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Drone assisted precision agriculture for boosting rice production in lateritic soils of Kerala

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Abstract

Lateritic soils being acidic and leached, are often deficient in secondary and micronutrients, limiting crop performance. Addressing these nutrient deficiencies can significantly improve crop yields in these regions. A study was conducted during 2023-24 and 2024-25 for evaluating the effect of foliar nutrition with drones for enhancement of yield in rice in lateritic rice tract of Ernakulam District. Treatments included soil application of recommended dose of fertilisers (T1), Soil test based fertiliser application(T2), RDF in soil + liquid *Pseudomonas@* 2.5L/ha at 20 DAT using drone (T3), T3+ KAU multimix Sampoorna @2.5kg/ ha at 30, 50 DAT using drone (T4) and T4 + Potassium nitrate@1.25kg/ha at flowering stage (T5) using drone. Soil application of recommended dose of fertiliser followed by spraying of liquid *Pseudomonas@* 2.5L/ha at 20 DAT, Sampoorna @2.5kg/ha at 30 and 50 DAT and Potassium nitrate @1.25kg/ha at flowering stage using drone offered a sustainable option for enhancing yield of rice. Drone technology proved to be a reliable tool for the effective distribution of foliar nutrients, ensuring uniform coverage and improved nutrient uptake. The findings highlight the role of advanced nutrient management and drone-assisted precision agriculture in optimizing rice production.

Key words: Drone technology, Foliar nutrition, Nutrient deficiencies

Introduction

Rice (*Oryza sativa*) is one of the most important staple crops worldwide. In the face of increasing demand due to population growth, enhancing rice production through sustainable and efficient agricultural practices is imperative. The prevailing practice of applying generalized NPK fertilizer doses without accounting for soil characteristics or crop-specific nutrient responses has been identified as a major constraint to yield enhancement. Laterite soils in Kerala characterized by their acidic reaction, are disposed to have deficiencies in nutrients including secondary and micronutrients that limit crop performance. In this context, foliar nutrient application has gained prominence as an alternative strategy, offering improved nutrient absorption, enhanced physiological efficiency, and potential yield advantages.KAU multinutrient mix Sampoorna, developed for rice as foliar spray, address micronutrient deficiencies commonly observed in Kerala soils (Thulasi et al.,2021). Addition of these nutrients could enhance yield to an extent of 20% (Thomas et al., 2022).

Drone technology has revolutionized the precision agriculture sector, providing a novel approach for the application of inputs. Drones allow targeted, efficient and rapid foliar spraying over large areas, which is particularly beneficial for rice cultivation in regions where traditional manual spraying is inefficient and labour-intensive. The study aims to assess the effectiveness of foliar nutrition applied using drone technology in enhancing rice grain yield.

Materials and methods

Experiment was conducted during rabi season of 2023-24 in lateritic rice tract of Ernakulam district of Kerala. Farmers' field (2 ha) at Karumaloor Panchayath located at ($10^0$08'N, $76^0$17`E) was taken for the study. The area of the experimental site enjoys a tropical humid climate.Initial soil before the conduct of trial was collected and analysed as per standard procedures (Table 1). Soil was rich in organic C, medium in available phosphorus and potassium, high in available Ca and Mg, but deficient in boron.

Trial was laid out in Randomised Block Design replicated four times. Treatments included soil application of recommended dose of fertilisers (RDF) as per Package of Practices (PoP) of Kerala Agricultural University at 90:45:45 NPK kg / ha(T1), Soil test based fertiliser application (T2), T1+ Liquid Pseudomonas @ 2.5L/ha at 20 DAT using drone (T3), T3+ KAU multimix Sampoorna @ 2.5kg/ha at 30, 50 DAT using drone (T4) and T4+ KNO3 @1.25kg/ha at flowering stage (T5) using drone.Based on initial soil test,

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Table1. Chemical properties of soil before the conduct of experiment

Parameter	Content	Reference
p H	5.2	Soil water suspension 1:2.5 and read in a pH meter (Jackson, 1958)
EC	0.311dS/m	Soil water suspension 1:2.5 read in a conductivity meter and (Jackson, 1958)
Organic carbon	2.57%	Chromic acid wet digestion method (Walkley and Black,1934)
Available P	10.4kg/ha	Bray -I extractant ascorbic acid reductant method and photoelectric colorimetry using spectrophotometer (Watnabe and Olsen, 1965)
Available K	119kg/ha	Neutral normal ammonium acetate extraction and estimation with flame photometer (Jackson, 1958)
Available Ca	1550 mg/kg	Neutral normal ammonium acetate
Available Mg	281 mg/kg	extractant using atomic absorption spectrophotometry (Jackson, 1958)
Available S	24.3 mg/kg	Calcium chloride extraction and estimation by turbidimetry (Tabatabai, 1982)
Available Zn	5.2 mg/kg	HCl extraction followed by estimation byatomic absorption spectrophotometry (Sims and Johnson,1991)
Available Cu	10.81mg/kg	Hot water extraction and estimation using (Sims and Johnson,1991)
Available B	0.32 mg/kg	Azomethine-H colorimetry (Gupta, 1967)

Table 2. Micronutrient content in the Sampoorna KAU multimix (rice)

Micronutrient	Nutrient content (%)
Zinc	4.0-6.5
Copper	0.3-0.5
Boron	3.5-4.5
Molybdenum	< 0.02
Iron	< 0.2
Manganese	< 0.2

treatment T2 was fixed as per NPK ratings and recommendations and including borax@10 kg/ha (Kerala Agricultural University, 2016). Soil application of NK fertilisers as per the treatment was given in three splits and phosphorus and boron were given as basal.

Long duration rice variety Ponmani was grown, following standard agronomic practices. Foliar spray of *Pseudomonas* was given at 20 DAT, Sampoorna at 30 and 50 DAT and potassium nitrate at flowering as per the technical programme. In treatments T1 and T2, no foliar nutrition was given. Treatment T3 received a single foliar spray of Pseudomonas, while T4 received one spray of Pseudomonas followed by two sprays of Sampoorna. Treatment T5 involved one spray of Pseudomonas, two sprays of Sampoorna, and an additional spray of potassium nitrate at the flowering stage.Micronutrient content in Sampoorna KAU multimix (rice) is given in Table 2. Crop pest management was carried out in line with the principles of Integrated Pest Management (IPM). Drone-based foliar applications were performed in the early morning to minimize evaporation and enhance nutrient uptake. FIA QD 10 Agriculture drone,amultirotor drone having 10 litre tank capacity, flying at a speed of 4-5m/sec spraying from a height of 1.5 m was used for the study.Spray width was adjusted at 3.5-4 m and 15 litres spray volume was used per acre. Spraying an acre of paddy field was completed in 9 minutes. Smaller droplet size 60-250 Micrometre (µm) ensured precision spraying and better absorption. The GPS and mapping capabilities of drone ensured uniform distribution over the experimental plots.

In the second year, during 2024-25 rabi season, the best result obtained from the first year was again demonstrated in the fieldand the result was established in 2 ha area. Growth and yield parameters including plant height, number of tillers per square meter, number of panicles per square meter, number of grains per panicle, 1000-grain weight, and total grain yield (kg/ha) were recorded and were subjected to statistical analysis. Leaf tissue samples were collected to assess the concentration of essential nutrients after spraying at panicle initiation and flowering stages and were subjected to chemical analysis as detailed in Table 3.

Results and discussion

Growth and Yield Parameters

The combined application of recommend dose of fertilisers (RDF) along with foliar spray of Pseudomonas, Sampoorna and potassium nitrate (T5) significantly improved plant growth and yield parameters (Table 4). This treatment produced the tallest plants with highest number of tillers and panicles ultimately leading to the highest yield (6000 kg/ha), which was 37% greater than the control yield of 4369 kg/ha. The second most effective treatment, involving RDF and foliar

Table 3. Analytical methods used for plant analysis

Element	Method	Reference
Nitrogen	Microkjeldhal method	Piper, 1966
Phosphorus	Digestion of plant samples using diacid extract followed by colorimetric estimation in spectrophotometer by Vanadomolybdate yellow color method.	Piper, 1966
Potassium	Digestion of plant samples using diacid extract followed by filtration and determined by flame photometer	Piper, 1966
Calcium and Magnesium	Determination using atomic absorption spectrophotometer	Piper, 1966
Sulphur	Turbidimetric method using spectrophotometer	Chesnin and Yein,1951
Fe,Mn,Cu,Zn	Diacid digestion and estimation in atomic absorption spectrophotometer	Bhargava and Raghupathi ,1993
Boron	Dry ashing of plant tissue followed by determination using Spectrophotometer	Gupta, 1967

Table 4. Growth and yield of rice as influenced by nutrient management practices

Treatment	Plant Height (cm)	Tillers/ m^2	No. of panicles/ m^2	grains/ panicle	100 seed wt(g)	Grain yield (kg/ha)
T1	109	400	361	208	2.1	4369
T2	113	383	365	202	2.4	5120
T3	117	393	347	194	2.2	4409
T4	113	412	334	181	2.3	5735
T5	122	416	381	198	2.4	6000
CD(0.05)	6.77	21.5	23.6	13.87	0.084	189.34

sprays of Pseudomonas and Sampoorna (T4), achieved a yield comparable to that obtained through soil test-based fertilizer application (T2). These findings highlight the importance of supplying primary, secondary, and micronutrients during critical growth stages to enhance rice growth and yield. Additionally, foliar application of potassium nitrate at the flowering stage significantly increased the number of panicles per square meter and grains per panicle, thereby contributing to a higher grain yield. Grain weight was also better in treatments with foliar applications. T5 resulted in the highest 100 seed weight. This improvement in grain quality could be attributed to better grain filling and maturation due to balanced nutrition provided by the foliar spray.

Application of major nutrient is most effective and economical via soil application as they are required in large quantities (Fageria et al.,2009). However, foliar application has proven to be an excellent method of supplying plant requirements for secondary nutrients and micronutrients while supplementing N-P-K needs for critical growth stage periods. Usually, when plants are in an exponential growth period to reach their maximum size, leaves are able to absorb nutrients very efficiently. Foliar application of nutrients at the maximum tilleringto panicle initiation stage resulted in the highest chlorophyll concentrations, leaf area index, and crop growth rate in the flowering stage (Mahmoodi et al 2020). It is also helpful to minimize the soil barriers for higher nutrient use efficiency and advantageous to optimize crop yield, produce quality and reduce environmental concerns, especially nutrients leaching and volatilization losses.

In the second year, the best result obtained from the first year (T5) was demonstrated during rabi (2024-25) season, in Karumaloor panchayath. Rice variety Uma was used for the trial. The trial could result in grain yield of 6325 kg/ hawith more number of panicles (460/m^2) and filled grains per panicle (173) confirming the results of the first year.

Nutrient content at different stages of crop growth

Leaf tissue analysis indicated a significant increase in the uptake of nitrogen (N), potassium (K), and micronutrients (Zn, B) in the T5 treatment compared to other treatments (Table 5). T2 and T4 also resulted in better nutrient content than control (T1), but to a lesser level than T5. This showed application of potassium nitrate at flowering stage significantly enhanced nutrient content which inturn resulted in a higher yield than other treatments. Based on the soil analysis, boron (B) was identified as the critical limiting factor. The highest yield was recorded in treatment T5, where the boron deficiency was effectively corrected through foliar application of Sampoorna.Besides, foliar application of sampoorna resulted in better yield compared to soil application of B. Boron content increased from 79.29 ppm to 99.81 ppm at flowering stage, the highest being in T5. Foliar application of B is the most effective means of enhancing the uptake of boron concentration producing higher crop yield (Sarkar et al., 2007) as it is immobile with in the plants.These increases were likely due to the enhanced nutrient availability and uptake facilitated by drone-assisted foliar spraying, which ensured more uniform coverage and effective delivery.

Drone Technology and Precision Agriculture

The use of drone technology proved to be an effective means for foliar application, ensuring accurate nutrient delivery to the plant canopy. The precision of drone spraying minimizes wastage and reduces the risk of over-application, ensuring that crops receive optimal nutrient doses. Additionally, drones can cover large areas in a short amount of time, reducing labour costs and improving the timeliness of nutrient application.Foliar application using drones could ensure

Table 5. Nutrient content in rice as influenced by nutrient management practices

	N (%)	P (%)	K(%)	Ca(ppm)	Mg(ppm)	S (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	B (ppm)
					Panicle initiation					
T1	1.62	0.03848	2.10	17380	1269	85.75	1030.40	212.28	1.19	81.51
T2	1.75	0.03845	2.30	17870	1699	62.65	1024.00	132.80	3.60	84.33
T3	1.64	0.0381	2.05	17650	1399	68.24	1066.00	184.23	1.45	81.23
T4	1.75	0.03843	2.40	17650	1617	75.40	984.00	105.36	3.72	84.06
T5	2.04	0.03861	2.50	18040	1634	67.58	812.00	154.76	3.80	84.45
					Flowering					
T1	1.67	0.03848	1.30	21970	1227	46.24	1116.40	80.80	68.00	82.23
T2	1.82	0.03844	1.30	22980	1530	61.01	803.60	69.56	61.72	98.53
T3	1.75	0.03853	1.40	17220	948	78.05	1677.20	75.32	292.72	79.29
T4	2.18	0.03844	1.40	23280	1851	50.93	1121.60	102.36	65.40	86.53
T5	2.33	0.03847	1.50	22270	1253	45.69	767.20	111.08	53.64	99.81

Table 6. Economics of crop cultivation as influenced by nutrient management practices

Treatment	Total cost(Rs/ha)	Returns (Rs)	B/C ratio
T1	78700	131070	1.66
T2	81792	153600	1.88
T3	82290	132270	1.61
T4	87292	172050	1.97
T5	89512	180000	2.01

uniform and timely application with less cost (Rs.1750/ha) and labour and further decreased the nutrient load in to the environment, compared to soil application.According to García-Munguía et al (2024)drones have proven to be useful tools for increasing spraying precision while simultaneously reducing water and chemical usage. This in some cases, had maintained their efficacy even with a 30% reduction in pesticide dosage.

Economics

Economics of crop cultivation as influenced by treatments is depicted in Table 6. As compared to the soil application of recommended dose of fertilisers (T1), combined application of recommend dose of fertilisers along with foliar spray of Pseudomonas, Sampoorna and potassium nitrate (T5) could enhance the B/C ratio from 1.66 to 2.01. Moreover, T5 accounted for 37% higher returns than T1.Though drone hiring costs were higher per acre than soil application, they provided precise and uniform applicationfinally leading to higher yield and returns.

Conclusion

Soil application of recommended dose of fertiliser combined with spraying of Pseudomonas @ 2.5L/ha at 20 DAT, KAU multimixSampoorna @2.5kg/ha at 30, 50 DAT and KNO3@1.25kg/ha at flowering stage using drone offer a sustainable option for management of nutrient deficiencies and enhancing yield and quality of rice in lateritic rice fields of Kerala. Drone technology further enhanced the effectiveness of nutrient application by ensuring precise and efficient coverage. This approach holds great potential for improving rice productivity and quality, particularly in large-scale agricultural operations where labour and resource optimization is crucial. The integration of drone-assisted precision agriculture with foliar nutrition is a promising avenue for sustainable and high-yielding rice production systems.

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