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Effect of Integrated Plant Nutrient Management based on Soil Test Crop Response on Primary Plant Nutrients Uptake and Quality Parameters of Blackgram on *Alfisols* in Western Zone of Tamil Nadu, India

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ABSTRACT

Background: Enhancing food security and nutrition for the expanding population is a significant concern. In this context, the application of inorganic fertilisers and organic manures and plays a pivotal role by supplying vital nutrients to plants. This practice elevates the nutrient content and overall nutritional quality of crops, thereby contributing substantially for meeting the nutritional requirements of a growing populace. Conversely, the repercussions of imbalanced nutrition are detrimental, leading to reduced agricultural productivity and soil fertility degradation. These factors, in turn, contribute to increased cultivation costs. Addressing this multifaceted issue necessitates a precise quantification of inorganic fertiliser integration with organic manures as an effective means of resolving these challenges.

Methods: The current research was conducted on a farmer's holding, using blackgram (variety: VBN 11) in Thondamuthur block of Coimbatore district, Western Zone of Tamil Nadu to study the effect of different N, P_2O_5, K_2O and IPNS dosages in nutrient acquisition and quality parameters. The treatments included absolute control, blanket, blanket + FYM, Soil test crop response (STCR) based fertiliser dose for an yield target of 1.0, 1.2 and 1.4 t ha^{-1}, STCR-IPNS based fertiliser dose for an yield target of 1.0, 1.2 and 1.4 t ha^{-1} and farmer's practice.

Result: The highest nutrient uptake and quality parameters were recorded when employing STCR-IPNS at a targeted yield of 1.4 t ha^{-1}. This finding strongly underscores the value of incorporating these practices into our agricultural approach. Doing so not only paves the way for sustainable, nutrient-rich food production but also effectively addresses the issue of imbalanced nutrition. Moreover, it plays a vital role in enhancing soil health. In sum, this comprehensive approach is pivotal in fortifying food security and elevating nutritional standards.

Key words: Blanket, IPNS dosages, Nutrient acquisition, Quality parameters, Soil test crop response, STCR-IPNS.

INTRODUCTION

Pulses serve as the most abundant source of protein for a significant portion of the vegetarian population in countries such as India (Shroti *et al*., 2018). Among pulses, blackgram [*Vigna mungo* (L.) Hepper] holds a special significance as it is cultivated both in pure and in mixed cropping systems alongside crops like maize, cotton, sorghum and various millets. The crop shows resilience to adverse weather conditions and contributes to soil fertility improvement by fixing atmospheric nitrogen in the soil (Ajaykumar *et al*., 2022). The diminished productivity of blackgram can be primarily ascribed to the inadequate application of macronutrients, a critical factor elucidated by Pandey *et al.* (2013). At present, organic nutrient sources are prioritized over synthetic chemicals. However, concerns arise regarding the availability of a sufficient quantity of organic materials for agricultural needs. Thus, there's a necessity to establish standardised practices for combining organic and inorganic nutrient sources (Sharma and Chauhan, 2011). The decline in soil health can be reversed by implementing an integrated nutrient management approach and ensuring a balanced fertilisation strategy (Gudadhe *et al*., 2015).

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The prevailing uniform crop recommendations fail to guarantee the efficient and cost-effective utilization of fertilisers, primarily because they disregard fertility variations,

leading to the uneven distribution of fertiliser nutrients (Singh, 2018). The targeted yield approach (Ramamoorthy *et al*., 1967) stands out as the most suitable method for achieving balanced fertilisation. This approach serves as the foundation for efficient resource utilization and the maintenance of well-balanced crop nutrient management. The utilization of soil test-based fertiliser application is a valuable tool and the fertiliser prescription equation is considered a distinctive technology for optimizing the application of fertilisers based on specific needs. Drawing upon the existing knowledge base, the current research was conducted with the objective of formulating an effective nutrient management technology. This technology encompasses various inorganic fertiliser and Integrated Plant Nutrient System (IPNS) dosages aimed at augmenting nutrient acquisition and enhancing the quality parameters of irrigated blackgram.

MATERIALS AND METHODS

Experimental site

During the *Rabi* season of 2022-2023, a field experiment was conducted at a farmer's field in the Thondamuthur block of Coimbatore district, using the blackgram variety VBN 11. The experimental site is located at an elevation of 449 meters above mean sea level (MSL), with coordinates at 11°00′24.9″ North latitude and 76°48′50.5″ East longitude. It is situated in the Western Agro-climatic zone of Tamil Nadu. The soil at the experimental site falls under the *Alfisol*s order with sandy loam texture and belongs to the sub-group *Typic Rhodustalf*. It is categorised as a non-calcareous red soil. The soils were lower in organic carbon (3.9 g kg^{-1}), lower in available nitrogen (255 kg ha^{-1}), higher in available P (42 kg ha^{-1}) and available K (380 kg ha^{-1}) as per rating chart of Tamil Nadu Agricultural University (https://agritech.tnau.ac.in/). However, soils were not limiting in available micronutrients *viz*., Zn, Cu, Fe and Mn. The research investigation was laid out following a Randomized Block Design (RBD) with ten treatments and three replications. The treatments comprised such as T_1 - STCR - NPK alone - 1.0 t ha^{-1}, T_2 - STCR - NPK alone - 1.2 t ha^{-1}, T_3 - STCR - NPK alone - 1.4 t ha^{-1}, T_4 - STCR - IPNS - 1.0 t ha^{-1}, T_5 - STCR - IPNS - 1.2 t ha^{-1}, T_6 - STCR - IPNS - 1.4 t ha^{-1}, T_7 - Blanket (100 % RDF alone), T_8 - Blanket + FYM @ 12.5 t ha^{-1}, T_9 - Farmer's practice, T_{10} - Absolute control. The plant samples were analysed for their nitrogen content using the micro Kjeldahl method, while the levels of phosphorus and potassium (HNO_3: H_2SO_4: $HClO_4$ in a 9:2:1 ratio) were determined following as the procedure of Jackson (1973). Nutrient uptake was computed by multiplying the yield with nutrient content of grain and haulm.

The analysis of variance (ANOVA) was carried out using R- Studio version 4.2.2. Software and as per procedure detailed by Ihaka and Gentleman (1996) for employing the RBD. In addition, the differences were compared by least significant difference (LSD) test at a significance level of $p<0.05$.

RESULTS AND DISCUSSION

Nitrogen uptake

The nitrogen uptake by the plants exhibited variations ranging from 9.25 to 19.14 kg ha^{-1} during the vegetative stage, 20.05 to 38.55 kg ha^{-1} in the flowering stage, 29.87 to 46.69 kg ha^{-1} during pod development and 34.76 to 55.44 kg ha^{-1} at maturity (Table 1). Among all the treatments, STCR - IPNS-1.4 t ha^{-1} consistently displayed the highest nitrogen uptake across all stages, while the absolute control recorded the lowest nitrogen uptake.

During the vegetative stage, the most significant N uptake was observed in STCR-IPNS-1.4 t ha^{-1} (19.14 kg ha^{-1}), followed by STCR-NPK alone-1.4 t ha^{-1} (18.38 kg ha^{-1}), while STCR-IPNS-1.2 t ha^{-1} (18.25 kg ha^{-1}) showed a similar level of uptake. In contrast, the absolute control exhibited the lowest nitrogen uptake, measuring 9.25 kg ha^{-1}. At peak flowering stage, when using only STCR-NPK treatments, the N uptake levels were 30.21 kg ha^{-1}, 35.86 kg ha^{-1} and 37.18 kg ha^{-1} for target yields of 1.0 t ha^{-1}, 1.2 t ha^{-1} and 1.4 t ha^{-1}, respectively. In comparison, the nitrogen uptake levels for STCR-IPNS treatments were 31.42 kg ha^{-1}, 36.93 kg ha^{-1} and 38.55 kg ha^{-1}, respectively. The STCR

Table 1: Effect of different fertiliser dosages and STCR-IPNS on N uptake at different physiological stages of blackgram.

Treatments	Vegetative	Peak flowering	Pod development	Maturity
T_1- STCR - NPK alone - 1.0 t ha^{-1}	15.22	30.21	36.55	42.91
T_2- STCR - NPK alone - 1.2 t ha^{-1}	16.13	35.86	40.11	46.90
T_3- STCR - NPK alone - 1.4 t ha^{-1}	18.38	37.18	42.08	47.44
T_4- STCR - IPNS - 1.0 t ha^{-1}	15.89	31.42	39.74	43.47
T_5- STCR - IPNS - 1.2 t ha^{-1}	18.25	36.93	41.88	47.32
T_6- STCR - IPNS - 1.4 t ha^{-1}	19.14	38.55	46.69	55.44
T_7- Blanket (100 % RDF alone)	13.41	25.77	30.45	35.59
T_8- Blanket (25:50:25) + FYM @ 12.5 t ha^{-1}	14.86	28.59	32.26	36.15
T_9- Farmer's practice	11.57	23.97	28.66	35.13
T_{10}- Absolute control	9.25	20.05	29.87	34.76
SEd	0.32	0.45	0.68	0.89
CD (P=0.05)	0.66	0.95	1.43	1.87

treatments outperformed both the farmer's practice (23.97 kg ha^{-1}) and the absolute control (20.05 kg ha^{-1}) in a statistically significant manner. A consistent pattern of findings was observed during the Pod development stage. The highest nitrogen (N) uptake was documented in the STCR-IPNS-1.4 t ha^{-1} treatment, registering at 46.69 kg ha^{-1}. Following this, the same treatment without organics produced the next highest nitrogen uptake at 42.08 kg ha^{-1}. Subsequently, the STCR-IPNS-1.2 t ha^{-1} treatment exhibited a nitrogen uptake of 41.88 kg ha^{-1}. The lowest nitrogen (N) uptake was observed in the absolute control treatment, amounting to 29.87 kg ha^{-1}. Significant variations in N uptake were observed during the maturity stage. Among all the treatments and treatment combinations, STCR-IPNS-1.4 t ha^{-1} demonstrated outstanding performance by achieving the highest N uptake of 55.44 kg ha^{-1}. In contrast, the lowest N uptake was recorded in the absolute control treatment, measuring at 34.76 kg ha^{-1}.

The enhanced nitrogen (N) uptake in blackgram can be attributed to the presence of an efficient and well-developed root system, which contributes to the decomposition of organic matter. This decomposition, in turn, increases the organic matter content in the soil, enhancing the availability of nutrients in the rhizosphere. This improved nutrient availability is a result of the combined application of organic and inorganic fertilisers, leading to increased nitrogen uptake by the plants. These findings align with the results reported by Singh *et al.* (2016) in chickpea, Sakarvadia *et al.* (2016) in pigeonpea and Salunkhe *et al.* (2018) in cowpea.

Phosphorus uptake

Table 2 provided a comprehensive illustration of the pronounced impact of diverse fertiliser recommendations on phosphorus (P) uptake by the plants across the distinct physiological stages of crop growth. In vegetative stage, the multitude of treatments demonstrated their individual efficacy in promoting P uptake in the plants. Remarkably, the STCR-IPNS-1.4 t ha^{-1} treatment exhibited the highest P uptake, registering at 7.14 kg ha^{-1} and it was closely followed by the same treatment without the inclusion of organic manures (6.28 kg ha^{-1}). The lowest phosphorus (P) uptake was documented in the absolute control, amounting to 4.06 kg ha^{-1}. At peak flowering stage, the highest phosphorus (P) uptake was observed in the STCR-IPNS-1.4 t ha^{-1} treatment, with a notable value of 16.85 kg ha^{-1}, showcasing its individual and more pronounced influence in facilitating P mobilization compared to other recommendations. Following closely, the same treatment without organics exhibited a P uptake of 16.19 kg ha^{-1}. The lesser P uptake was documented with absolute control (11.89 kg ha^{-1}). Notable differences were observed during the pod development stage, with the highest phosphorus (P) uptake recorded in the STCR-IPNS treatment targeting a yield of 1.4 t ha^{-1}, at 21.59 kg ha^{-1}. This was followed closely by the STCR-NPK alone treatment targeting 1.4 t ha^{-1} and the STCR-IPNS treatment targeting 1.2 t ha^{-1}, with P uptakes of 20.55 kg ha^{-1} and 19.87 kg ha^{-1}, respectively, which were comparable to each other. The lowest P uptake was observed in the absolute control, at 12.45 kg ha^{-1}. A consistent pattern of results was also observed during the maturity stage. The highest phosphorus (P) uptake was achieved by the STCR-IPNS-1.4 t ha^{-1} treatment, at 25.37 kg ha^{-1} and the STCR-NPK alone-1.4 t ha^{-1} treatment, at 24.39 kg ha^{-1}. These two treatments outperformed all other treatments and treatment combinations in facilitating P uptake by the plants. In contrast, the lowest P uptake was recorded in the absolute control treatment, with only 13.08 kg ha^{-1}.

The application of farmyard manure (FYM) reduces phosphorus (P) fixation by releasing a significant amount of various organic substances and organic acids during decomposition. Additionally, it induces chelating effects on micronutrients, which likely enhances the availability of phosphorus. Consequently, the combined application of inorganic and organic fertilisers has led to a significant overall increase in nutrient uptake, offering a cost-effective and long-lasting solution. FYM plays a crucial role in solubilizing insoluble or fixed phosphorus, rendering it readily available to plants in an easily absorbable ionic form. These findings align with the research of Kumpawat (2010), Patil *et al.* (2010) and Mehta *et al.* (2015).

Table 2: Effect of different fertiliser dosages and STCR-IPNS on P uptake at different physiological stages of blackgram.

Treatments	Vegetative	Peak flowering	Pod development	Maturity
T_1- STCR - NPK alone - 1.0 t ha^{-1}	5.28	15.24	18.73	20.82
T_2- STCR - NPK alone - 1.2 t ha^{-1}	5.85	15.91	19.42	23.48
T_3- STCR - NPK alone - 1.4 t ha^{-1}	6.28	16.19	20.55	24.39
T_4- STCR - IPNS - 1.0 t ha^{-1}	5.46	15.58	18.94	21.46
T_5- STCR - IPNS - 1.2 t ha^{-1}	6.21	16.06	19.87	24.12
T_6- STCR - IPNS - 1.4 t ha^{-1}	7.14	16.85	21.59	25.37
T_7- Blanket (100% RDF alone)	5.03	13.46	16.68	18.73
T_8- Blanket (25:50:25) + FYM @ 12.5 t ha^{-1}	5.14	14.67	18.19	21.57
T_9- Farmer's practice	4.88	12.75	14.03	15.44
T_{10}- Absolute control	4.06	11.89	12.45	13.08
SEd	0.11	0.24	0.32	0.39
CD (P=0.05)	0.24	0.51	0.68	0.82

Potassium uptake

Table 3 provides data on the uptake of potassium by plants at different stages of crop growth.

Significant variations in potassium uptake were observed during the vegetative stage, with the highest uptake recorded in the STCR-IPNS-1.4 t ha^{-1} treatment, amounting to 18.47 kg ha^{-1}. This uptake was notably higher than that of other treatments with various fertiliser dosages at this stage. The subsequent highest potassium uptake observed in the STCR-NPK alone - 1.4 t ha^{-1}, measuring 18.19 kg ha^{-1}. Additionally, the STCR-IPNS-1.2 t ha^{-1} showed a potassium uptake of 17.59 kg ha^{-1} and these values were found to be similar to each other. The lowest potassium uptake was observed in the absolute control, with only 10.25 kg ha^{-1}. There were remarkable variations observed among the treatments in potassium uptake by plant at peak flowering stage. The higher uptake of K was registered with STCR-IPNS-1.4 t ha^{-1} (40.83) and it was closely followed by STCR-NPK alone-1.4 t ha^{-1} (38.39). The lowest uptake was recorded with absolute control (22.56). During the pod development stage, there were notable variations in potassium uptake among the treatments with different fertiliser and IPNS dosages. In the case of the STCR-IPNS-1.4 t ha^{-1} treatment, the highest potassium (K) uptake was recorded at 51.68 kg ha^{-1}, followed closely by the same treatment without organic components, which achieved a K uptake of 50.54 kg ha^{-1}. All STCR and blanket fertiliser recommendations, including the farmer's practice, exhibited their distinct effects on potassium uptake. The lowest K uptake, measuring 31.88 kg ha^{-1}, was observed in the absolute control. A comparable pattern of results was observed during the maturity stage, with the highest potassium (K) uptake achieved by the STCR-IPNS-1.4 t ha^{-1}, recording a value of 60.68. Following closely, the STCR-NPK alone-1.4 t ha^{-1} exhibited a potassium uptake of 59.73, which was similar to the former. In contrast, the lowest K uptake, at 39.47 kg ha^{-1}, was recorded in the absolute control.

This phenomenon could be attributed to the enhanced development of the root system, which in turn facilitates improved nutrient transportation, maintains cell wall integrity and ultimately contributes to higher crop yields. Given that nutrient uptake is inherently linked to both nutrient content and crop yield, the increased yield of black gram, along with higher potassium (K) content distributed throughout the plant, likely resulted in the elevated uptake of these nutrients by the crop. These findings align with the research conducted by Kumar *et al.* (2020); Movalia *et al.* (2020) and Naznin *et al.* (2020).

Quality parameters

Crude protein and crude protein yield

Significant fluctuations in both crude protein levels and crude protein yield within and across the various treatments and treatment combinations (Fig 1). The highest levels of crude protein and yield were achieved with STCR-IPNS-1.4 t ha^{-1} (24.09% and 332 kg ha^{-1}), closely followed by STCR-NPK alone-1.4 t ha^{-1} (23.58% and 310 kg ha^{-1}). These two STCR treatments exhibited a significant individual impact compared to other fertiliser recommendations. In contrast, all other treatments and treatment combinations showed similar effects in terms of both crude protein and crude protein yield. The lowest values for crude protein and yield were observed in the absolute control (19.45% and 163 kg ha^{-1}).

The synergistic use of inorganic fertilisers in conjunction with organic manures had a clear and significant positive impact on both the production of crude protein and the absorption of nitrogen, as visually exemplified in Fig 2. Enhancing the absorption of nitrogen, a crucial element forming the building blocks of amino acids and proteins, likely contributed to the rise in crude protein content through these treatment combinations. The improvement in grain quality attributed to the application of organic manures can be attributed to better nutrient availability for the crop, potentially resulting in the

Table 3: Effect of different fertiliser dosages and STCR-IPNS on K uptake at different physiological stages of blackgram.

Treatments	Vegetative	Peak flowering	Pod development	Maturity
T_1- STCR - NPK alone - 1.0 t ha^{-1}	15.83	31.65	40.11	43.37
T_2- STCR - NPK alone - 1.2 t ha^{-1}	16.97	36.54	48.87	54.65
T_3- STCR - NPK alone - 1.4 t ha^{-1}	18.19	38.39	50.54	59.73
T_4- STCR - IPNS - 1.0 t ha^{-1}	16.62	33.18	45.79	49.28
T_5- STCR - IPNS - 1.2 t ha^{-1}	17.59	38.33	50.15	57.85
T_6- STCR - IPNS - 1.4 t ha^{-1}	18.47	40.83	51.68	60.68
T_7- Blanket (100% RDF alone)	13.94	25.14	34.92	42.25
T_8- Blanket (25:50:25) + FYM @ 12.5 t ha^{-1}	15.14	28.71	37.26	44.88
T_9- Farmer's practice	12.51	23.42	32.36	40.66
T_{10}- Absolute control	10.25	22.56	31.88	39.47
SEd	0.42	0.59	0.68	1.35
CD (P=0.05)	0.89	1.24	1.43	2.84

accumulation of increased quantities of seed components such as calcium carbonate. Additionally, this enhanced nutrient uptake might have led to heightened lipid metabolism, ultimately aiding in the augmentation of protein content in the grains. These outcomes align with similar observations made by Kadam *et al.* (2014); Amruta *et al.* (2016) and Singh *et al.* (2017) regarding both crude protein content and yield.

Crude fibre

The various treatments did not exert a significant influence on the crude fibre content of blackgram, which ranged from 3.34 to 3.51 per cent (Table 4). The lowest crude fibre content was observed in the case of STCR-IPNS-1.4 t ha^{-1} (3.34%), followed closely by STCR-IPNS-1.2 t ha^{-1} (3.36%) and STCR-IPNS-1.0 t ha^{-1} (3.38%), all of which exhibited similar levels. In contrast, the highest crude fibre content was found in the absolute control (3.51%). Crude fibre represents the insoluble remnants resulting from acid-alkaline hydrolysis, comprising true cellulose and insoluble lignin. Notably, the crude fibre content tends to decrease with higher nitrogen doses, which is a critical parameter for supplementation in feed applications. Modgil *et al.* (2019); Kanchana (2020) and Kanth *et al.* (2021) have documented congruent findings in their respective studies.

Total sugars and true protein

Sugar plays a crucial role as a fundamental energy source necessary for the sustenance of all living organisms. This organic molecule is produced by plants *via* photosynthesis and subsequently undergoes decomposition in the course of respiration.

Total sugars and true protein had significant variations among treatment and treatment combinations has illustrated in the Table 4. The highest content of total sugars and true protein was recorded with STCR-IPNS-1.4 t ha^{-1} (29.43 mg g^{-1} and 2.80%) followed by the same treatment without organics (28.59 mg g^{-1} and 2.71%) comparable with each other. The lowest total sugars were recorded with absolute control (22.62 mg g^{-1} and 1.98%). The rise was likely the

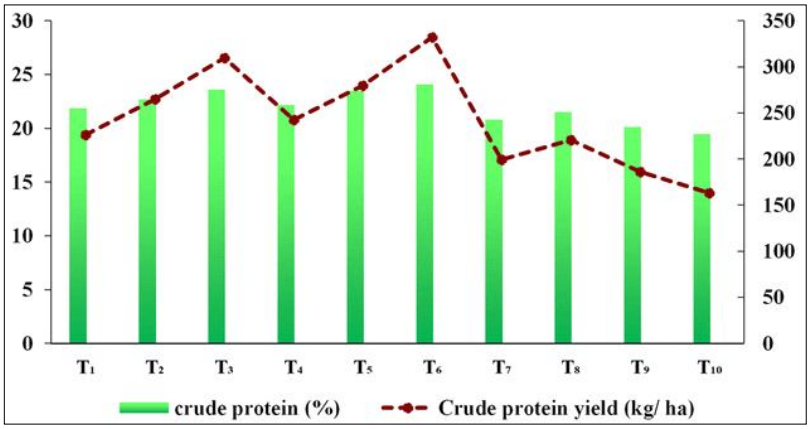


Fig 1: Effect of different fertiliser dosages and STCR-IPNS on crude protein (%) and crude protein yield (kg ha^{-1}) of blackgram.

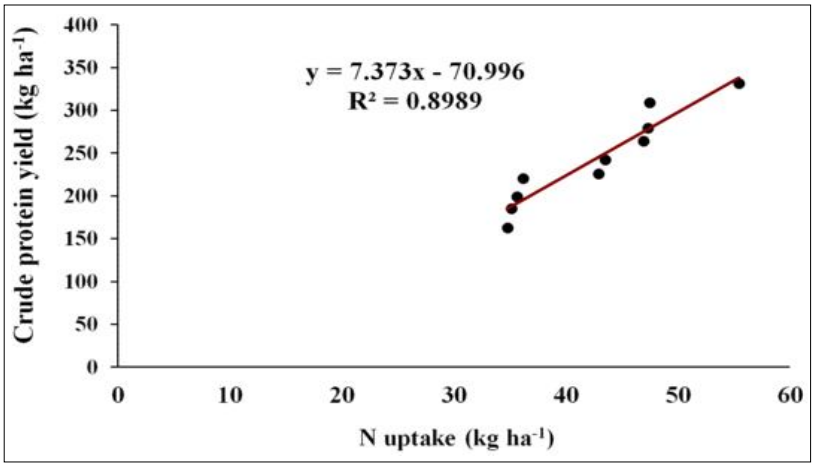


Fig 2: Relationship between crude protein yield and N uptake at maturity with different fertiliser and STCR - IPNS dosages.

Table 4: Effect of different fertiliser dosages and STCR-IPNS on quality parameters of blackgram.

Treatments	Crude fibre (%)	Total sugars (mg g^{-1})	True protein (%)
T_1- STCR - NPK alone - 1.0 t ha^{-1}	3.43	26.84	2.52
T_2- STCR - NPK alone - 1.2 t ha^{-1}	3.41	27.38	2.61
T_3- STCR - NPK alone - 1.4 t ha^{-1}	3.45	28.59	2.71
T_4- STCR - IPNS - 1.0 t ha^{-1}	3.38	27.16	2.57
T_5- STCR - IPNS - 1.2 t ha^{-1}	3.36	28.55	2.69
T_6- STCR - IPNS - 1.4 t ha^{-1}	3.34	29.43	2.80
T_7- Blanket (100 % RDF alone)	3.43	24.31	2.26
T_8- Blanket (25:50:25) + FYM @ 12.5 t ha^{-1}	3.41	25.58	2.45
T_9- Farmer's practice	3.45	23.66	2.14
T_{10}- Absolute control	3.51	22.62	1.98
SEd	0.07	0.58	0.06
CD (P=0.05)	NS	1.22	0.13

result of nutrients stimulating RNA synthesis, which in turn causes plants treated with nutrients to have higher protein concentrations. Parthasarathi *et al*. (2008) and Modgil *et al*. (2019) likewise demonstrated the significant influence of protein and total sugars.

CONCLUSION

On the basis of field experiment, it was concluded that integration of chemical fertilisers with organics exerts a discernible influence on the plant's nutrient uptake and various quality parameters. Among the array of ten experimental treatments, the most pronounced enhancement in nutrient absorption, encompassing nitrogen, phosphorus, potassium and pertinent quality parameters, was achieved with the application of STCR-IPNS-1.4 t ha^{-1}. This finding underscores the synergistic efficacy of combining inorganic fertilisers and organic manures in augmenting nutrient content and the holistic nutritional attributes of the black gram.

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Conflict of interest

All authors declared that there is no conflict of interest.

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