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YIELD RESPONSE TO LIME AND RESIDUAL EFFECT OF LIMING - A STATISTICAL EVALUATION

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Abstract: A pot culture experiment was conducted to study the residual effect of liming under continuous cropping with different soils on crop yield especially in terms of residual response patterns. The residual effect of liming is very much in evidence in the second succeeding crop for kole and kari soils and up to third crop for pokkali soils. In case of lateritic alluvium, application of lime at 0.25 LR has resulted in maximum yield. Response function for the first crop and residual response function for the second crop could not be worked out. This indicates that maximum yield might have been attained at a level of liming below 0.25 LR dose.

INTRODUCTION

Some soil processes which result in acidification are nitrification, respiration of CO_2 and subsequent fomation of carbonic acid and mineralisation of organic acids. Liming on acid soil would thus favour these processes and result an accelerated formation of products including H^+ and leaching anions. Stimulation of nitrification by liming would contribute to more rapid reacidification (Doerge *el al.*, 1985). The replacement of exchangeable cations by H^+ ions and leaching of Ca salts during the period of excess precipitation and over-irrigation will result soil reacidification (Bolton, 1977 and Hoyt and Henning, 1982).

MATERIALS AND METHODS

A pot culture experiment with five different levels of lime in four acid soil types was conducted successfully for four seasons using a responsive rice variety (Jyothi) in order to study the residual effect of the amendments on crop yields especially in terms of residual response patterns. The soil type selected were, a lateritic alluvium from Panancherry, Thrissur district (S_1), kole soil from Variampadave, Thrissur district (S_2), pokkali soil from Vyttila, Ernakulam district (S_3) and kari soil from Kallara, Kottayam district (S_4). The surface soil samples were collected from the above locations. The levels of lime were control (without lime), fully burnt lime at the rate of 0.25 lime requirement (LR) of the soil (L_1), 0.5 LR (L_2), 0.75 LR (L_3) and full LR of the soil (L_4). The experiment was laid out in a completely randomised design with three replications. The lime requirement and important physicochemical characteristics of the four soil types were determined by standard procedures described by Jackson (1958), Hesse (1971) and Black (1965) and are presented in Table 1.

Earthen pots of uniform size were filled with 15 kg of the dried soil sample. Sufficient water was added to the pots to wet the soil and to bring about puddled condition. Lime as per treatments was added to the soil only for the first crop. Two healthy seedlings of Jyothi variety were transplanted at the rate of four hills per pot. N, P and K were applied uniformly for every crop as per the recommendations of the Kerala Agricultural University (Anon., 1981). Yield attributes were taken and response curves were worked out. (Cochran *et al*, 1957 and Harry, 1978).

RESULTS AND DISCUSSION

Yield data were taken and response curves were worked out for the four soils separately and for each of the four crops studied.

Kole soil (Fig.1)

The estimated response functions for yield in the four cropping seasons in sequence are respectively,

$Y_1 = 24.70 + 34.38X - 27.54X^2$ ($R^2 = 0.91$)

$Y_2 = 23.73 + 30.96X - 24.11X^2$ ($R^2 = 0.87$)

$Y_3 = 15.10 + 30.26X - 17.14X^2$ ($R^2 = 0.89$)

$Y_4 = 9.42 + 15.10X - 10.06X^2$ ($R^2 = 0.96$)

The response functions show the quadratic nature of response for the application of amendments. The constants for the successive response functions show a decreasing trend. The nearness of the constants of the response function for the season in which the liming material was applied (equation 1) to that of the response function for the residual effect when amendments were not been applied i.e., the second season (equation 2) show that the effect persists to a significant level and at all doses of application. However, in the third cropping season the constants for response function (equation 3) rapidly decrease from previous values in equations (2) and (1). This decrease is nearly 50 per cent of the constant in the response equation for the first season. Further in the fourth crop, the constant in the response function is only nearly 50 per cent of the value of the constant for the third season's response function. The R^2 values for the response functions lie between 0.87 and 0.96 which is indicative of the response function accounting for 87 to 96 per cent of the variation in yield.

From the graph it may be clearly observed that the curve for equation (3) is in fact not parallel to equations 1 and 2, which are themselves however close and parallel to one another. In fact, curve Y_3 tends to join Y_1 and Y2 at the higher rates of liming indicating greater response to residual lime at high levels of initial application but in the third season. The optimum levels of lime for the initial application for first crop and residual effect for the second, third and fourth crops were worked out to be respectively 0.62 LR, 0.64 LR, 0.88 LR and 0.75 LR of the soil. This indicates that in the curves Y_1, Y2, Y_3 and Y_4 the response optimum shifts to a higher level of initial lime application with successive cropping indicative of a higher residual effect for higher levels of lime than the optimum dose of lime for the first season. Thus the dose giving a depressive yield in the first season become the optimal dose for the second season and so on.

Pokkali soil (Fig. 2)

The estimated response functions for yield in the four cropping seasons in sequence in the pokkali soils are respectively

$Y_1 = 21.8 + 44.50X - 21.94X^2$ ($R^2 = 0.99$)

$Y_2 = 19.14 + 51.12X - 32.00X^2$ ($R^2 = 0.96$)

$Y_3 = 17.74 + 21.18X - 13.14X^2$ ($R^2 = 0.99$)

$Y_4 = 6.600 + 3.420X - 1.940X^2$ ($R^2 = 0.99$)

A perusal of the response functions reveals the quadratic nature of the response to both liming and residual effects arising out of liming in the first season followed by three subsequent seasons of continuous cropping without liming. The constants for the response functions show a decreasing trend. However, a drastic reduction in the value of the constant appears only in equation (4) while from equations 1 to 3 the decrease in the value of the constant is gradual. This is indicative of the persistence of the effect of liming till three cropping seasons are over, and the closeness of the response to the quadratic model. However, in the fourth season, the value of the constant falls to nearly one-third of the previous season's response constant value. The R^2 values for the response function lie between 0.96 and 0.99 indicating the high degree of fitness of the models.

From the equation, it may be seen that the curve Y_3 is not parallel to Y_2 and Y_1 which are, however, fairly parallel and close to one another. In fact Y_3 tends to diverge from Y_1 and Y_2. This is again indicative of a greater residual response in the third season to lower rates of initial liming in the first season. From the graph it may be observed that by the fourth crop, the residual effect becomes so low, that the effect of liming carried out three seasons earlier had no discernible effect in maintaining the initial high yields established.

Kari soil (Fig. 3)

The estimated response functions for yield in four cropping seasons in sequence are respectively:

$$Y_1 = 8.23 + 53.03X - 24.11X^2 \; (R^2 = 0.98)$$
$$Y_2 = 6.93 + 36.65X - 7.89X^2 \; (R^2 = 0.97)$$
$$Y_3 = 3.26 + 13.89X - 6.86X^2 \; (R^2 = 0.99)$$
$$Y_4 = 1.65 + 1.21X - 0.23X^2 \; (R^2 = 0.95)$$

The response functions show the quadratic nature of response of yield in relation to both liming (equation 1) and residual effect of liming (equation 2, 3 and 4). The response for the residual effects maintains the quadratic nature. From the curve it is clear that the maximum yield (plateau of the curve) is not attained even at the highest rate of liming viz., full LR dose nor the maxima shown for the residual effects in curves Y_2, Y_3 and Y_4 for this rate (1 LR) of initial liming. The constants for the successive responses show a decreasing trend. The curve Y_2 is very near the curve Y_1 at 0 and at full dose of lime (1 LR) while for in between levels the curves are lying a little wide apart. This is indicative of greater residual effects at low rates of liming. Under these circumstances, this effect may even be called persistence of beneficial effects. However, the residual effect appears to decrease rapidly by the third crop as indicated by the decrease in the value of the constant in the regression equation 1 to 3 from 8.23 to 3.26. This decrease in the effect is nearly 61 per cent. The R values for the response function lie between 0.95 to 0.99 indicating a statistical accounting of 95 to 99 per cent of the response by quadratic model both for the initial and residual effects.

From the graph it may be observed that by the fourth crop, the residual effect becomes so low, that the effect of liming three seasons earlier, had left no marked effect in maintaining the initial high yields established as a result of liming. However, compared to the no lime treatment the limed series still maintained statistically higher though comparatively poor yields.

Lateritic alluvium (Fig. 4)

In the case of lateritic alluvium, application of lime at 0.25 LR dose resulted in a maximum yield and at higher doses yield decreased significantly and rapidly. The R value was only 0.107 for linear regression equation ($Y_1 = 42.46X - 3.88$) and 0.338 for the quadratic function ($Y_1 = 37.61 + 15.43X - 19.31X^2$). In the second season, the R^2 value was 0.008 for linear regression ($Y_2 = 38.86X - 1.0$) and 0.360 for quadratic function ($Y_2 = 33.46 + 20.8X - 21.82X^2$).

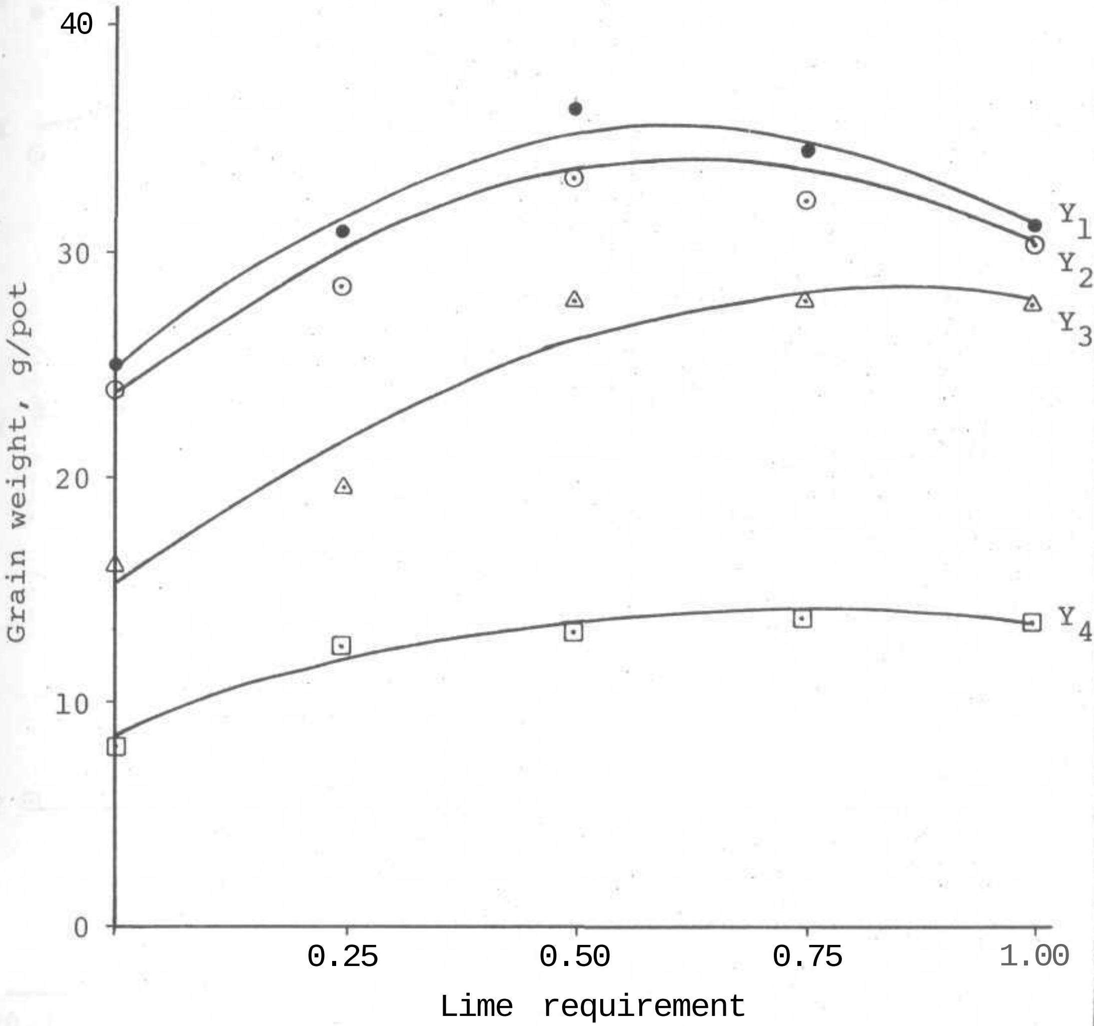
RESPONSE FUNCTION

$$Y_1 = 24.70 + 34.38\,x - 27.54\,x^2 \quad (R^2 = 0.91)$$

$$Y_2 = 23.73 + 30.96\,x - 24.11\,x^2 \quad (R^2 = 0.87)$$

$$Y_3 \quad 15.10 + 30.26\,x - 17.14\,x^2 \quad (R^2 = 0.89)$$

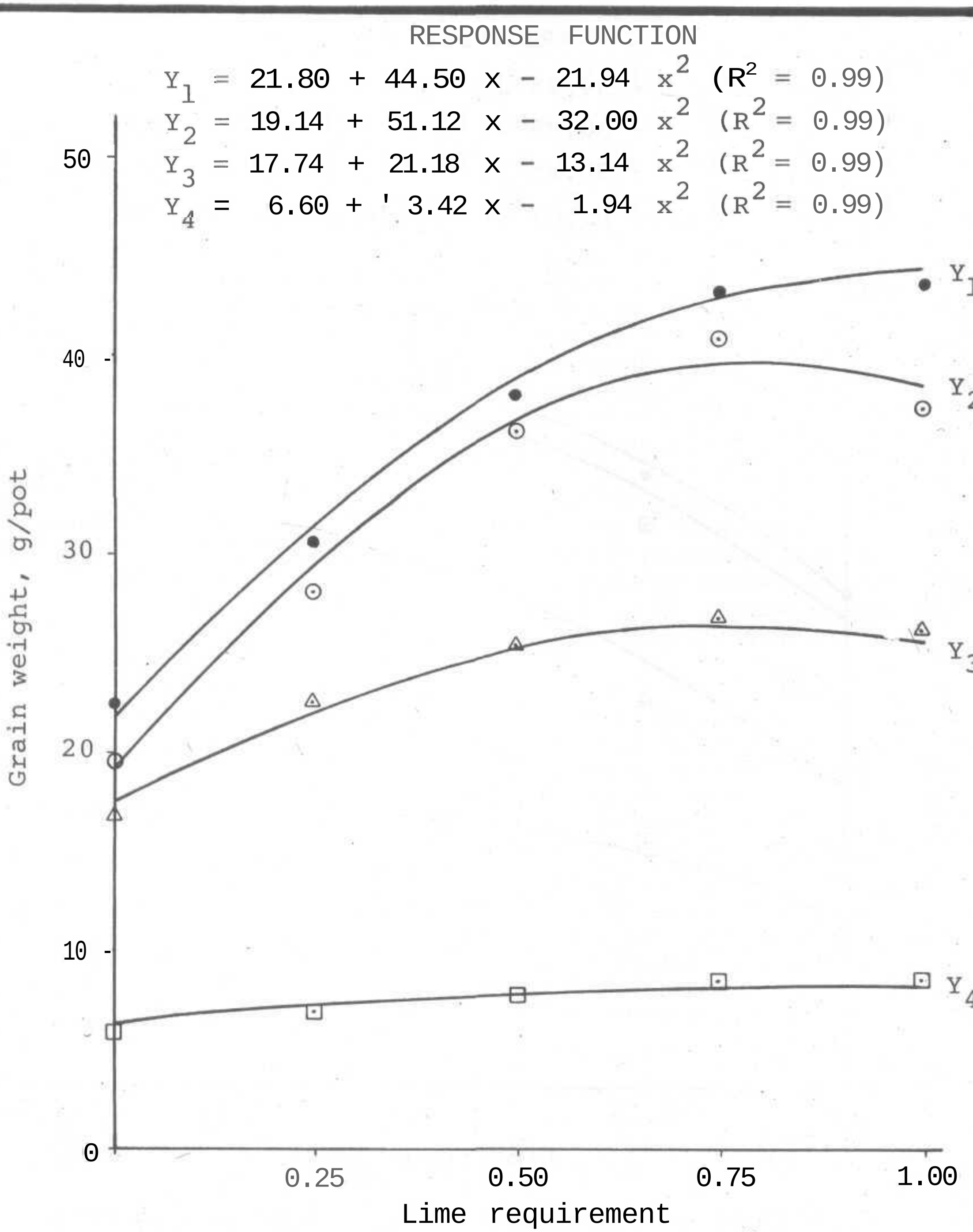
$$Y_4 = 8.42 + 15.03\,x - 10.06\,x^2 \quad (R^2 = 0.96)$$



Y_1 - Yield of 1st crop Y_3 - Yield of 3rd crop

Y_2 - Yield of 2nd crop Y_4 - Yield of 4th crop

Fig. 1 Yield response to lime in **kole** soil



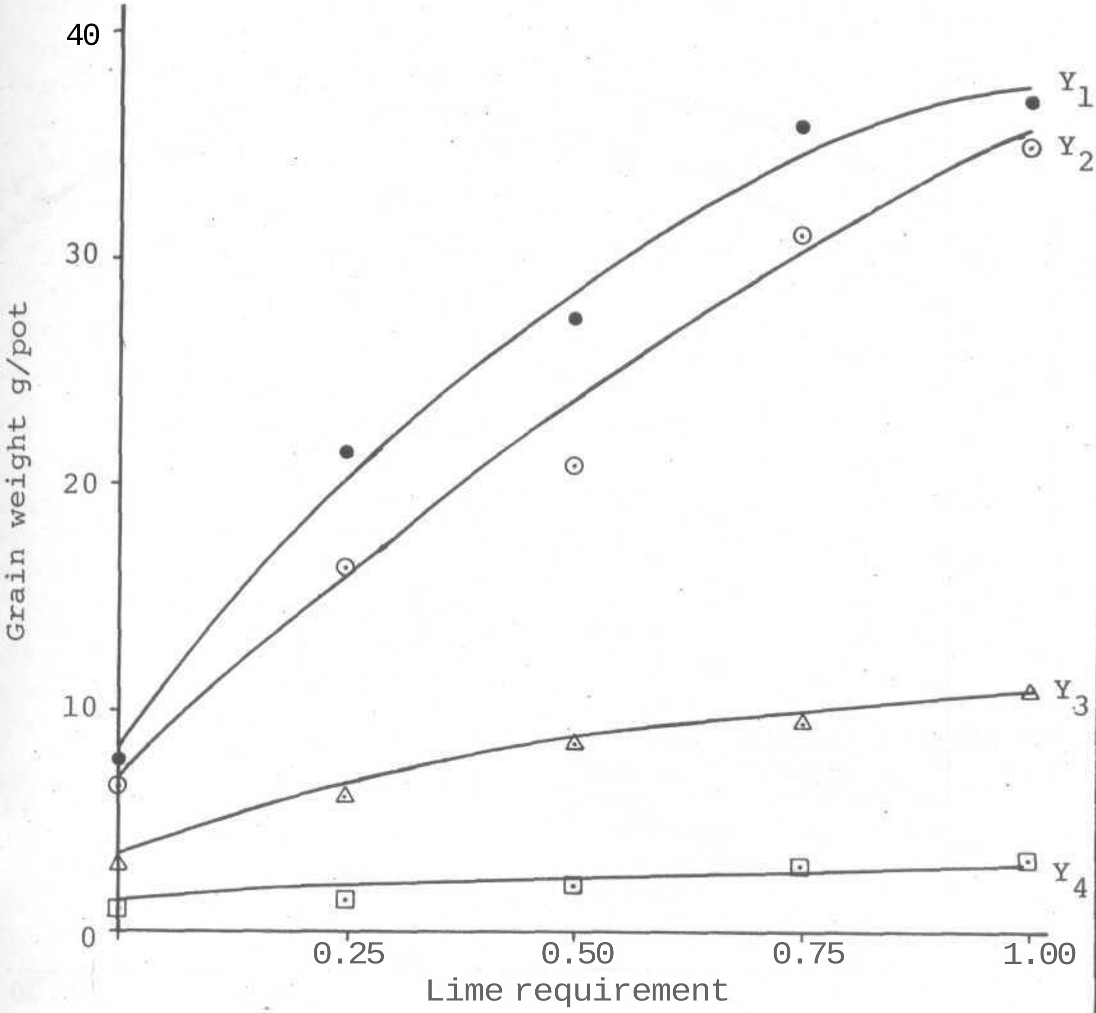
Y_1 Yield of 1st crop Y_3 Yield of 3rd crop

Y_2 Yield of 2nd crop Y_4 Yield of 4th crop

Fig. 2 Yield response to lime in pokkali soil

RESPONSE FUNCTION

$$Y_1 = 9.23 + 53.03\ x - 24.11\ x^2 \quad (R^2 = 0.98)$$
$$Y_2 = 6.93 + 36.65\ x - 7.89\ x^2 \quad (R^2 = 0.97)$$
$$Y_3 = 3.26 + 13.89\ x - 6.86\ x^2 \quad (R^2 = 0.99)$$
$$Y_4 = 1.65 + 1.21\ x + 0.23\ x^2 \quad (R^2 = 0.95)$$



Y_1 Yield of 1st crop Y_3 Yield of 3rd crop

Y_2 - Yield of 2nd crop Y_4 Yield of 4th crop

Fig. 3 Yield response to lime in kari soil

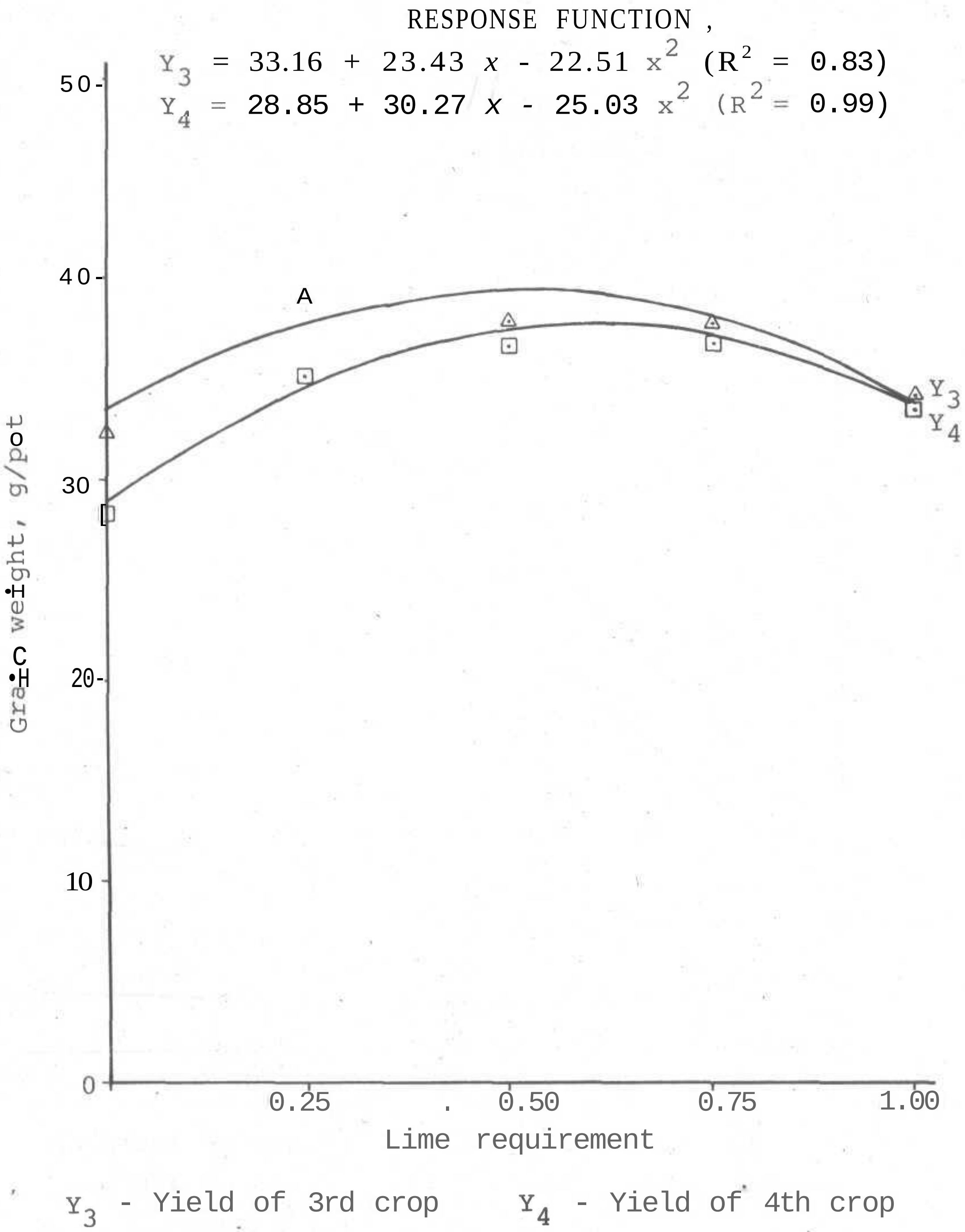


Fig. 4 Yield response to lime in laterite alluvium soil

Table 1. Physicochemical characteristics of soils used for pot culture studies

Characteristics	Kole	Kari	Pokkali	Lateritic alluvium
Moisture (%)	2.10	2.58	2.20	1.98
Sand (%)	3.20	1.96	11.56	52.00
Silt (%)	15.99	15.90	17.50	10.50
Clay (%)	75.98	64.50	61.50	5.65
Dry soil pH	4.60	2.60	3.60	5.65
Wet soil pH	4.75	3.00	3.80	5.75
Eh (mV)	320.00	410.00	380.00	320.00
EC (dS/m)	0.10	3.95	4.00	0.04
Organic carbon (%)	2.61	10.62	2.28	1.78
Lime requirement as CaO (t/ha)	3.64	9.97	2.69	1.23

This indicates that the maximum yield might have been attained at a level of liming below 0.25 LR dose. But 0.25 LR dose was the lowest dose tried. So response functions for the effect of liming for the first crop and the residual effect in the subsequent second season could not be worked out.

However, for the third and fourth crops, the residual effects due to liming followed a quadratic response model. The equations are respectively:

$$Y_3 = 33.16 + 23.43X - 22.15X^2 \ (R^2 = 0.83)$$

$$Y_4 = 28.85 + 30.2 - 25.03X^2 \ (R^2 = 0.99)$$

The significant result to be noticed is that maximum residual response is for an initial low application of 0.5 LR lime dose. But initially this itself is yield depressing as already pointed out and the maximum yield is at a dose well below 0.25 LR, the lowest level lime application tried. In other words, lime dose equivalent to 0.75 LR initially applied can have a depressing effect on the yield of immediate crop and the residual depressing effect continues to persist for another three seasons. Another significant aspect is that the curves Y_2 and Y_4 meet at full LR dose.

These results thus indicate low initial rates of liming for lateritic alluvium even below 0.25 LR. This may be often less than the present recommended blanket dose in the package of practices viz., 600 kg of lime, $CaCO_3$ equivalent. However, for the more acidic soils like the kari soils, kole soils and pokkali soils, a dose equal to 1 LR, 0.5 LR and 0.75 LR respectively with little residual effect is to be recommended. In fact, in such soils, acceleration of reacidification by higher rates of liming which is desirably to be avoided, warrants application of divided doses as a better crop management exercise.

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