Plant Archives Vol. 26, Supplement 2, 2026 pp.507-511 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-2.054

VARIETAL IMPACTS ON NUTRITIONAL STATUS OF RICE IN FARMER FIELDS IN RELATION TO PRODUCTIVITY

Brajendra, M.B.B. Prasad Babu, Manasa V., Bandeppa, Gobinath R. and Vijai Pal Bhadana*
ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad, Telangana, India
*Corresponding author E- mail: bhadanavijai@gmail.com
(Date of Receiving : 20-05-2026; Date of Revision : 24-06-2026; Date of Acceptance : 31-07-2026)

ABSTRACT

Nutrient application in right proportions to meet the growth requirements of a genotype is vital for realizing the yield potential of modern high yielding varieties. Release of varieties and hybrids of high yield potential with varied yield expression under different growing environments warrants precise assessment of nutrient requirements of such varieties for arriving at the fertilizer prescriptions to ensure harvestable yield potential on sustainable basis besides optimizing input use. A study was, therefore, proposed in *Kharif*, 2008 at few locations representing major rice growing regions to assess the nutritional status and productivity of the crop under farmer's current management practices in selected farmer fields for further refinement in fertilizer practices and improvement in rice productivity. The study involved survey and record of all the package of fertilizer and crop management practices of the farmer, besides information about the nutrient status of the soils before cropping and the crop at maximum tillering stage including the crop productivity and dry matter yield. Simultaneously the nutrient supply potential of the soil was also assessed at the research farm representing the area of study.
***Keywords* :** Varietal Impacts, Nutritional Status, Rice, Productivity.

Introduction

In the scenario of ever-changing fertilizer management practices followed across rice fields in India, it is always necessary to fine-tune the fertilizer recommendations based on site specific soil nutrient supply capacities and crop demand as new high yielding cultures with increasing yield potential are being regularly introduced. There cannot be a single blanket fertilizer formulation followed for diverse soil ecosystems with less importance given to management induced site variations which has been the major reason for nutrient imbalances and unsustainability in realizing the yield potentials of modern varieties. Fertilizer nutrient management not matching with the variability in soil fertility in the farmer fields is one of the important factors responsible for low rice productivity, imbalanced nutrition and unsustainability of the production system. Variability in nutrient acquisition and its utilization by genotypes for yield expression is well documented which is being exploited to develop of nutrient efficient green varieties as well as utilize in biofortification studies.

Materials and Methods

An exploratory study was conducted in *kharif* 2011 from 15 farm sites around Ghagraghat, 25 from Mandya representing Indo Gangetic and Brahamputra plains to record all the package of fertilizer and crop management practices followed by the farmers, besides information about the nutrient availability status of the soils, and crop productivity. The study involved survey and record of all the package of fertilizer and crop management practices followed by the farmer, besides information about the nutrient availability status of the soils before cropping, nutritional status of the crop at maximum tillering stage including crop productivity and dry matter yield at harvest. Simultaneously the nutrient supply potential of the soil was also assessed at the research farm representing the study area to assess the variability in nutrient supply, its relationship with rice yields at current recommended and farmers' fertilizer practices, and fine-tune the fertilizer nutrient requirement for specific target yields in the given environment. Data received from two locations (Ghagraghat and Mandya) representing Indo gangetic plains and the plateau region collected from farmer fields in *Kharif* 2008 are presented in the Tables 1 to 4 and briefly discussed. The farmers in the study area cultivated high yielding cultivars and hybrids (PA6444, KRH-2) applying a range of nutrient management levels of 100:50:0 and 80:40:0 in IGP (Ghagraghat) and 100:50:50, 150:50:50, 200:50:50,250:25:50, 300:50:50 and 200:50:25 in Mandya (Karnataka).

Triplicate surface soil samples from each of 2 blocks of the district were collected by adopting the standard procedures of soil sample collection. The depth of the soil sampling was 0-15 cm. Total no of 100 samples were collected. The collected samples were air dried and filled into polythene bags, labelled and transported to laboratory. The area was selected for evaluation of the soil fertility status and a systematic survey work was be carried out. Triplicate soil samples from all plots from 0-15 cm depths were collected in 2014 from three locations under each land use systems using a core sampler. The entire volume of soil from each land use systems were mixed thoroughly and representative samples were used for the analysis. Soil samples were air-dried for 7 days, sieved through 2 mm sieve, mixed and stored in sealed plastic jars for further analysis. Representative sub samples were drawn to determine various physico-chemical properties using standard procedures (Piper, 1950). The soil samples were analyzed for different physico-chemical properties such as pH, E.C. Organic carbon, Available N, Available P, Available K and micronutrients viz; Fe, Mn, Cu, Zn. Soil pH was measured by glass electrode pH meter by Black, and Evans, (1965). The EC of supernatant liquid was determined by Solubridge as described by Black, and Evans, (1965). OC was estimated by Walkley and Black's rapid titration method as described by Jackson (1967). Available nitrogen was determined by alkaline potassium permanganate method as described by Subbiah and Asija (1956). Available phosphorus of the soil was estimated by Olsen's method as described by Olsen (1954). Soil potassium was extracted by shaking with neutral normal ammonium acetate as described by Jackson (*1967*). Correlation coefficients were worked out using the procedure suggested by the Steel and Torrie (1960). NUE was marginally higher under farmers' fertilizer practices because of comparatively low level of rice productivity and less nutrient applications.

Results and Discussion

Soil characteristics

Important soil fertility characteristics (pH, SOC, available N, P and K) collected from the farmer fields were grouped under HYVs and hybrids and presented in the Table 1. The parameters assessed showed a fairly wide range of variability. Soils at Ghagraghat were sandy loam in texture with pH 7.8 to 8.7, 0.2-0.6% soil organic carbon, 104-232 kg/ha available N, 8.4-25.1 kg/ha available P and 148 to 249 kg/ha available K. Results of soil analyses showed little differences between the two groups (HYVs and hybrids) with regard to soil fertility. Similarly, the soils in the farmer fields around Mandya (Karnataka) were sandy loam in texture with pH 6.35 to 7.36, 0.33-0.42% soil organic carbon, 178-288 kg/ha available N, 18-26 kg/ha available P and 164 to 212 kg/ha available K. Soil quality index (SQI) was estimated from the observed values which rated the farmer fields around Ghagraghat as poor (SQI 0.4) and good in Mandya (SQI 0.6). These results are in conformity with earlier reported by Sharma *et al*. (2022), Patel *et al*. (2025) and Kumar *et al*. (2025).

Nutrient concentration and uptake by the rice plant in farmer field

Grain and straw nutrient concentration varied considerably between Hybrids and HYVs in the farmer fields at both the places. Hybrids had higher nutrient concentration than HYVs in both grain and straw at Ghagraghat (Table 2) unlike Mandya where the contents were much lower compared to that in Ghagraghat particularly that of N and P in the grain and K content in the straw. Nutrient translocation (ratio between nutrient in the grain and total aboveground nutrients) for both the groups of varieties systems were almost the same with a respective value of 73% N, 74% P, and 16% K for Hybrid and HYV. However, Mandya was lower in trient translocation ratio as it varied from 42.7 % to 49.2% for N, 2.4% to 50.9% for P and 46.8% to 49.3% for K. These results are in conformity with earlier reported by Sharma *et al*. (2020), Sharma *et al*. (2022), Patel *et al*. (2025) and Kumar *et al*. (2025).

Nutrient Accumulation

The test genotypes accumulated nutrients differentially reflecting broadly the location environment and genotype yield potential. Grain and straw nutrient concentration varied considerably at the test locations. Total aboveground nutrient accumulation in grain and straw averaged 81 kg N ha^{-1}, 20kg P ha^{-1} and 154.6 kg K ha^{-1} for the Hybrids while that of HYVs system averaged 52.1 kg N ha^{-1}, 17.1 kg P ha^{-1} and 117.9 kg K ha^{-1} (Table 3) at Ghagraghat. At Mandya, nutrient accumulation averaged 82.8 kg N ha^{-1}, 41.7 kg P ha^{-1} and 77.8 kg K ha^{-1} for the Hybrids and in HYVs 45.5 kg N ha^{-1}, 21.4 kg P ha^{-1} and 52.6 kg K ha^{-1} (Table 3). The higher accumulation of nutrients in hybrids at both locations reflect the dry matter yields at these locations. K, and the lower increase of accumulated N, P indicated that possibly HYV plants had either a lower N and P uptake or a higher K uptake. This also indicated poor nutritional status of the crop as reflected by low soil nutrient availability and highly imbalanced fertilizer use by the farmers mismatching with the soil nutrient status. These results are in conformity with earlier reported by Kale *et al*. (2021), Rathod *et al*. (2021), Parmar *et al*. (2022) and Patel *et al*. (2025).

Site variations for Internal efficiency and nutrient ratios between Hybrids and HYVs

The values of Internal Efficiency (IE, kg grain/kg nutrient accumulation) of nutrients varied between the sites and genotypes. Nutrient ratios indicated sharp differences among farm sites with regard to nutrient uptake among genotypes indicating highly imbalanced nutrition which did not match with the crop nutrient requirements. Internal efficiency varied significantly along the regions of study. For instance, the average IE of Hybrid at Ghaghraghat was 70.6 kg grain kg^{-1} N, 280.6 kg grain kg^{-1} P, and 211.6 kg grain kg^{-1} K. This is equivalent to 14.1 kg N, 3.6 kg P and 4.7 kg K per 1000 kg grain. The average internal nutrient efficiencies (IEs) for HYV was 84 kg grain kg^{-1} N, 232.6 kg grain kg^{-1} P, and 227.3 kg grain kg^{-1} K, which is the equivalent of 11.9 kg N, 4.3 kg P, and 4.4 kg K per 1000 kg grain at Ghaghraghat. The IE at Mandya region indicated an average of 178.6 kg grain kg^{-1} N, 333.3 kg grain kg^{-1} P, and 172.4 kg grain kg^{-1} K for Hybrid, and 170.7, 348.2, and 149.5 kg grain kg^{-1} N, P and K for the HYVs. The nutrient ratio for the Hybrid was 3.9:1.0:1.33 was considerably higher than that of the HYV's 2.7 :1.0:1.02. The average plant N:P: K ratio is of 5.3:1:5.4. Nutrient harvest index calculated across farmers' fields at test locations indicated steep variation for all the nutrients. Low nutrient harvest index was recorded for N and K at Mandya due to poor nutrient concentration in the grain and straw, which is a deviation from the reported values and did not reflect the management practices being followed. Unlike the grain yields, the nutrient harvest index recorded at Ghagraghat was substantially higher for N and P and was very low for K. The values of IE and nutrient ratios indicated sharp differences among farm sites with regard to nutrient uptake among genotypes indicating highly imbalanced nutrition which do not match with the crop nutrient requirements. This suggests for refinement of the current fertilizer practice being followed by the farmer. These results are in conformity with earlier reported by Bharamappanavara *et al*. (2020), Kale *et al*. (2021) and Gorlapalli *et al*. (2022)

Grain yield comparison in the farmer fields

Rice productivity was higher at Mandya compared to Ghaghraghat reflecting the soil quality rating. Substantial differences were observed in the grain yield of hybrid and HYVs (Tables 4). The highest yield was obtained with hybrid (4200 kg/ha) at Ghaghraghat where as it was 5633 kg/ha at Mandya. Hybrids, in general, recorded higher yields than HYVs.

Trials conducted at Research farm in Mandya

Table 5 gives information on yields obtained, nutrient uptake in nutrient omission plots (N, P and K) where nutrients other than the omitted ones were supplied in sufficient quantities. Grain yield and nutrient uptake showed wide variation. In the absence of applied N, the mean yield was 4.21t/ha. Similarly, in P or K omitted plots, average grain yield was 3.85 and 4.19t/ha. Estimation of INS, IPS, and IKS was followed as nutrient uptake measured in omission plots and soil test results to arrive at an estimate of how much N, P, and K were available from indigenous sources during one cropping season (in kg ha^{-1}). Indigenous N supply was found to vary from 50.1 kg/ha in –P omission plot to 54.7kg/ha in –N plot. Indigenous P supply was 8.9 kg/ha in –P omission plot to 9.6 kg/ha in –P plot. Indigenous K supply was found to be 57.8 kg/ha in –P plot to 62.9 in –K plot. However, the highest INS, IPS, IKS supply was found to be in the Farmer fields plots. These results are in conformity with earlier reported by Srilatha *et al*. (2019), Sahoo *et al*. (2022), Tuli *et al*. (2022) and Zoureen *et al*. (2025).

Conclusion

Indicated wide variability among farm sites in rice productivity, soil nutrient supply and nutrient use efficiency by genotypes. Average rice productivity across different agro ecosystems reflecting broadly the soil quality status. Nutrient harvest index calculated across farmers' fields at these sites indicated steep variation for all the nutrients. the results indicate differential response of genotypes to nutrient application and test environment with reference to yield and nutrient accumulation.

Table 1: Soil characteristics in the farmer fields prior to planting during *Kharif*, 2008

Ghaghraghat, UP*								
Parameters	**Variations in nutrient concentration for Hybrid**			**Standard deviation**	**Variations in soil characteristics for HYV**			**Standard deviation**
	Min	Max	Average		Min	Max	Average	
pH	7.8	8.7	8.1	0.2	7.8	8.7	8.3	1.6
SOC%	0.2	0.5	0.3	0.1	0.2	0.6	0.3	0.1
Avail. N(kg/ha)	104	232	168	46.3	109	230	146	48.8

Avail.P_2O_5 (kg/ha)	8.4	25.1	15.4	6.9	8.6	22.2	12.6	6.1
Avail.K_2O (kg/ha)	148.0	245.0	182.4	34.0	155.0	249.0	178.4	43.4
Mandya, Karnataka**								
	Min	Max	Average	NA	Min	Max	Average	
pH	NA	NA	6.7	NA	6.35	7.3	6.8	0.30
SOC%	NA	NA	0.3	NA	0.33	0.2	0.3	0.03
Avail. N(kg/ha)	NA	NA	202	NA	179	289	222	34.1
Avail.P_2O_5 (kg/ha)	NA	NA	21	NA	18.86	26.2	22.3	2.4
Avail.K_2O (kg/ha)	NA	NA	177.4	NA	164.2	212.1	193.2	18.8

* Mean of farmer fields ** Mean of farmer fields

Table 2: Nutrient concentration and translocation ratio in rice in the farmer fields

Ghaghraghat, UP						
Parameters	**Variations in nutrient concentration for Hybrid**			**Variations in nutrient concentration for HYV**		
	Grain	**Straw**	**Translocation ratio**	**Grain**	**Straw**	**Translocation ratio**
N (%)	1.41	0.55	71.9	1.25	0.43	72.4
P (%)	0.36	0.13	73.5	0.44	0.13	74.2
K (%)	0.47	2.34	16.7	0.43	2.38	16.3
Mandya, Karnataka						
N (%)	0.56	0.75	42.7	0.59	0.61	49.2
P (%)	0.28	0.38	42.4	0.29	0.28	50.9
K (%)	0.58	0.66	46.8	0.68	0.70	49.3

Table 3 : Nutrient translocation ratio in rice in the farmer fields

Ghaghraghat, UP						
Parameters	**Grain**	**Straw**	**Total above ground**	**Grain**	**Straw**	**Total above ground**
	Hybrid			**HYV**		
N	53.09	27.86	80.95	33.85	18.25	52.11
P	13.36	6.64	20.00	12.25	4.83	17.09
K	17.72	119.11	154.55	12.54	92.82	117.9
Mandya, Karnataka						
N	31.5	51.3	82.8	21.9	23.6	45.5
P	15.8	26.0	41.7	10.7	10.7	21.4
K	32.7	45.1	77.8	25.5	27.0	52.6

Table 4: Grain and straw yield variations between hybrids and HYVs

Ghaghraghat, UP								
Parameters	**Variations in yield for Hybrid**			**Standard deviation**	**Variations in yield for HYV**			**Standard deviation**
	Min	Max	Average		Min	Max	Average	
Grain	3200	4200	3750	365.72	2100	3200	2650	2680.8
Straw	4200	5800	5096	546.06	3050	4650	3850	3750
Mandya, Karnataka								
	Min	Max	Average		Min	Max	Average	
Grain			5633.3		2853.3	4826.7	4826.7	656.9
Straw			6833.3		2666.7	5033.3	5033.3	808.9

Table 5 : Grain yield content of nutrients and uptake pattern among different omission plots at Mandya

Treatments	**Grain Yield**	**Straw yield**	**UN**	**UP**	**UK**
(-N) +100% RDF P, K	4211.1	4666.7	28.7	11.6	42.2
(-P) +100% RDF N, K	3857.8	3722.2	27.6	9.2	38.4
(-K) +100% RDF N, P	4195.6	4277.8	32.4	11.9	26.0
100% RDF NPK	4540.0	4444.4	36.6	14.3	47.9
FFP	4637.8	4466.7	38.1	15.1	49.9
CD	646.5	708.5	14.4	NS	2.8
CV	8.0	8.7	18.8	20.5	13.8

References

Bharamappanavara, M., Siddaiah, A. M., Ponnuvel, S., *et al.* (2020). Mapping QTL hotspots associated with weed competitive traits in backcross population derived from *Oryza sativa* L. and *O. glaberrima* Steud. *Scientific Reports*, **10**, 22103. https://doi.org/10.1038/s41598-020-78675-7

Black, C. A. and Evans, D. D. (1965). *Methods of soil analysis*. American Society of Agronomy, Madison, Wisconsin, USA, 131–137.

Gorlapalli, A., Kallakuri, S., Sreekanth, P. D., Patil, R., Bandumula, N., Ondrasek, G., Admala, M., Gireesh, C., Anantha, M. S., Parmar, B., *et al*. (2022). Characterization and prediction of water stress using time series and artificial intelligence models. *Sustainability*, **14**, 6690. https://doi.org/ 10.3390/su14116690

Jackson, M. L. (1967). *Soil chemical analysis*. Prentice Hall of India Pvt. Ltd., New Delhi.

Kale, R. R., Anila, M., Mahadeva Swamy, H. K., Bhadana, V. P., Durga Rani, C. V., Senguttuvel, P., Subrahmanyam, D., Hajira, S. K., Rekha, G., Ayyappadass, M., *et al*. (2021). Morphological and molecular screening of rice germplasm lines for low soil P tolerance. *Journal of Plant Biochemistry and Biotechnology*, **30**, 275–286.

Kale, R. R., Durga Rani, C. V., Anila, M., Mahadeva Swamy, H. K., Bhadana, V. P., Senguttuvel, P., *et al*. (2021). Novel major QTLs associated with low soil phosphorus tolerance identified from the Indian rice landrace, Wazuhophek. *PLoS ONE*, **16**(7), e0254526. https://doi. org/10.1371/journal. pone.0254526

Kumar, V., Kumar, A., Kumar, U., Naseem, M., Brajendra and Lal, M. (2025). Field evaluation of rice (*Oryza sativa* L.) genotypes for resistance against brown spot disease (*Drechslera oryzae*). *Acta Scientific Agriculture*, **9**(10), 1–8.

Olsen, S. R. (1953). Inorganic phosphorus in alkaline and calcareous soils. In W. H. Pierre & A. G. Norman (Eds.), *Soil and fertilizer phosphorus* (pp. 81–122). American Society of Agronomy, Madison, Wisconsin, USA.

Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean, L. A. (1954). *Estimation of available phosphorus in soils by extraction with sodium bicarbonate*. USDA Circular 939. U.S. Department of Agriculture.

Patel, M. K., Meena, R., Singh, Y. V., Meena, R., Lal, M. and Brajendra. (2025). Effect of phosphorus and bio-organics on yield and nutrient uptake by mung bean [*Vigna radiata* (L.) Wilczek] in an Inceptisol of Varanasi. *The Journal of Rural and Agricultural Research*, **25**(2), 69–73.

Patel, M. K., Meena, R., Singh, Y. V., Meena, R., Lal, M. and Brajendra. (2025). Enhancing mung bean [*Vigna radiata* (L.) Wilczek] growth with phosphorus and bio-organics in an Inceptisol. *The Journal of Rural and Agricultural Research*, **25**(2), 74–77.

Parmar, B., Vishwakarma, A., Padbhushan, R., Kumar, A., Kumar, R., Kumari, R., Yadav, B. K., Giri, S. P., Kaviraj, M. and Kumar, U. (2022). Hedge and alder-based agroforestry systems: Potential interventions to carbon sequestration and better crop productivity in Indian Sub-Himalayas. *Frontiers in Environmental Science*, **10**, 858948. https://doi.org/ 10. 3389/fenvs.2022.858948

Piper, C. S. (1950). *Soil and plant analysis*. Inter-Science Publication, New York.

Piper, C. S. (1967). *Soil and plant analysis*. Inter-Science Publishers Inc., New York.

Rathod, S., Saha, A., Patil, R., Ondrasek, G., Gireesh, C., Anantha, M. S., Rao, D. V. K. N., Bandumula, N., Senguttuvel, P., Swarnaraj, A. K., *et al*. (2021). Two-stage spatiotemporal time series modelling approach for rice yield prediction & advanced agroecosystem management. *Agronomy*, **11**, 2502. https://doi.org/10.3390/agronomy 111 22502

Sahoo, S., Mukhopadhyay, P., Sinha, A. K., Bhattacharya, P. M., Rakesh, S., Kumar, R., Padbhushan, R., Bijay-Singh, Parmar, B., Vishwakarma, A., Kumar, A., Yadav, B. K., Bhushan, S., Kumar, A., Kaviraj, M. and Kumar, U. (2022). Yield, nitrogen-use efficiency, and distribution of nitrate-nitrogen in the soil profile as influenced by irrigation and fertilizer nitrogen levels under zero-till wheat in the eastern Indo-Gangetic plains of India. *Frontiers in Environmental Science*, **10**, 970017. https://doi.org/10.3389/fenvs.2022.970017

Sharma, K. L., Indoria, A. K., Srinivas, K., Sammi Reddy, K., Ravindra Charry, G., Lal, M., Srinivasarao, C., Suma Chandrika, D., Osman, M., Prasad, J. V. N. S., Balloli, S. S., Pratibha, G., Parmar, B., Girija Veni, V., Pushpanjali, P., Vasavi, M., Haindavi, P. and Lakshmi Aruna Gayatri, D. (2020). Effect of long-term use of tillage, crop residue and N application on phosphorus fractions in soil under sorghum (*Sorghum vulgare* L.)–castor system (*Ricinus communis*) in rainfed Alfisol soils. *Communications in Soil Science and Plant Analysis*, **51**(1), 1–13. https://doi.org/10.1080/00103 624. 2019.1689252

Sharma, K. L., Munna Lal, Sammi Reddy, K., Indoria, A. K., Srinivas, K., Singh, V. K., Prabhakar, M., Chandrika, D. S., Brajendra, Vasavi, M., Haindavi, P. and Gayatri, D. L. A. (2022). Long-term effect of different levels of surface crop residue application on hydrolyzable and non-hydrolyzable nitrogen fractions in sorghum (*Sorghum bicolor* (L.) Moench)–cowpea (*Vigna unguiculata*) system in rainfed Alfisols. *Communications in Soil Science and Plant Analysis*, **53**(3), 337–345. https://doi.org/10.1080/00 103624.2021. 2008415

Sharma, K. L., Munna Lal, Sammi Reddy, K., Indoria, A. K., Srinivas, K., Indoria, A. K., Chandra Sekhar, C., Srinivas, K., Prabhakar, M., Singh, V. K. and Gayatri, D. L. A. (2022). Effect of different levels of surface application of sorghum residue under minimum tillage on crop yields and sustainable yield index of sorghum (*Sorghum bicolor* (L.) Moench) and cowpea (*Vigna unguiculata* (L.) Walp) and nutrient status in rainfed Alfisol soils. *Communications in Soil Science and Plant Analysis*, **53**(2), 268–280. https://doi.org/10.1080/ 00103624.2021. 1993883

Srilatha, P., Yousuf, F., Methre, R., Vishnukiran, T., Agarwal, S., Poli, Y., Reddy, M. R., Vidyasagar, B., Shanker, C., Krishnaveni, D., *et al*. (2019). Physical interaction of RTBV ORFI with D1 protein of *Oryza sativa* and Fe/Zn homeostasis play a key role in symptoms development during rice tungro disease to facilitate the insect-mediated virus transmission. *Virology*, **526**, 117–124.

Subbiah, B. V. and Asija, G. L. (1956). A rapid procedure for the determination of available nitrogen in soils. *Current Science*, **25**, 259–260.

Tuti, M. D., Rapolu, M. K., Sreedevi, B., Bandumula, N., Kuchi, S., Bandeppa, S., Saha, S., Parmar, B., Rathod, S., Ondrasek, G., *et al*. (2022). Sustainable intensification of a rice–maize system through conservation agriculture to enhance system productivity in southern India. *Plants*, **11**, 1229. https://doi. org/10.3390/plants11091229

Walkley, A. and Black, C. A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*, **37**, 29–38.

Zoureen, S., Brajendra, Gobinath, R., Tuti, M. D., Lal, M., Rani, V., Sinha, S. K. and Kumar, A. (2025). Effect of different growing environments on available macro and micro nutrient in soil under various establishment methods. *The Journal of Rural and Agricultural Research*, **25**(2), 64–68.