https://doi.org/10.29321/MAJ.10.A02113

Madras Agric. J. 75 (5-6) : 206-211 May-June 1988.

THEORETICAL BASIS FOR MAKING FERTILIZER RECOMMENDATIONS TO RICE

V. MURUGAPPAN[1], LEKHA SREEKANTAN[2] and SP. PALANIAPPAN[3]

Yield data of rice (ADT 31 and IR 20) from experiments (type A) conducted in cultivators' fields under the auspices of All India Coordinated Agronomic Research Project were utilized to explore the possibility of formulating a theoretical basis for rationalizing fertilizer recommedation to rice. Relationship of grain yield of rice with applied major nutrients was established in quadratic response function. An optimization procedure for working out the N, P_2O_5 and K_2O doses corresponding to maximum yield is proposed. From the results it appears that the present level of blanket recommendation for N application to rice is lower than the optimal dose in kharif in the four agro-climatic zones studied. For rabi, there is need for further experimentation with wider ranges of N levels as optimal levels of N obtained were very high and unrealistic. With respect of P_2O_5 and K_2O the present level of recommendation is rather close to the optimal values obtained in this study.

The need for increased food production and higher returns from agriculture makes the rational use of fertilizers imperative, particularly because of the escalating cost of this input. A theoretical basis for rationalizing fertilizer recommendations for various crops assumes importance in this context.

Fertilizer recommendations based on soil testing is no doubt, site specific and a viable tool for rationalizing the recommendation; yet generalized (blanket) recommendation for a particular crop cannot be avoided due to the constraints in timely collection of soil samples, analysis and making recommendations. Generalized recommendations are to be based not on arbitrary considerations but on theoretical basis derived from factual information obtained from field experiments. Otherwise production maximization with efficient use of ferilizer input cannot be achieved.

Research work conducted all over the world in the past had proved the superiority of crop response models over simple estimates like response per kg of nutrients in determining the fertilizer dose for crops for production maximization (Finney, 1963). Further the fertilizer needs of crops vary greatly between sites and seasons and hence planning of a series of experiments in well defined boundary conditions is necessary for arriving at correct levels (Wimble, 1980). The need for detailed research on the variations in the amounts of fertilizer needed for different crops under varying climatic and soil conditions was stressed by Cooke (1980). Considering all these aspects.

1 : Associate Professor, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore-3.

2 : Ph. D. Scholar, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore-3.

3 : Professor and Head, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore-3.

the present practice of making state-wide or region-wise generalized fertilizer recommendations for various crops with the resulis obtained from fewer number of experiments and without any sound theoretical basis is inadequate in acheiving the desired goal. Wtth this in view, the present investigation was undertaken to explore the possibility of utilizing the existing data for formulating a theoritical basis for rationalizing fertilizer recommendations to rice.

MATERIALS AND METHODS

Yield data of rice (ADT 31 and IR 20) from experiments (type A) conducted in cultivars, fields under the auspices of All India Coordinated Agronomic Research Project were utilized in the present investigation The data are related to experiments conducted during the years 1979-84 in four agro-climatic zones of Tamil Nadu, viz., Cauvery Delta zone, North Western zone, North Eastern zone and in two seasons, viz., kharif (June-September) and rabi (October-February). The varieties used were ADT 31 (105 days) in kharif and IR 20 (135 days) in rabi. There were eleven treatments, viz., $N_0P_0K_0$, $N_{40}P_0K_0$, $N_{80}P_0K_0$, $N_{120}P_0K_0$, $N_{40}P_{20}K_0$, $N_{80}P_{40}K_0$, $N_{120}P_{60}K_0$, $N_{40}P_{20}K_{20}$, $N_{80}P_{40}K_{40}$, $N_{120}P_{60}K_{60}$ and $N_{120}P_{60}K_{40}$ (figures in subscripts indicate kg of nutrients as N, P_2O_5 and K_2O applied per ha).

The number of locations from where the data were obtained under each agro-climatic zone and season are furnished in Table 1. Relationship of grain yield of rice with applied nutrients was established in quadratic response function by following the procedure outlined by Snedecor and Cochran (1968) on a HCL 1800 computer separately for different agro.climatic zones and seasons.

Optimization Procedure

For quadratic response function of the form

$$Y = a_0 + a_1N + a_2p + a_3K + b_1N^2 + b_2p^2 + b_3K^2 + C_1NP + C_2PK + C_3NK$$

the first order condition for the maximum is that the first partial derivative with respect to each input variable must be equal to zero. This gives

$$fN = \frac{Y}{N} = a_1 + 2b_1N + C_1P + C_3K = 0$$

$$fP = \frac{Y}{P} = a_2 + C_1N + 2b_2P + C_2K = 0$$

$$fK = \frac{Y}{K} = a_3 + C_3N + C_2P + 2b_3K = 0$$

This set of equations can be written in the matrix form as

$$\begin{bmatrix} 2b_1 & C_1 & C_3 \\ C_1 & 2b_2 & C_2 \\ C_3 & C_2 & 2b_3 \end{bmatrix} \begin{bmatrix} N \\ P \\ K \end{bmatrix} = - \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix}$$

This is of the form

$$AX = -B$$

$$\text{Where} \quad A = \begin{bmatrix} 2b_1 & C_1 & C_3 \\ C_1 & 2b_2 & C_2 \\ C_3 & C_2 & 2b_3 \end{bmatrix}$$

$$X = \begin{bmatrix} N \\ P \\ K \end{bmatrix}$$

$$\text{and} \quad B = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix}$$

The solution gives

$$X = -A^{-1} B$$

This solution may give a maximum for a function, a minimum or neither. For testing this, the sufficiency condition is to be satisfied. The sufficieny condition involves the second order derivatives and mixed derivatives whose values are

$$fNN = \frac{\partial^2 Y}{\partial N^2} = 2b_1$$

$$fpp = \frac{\partial^2 Y}{\partial P^2} = 2b_2$$

$$fKK = \frac{\partial^2 Y}{\partial K^2} = 2b_3$$

$$fNP = \frac{\partial^2 Y}{\partial N \partial P} = C_1$$

$$fPK = \frac{\partial^2 Y}{\partial P \partial K} = C_2$$

$$fNK = \frac{\partial^2 Y}{\partial N \partial K} = C_3$$

Now the Hessian (H) is

$$H = \begin{bmatrix} fNN & fNP & FNK \\ fPN & fPP & fPK \\ fKN & fKP & fKK \end{bmatrix}$$

The condition for the existence of a positive maximum with respect of Y is that

$$[H_1] < 0; \quad [H_2] > 0; \quad [H_3] < 0;$$

where.

$$[H] = [fNN]$$

$$\begin{bmatrix} H_2 \end{bmatrix} = \begin{bmatrix} fNN & fNP \\ fPN & fPP \end{bmatrix}$$

$$[H_3] = [H]$$

RESULTS AND DISCUSSION

The fitted quadratic response functions along with ths respective coefficients of multiple determination(R^2) are presented in Table 1. The R^2 values indicated that 96 to 99 per cent of variations in yield were accounted by the dependent variables incorporated in the response function in all agro-climatic zones and for the two seasons. Thus the quadratic response function was considered sufficient for the purpose of optimization of fertilizer requirements for rice crop.

Out of the eight quadratic response functions presented in Table 1, except the ones relating to rabi season of Cauvery Delta Zone and kharif season of North Eastern zone, others satisfied the condition for the existence of a positive maximum with respect to Y. Hence, utilizing these six quadratic functions the doses for N, P_2O_5 and K_2O corresponding to maximum yield were worked out by following the procedure outlined above under the optimization procedure and are presented in Table 2.

From the results it can be seen that the optimum dose for N varied from 203 to 917 kg/ha. The dose for the short duration variety, ADT 31, in kharif was of a lower magnitude (203 to 323 kg/ha), while the highest yields obtained were from 53 to 59 quintals/ha. It becomes evident that the present blanket recommendation of 75 to 100 kg N/ha is well below the quantity needed to obtain the maximum yield. There is also a view that the quadratic model tends to over-estimate the optimal dose compared to other models (Wimble, 1980). Before making a regional recommendation there is need to test other models such as inverse quadratic, modified inverse linear, modified exponential and two straight lines for their suitability. Once fitness of the model is established a regional economic optimal dose can be recommen-

Table 1. Relationship of grain yield of rice with applied nutrients

Agro-climatic Zone	Season	No. of experiments	Response equation	R^2 value
Cauvery Delta Zone	Kharif	31	$Y = 37.9648 + 0.1215 N + 0.2445 P - 0.0008 K - 0.0003 N^2 + 0.0031 P^2 - 0.0006 K^2 + 0.00000003 NP$ $0 PK + 0.0014 NK$	0.9951**
	Rabi	20	$Y = 34.4557 + 0.0447 N + 0.1689 P + 0.2398 K + 0.00006 N^2 - 0.0017 P^2 - 0.0011 K^2 + 0.00000006 NP + 0 PK - 0.0005 NK$	0.9821**
North Western	Kharif	27	$Y = 38.0.215 + 0.0452 N + 0.1493 P + 0.1518 K - 0.00007 N^2 - 0.0014 P^2 - 0.0026 K^2 + 0.00000003 PK - 0.0000000002 PK + 0.0009 NK$	0.9761**
	Rabi	16	$Y = 34.3785 + 0.0550 N + 0.1407 P + 0.1418 K - 0.00003 N^2 - 0.0014 P^2 - 0.0014 K^2 + 0.00000003 NP + 0 PK + 0.0008 NK$	0.9929**
North Eastern zone	Kharif	10	$Y = 33.3675 + 0.0789 N + 0.6101 P + 0.0650 K + 0.0003 N^2 - 0.0091 P^2 - 0.0026 K^2 + 0.00000006 NK + 0 PK + 0.0019 NP$	0.9802**
	Rabi	20	$Y = 29.9640 + 0.0544 N + 0.3228 P + 0.3237 K - 0.00007 N^2 - 0.0037 P^2 - 0.0030 K^2 + 0.00000006 NP + 0 PK - 0.0002 NK$	0.9679**
Western Zone	Khari	24	$Y = 38.6926 + 0.1112 N + 0.2135 P + 0.0747 K - 0.0002 N^2 - 0.0030 P^2 - 0.0004 K^2 + 0.00000003 NP + 0 PK + 0.0001 NK$	0.9673**
	Rabi	15	$Y = 34.4184 + 0.0650 N + 0.2114 P + 0.365 K - 0.00006 N^2 - 0.0025 P^2 - 0.0007 K^2 + 0.00000003 NP + 0 PK + 0.0011 NK$	0.9948**

Table 2. Fertilizer doses for maximum yield

Agro-Climatic Zone	Season	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Cauvery Delta zone	Kharif	203	54	63
	Rabi	—	—	—
North Western Zone	Kharif	323	66	41
	Rabi	917	70	71
North Eastern Zone	Kharif	—	—	—
	Rabi	389	42	53
Western Zone	Kharif	278	37	98
	Rabi	542	58	72

ded based on the prevailing market prices of the input and output.

In general, the N optima for rabi season were very high and unrealistic. In Tamil Nadu, north east monsoon rains are received during this season leading to water logging and low sunlight intesity. These climatic conditions are not congenial for growing rice though farmerrs have no choice but to raise rice in high rainfall regions due to field inundation. The rice yields are low in this season. When the available data were fitted to a quadratic model on the ascending part of the curve and extrapolated to work out the optima, unrealistically high optimal dose was obtained for N. There is need for further field experimentation with a wide range of N levels for arriving at a reasonable and realistic recommendation.

No optima could be obtained for rabi season in Cauvery Delta Zone and for kharif season in North Eastern Zone. This was probably due to variability of the data. This needs further testing and verification

Optimal doses varied from 37 to 70 kg/ha for P_2O_5 and 41 to 98 kg/ha for K_2O in different zones and seasons. The present recommendation of 50 to 60 kg/ha each for P_2O_5 and K_2O is rather close to the optimal values obtained in this study. Hence the economic optimal doses for P_2O_5 and K_2O, can be recommended for different zones and seasons based on such studies.

In conclusion it appears that our blanket recommendation for N application to rice is lower than the optimal dose in kharif in the four zones studied. For rabi, there is need for further experimentation with wider ranges of N levels. For P_2O_5 and K_2O, realistic recommendations can be made based on such studies.

REFERENCES

COOKE, G. W. 1980. Fertilizer recommendation-their formulation and use. Chemistry and Industry, 6 : 677-680.

FINNEY, D. J. 1953. Response curves and the planning of experiments. *Indian J. of Agric. Sci.*, *23* : 167-186.

SNEDECOR, G. W. and W. G. COCHRON. 1968. *Statistical methods*, 6th Edn. Oxford and IBH publishing Co., Eton. press, Calcutta

WIMBLE, R. 1980. Theoretical basis for fertilizer recommendation. Chemistry and Industry, 6 : 680-683.