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Optimizing Primary Macronutrients for Improved Productivity and Carbon Accumulation in Green Gram

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ABSTRACT

A field experiment was conducted at Research Farm of Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala during summer season of 2023-24. The experiment was laid out in factorial randomized complete block design with three replications involving two factors i.e. nutrient combinations (Factor A) and green gram varieties (Factor B). Factor A comprised eight N:P:K fertilizer levels (kg/ha): F_1–15:40:00, F_2–15:40:20, F_3–15:50:00, F_4–15:50:20, F_5–20:40:00, F_6–20:40:20, F_7–20:50:00 and F_8–20:50:20, while the Factor B included two different green gram varieties V_1–MH 1142 and V_2–MH 421. The required amounts of nitrogen, phosphorus and potassium were applied to each plot separately based on the treatment schedule as a basal application before sowing. The results revealed that the application of 20:50:20 kg/ha N:P:K (F_8) significantly resulted in higher plant height, number of leaves/plant, dry matter accumulation and seed yield which were also found statistically at par with application of 15:50:20 kg/ha N:P:K (F_4) and 20:40:20 kg/ha N:P:K (F_6) indicating higher carbon accumulation in plant foliage in these treatments. Further, the data revealed a positive and strong correlation between different growth parameters and seed yield of green gram. It can be concluded that application of 20:50:20 kg/ha N:P:K was found to be the most effective treatment for enhancing productivity of green gram as well as carbon sequestration. Hence, this approach offers a viable pathway to sustain pulse productivity while simultaneously contributing to agroecosystem carbon-mitigation strategies.

Key words: Carbon sequestration, growth, green gram varieties, nutrients, yield

INTRODUCTION

Pulses, commonly referred to as food legumes, occupy a pivotal position in sustainable agricultural systems and are secondary only to cereals in terms of production and consumption in India (Patidar *et al*., 2025). Among pulses, green gram (*Vigna radiata* L.) is an important short-duration legume crop, valued for its high nutritional quality, containing nearly 25% protein-approximately twice that of wheat and three times that of rice. India is considered the centre of origin of green gram, cultivating it over an area of 5.18 million hectares with a production of 3.10 million tonnes and an average productivity of 598 kg/ha (Anonymous, 2023). Major green gram-growing states include Rajasthan, Madhya Pradesh, Maharashtra, Karnataka, Bihar and Gujarat (Chavan *et al*., 2024). In Haryana, the crop occupies about 32,320 ha with a production of 21,880 tonnes and a productivity of 677 kg/ha (Anonymous, 2023). Apart from the nutritional value, the role of green gram is essential for enhancing carbon levels in agricultural ecosystems. Being a legume crop, green gram can fix nitrogen directly from the atmosphere using rhizobia. The nitrogen fixation capability of the crop ensures low dependency on nitrogen fertilizers, which can help build carbon in the soil (Yin *et al*., 2018). The inclusion of legume crops into agricultural production ensure higher carbon levels in the soil by improving microbial life as well as improving aggregate stability. All these qualities of green gram help in carbon sequestration. The inclusion of green gram in cropping system can ensure lower carbon levels in the atmosphere by acting as carbon sinks.

Besides inherent capability of nitrogen fixation in green gram, a balanced supply of nitrogen is required for proper physiological activities, as it acts as an important component of proteins, nucleic acids and chlorophyll (Rana *et al*., 2016). Phosphorus acts as a prime mover in transporting energy, root and nodulation processes, which in turn promotes biologically fixed nitrogen and, consequently, carbon in the

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soil through the increase in root mass (Balai *et al*., 2017). While, potassium helps in improving stress resistance, mainly in drought conditions along with assimilate translocation and better seed quality in pulses (Islam *et al*., 2024). Proper use of primary macronutrients (N, P and K) in a balanced manner can increase productivity of green gram (Bhandari *et al*., 2024) and also help in increasing the biological reserves of carbon in the soils through improved growth, quality and root biomass, which can help in increasing carbon sequestration in green gram based cropping systems.

MATERIALS AND METHODS

A field experiment was conducted during summer season of 2023-24 at Research Farm of Department of Agriculture, Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala. Geographically, the experimental site is located at 30º17′0″ North latitude, and 77º3′0″ East longitude at an elevation of 264 meters above mean sea level. The experimental site falls in the subtropical region of Haryana. The region receives 750 mm of rain on average each year. The soil of experimental field was sandy loam in texture with near neutral in reaction. The soil was low in organic carbon and available nitrogen while medium in available phosphorus and potassium. The experiment was laid out in factorial randomized complete block design with two factors and three replications. The two factors included eight levels of primary nutrients (N:P:K kg/ha) application (Factor A) which were F_1–15:40:00, F_2–15:40:20, F_3–15:50:00, F_4–15:50:20, F_5–20:40:00, F_6–20:40:20, F_7–20:50:00, F_8–20:50:20 and two varieties (Factor B) including V_1–MH 1142 and V_2–MH 421. Nitrogen (N), phosphorus (P) and potassium (K) were supplied plot wise separately as per the treatment requirements through urea, single super phosphate and muriate of potash, respectively. All the fertilizers were applied as basal application at the time of sowing of crop. Seed was sown at 3-4 cm depth manually by *kera* method at row spacing of 30 cm using 20 kg/ha seed rate. Five plants selected randomly from each plot were tagged for taking observations on plant height and number of leaves/plant, whereas destructive sampling was carried out from second outermost row of either side of plot for recording dry matter accumulation at periodic intervals. To determine the seed yield, crop was harvested from the net plot followed by sun drying and threshing. The stover yield was recorded by subtracting the seed yield from the total biological yield of the respective treatment. The correlation coefficients between different growth parameters at harvest stage and seed yield of green gram were estimated using R-studio. The crop data collected in the field encompassing various parameters underwent statistical analysis using standard methodology using OPSTAT software developed by CCSHAU, Hisar, Haryana.

RESULTS AND DISCUSSION

The growth and development of green gram recorded in terms of plant height, number of leaves/plant and total dry matter accumulation (g/plant) recorded at 20 DAS (days after sowing), 40 DAS and at harvest stage were significantly enhanced by application of primary macronutrients.

The data recorded at 20 DAS revealed application of different doses of primary nutrients as non-significant (Table 1). However, at 40 DAS, application of 20:50:20 kg/ha N:P:K (F_8) recorded significantly higher plant height (33.23 cm) and it was found statistically at par with application of 15:50:20 kg/ha N:P:K (F_4) as well as 20:40:20 kg/ha N:P:K (F_6). A similar statistical trend was also observed at harvest stage of green gram. Among both the varieties *viz.,* MH 1142 and MH 421, non-significant effect was observed on overall plant height of green gram at all the stages of observation. The increase in plant height of green gram might be attributed to application of higher doses of primary macro nutrients especially phosphorus and potassium. Application of higher doses of primary macro nutrients might have enhanced cell division and cell elongation of green gram, promoting initial vegetative growth which leads to higher plant height supporting better growth and development of plant (Debnath *et al.,* 2020).

Number of leaves of crop determines the amount of solar radiation intercepted by crop canopy to be utilized for normal metabolic activities of plant. The perusal of data on the number of leaves presented in Table 2 recorded

Table 1. Effect of primary nutrients and varieties on plant height of green gram

Treatment		Plant height (cm)		
		20 DAS	40 DAS	At harvest
Factor A: Nutrient levels (N:P:K) kg/ha				
F_1	15:40:00	13.03	27.41	43.01
F_2	15:40:20	14.47	31.30	47.97
F_3	15:50:00	13.27	28.93	45.28
F_4	15:50:20	12.52	32.67	50.37
F_5	20:40:00	13.50	28.33	44.73
F_6	20:40:20	14.10	32.08	48.87
F_7	20:50:00	13.68	29.38	46.49
F_8	20:50:20	12.83	33.23	51.47
S. Em±	1.27	0.66	1.26	
C. D. at 5%	NS	1.91	3.39	
Factor B: Varieties				
V_1	MH 1142	14.01	30.74	47.69
V_2	MH 421	12.83	30.10	46.86
S. Em±	0.64	0.33	0.63	
C. D. at 5%	NS	NS	NS	
Interaction (C. D. at 5%)				
A × B	NS	NS	NS	

NS–Note Significant.

Table 2. Effect of primary nutrients and varieties on number of leaves/plant of green gram

Treatment		No. of leaves/plant		
		20 DAS	40 DAS	At harvest
Factor A: Nutrient levels (N:P:K) kg/ha				
F_1	15:40:00	6.08	14.62	21.12
F_2	15:40:20	6.60	17.37	25.42
F_3	15:50:00	6.25	15.62	22.47
F_4	15:50:20	7.22	18.63	27.03
F_5	20:40:00	6.85	15.47	22.05
F_6	20:40:20	7.15	18.37	26.53
F_7	20:50:00	7.40	16.50	23.15
F_8	20:50:20	7.73	19.32	27.72
S. Em±	1.03	0.46	0.61	
C. D. at 5%	NS	1.34	1.76	
Factor B: Varieties				
V_1	MH 1142	7.01	17.20	24.75
V_2	MH 421	6.81	16.77	24.13
S. Em ±	0.51	0.23	0.30	
C. D. at 5%	NS	NS	NS	
Interaction (C. D. at 5%)				
A × B	NS	NS	NS	

NS–Note Significant.

non-significant effect of different doses of primary nutrients application on overall number of leaves of crop at 20 DAS. While, at 40 DAS, application of 20:50:20 kg/ha N:P:K (F_8) recorded significantly higher number of leaves (19.32 cm) and it was statistically at par with application of 15:50:20 kg/ha N:P:K (F_4) as well as 20:40:20 kg/ha N:P:K (F_6). A similar statistical trend was also observed at harvest stage of crop. Whereas, both the varieties i.e. MH 1142 and MH 421 recorded non-significant effect on number of leaves/plant in green gram crop at all the stages of observation. The increased level of primary nutrients (NPK) application might have favourable effect on cell division and tissue organization that ultimately led to significant improvement in number of leaves/plant (Islam *et al.,* 2024).

Dry matter accumulation is an important index indicating the photosynthetic efficiency of the crop which ultimately influences the crop biomass and carbon content. The perusal of data on the total dry matter accumulation as presented in Table 3 revealed that the data recorded at 20 DAS, showed non-significant effect on overall total dry matter accumulation of crop. However, at 40 DAS, application of 20:50:20 kg/ha N:P:K (F_8) recorded significantly higher total dry matter accumulation (5.92 g/ plant) and it was found statistically at par with application of 15:50:20 kg/ha N:P:K (F_4) and 20:40:20 kg/ha N:P:K (F_6). A similar statistical trend was also observed at harvest stage of crop. At harvest, the corresponding carbon content (45% of biomass) varied from 5.10 g C/plant (F_1) to 6.63 g C/plant (F_8). F_8, F_4 and F_6 treatments exhibited greater carbon sequestration than F_1. Among both the varieties viz. MH 1142 and MH 421, non-significant effect on total dry matter accumulation was observed at all the stages

Table 3. Effect of primary nutrients and varieties on total dry matter accumulation of green gram

Treatment		Total dry matter accumulation (g/plant)		
		20 DAS	40 DAS	At harvest
Factor A: Nutrient levels (N:P:K) kg/ha				
F_1	15:40:00	0.44	4.95	11.33
F_2	15:40:20	0.55	5.47	13.23
F_3	15:50:00	0.46	5.32	12.37
F_4	15:50:20	0.52	5.82	14.45
F_5	20:40:00	0.48	5.17	12.07
F_6	20:40:20	0.50	5.68	14.05
F_7	20:50:00	0.47	5.38	12.92
F_8	20:50:20	0.45	5.92	14.73
S. Em ±	0.03	0.15	0.33	
C. D. at 5%	NS	0.43	0.94	
Factor B: Varieties				
V_1	MH 1142	0.49	5.53	13.29
V_2	MH 421	0.47	5.39	13.00
S. Em±	0.01	0.07	0.16	
C. D. at 5%	NS	NS	NS	
Interaction (C. D. at 5%)				
A × B	NS	NS	NS	

NS–Note Significant.

of observation. The significant increase in dry matter production could be attributed to better synchronization of primary macronutrients supply with crop nutrient demand. Potassium application might have increased leaf area and shoot dry weight of green gram thus leading to higher dry matter accumulation. Phosphorus is an important plant nutrient affecting seed germination, cell division and regulation of metabolic pathways. It covers an essential role for crop development in the early growth stages as it is involved in nodulation of leguminous crops which stimulated root development mainly during seed germination thus leading to better uptake of nutrients and higher dry matter accumulation in plant biomass. These results are in close argument with the findings of Debnath *et al.* (2020) and Meena and Varma (2016).

The perusal of data on seed yield, stover yield and biological yield presented in Figs. 1 and 2 recorded at harvest of crop revealed that the application of 20:50:20 kg/ha N:P:K (F_8) recorded significantly higher seed yield (1090 kg/ha), stover yield (2480 kg/ha) and biological yield (3570 kg/ha) which were found statistically at par with application of 15:50:20 kg/ha N:P:K (F_4) and 20:40:20 kg/ha N:P:K (F_6). Further, it was observed that the application of 15:40:00 kg/ha N:P:K (F_1) recorded significantly lower seed yield (979 kg/ha), stover yield (2012 kg/ha) and biological yield (2808 kg/ha). Overall, application of 20:50:20 kg/ha N:P:K (F_8) resulted in 36.76, 23.26 and 27.13% increment, while application of 15:50:20 kg/ha N:P:K (F_4) recorded 32.74, 19.33 and 23.14% increase in seed, stover and biological yield, respectively, over that of application of 15:40:00 kg/ha N:P:K (F_1). Both the varieties viz. MH 1142 and MH 421 recorded non-significant effect on yield of green gram (Fig. 2). However, variety MH 1142 recorded

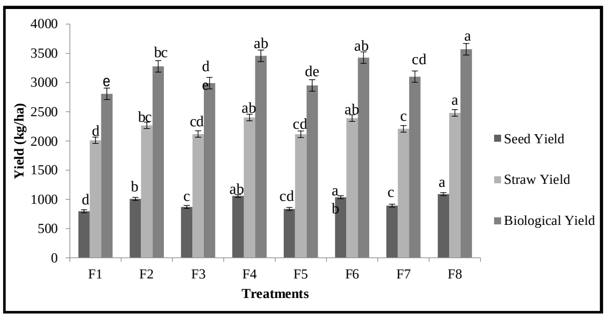

Fig. 1. Effect of primary nutrients on crop yield of green gram.

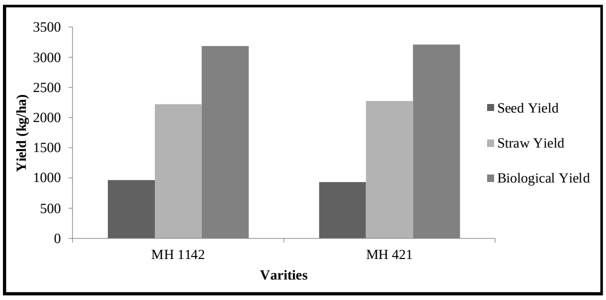

Fig. 2. Effect of green gram varieties on seed, straw and biological yield.

numerically higher seed, stover and biological yield with corresponding value of 965, 2221 and 3186 kg/ha, respectively.

Optimum use of nutrients in green gram might have resulted in favourable effect on root development, metabolic activity and energy transformation in plant system which ultimately cause higher translocation of photosynthates towards sink development due to better source sink relationship thus leading to greater production of yield attributes and dry matter accumulation which consequently was responsible for higher seed and stover yield of green gram. The results are in line with the findings of Dharwe *et al*. (2019), Kaysha *et al*. (2020) and Hassan *et al*. (2023).

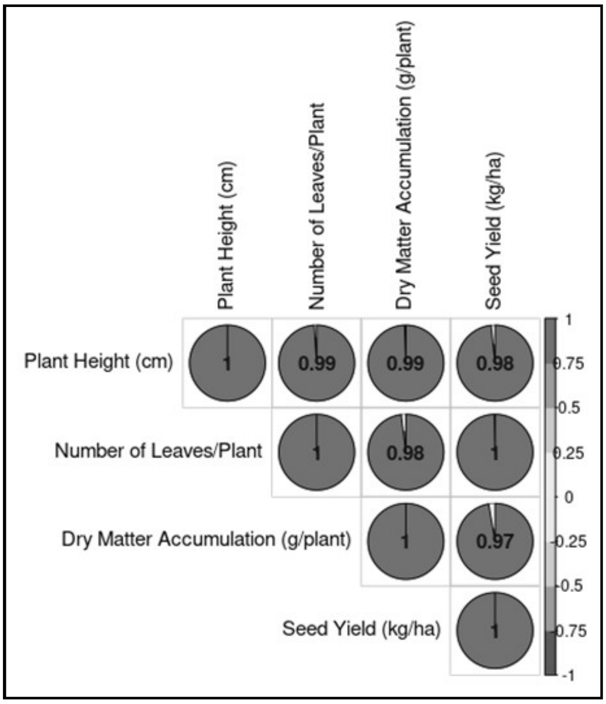

Fig. 3. Correlation matrix indicating relationship among growth traits and seed yield of green gram.

The correlation matrix (Fig. 3) depicted highly positive correlations between all the studied variables i.e. growth parameter at harvest stage of crop (plant height, number of leaves/ plant and dry matter accumulation) as well as seed yield. The correlation coefficient varied between 0.97 and 1.00. Most of the variables correlated almost perfectly (r H" 0.99-1.00), and only slight decrease was found between a few variables (r H" 0.97–0.98). Such strong and positive correlations imply that there is a synergistic interaction between crop growth and carbon accumulation. Nutrient availability may have promoted biomass and root growth; hence, leading to more carbon sequestration through residues and rhizodeposition.

CONCLUSION

Based on experimental results, it may be concluded that among different levels of primary nutrients, application of 20:50:20 kg/ ha N:P:K (F_8) performed significantly better in terms of growth parameters and yield of green gram and it was found statistically at par with application of 15:50:20 kg/ha N:P:K (F_4) and 20:40:20 kg/ha N:P:K (F_6). Among both the varieties, non-significant effects were recorded on growth parameters, yield attributes and yield of green gram crop. However, variety MH 1142 performed numerically superior over MH 421. Therefore, it can be concluded that irrespective of varieties, the application of higher dose of primary macronutrients is significantly important for increased productivity as it simultaneously favours soil carbon accumulation and agroecosystem sustainability.

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