Site specific nutrient management approach for enhanced yield realisation in rice - a case study

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Abstract

The existing practice of application of general doses of NPK fertilizers to a crop without consideration of soil fertility level and crop response, needs new dimension, as it forms the major reason for low productivity. A project was implemented during 2018-19 and 2019-20 to formulate scientific package for higher yield realization in major rice tracts of Ernakulam district of Kerala, India under Good Agricultural Practices. In this project the present Package of Practice recommendations of Kerala Agricultural University for manures and fertilisers was compared with fertilizer dose providing major, secondary and micronutrients and a control with farmers' practice of no FYM and lime, but recommended dose of NPK. Piravom, Poothrikka and Mulamthuruthy blocks of Ernakulam district were adopted for trial and on analysis, it was found that the soils were acidic, inherently poor in bases and other essential plant nutrients. Addition of manures, lime, NPK fertilisers, magnesium sulphate and spraying of multi nutrient mixture "Sampoorna" had significant effect on the number of grains per panicle and grain filling. This has resulted in an average yield increase of more than 30 per cent over farmers' practice and more than 20 per cent over the present Package of Practices recommendation in all the three locations.

Keywords: Micronutrients, Nutrient management, Rice yield, Secondary nutrients.

Introduction

Ernakulam district, located in the Central part of Kerala State spans an area of about 3068 sq. km possessing a total cropped area of 2.1 lakh ha. Rice is the principal crop cultivated in the wet lands. The area under paddy cultivation in the district has been decreasing steadily over the last three decades. During 2017-18 the paddy cultivated area of Ernakulam was 5440 ha (Department of Economics and Statistics, 2019). The total production of rice in the district was 12888 t with an average productivity of 2176 kg/ha which was below the state average of 2699 kg/ha and much lower than the potential realisable yield of 5-7 t/ha depending upon the soil and climatic conditions. The reduction in crop production has been a matter of considerable concern in the district.

Productivity enhancement and sustained crop production calls for comprehensive knowledge on fertility levels to be maintained in the soil to meet the nutrient needs for higher yield without degrading the environment. The existing practice of application of general doses of NPK fertilizers to a crop without consideration of soil type and crop response requires a revisit/rethinking, as it forms a major reason for low productivity. This provided a solid framework for taking into account of all the nutrients including major, secondary and micronutrients that the crop requires and are present in the soil. Higher yields can be obtained by ensuring adequate availability of these nutrients in the plants, either from soil or from added fertilisers. Hence, a study was launched to develop a scientific package for reaching improved yield in major rice tracts of the Ernakulam District by using Good Agricultural

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Practices. In this trial, the present Package of Practice recommendations (PoP) of Kerala Agricultural University for manures and fertilisers (T1) was compared with fertilizer dose providing major, secondary and micronutrients (T_2) and a control (T_3) with farmers' practice of no FYM and lime, but recommended dose of NPK.

Materials and Methods

The experiment was conducted during Puncha season (December – January to April) of 2018-19 and 2019-20. Mulanthuruthy, Poothrikka and Piravom constituted a major rice tract in Ernakulam District, with an area of 1835 ha under cultivation during 2017-18. Edakkattuvayal panchayath of Mulamthuruthy Block, Thirumarady panchayath of Piravom block and Thiruvaniyur Panchayath of Poothrikka block, were selected. Composite soil samples were drawn from the experimental sites at 0-15 cm depth prior to lay out of the experiment. The soil samples were analysed as per procedures detailed in Table 1, for soil reaction, major, secondary and micronutrients. For major nutrients, soil fertility class (high, medium or low) was identified. The secondary and micronutrients were rated as deficient or sufficient based on critical levels suggested by Kerala Agricultural University (2016) and recommendations were developed.

The soil of Edakattuvayal on analysis was found to be moderately acidic with organic carbon content of 1.64 per cent (Table 2). The soil was low in K, Ca and B and very low in Mg content. Available phosphorus content was medium, while iron and manganese were high. Zinc status was sufficient. In Thiruvaniyur the soil was moderately acidic, had high organic carbon, but very low in K, Ca, Mg, B and Zn. In Thirumarady, the field was medium in organic carbon, low in P, K, Ca, Mg and B. So the treatment T_2 which was specific to each location was formulated including the addition of organic

Table 1. Analytical methods used for soil analysis

Parameter	Method	Reference
pH	Soil water suspension 1:2.5 read in pH meter	Piper,1966
EC	Soil water suspension 1:2.5 read in a conductivity meter	Piper,1966
Organic carbon	Walkley and Black chromic acid wet digestion method	Piper,1966
Available N	Alkaline permanganate method	Subbiah and Asija, 1956
Available P	Bray extraction and photoelectric colorimetry using spectrophotometer	Watanabe and Olsen, 1965
Available K and Na	Neutral normal ammonium acetate extraction and estimation with flame photometer	Jackson, 1958
Available Ca and Mg	Extraction using neutral normal ammonium acetate and estimation using Atomic Absorption Spectrophotometer	Jackson, 1958
Available B	Hot water extraction and estimation using Azomethine-H colorimetry	Gupta, 1975
Available micronutrients (Fe, Mn Cu, Zn)	0.1 M HCl extraction and determination using atomic absorption spectrophotometer	Sims and Johnson(1991)

Table2. Chemical properties of soil of experimental sites at Edakkattuvayal, Thirumarady and Thiruvaniyur

Soil Parameters	Edakkattuvayal	Thirumarady	Thiruvaniyur
pH	5.66	5.95	5.7
Org. C(%)	1.64	0.9	1.58
P (kg/ha)	19.0	4.25	33.25
K(kg/ha)	31.9	70.40	37.4
Ca(mg/kg)	161.3	90.8	166
Mg (mg/kg)	14.92	15.74	14.20
B (mg/kg)	0.49	0.19	0.07
Zn (mg/kg)	3.07	2.8	0.88
Cu (mg/kg)	4.2	0.53	0.41
Fe (mg/kg)	454	443.9	411.3
Mn (mg/kg)	4.8	0.86	2.11

Table3. 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

manure, lime, NPK fertilisers, magnesium sulphate and spraying of multi nutrient mixture "sampoorna". Micronutrient content in the multimix is given in Table 3. KAU Multimix sampoorna formulated to meet the micronutrient needs, have K and Mg also in the added filler materials (Thulasi et al*.,* 2021).

An area of 1.0 acre (0.4 hectare) was designated as the experimental site in each block. Medium duration rice variety, Sabari (locally famed as red IR-5) was used in Edakkattuvayal. Short duration varieties Jyothi and Kunjukunjuvarna were used in Thirumarady and Thiruvaniyur respectively. All operations *viz.,* levelling, water management, weed management, plant protection measures *etc.* were performed in accordance with the KAU recommendations. The treatments were replicated seven times (plot size 100 m^2 each) adopting Randomised Block Design. The treatments included

T_1: Package of practices (POP) recommendations of KAU ie., FYM-5 t/ha as basal, Lime- 600 kg/ha and NPK- 90:45:45 kg/ha in Edakkattuvayal and 70:35:35 kg/ha in other locations

T_2: FYM 5 t/ha basal, lime @ 250 kg/ha and NPK specific to location was given in splits (In Edakkattuvayal 64:32:58 kg/ha, in Thirumarady, 64:41:41 kg/ha and in Thiruvaniyur, 50:9:41 kg/ha were recommended. Mg was applied as magnesium sulphate @ 80 kg/ha as basal and multi nutrient mixture "sampoorna was recommended as foliar spray @ 10 g per litre of water respectively at tillering and panicle initiation stages).

T_3: NPK 90:45:45 kg/ha in Edakkattuvayal and 70:35:35 kg/ha in other locations

Observations on crop growth and yield recorded at tillering, flowering and harvest stages were subjected to ANOVA. The treatment means were compared at 5% probability level. The nutrient content of plant samples were analysed by standard procedures given in Table 4.

Based on the previous years' results, a large area of the padasekharam (20 acres) was adopted at Edakkattuvayal of Mulamthuruthy block, and demonstration of the agronomic package using the variety Sabari for the location was held in 2019-20. Variety used was Sabari. Scientific crop production operations and need based plant protection measures were adopted uniformly as per the recommendations of KAU package of practices (2016). Tillering, an important agronomic trait for rice yield was enhanced by effective water management. Draining water and maintaining a low water level after liming and at the start of tillering could washout the acidity which favoured better nutrient absorption and production of more number of tillers. Nutrient management included application of organic manures 5 t/ha basal, lime @ 250 kg/ha and NPK @ 64:32:58 kg/ha. Basal application in the form magnesium sulphate @ 80 kg/ha and foliar application of multi nutrient mixture "sampoorna" @ 10 g per litre of water was carriedout at tillering

Table 4. Analytical methods used for plant analysis

Parameters	Method used	Reference
N	Microkjeldhal digestion and distillation method	(Piper,1966)
P	Vanadomolybdophosphoric yellow colour method	(Piper,1966)
K	Flame photometry	(Piper,1966)
Ca and Mg	Determination using atomic absorption spectrophotometer	(Piper,1966)
Fe, Mn, Cu, Zn	Nitric acid extraction method using Atomic Absorption Spectrophotometer	(Piper,1966)
B	Dry ashing of plant tissue followed by determination using Spectrophotometer	(Gupta, 1975)

and panicle initiation stages.

Results and Discussion

The results of the study showed that improving and maintaining soil fertility for productivity enhancement was of paramount importance in sustaining crop production. On analysis, it was found that in Edakkattuvayal, the soil contained high N, medium P and low K. So the treatment T_2 had lower N and P and higher K than the recommendation. In Thirumarady, T_2 was supplied with higher dose of P and K than POP. In Thiruvaniyur, N and P content were high and hence a lower dose of N and P and a higher dose K were provided. All the three locations were rich in organic carbon content, but found low in K, Ca, Mg and B. Effect of adequate supply of these nutrients on growth characters and yield of rice is presented in Table 5. It showed that growth and yield parameters were significantly influenced by the treatments. Treatment T_2, providing all major, secondary and micronutrients recorded the highest grain yield (8917 kg/ha) followed by PoP recommendations (7409 kg/ha) in Edakkattuvayal. In Thirumarady and Thiruvaniyur, the increase in yield in T2 over T_1 was 887 and 818 kg/ha respectively. When no lime and organic manure were applied (T_3), substantial reduction in yield was recorded. The yield increase was to the extent of 37.3, 38.6 and 30.06 per cent in Edakkattuvayal, Thirumarady and Thiruvaniyur as acidity was limiting the nutrient availability in soil. Addition of lime increased the availability of nutrients, which otherwise would be strongly limited by low soil pH (Mkhonza et al., 2020). A lower dose of N and P and higher level of K on soil test basis (T_2) compared to PoP thus resulted in better nutrient absorption, more number of panicles per m^2 and yield. Dobermann and Witt (2004) reported that many rice farmers often apply fertilizer N and P but seldom apply sufficient fertilizer K, leading to soil K mining and subsequently to yield decline. A very low K_2O content of 31.9, 70.4 and 37.4kg/ha respectively in Edakkattuvayal, Thirumarady and Thiruvaniyur confirmed the soil K mining in these areas. So a higher K application could maintain K supply at levels that enhance crop growth and increase plant resistance to pests and abiotic stresses like drought.

Equally important was the deficiency of secondary nutrients and micronutrients. Ca, Mg and B were deficient in all the three locations. Added to this, Zn deficiency also was observed in Thiruvaniyur. Addition of these nutrients favoured yield and yield components of rice in T_2 plot. This could be attributed to the role of secondary and micronutrients in plant metabolic procedures and enzymes activation that affected crops' vegetative growth and productivity. Calcium, becomes a

Table 5. Effect of nutrient management on growth, yield parameters and yield of rice at different locations

	Plant height(cm)	No.of tillers/m^2	Panicles /m^2	grains / panicle	100 seed weight (g)	Grain yield (kg/ha)
			Edakkattuvayal			
T1	101	470	387	124.8	2.8	7409
T2	95	642	459	100	2.9	8917
T3	100	425	264	140.2	3	6493
CD(0.05)	1.88	24.08	20.09	6.013	NS	247.2
			Thirumarady			
T1	101	560	399	165	2.5	3832
T2	106	599	416	171	2.9	4719
T3	101	543	385	154	2.8	3403
CD(0.05)	NS	26.960	16.832	NS	NS	184.28
			Thiruvaniyur			
T1	97	563	333	147	3.2	3504
T2	103	609	396	173	3.3	4322
T3	97	574	341	137	3.0	3323
CD(0.05)	5.439	28.974	19.539	9.977	NS	118.67

Table 6. Effect of nutrient management on plant nutrient content of rice at different locations

Treatment	N %	P %	K%	Ca (mg/kg)	Mg (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	B (mg/kg)
					Edakkattuvayal				
T1	3.51	0.082	1.76	5840	311.2	2695.2	166.1	46.16	0.033
T2	3.57	0.082	1.98	5400	576	2497.6	129.2	64.48	0.052
T3	2.95	0.044	1.84	4820	405.2	4168	337.3	60.28	0.048
					Thirumarady				
T1	2.19	0.03	1.36	6080	340.7	2610	64.8	58.8	0.034
T2	2.82	0.044	1.84	5840	412.8	2452	32.9	61.28	0.042
T3	2.07	0.03	1.12	5440	228.5	2796.4	55.9	57.96	0.039
					Thiruvaniyur				
T1	3.45	0.028	1.47	5000	536	1779.6	135.3	45.36	0.0321
T2	2.83	0.07	1.79	4860	627.6	1884.2	212.6	66.32	0.0603
T3	2.52	0.028	1.64	4380	445.2	2683.3	395.6	58.56	0.0343

constituent of cell wall, while magnesium an essential constituent of chlorophyll, involves in several enzyme activities in plants, including carbon dioxide (CO_2) assimilation and protein synthesis, and the cellular pH and the cation-anion balance activation. Ahamad et al. (2009) reported the function of B in plant related to sugar transport, flower production, retention, pollen tube elongation, its germination and translocation of carbohydrate and sugars to reproductive organs, which in turn improved the spikelet number and fertility that influenced the yield and productivity. Furthermore, the absorption and transportation time could be decreased by the leaf spraying of the micronutrients and this was vital for rice plant during the rapid growth phase. Lahijani et al. (2020) reported that leaf spraying of essential micronutrients favoured leaf area, 1000 grain weight and finally rice yield. Demonstrations conducted at various locations across the state of Kerala indicated that foliar application of Sampoorna KAU Multimix (rice) resulted in a yield advantage of more than 20 % over control (Thulasi et al., 2021).

Perusal of the data on foliar nutrient contents (Table 6) showed that soil test based NPK application showed higher absorption of nutrients when compared to PoP recommended NPK application. Need based application of nutrients resulted in balanced fertilization and increased uptake of other nutrients. Apart from the apparent content of an element in the plant, the interaction effect of nutrient elements also influenced the yield. Higher absorption of elements like Fe and Mn and lower absorption of N and K contributed to low yield in T_3. Higher soil reactivity and no lime favoured release of more Fe and Mn which turned toxic and resulted in negative correlation with yield. Native non applied elements when absorbed in excess of actual metabolic requirement suppressed the yield directly and also by inhibiting the positive effects of applied NPK fertilisers. Change in reactivity due to liming reduced the toxic level uptake of Fe and Mn in T_2. Moreover, higher N, K, Mg as well as Zn and B content favoured higher grain yield in T_2. This was ascertained by the analysis of correlation of yield with plant nutrient content at flowering (Table 7). All the applied nutrients including secondary and micronutrients had significant positive correlation with yield, while Fe and Mn had negative correlation. Thus, a management strategy that promoted balanced application of nutrients (including macro and micronutrients) was found important to ensure sustainable productivity from rice soils.

Table 7. Correlation between nutrient content in plant at flowering and yield.

	Edakkattuvayal	Thirumarady	Thiruvaniyur
N	0.8387	0.9845	-0.02763
P	0.7877	0.9475	0.9854
K	0.731	0.9999	0.7448
Ca	0.4462	0.4516	0.4595
Mg	0.7378	0.9482	0.9393
Fe	-0.8479	-0.9699	-0.555
Mn	-0.8791	-0.82587	-0.3904
Zn	0.3529	0.9968	0.6651
B	0.3345	0.5468	0.9711

Table 8. Effect of nutrient management on post harvest soil analysis at different locations

Treatment	OC(%)	P(kg/ha)	K(kg/ha)	Ca(mg/kg)	Mg(mg/kg)	Fe(mg/kg)	Mn(mg/kg)	Zn(mg/kg)	B(mg/kg)
					Edakkattuvayal				
T1	1.475	5.74	74.8	133.5	37.65	427.4	19.78	7.898	0.593
T2	1.995	8.74	77	252.5	47.05	459.7	28.98	8.589	0.471
T3	1.455	6.49	68.2	152	36.25	386.7	15.33	6.501	0.406
					Thirumarady				
T1	1.44	6.0	78.1	111.5	45.08	351.2	12.82	2.454	0.382
T2	1.275	13.75	79.2	98	41.78	303.7	8.884	2.551	0.292
T3	1.035	16.25	79.2	133.5	51.05	278.1	11.26	2.339	0.593
					Thiruvaniyur				
T1	1.065	52	78.1	103.5	30.70	308.8	6.314	2.542	0.544
T2	1.275	28.25	73.7	94.5	25.76	297.0	13.14	2.220	0.398
T3	0.93	29.5	79.2	92.5	23.17	155.1	3.631	2.133	0.943

Post harvest soil analysis (Table 8) also showed that the soil was deficient in K, Ca, and Mg in all locations. Nutrient contents in the plant could meet the crop metabolic requirement to produce a higher yield, but did not add to the soil nutrient status. This warranted that the soil has to be analysed before every crop and nutrients are to be supplied accordingly.

During 2019-20, the results of the first year crop was established in a large area of the padasekharam (20 acres) at Edakkattuvayal. The agronomic practices that were given importance included the levelling of field, water management, weed management, liming, integrated nutrient management including organic manure, low N and P and additional potassium and magnesium based on soil test and spraying of Sampoorna twice. The adoption of the same resulted in an average yield of 8178 kg/ha (Table 9).

Data on analysis of soil and plant samples (Table 10) showed that the addition of soil test based fertilisers enriched the soil and brought the nutrient content to a medium level for P and K, while the content of Ca and Mg remained deficient. B was applied as foliar spray and hence soil remained deficient. This suggested that the soil application of macronutrients in combination with foliar spray of micronutrients could meet the crop demand, producing better yield. Nutrient uptake by the crop was in accordance with the report that a high yielding rice crop takes up 14.6 kg N, 2.7 kg P, and 15.9 kg K to produce a ton of grain yield (Buresh et al., 2010).

Table 10. Nutrient content in soil and nutrient uptake at harvest of the crop

Parameters	Soil	Nutrient uptake (kg/ha)
N	540 kg/ha	94.6
P	23.31 kg/ha	14.50
K	141.63kg/ha	100.94
Ca	226.88mg/kg	42.56
Mg	45.33mg/kg	14.03
B	0.38mg/kg	0.23
Zn	5.87mg/kg	0.347

The yield limiting factors in the major rice tract of Ernakulam was deficiency of K, Ca, Mg, and B. Studies have already revealed widespread deficiency of secondary nutrients Ca and Mg, as

Table 9. Growth and yield parameters of rice at Edakattuvayal during 2019-20 (of 5 randomnly selected farmers)

	Plant height(cm)	No.of tillers/m^2	Panicles /m^2	Filled grains per panicle	100 seed weight(g)	Grain yield kg/ha
F1	102	448	360	130	2.7	8645
F2	92	544	420	98	3.0	8348
F3	90	452	400	114	2.8	7750
F4	93	448	380	113	2.9	8408
F5	97.5	448	354	112	3.0	7738
Mean	94.9	468	382.8	113.4	2.88	8178

well as micronutrients Zn and B in Kerala soils (Department of Agriculture Development and Farmers' Welfare, 2019). Application of nutrients, including primary, secondary and micronutrients both as soil application and foliar spray improved the plant nutrient status in all crop stages.

The major rice tracts of Ernakulam were acidic, inherently poor in bases and other plant nutrients. All the three locations under investigation were found to be deficient in K, Ca and Mg and B. Data on soil analysis clearly outlined the requirement for fertiliser management for major, secondary and micronutrients as well as liming to curtail soil acidity. The crops responded well to both agronomic management and soil test based nutrient application. The addition of FYM, lime, magnesium sulphate, NPK fertilisers and spraying of Sampoorna increased the number of grains per panicle and grain filling significantly. This resulted in an average yield increase of 37.3, 38.6 and 30.06 per cent over the control treatment of recommended dose of NPK alone and 20.3, 23.2 and 23.3 per cent over the current POP recommendation of Kerala Agricultural University respectively in Mulamthuruthy, Piravom and Poothrikka blocks of Ernakulam district of Kerala state.

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