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Nutrient optimization strategy for rice by eliminating surprise nutrient deficiencies

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Abstract : An incubation experiment was carried out to know if any of the applied plant nutrients, viz., P, K, S, Zn, Cu, Mn and B react (fix or complex) abnormally with the experimental soil. On the basis of critical level of nutrient in the soil and nutrient sorption curves, an Optimum Nutrient Treatment (ONT) consisting of P, K and Zn besides N, which are deficient in the soil, was formulated for the experimental soil. The evolved ONT was tested by means of a green house nutrient survey experiment with sorghum (Co 27) as the test crop. These results confirmed that the exclusion of N, P, K and Zn significantly reduced the dry matter yield. But the addition of other nutrients like Ca, Mg, S, Cu, Fe, Mn, Mo and B did not significantly influence the dry matter yield. A field experiment was conducted to evolve the fertilizer optima for rice with a treatment structure developed based on the ONT. Short duration rice (ADT 36) was grown during *Kuruvai* season (June - September, 1999) and medium duration rice (Co 43) during *thaladi* season (October, 1999 - January, 2000). From a fit of the grain yield data on a quadratic polynomial surface, the optimum amounts of nutrients which ensures balanced fertilization were evolved. The results revealed that 175, 54, 50 and 30 kg ha $^{-1}$ for ADT 36 rice and 165, 63, 65 and 30 kg ha $^{-1}$ for Co 43 rice, respectively of N, P_2O_5, K_2O and $ZnSO_4$. $7H_2O$ ha $^{-1}$ were the optimum doses of nutrients in this soil. Economics of balanced fertilization through this systematic approach was compared with the blanket fertilizer recommendation by test verification in the field. The results revealed that the rice yield as well as profit were higher with balanced fertilization by systematic approach as compared to the blanket fertilizer recommendation (*Key words*: Rice, Yield limiting nutrients, Fertilizer optima)

The global average yield of irrigated rice is 5 tonnes ha $^{-1}$, but national, regional and seasonal yield averages vary widely. The per hectare production in Tamil Nadu is about 3.5 tonnes where as in India it is hardly 2.0 tonnes. The average yield growth has reached a pleateau in recent years. Intensive cultivation with modern high yielding varieties using high analysis fertilizers has induced nutrient imbalances and deficiencies and are some of the causes for this trend in yield growth. These nutrient deficiencies have to be identified and removed before defining fertilizer optima for ensuring balanced fertilization. In this paper, a systematic approach of experimentation, which enables the identification and removal of such surprise nutrient deficiencies if any in soils of experimentation, is employed and evaluated in defining fertilizer optima for rice.

Materials and Methods

The experiement was conducted in a farmer's field in Ramapuram village in Thanjavur district which represents the major rice growing tract of Tamil Nadu state of India, *viz.*, Cauvery Delta Zone in a calcareous black soil belonging to Kalathur series (Typic Haplusterts). The soil was clay loam in texture and contained 0.66 per cent organic carbon, 240, 15 and 300 kg ha^{-1}, respectively of $KMnO_4$-N(Subbiah and Asija,1956), Olsen-P(Olsen *et al.* 1954), NH_4OAc-K(Hanway and Heidal, 1952) and 3.31 mg kg^{-1} of DTPA-Zn (Lindsay and Norvell, 1978). Its pH was 7.3 and EC 0.66 dS m^{-1}.

The study was conducted in four phases. In the first phase, an incubation experiment was carried out to know if any of the applied plant nutrients, *viz.*, P, K, S, Zn, Cu, Mn and B react (fix or complex) abnormally with the experimental soil (Hunter, 1980). This was accomplished by adding and incubating series of concentrations of all these nutrients to a sample of soil and subsequently extracting them. If in any case, the amount extracted at zero level of addition exceeds three times the critical level that particular nutrient was considered as sufficient for rice growth. In other cases optimal amout of a nutrient was derived using the nutrient sorption curves obtained by plotting the amount of nutrient extracted (Y axis) against the amount added (X axis) and extrapolating the point corresponding to three times of the critical level on the Y axis to X axis through the intersecting point on the sorption curve. On this basis an Optimum Nutrient Treatment (ONT) consisting of those nutrient which limit yield in the soil was defined for the experimental soil. Since N was generally found to be deficient in soils it was also included in the ONT.

In the second phase of study, testing of the evolved ONT by means of a green house nutrient

survey experiment was accomplished by following the fundamentals of missing element study (Hunter, 1980). There were 14 treatments in this experiment replicated four times in a CRD. Treatment 1 was the ONT. Treatments 2-13 (Table 1) received the same amount of each element as that of ONT except for the element under study. If the element was added in the optimum then it was excluded in the particular treatment and *vice versa*. Treatment 14 was the check. Sorghum (Co 27) was sown as the test crop. The seedlings were maintained in plastic tumblers fed with the respective nutrient solutions as per treatment and harvested after three weeks. The relative dry matter yield (relative to the yield in the ONT) in each treatment was calculated.

The third phase of study was the field experiment to work out the fertilizer optima. A treatment structure for the field experiment was formulated based on the ONT. In this structure, the ONT formed the central treatment. In each case of N, P and K there were three more levels, *viz.*, a zero level, one below and another one above the ONT level. Except the variable nutrient in each case, other nutrients are kept equal to that of ONT. All these ten treatments received Zn as in ONT. Besides there was one treatment which was ONT minus Zn. Also a blanket recommendation treatment was included for comparison. Thus there were 12 treatments in the field experiment (Table 2). A short duration rice (ADT 36) was grown as the test crop during *kuruvai* season (June - September, 1999). A medium duration rice (Co 43) was grown as the test crop during *thaladi* season (October, 1999 - January, 2000) in the same field without disturbing the plots and by field preparation by spade digging. The crops were harvested at maturity. From the plot of data of grain yields of both rice crops on quadratic polynomial surface, the optimum amounts of fertilizers which ensures balanced fertilization were evolved.

In the fourth phase, the fertilizer optima evolved by the above phase for the two rice crops were verified in farmers' fields through on farm trails (OFT) in two locations in Thanjavur district. The soils of these locations belonged to the same series as that of the experimental soil. Economics of balanced fertilization through this new approach was calculated and compared with that of blanket fertilizer recommendation.

Results and Discussion

The results of incubation studies indicated that among the nutrients P, K and Zn were found to limit yield in both the experimental soils as the level of each of them extracted at zero level of incubation was less than three times of the critical level. 10.0 mg Olsen-P kg^{-1} (Anon, 1980), 0.18 me HN_4OAc-K $100g^{-1}$ (Anon, 1980) and 1.20 mg DTPA-Zn kg^{-1} (Savithri, 1978) were the critical levels used to arrive at this conclusion. Since N was generally found to be limiting in soils it was also included in the ONT. The Optimum Nutrient Treatment (ONT) consisted of 50 mg kg^{-1} N, 12 mg kg^{-1} P, 0.045 me 100 g^{-1} K and 3.25 mg kg^{-1} Zn as derived from the sorption curves (Fig. 1a, 1b and 1c). The data on relative dry matter yield (relative to the yield in the ONT) from the green house experiment (Table 1) confirmed that the exclusion of N, P, K and Zn reduced the dry matter yield significantly. But the addition of other nutrients like Ca, Mg, S, Cu, Fe, Mn, Mo and B did not significantly influence the dry matter yield of sorghum. Thus, through this green house study it was confirmed that in the experimental soil, N, P, K and Zn were the yield limiting nutrients.

The grain yield data from the field experiment are furnished in Table 2. It is evident from these data that there was significant response for all the nutrients studied, *viz.*, N, P, K and Zn in both the crops. From a fit of the grain yield data of both the crops on quadratic polynomial surface (Table 3), the optimum amounts of nutrients which ensures balanced fertilization were evolved (Table 4). The optimum N, P and K requirements corresponding to maximum profit as well as $ZnSO_4$ requirement were higher than those that are presently followed as blanket recommendation for both the crops. For the short duration ADT 36 rice, the N, P_2O_5 and K_2O requirements were higher, respectively by 55, 16 and 12 kg ha^{-1} whereas for the medium duration Co 43 rice their requirements were higher, respectively by 15 13 and 15 kg ha^{-1} than the presently followed blanket recommendation. For both these crops the $ZnSO_4$

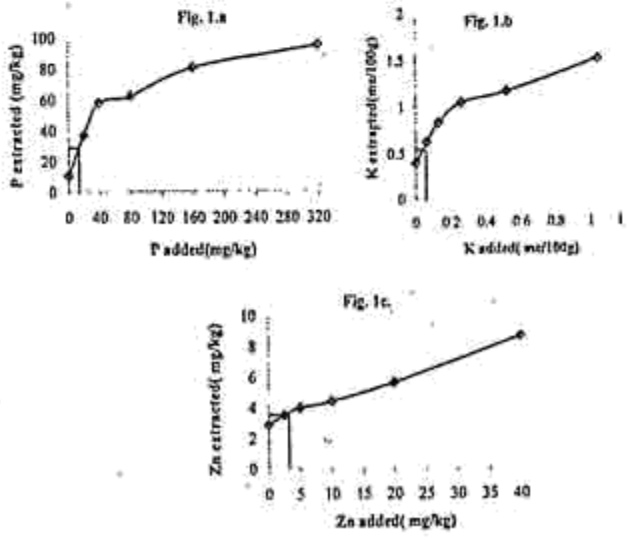

Fig. 1. Sorption curves in Kalathur series

requirement was higher by 5 kg ha^{-1} as compared to the blanket dose.

The results of test verification of these fertilizer optima in the field revealed that the rice yield as well as profit were higher with balanced fertilization by the newly evolved fertilizer optima as compared to that of blanket fertilizer recommendation (Table 5). In the case of ADT 36 rice there was an average yield increase of 23 per cent due to the adoption of newly evolved optima which in monetary terms was Rs. 4333/- per hectare more than that of the blanket recommendation. For Co 43 rice this average increase was 14 per cent which in monetary terms was Rs. 3356/- per hectare.

Thus, the fertilizer optima developed through the newly employed systematic approach of fertilizer opimization which envisages identification and accounting of any unknown or surprise nutrient deficiencies before any field experimentation to define fertilizer optima, is realistic and is the key to sustainable rice production. Based on these fertilizer optima derived by this study there is a scope to revise the existing blanket recommendation for rice for this rice growing region to increase the production.

Table 1. Response of sorghum (Co 27) in green house nutrient survey study in the experimental soils

Treatments	Dry matter yield) (g/5 plants)	Relative yield (%)
ONT	2.57	100
ONT (+) Ca 2 me 100g^{-1}	2.50	97
ONT (+) Mg 2me 100g^{-1}	2.34	91
ONT -(1) N	1.57	61
ONT (-) P	1.71	66
ONT (-) K	1.93	75
ONT (+) B 2 mg kg^{-1}	2.37	92
ONT (+) Cu 4 mg Kg^{-1}	2.44	94
ONT (+) Fe 20 mg kg^{-1}	2.83	110
ONT (+) Mn 30 mg kg^{-1}	2.48	96
ONT (+) Mo 2 mg kg^{-1}	2.66	103
ONT (+) S 60 mg kg^{-1}	2.58	101
ONT (-) Zn	1.92	75
Control	1.27	49
Mean	2.22	
SE(d)	0.29	
CD (P=0.05)	0.60	

Table 2. Grain yield of rice

Treatments	Grain yield (kg ha^{-1}) ADT 36 rice	Co 43 rice
$N_0P_2K_2$	5018	5043
$N_1P_2K_2$	6821	6443
$N_2P_2K_2$(ONT)	6984	6545
$N_3P_2K_2$	6993	6559
$N_2P_0K_2$	6120	5874
$N_2P_1K_2$	6912	6373
$N_2P_3K_2$	6940	6590
$N_2P_2K_0$	5823	5857
$N_2P_2K_1$	6718	6238
$N_2P_2K_3$	7001	6574
ONT - Zn	6325	6212
BF*	5920	6294
Mean	6465	6216
SE(d)	83	108
CD (P=0.05)	169	220

*Blanket recommendation : 120, 38, 38 kg ha^{-1} for ADT 36 and 150, 50 and 50 kg ha^{-1} for Co 43 of N, P_2O_5, K_2O, respetively along with 25kg ha^{-1} of $ZnSO_4$. $7H_2O$
(N_1, N_2, N_3 are 140, 170, 200 kg N ha^{-1}, respectively
P_1, P_2, P_3 are 12, 24, 36 kg P ha^{-1}, respectively
K_1, K_2, K_3 are 20, 35, 50 kg K ha^{-1}, respectively
Zn as 30 kg Zn $S0_4$. $7H_2O$ ha^{-1})

Table 3. Rice response in quadratic polynomial response surface

Season / Crop / Variety	R^2
Kuruvai rice (ADT 36)	
$Y=5017.30+20.20FN-0.0515FN^2$	0.9851**
$Y=6150.20+73.35FP-1.4514FP^2$	0.8870**
$Y=5827.00+57.39FK-0.6806FK^2$	0.9660**
Thaladi rice (Co 43)	
$Y=5042.80+15.82FN-0.0414FN^2$	0.9286**
$Y=5884.00+47.69FP-0.7878FP^2$	0.7596**
$Y=5845.00+26.69FK-0.2348FK^2$	0.7222**

Table 4. Optimum fertilizer to realize maximum profit in rice

Season/Crop/Var.	Economic Optimum dose (kg ha^{-1})			Optimum Zn dose (kg ha^{-1})
	N	P_2O_5	K_2O	$ZnSO_4.7H_2O$
Kuruvai rice ADT 36	175	54	50	30
Thaladi rice Co 43	165	63	65	30

Table 5. Results of test verification of ADT 36 and Co 43 rice

Test treatment	At location Ramapuram		At location Manankorai	
	Yield (kg ha^{-1})	Profit (Rs.)	Yield (kg ha^{-1})	Profit (Rs.)
Kuruvai season ADT 36 rice				
Blanket recommendation	5827	21,043	5444	19,511
Fertilizer optima	7054	25,056 (4,013)	6831	24,164(4653)
Thaladi season Co 43 rice				
Blanket recommendation	6079	26,059	5812	24,791
Fertilizer optima	6815	29,042(2983)	6705	28,520(3729)

Figures in parenthesis gives the net returns over blanket recommendation due to fertilizer optima

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