of different nutrient management practices on agronomic efficiency of the applied N, P, K and S fertilizers in chickpea.

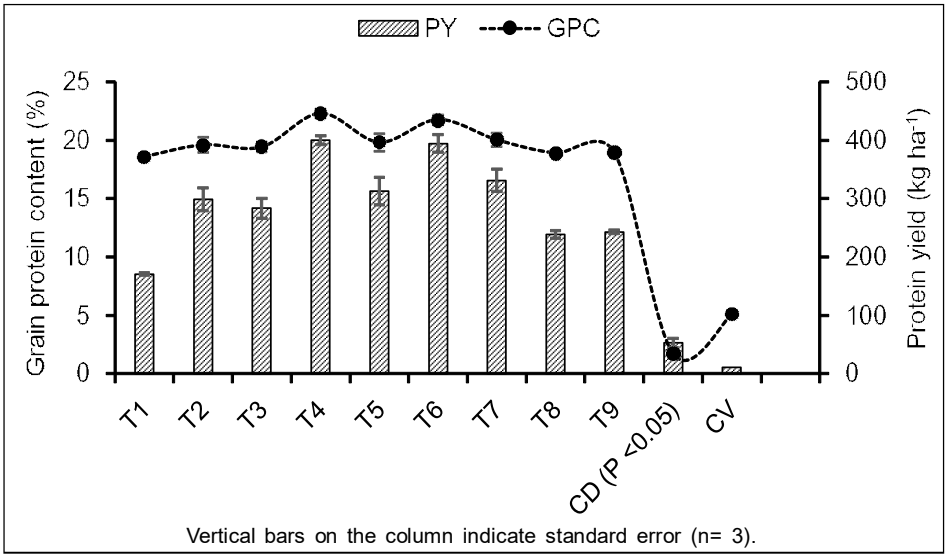


Fig 3: Effect of different nutrient management practices on grain protein content and protein yield of chickpea.

by the chickpea plants. This resulted in increased N assimilation and protein synthesis within the grains. The balanced use of inorganic and organic fertilizers ensured a comprehensive nutrient supply, including N, which positively affected GPC since it is directly linked to N uptake. The enhanced plant vigour and biomass resulting from the fertilizer combination further contributed to higher PY (Kemal *et al.,* 2018). Overall, the synergistic effects of inorganic fertilizers and manures played a vital role in improving GPC and PY in chickpea. Once synthesized, proteins are either used for various cellular functions within the plants or stored in specific tissues, such as seeds, which leads to higher protein content in seeds (Karthika *et al.,* 2023; Rasheed *et al.,* 2020). So, higher N uptake by the plant resulted into higher protein content in the grain.

CONCLUSION

Population explosion in India enhance the demand of pulses and can be met out of higher pulse production with quality grain protein. The above findings demonstrated the significance of incorporating organic amendments like FYM and/or vermicompost at 5 t ha^{-1} in nutrient management regimes to enhance the nutrient cycling and improve the overall crop growth and yield and protein content in chickpea grown in drought-prone *Bundelkhand* region. The results also showed that adding the recommended dose of chemical fertilizers alone may not be adequate for sustainable chickpea production and for enhancing grain protein content for fulfilment of dietary protein requirements of Indians. Thus, by promoting nutrient cycling and enhancing protein content, organic amendments (FYM and/or vermicompost) could be a sustainable solution for maximizing crop productivity and nutritional quality in staggering chickpea production systems in this region.

ACKNOWLEDGEMENT

The authors are highly thankful to ICAR-Central Agroforestry Research Institute and Rani Lakshmi Bai Central Agricultural University for providing necessary facilities to carry out the research.

Conflict of interest statement

The authors declare no conflict of interests with the data reported in this study.

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