RATE OF RETURN ON CHEMICAL FERTILIZERS IN THE PACKAGE PROGRAMME DISTRICTS

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The consumption of nitrogenous fertilizers has increased at an annual rate of 80 per cent during the decade 1951-61. It needs to be noted that the Indian farmer pays excessively high price for chemical fertilizers. Table I shows the prices of fertilizers (1961-62) to be charged from farmers in selected countries. India is importing fertilizers to a large extent from all these countries.

TABLE I—PRICES OF NITROGENOUS FERTILIZERS IN 1961-62 IN SELECTED COUNTRIES

(in rupees per ton)

Material	Price to be charged from farmers in India	Imported† price (at port)	Name of the countries			
			Japan	Holland	Italy	U.S.A.
Ammonium sulphate ..	360	216	264	249	231	286
Urea	615	451	522	—	—	—

† The imported price of fertilizers is the landed cost at ports.

It can be seen that the imported price is Rs. 150 per ton lower for ammonium sulphate and Rs. 160 lower for urea than domestic price approximately. In this study, it is proposed to examine and measure the rate of return on chemical fertilizers when the price of chemical fertilizers charged from the farmers is considerably high.

The study is divided into three sections. Section I discusses the data and general methodology adopted in the study. In section II, the rate of return on chemical fertilizers for each crop in each of the district is measured. An explicit allowance for the variation in the soil fertility between different blocks is made. In section III, the limitations and emerging conclusions from the study are brought out.

I

The Intensive Agricultural District Programme scheme or 'Package Programme' commenced in 1960-61 in three districts and extended to 4 more districts of the country in 1961-62. Later on, the programme was extended to 18 districts. An attempt is made here to measure the quantitative significance of chemical fertilizers in increasing the yield of various crops in the six selected districts where the Package Programme has been launched. These districts are : (i) West Godavari, (ii) Thanjavur, (iii) Aligarh, (iv) Shahabad, (v) Ludhiana, and (vi) Surat.

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Data on demonstration programme carried out on cultivators' blocks are available from the Extension Section of the Ministry of Food and Agriculture. However, such data are not available continuously for all these six districts for two seasons : *Rabi* and *Kharif*.[1] Normal yield data (both in physical quantities and in value terms) are available while the disaggregate cost data, *viz.*, per acre cost incurred on preparatory tillage, seed, sowing organic manures, fertilizers, interculture, irrigation, harvesting and threshing, etc., are given in value terms. In addition, the number of demonstrations held, average yield, total area covered by demonstrations and yield on controlled blocks are obtained for various blocks. Controlled blocks are selected in such a way that they are as similar as possible to the programme blocks in a district in respect of factors like irrigation, rainfall, soil types, crop pattern, credit and marketing facilities and agricultural practices. This does not mean that cultivation practices could not vary from one demonstration block to another block in the chosen district. The U.P. method of wheat and barley cultivation and Japanese method of paddy cultivation are the methods adopted in the Aligarh and West Godavari districts respectively. Separate data on soil classification are not available.

It is decided to adopt two to three approaches to measure the marginal value product with respect to chemical fertilizers. These approaches are described in general here. In the unconstrained production function approach, total output is made a function of various inputs. $P = CX_1^{b_1} X_2^{b_2} X_3^{b_3} E_i$, where X_1 is the total cost on chemical fertilizers, X_2 is the total cost on other inputs and X_3 is the area. The parameters $(b_1 + b_2 + b_3)$ do not necessarily sum to unity which means that they are unconstrained. This form is adopted for West Godavari district but is found to be unsuitable owing to the problems of intercollinearity between expenditures on different inputs. Secondly, the per acre production function approach is tried. The relationship is presumed to be linear.

$$Y/A = a + b_1 (X_1/A) + b_2 (X_2/A) + b_3 (X_3/A) + U_i$$

where

Y/A is the yield per acre on demonstration blocks.

X_1/A is the cost of fertilizer input per acre.

X_2/A is the cost on other inputs per acre.[2]

X_3/A is the per acre yield on controlled blocks.

The substitution elasticity between two or more inputs in the above form will be infinite.

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1. *Kharif* months are from May to October and *Rabi* months are from 15th October to middle of April.

2. Expenditure on other inputs might be already accounted in the yield per acre on controlled blocks. Using X_2/A as a separate variable may mean the reconsideration of the accounted expenditures in X_3/A. However, the data on total expenditure over control showed that three-fourth of the expenditure on other inputs are not accounted in the yield on controlled blocks. It is true that our estimated coefficient with respect to X_2/A is slightly an under-estimate since there is some duplication.

b_1 and b_2 are the marginal productivities with respect to chemical fertilizers and other inputs respectively. These coefficients give the net values adjusted for soil differences between blocks when X_3/A is used as an explanatory variable. The inclusion of yield on controlled blocks (X_3/A) is made in the regression model as the soil fertility varies from block to block. In all the cases, the coefficient of X_3/A is statistically significant. The per acre logarithmic form is tried in few cases but it did not yield better results than per acre form.

Thirdly, where the data on additional yield per acre over control and additional cost per acre over control are available and the entire additional amount is spent on chemical fertilizers, the ratio of additional yield over control to the additional cost over control will represent the productivity with respect to chemical fertilizers. If, however, the additional costs over control are incurred both on other inputs and chemical fertilizers, the ratio with respect to each one of them will amount to partial productivity approach. Partial productivity ratios, while useful for measuring savings in particular inputs achieved over time, do not measure overall changes in productive efficiency since they are influenced by changes in the composition of input, *i.e.*, by factor substitution. In such an eventuality, additional output over control per acre is made a function of additional cost on chemical fertilizers over control and additional cost on other inputs per acre. This implies that chemical fertilizers and other inputs are combined in arithmetic proportions (in simple linear form) in the functional approach. The functional approach considers the relationship between different inputs while estimating the coefficients. The substitution elasticities between inputs will vary according to the form of the function chosen. Wherever the data are amenable to functional approach, we adopt the function, *viz.*, additional output over control is dependent on additional inputs over control.

II

So far, we discussed the data and general methodology useful in computing the marginal rate of return on chemical fertilizers. For each district, the general background and effect of rainfall and results are presented in the subsequent analysis. The background of the district is based on the IADP Expert Committee Report.

WEST GODAVARI DISTRICT

Paddy is the major crop of the West Godavari district and it accounts for 70 per cent of the total cropped area. Tobacco is the second major crop and contributes 9 per cent to the total value of the crops in the district. The use of chemical fertilizers for paddy crop is not as widespread as for the tobacco crop. The consumption of nitrogenous fertilizers increased from 18.6 thousand tonnes during 1960-61 to 49 thousand tonnes during 1962-63, *i.e.*, by 164 per cent. The consumption of phosphatic fertilizers rose by 350 per cent. The average expenditure per acre on consumption of chemical fertilizers in 1960-61 (*Rabi*), 1961-62 (*Kharif*), 1961-62 (*Rabi*) and 1962-63 (*Kharif*) were Rs. 36.41, Rs. 34.85, Rs. 40.90 and Rs. 37.00 respectively. Both quantitative and qualitative improvements are significant for paddy under the normal rainfall of 1778 millimetres (70") even in irrigated conditions.

TABLE II—PER ACRE UNTRANSFORMED FORM : REGRESSION COEFFICIENTS, THEIR STANDARD ERRORS AND R^2

District/State	Season/Year	Constant of equation	Regression coefficients of			Multiple coefficient of determination	Number of observations	Units for variables	M. V. P. of fertilizer
			X_1/A	X_2/A	X_3/A				
West Godavari (A. P.)	*Rabi* 1960-61	—6.2150	0.7025 (0.4009)	0.0892 (0.1043)		0.2954	15	Y/A and X_3/A in maunds X_1/A and X_2/A in Rs.	—
,,	,,	—9.1065	0.3460* (0.1503)	0.0353 (0.0382)	0.8852* (0.0991)	0.9147	15	,,	4·84
,,	*Kharif* 1961-62	36.5501	—0.1031 (0.1512)	0.0397 (0.0593)		0.0496	20	,,	—
,,	,,	—6.6718	0.1263* (0.0401)	0.0467* (0.0189)	1.0554* (0.0617)	0.9508	20	,,	1.77
,,	*Rabi* 1961-62	28.8444	0.1711 (0.1311)	—0.0296 (0.0478)		0.1276	15	,,	—
,,	,,	9.2446	0.0920 (0.0705)	—0.0430 (0.0238)	0.9189* (0.1491)	0.8040	15	,,	1.29
,,	*Kharif* 1962-63	11.9404	—0.1398 (0.1011)	0.0438 (0.0333)		0.1470	20	Y/A and X_3/A in quintal and X_1/A and X_2/A in Rs.	—
,,	,,	0.6173	0.0105 (0.0280)	—0.0020 (0.0062)	1.1078* (0.0484)	0.9747	20	,,	0.35

* Significant at 5 per cent level.
Note : Standard errors are shown in parentheses.

TABLE III—PER ACRE TRANSFORMED FORM : REGRESSION COEFFICIENTS, STANDARD ERRORS AND R^2

District	Year/Season	Size of sample	Units for variables	Constant of the equation	Regression coefficients of			R^2	Marginal productivity of fertilizer input MP_{x1} (Rs.)
					$\text{Log}\frac{X_1}{A}$	$\text{Log}\frac{X_2}{A}$	$\text{Log}\frac{X_3}{A}$		
West Godavari	*Rabi* 1960-61	15	Y/A and X_3/A in maunds per acre and X_1/A and X_2/A in Rs. per acre	—0.3103	0.8089 (0.5093)	0.2450 (0.4133)		0.2305	
,,	,,	15	,,	—0.4506	0.3861* (0.1666)	0.1184 (0.1349)	0.7733* (0.0743)	0.9290	5.30
,,	*Rabi* 1961-62	15	,,	1.4431	0.2001 (0.1639)	—0.1244 (0.1672)	—	0.1384	—
,,	,,	15	,,	0.5584	0.1052 (0.0839)	—0.1510 (0.0842)	0.7681* (0.1273)	0.8000	1.45
,,	*Kharif* 1961-62	20	,,	1.5766	—0.0935 (0.1480)	0.0657 (0.1887)	—	0.0317	—
,,	,,	20	,,	0.0325	0.0946* (0.0436)	0.0240 (0.0530)	0.8931* (0.0621)	0.9283	1.35
,,	*Kharif* 1962-63	20	Y/A and X_3/A in quintals per acre and X_1/A and X_2/A in Rs. per acre	0.3734	—0.0793 (0.3053)	0.3924 (0.2837)	—	0.1172	—
,,	,,	20	,,	0.0763	0.0334 (0.0766)	0.0119 (0.0758)	0.9220* (0.0593)	0.9469	0.73

* Significant at 5 per cent level.
Note : Standard errors are given in parentheses.

We propose to adopt two of the approaches (mentioned in the general methodology) in order to measure the marginal productivity with respect to chemical fertilizers. In the production function approach, total output is made a function of total cost on chemical fertilizers (X_1), total cost on other inputes (X_2) and area (X_3). The elasticity coefficient (b_1) with respect to chemical fertilizers is positive and statistically significant in case of *Rabi* 1961-62. In case of *Rabi* 1961-62 one per cent increase in expenditure on chemical fertilizers will result on an average 0.64 per cent increase in physical output, when all other inputs are held constant. Value of the elasticity coefficients cannot be compared with the Farm Management study[3] of the district since the definitions of chosen variables,[4] coverage and time-period are different. Negative and insignificant coefficients are obtained for *Kharif* 1961-62 and *Kharif* 1962-63. This may have happened due to the presence of multicollinearity between area and cost of fertilizers, or soil differences between blocks. For *Kharif* 1961-62, the variance-covariance matrix of independent variables is nearly singular. In order to remove intercollinearity, we tried per acre logarithmic form.[5] The fertilizer elasticity coefficient turned out to be negative here again. On the assumption of constant returns to scale, we estimated the area elasticity coefficient which turns out to be 1.03.

The marginal productivity calculated in the per acre (linear form) function with respect to chemical fertilizers for *Rabi* 1960-61 and 1961-62 is Rs. 7.65 and Rs. 6.28 respectively. This is computed at mean values on the assumption that the price is Rs. 14 per maund or Rs. 33 per quintal for paddy. Such a high rate of return on chemical fertilizers is suspected on *a priori* grounds. The constant returns to scale appears to be prevalent in almost all the cases under the analysis. It may be that demonstration plots may be of the same size and hence the scale variation is small. The elasticity coefficients with other inputs and area are positive as expected. However, the area elasticity coefficient is statistically significant only in case of *Kharif* 1961-62. All the results obtained for total product form are subject to soil heterogeneity bias. This has been considered explicitly both in per acre linear (untransformed) form and per acre double logarithmic (transformed) form.

In per acre form, firstly, we adopt a simple linear relationship between output per acre and inputs per acre. As mentioned in the general methodology, we have used X_3/A as an explanatory variable in order to consider the varying fertility between different blocks. In each case, the regression with two variables (X_1/A and X_2/A) and three variables (including X_3/A also) are carried out. It has been found in all the cases that the variations in soil fertility represent-

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3. Studies in Economics of Farm Management in West Godavari District, Report for the Years 1957-58, 1958-59 and combined Report for the period 1957-58 to 1959-60.

4. In case of Farm Management Survey of the year 1957-58, A is the land in standardized units, X_1 is the human labour, X_2 is the capital (fixed investment) and X_3 is the production expenses including bullock labour ; while for 1958-59, bullock labour is separated from X_3 and is used as an independent variable. The number of observations are 67 and 70 for 1957-58 and 1958-59 respectively covering a wider area than IADP.

5. The production function is $\frac{P}{X_3} = C \left(\frac{X_1}{X_3}\right)^{b_1} \left(\frac{X_2}{X_3}\right)^{b_2}$. Multiplying by X_3, we get $P = C X_1^{b_1} X_2^{b_2} X_3^{1-b_1-b_2}$. We obtained $b_1 = -.093$ and $b_2 = .065$ which are statistically insignificant.

ed by the yield on controlled blocks improved R^2 significantly. The effect of X_3/A at times is significant on coefficients of both fertilizers per acre and other inputs per acre. In Table II the regression coefficient associated with yield on controlled blocks is highly significant in all cases. For *Rabi* 1960-61 and *Kharif* 1961-62, the marginal coefficient with respect to chemical fertilizers is positive and significant. One rupee increase in the expenditure on chemical fertilizers results in 0.34 maunds of additional output, giving the additional value of output as Rs. 4.84 for *Rabi* 1960-61; while one rupee invested in fertilizers yields Rs. 1.77 for *Kharif* 1961-62. Comparing the marginal coefficients with respect to chemical fertilizers for *Kharif* 1961-62 with *Kharif* 1962-63, we find that the rate of return is lower for the latter year. *Kharif* season is from 1st May to 15th October which are monsoon months. Rainfall deficit in 1962-63 may have led to lower output, hence a lower coefficient may have been obtained. Moreover, there is uncertainty with regard to the use of fertilizers during *Kharif* because output is dependent upon rainfall. During the *Kharif* 1962-63, however, as a result of the widespread natural calamities, there was a general decline in the level of yields in almost all the districts as compared to the previous year.[6]

For all cases, we have computed the rate of return on chemical fertilizers. It is found that the marginal rate of return is more than one rupee upto the year 1961-62 (*Rabi*) but in 1962-63 it is only Re. 0.35 per additional rupee invested. The additional return on chemical fertilizers is Rs. 4.84 in *Rabi* 1960-61. This implies that the chemical fertilizers are not used till the marginal return is one rupee and/or larger; reporting bias may have also yielded such results.

In per acre logarithmic form, we have obtained elasticity coefficients with respect to chemical fertilizers, other inputs and yield on controlled blocks. The results for two and three variable cases given in Table III indicates that the variations in yield on account of soil heterogeneity are significant. R^2 the total explanation, improved considerably with the inclusion of yield on controlled blocks as an independent variable. The net regression coefficient for chemical fertilizers (adjusted for soil heterogeneity) is found to be positive and significant for *Rabi* 1960-61 and *Kharif* 1961-62. The marginal productivities at mean values work out to be Rs. 5.30 and Rs. 1.35 for *Rabi* 1960-61 and *Kharif* 1961-62. These results are in agreement with those of untransformed form. For *Rabi* 1961-62 and *Kharif* 1962-63, the fertilizer elasticity coefficients are positive although insignificant. The elasticity coefficient with respect to yield on controlled blocks is highly significant in all cases.

THANJAVUR DISTRICT

This district is having alluvial soil and the main crop is paddy which accounts for 80 per cent of the total cropped area. Most of the paddy cultivation is under irrigated conditions. The average rainfall is 1410 millimetres per annum and monsoon months are from May to December. The amount of chemical fertilizers increased considerably during the last three years.

Three paddy crops are normally taken in the Thanjavur district. They are : *Kuruvai*, *Samba* and *Thaladi*. *Kuruvai* paddy accounts for 16 per cent, *Samba*

6. Notes—"IADP Outlook for 1963-64," *Agricultural Situation in India*, Annual Number, Vol. XVIII, No. 5, August, 1963.

for 68 per cent and *Thaladi* for 16 per cent of the total paddy area. Data for all these three crops are available for the period 1962-63 and 1963-64. We adopt the per acre production function approach and compute the marginal productivities of chemical fertilizers for each crop in different seasons. Our results are indicated in Table IV.

The results shown in Table IV indicate that the marginal productivity with respect to chemical fertilizers is Rs. 2.36 for *Kuruvai* season of 1962-63 and Rs. 2.46 for *Samba* season of 1962-63 and Re. 0.79 for *Samba* season of 1963-64. All other marginal productivity coefficients with respect to chemical fertilizers are statistically insignificant. The coefficient with respect to yield on controlled blocks per acre is statistically significant in all the cases. The year 1962-63 was an exceptionally good year for the Thanjavur district. The actual rainfall did not deviate much from normal. Actual rainfall figures together with the normal rainfall are shown below :

Year	Rainfall	
	Actual (in millimetres)	Normal
1960-61 ..	2603	1406
1961-62 ..	797	1406
1962-63 ..	1362	1406
1963-64 ..	2255	1406

During the first two paddy crops, the rainfall was just adequate. The year 1963-64 was a year of heavy rainfall. Consequently, the effect of fertilizers might have been washed out as the yield did not rise. Average expenditure on chemical fertilizers has remained almost the same. It can be seen from below :

AVERAGE EXPENDITURES ON CHEMICAL FERTILIZERS/ACRE

Year	Season	Rs.
1962-63 ..	.. *Kuruvai*	52.00
1962-63 ..	.. *Samba*	52.60
1962-63 ..	.. *Thaladi*	54.44
1963-64 ..	.. *Kuruvai*	49.40
1963-64 ..	.. *Samba*	48.00
1963-64 ..	.. *Thaladi*	48.00

TABLE IV—PADDY CROP : THANJAVUR

Model : $\frac{Y}{A} = a + b_1\left(\frac{X_1}{A}\right) + b_2\left(\frac{X_2}{A}\right) + b_3\left(\frac{X_3}{A}\right) + E$

Year	Season	Dependent variable	Coefficients with respect to independent variables			R^2	No. of observations	Marginal value product	Price of paddy (Rs.)
			X_1/A	X_2/A	X_3/A				
1962-63	*Kuruvai*	Y/A	2.3605 (.8274)	.2176 (.1506)	.9426* (.0854)	.8470	25	2.36	——
1962-63	*Samba*	Y/A	2.4610* (1.1075)	.3301 (.3211)	1.0447* (.1823)	.6913	22	2.46	——
1962-63	*Thaladi*	Y/A	.1418 (.9310)	—.1481 (.3930)	1.0111* (.1160)	.7837	25	.14	38.00 per quintal
1963-64	*Kuruvai*	Y/A	—.7320 (.8270)	—.3384 (.2730)	1.1029 (·1340)	.8023	24	—.73	32.65 per quintal
1963-64	*Samba*	Y/A	.7954* (.3770)	—.1185 (.3510)	1.4171 (.1810)	.7786	22	.79	37.33 per quintal
1963-64	*Thaladi*	Y/A	—.1703 (.6540)	.5535* (.2720)	1.0162* (.1450)	.7798	23	—.17	36.47 per quintal

Y/A Yield per acre in value terms (in Rs.) on demonstration block.
X_1/A Cost on chemical fertilizers per acre (in (Rs.).
X_2/A Cost on other inputs per acre (in Rs.).
X_3/A Yield per acre in value terms (in Rs.) on controlled blocks.

Our conclusion is that for the year when the rainfall was normal and adequate, the chemical fertilizers increased the yield significantly.

ALIGARH DISTRICT

This is the western district of Uttar Pradesh. The proportion of area irrigated in the district is the highest in the State. Canals, tube-wells and wells are the major sources of irrigation. It gets ample rainfall during the *Kharif* season. Rainfall averaging 830 millimetres is received mostly during the months of July and August. Seventy-eight per cent of the area is under food crops. Bajra and maize are the important food crops of the *Kharif* while barley, gram and pea dominate during the *Rabi* season. The consumption of nitrogenous fertilizers increased by 20 per cent during 1961-62 and further by 197 per cent during 1962-63. The bench-mark survey carried out by the IADP Expert Committee assessed that only 6 per cent of cultivators used fertilizers in each of the two main agricultural seasons. Their use was prevalent more among the large holders. About 18 per cent of large holders used fertilizers as against 3 per cent of cultivators in the size-group of very small holdings.

Two of the approaches outlined in the general methodology section have been adopted. Data on yield are available both for the demonstration and controlled blocks. Disaggregate cost of cultivation on controlled blocks and demonstration blocks are available for wheat crop of *Rabi* 1962-63 and 1963-64 and maize crop of the year 1962-63. Where such data are available, partial productivity is computed by taking the ratio of additional output over control to additional expenditure on chemical fertilizers: $\Sigma(Y/A—X_3/A)/\Sigma(X_1/A—X'_1/A)$. In the second approach per acre output on demonstrations is made a function of per acre cost on chemical fertilizers, per acre cost on other inputs and yield per acre on controlled blocks. The results of both the approaches are presented in Table V (A) and V (B).

In Table V(A), it is attempted to show the marginal value products with respect to chemical fertilizers. None of the coefficients with respect to chemical fertilizers and other inputs is statistically significant. Only the coefficient of the variable explaining differences in soil heterogeneity between blocks is statistically significant in all cases. The survey conducted by the Agro-Economic Research Centre, Delhi,[7] indicated that data for Aligarh were subject to large errors of observation. Reporting bias may be very high. In the year 1962-63, there was an excessive rainfall in Aligarh. The normal rainfall is 692 millimetres while the actual rainfall was 1306 millimetres, nearly double the normal. This implies that the effect of chemical fertilizers might have been washed out. In 1961-62, the recorded actual rainfall was 607 millimetres, which is near about normal. Our marginal value product of Re. 0.71 per rupee invested, although statistically insignificant, indicates a positive return.

In Table V(B), we have computed the ratio of additional value of yield over control to the additional cost over control on chemical fertilizers. Most of the additional expenditure is on chemical fertilizers. The expenditure on other inputs

7. Effectiveness of Crop Demonstrations—A Study of Wheat Demonstrations in Aligarh, U.P., Agricultural Economics Research Centre, Delhi, 1964 (mimeo.).

TABLE V(A)—ALIGARH : $\frac{Y}{A} = a + b_1 \left(\frac{X_1}{A}\right) + b_2 \left(\frac{X_2}{A}\right) + b_3 \cdot \left(X_3\right) + E_t$

Year	Crop	Season	Dependent variable	Coefficients with respect to independent variables			R^2	No. of observations	Price of crop (Rs.)
				X_1/A	X_2/A	X_3/A			
1961-62	Maize	*Kharif*	Y/A	.7155 (.8670)	.0733 (.3050)	.7633* (.3680)	.5232	13	12.50 per maund
1961-62	Wheat	*Rabi*	Y/A	—.0661 (3.5980)	—	.6987* (.3228)	.4268	14	—
1962-63	Maize	*Kharif*	Y/A	.2564 (.2832)	—	1.0166* (.2189)	.6518	15	30.50 per quintal

TABLE V(B)—PARTIAL PRODUCTIVITY RESULTS

Year	Crop	Season	$\frac{\Sigma\left(Y/A - X_3/A\right)}{\Sigma\left(X_1/A - X'_1/A\right)}$	Number of observations	Price of crop (Rs.)
1962-63	Wheat	*Rabi*	6.26	18	66 per quintal
1963-64	Wheat	*Rabi*	5.82	17	55 per quintal

* Significant at 5 per cent level.

over control is negligible in the IADP blocks. The ratio will indicate the additional value product which is around Rs. 6.26 for wheat crop of 1962-63 *Rabi* and Rs. 5.82 for wheat crop of 1963-64 *Rabi*. The actual price of wheat during these two years was Rs. 60 and Rs. 55 per quintal respectively. The average expenditure on chemical fertilizers for wheat crop during the years 1962-63 and 1963-64 was Rs. 28 and Rs. 34 respectively. It may be misleading to say that the rate of return on chemical fertilizers is Rs. 6 per additional rupee invested because this approach does not consider variations in output caused by only fertilizers. This is taken care of in the functional approach, results of which are shown in Table V(A). On account of the U.P. method of barley and wheat cultivation on demonstration blocks the yield might be very high. Secondly, the yield on controlled blocks does not actually take account of the varying local practices between blocks. The cultivator's practices do not correspond to the control as is generally kept in trials held in cultivators' fields to assess the impact of a practice or a combination of practices.

SHAHABAD DISTRICT

The major crop of Shahabad is paddy which accounts for 41 per cent of the total cropped area. The average yield per acre over the three-year periods 1957-58 to 1959-60 was 8.9 quintals per hectare. Fertilizers were used more widely during *Kharif* than *Rabi* season and their use was prevalent more or less to the same extent in the various size-groups of holdings. The average expenditure (per acre) on consumption of chemical fertilizers for paddy crop in 1962-63 (*Kharif*) was Rs. 66.20. With the introduction of Package Programme, the use of chemical fertilizers and improved techniques of using them may produce better result on the crop.

Data on demonstration and cultivators' blocks are available. On account of different crop variety other than BR-34, it was decided to eliminate three observations for 1962-63 paddy crop. For wheat and paddy of 1963-64 all observations are used. We have used per acre production function form in order to compute the rate of return on chemical fertilizers. The results are shown in Table VI.

For paddy crop of *Kharif* 1962-63, the coefficient with respect to chemical fertilizers is not statistically significant. The additional return on chemical fertilizers is Re. 0.86 per additional rupee invested. For *Rabi* 1963-64, the rate of return turns out to be Rs. 2.22 per additional rupee invested. Rainfall data for 1962-63 *Kharif* are not available. Probably, inadequate rainfall might have led to such a low rate of return on chemical fertilizers for paddy crop in the year 1962-63 *Kharif* as compared to 1963-64. For wheat crop, the results are not significant although the coefficient is positive with respect to chemical fertilizers.

LUDHIANA DISTRICT

This district is situated in the central part of Punjab and forms a part of Indo-Gangetic plain. The rainy season is from July to October and December to January. The average rainfall is 525 millimetres per annum. Fifty-eight per cent of the gross cropped area is irrigated. Wells and tube-wells are the most important sources of irrigation accounting for 80 per cent of the irrigated area. The

TABLE VI—SHAHABAD : $\frac{Y}{A} = a + b_1 \left(\frac{X_1}{A}\right) + b_2 \left(\frac{X_2}{A}\right) + b_3 \left(\frac{X_3}{A}\right) + E_t$

Year	Crop	Season	Dependent variable	Coefficients with respect to independent variables			R^2	No. of observations	Marginal value product	Price of crop (Rs.)
				X_1/A	X_2/A	X_3/A				
1962-63	Paddy	*Kharif*	Y/A	.0262 (.0185)	0.0272 (.0194)	1.4384* (.3606)	.7855	14	.86	33 per quintal
1963-64	Paddy	*Rabi*	Y/A	2.2222 (1.4450)	1.2471* (.6930)	1.4424* (.2560)	.7255	20	2.2222	—
1963-64	Wheat	*Rabi*	Y/A	.6042 (.8940)	—.1263 (.6650)	1.2266* (.4050)	.5009	18	.6042	55 per quintal

* Significant at 5 per cent level.

TABLE VII—SURAT: $\left(\frac{Y}{A} - \frac{Y'}{A}\right) = b_1 \left(\frac{X_1}{A} - \frac{X'_1}{A}\right) + b_2 \left(\frac{X_2}{A} - \frac{X'_2}{A}\right)$

Crop	Season	Year	Coefficient with respect to		R^2	Price of crop (Rs.)
			$\left(\frac{X_1}{A} - \frac{X'_1}{A}\right)$	$\left(\frac{X_2}{A} - \frac{X'_2}{A}\right)$		
Cotton	*Kharif*	1962-63	1.1470 (.6360)	.3043 (.6118)	.1805	—
Paddy	*Kharif*	1962-63	.6856 (1.5904)	—2.0466* (.8512)	.2212	35 per quintal
Wheat	*Rabi*	1962-63	.9109 (1.1150)	.0234 (1.8280)	.0430	62.30 per quintal
Wheat	*Rabi*	1963-64	1.2512 (1.9560)	—	.0248	74 per quintal
Groundnut	*Kharif*	1963-64	1.5255 (2.5692)	.4258 (.3453)	.1266	60 per quintal

All variables are measured from their means.
* Significant at 5 per cent level.

analysis of cropping pattern shows that 76 per cent of the gross cropped area is under foodgrains. *Rabi* is the important harvest season.

During *Kharif* 1961-62, 1390 composite demonstrations were laid out. The consumption of nitrogenous fertilizers went up sharply. Later, the crop-cutting experiments were conducted to assess the impact of the programme on yield rates. The high level of productivity attained by a significant number of cultivators and the wide variations between individual fields indicate the potentialities for raising the yield rate.

Data on demonstrations for all crops are obtained. Crop-wise observations are very few and meaningful results may not be obtained by fitting a productivity per acre relationship to six or seven observations. Hence, it was decided to take the value of output (of all crops) and the function was fitted to 36 observations. Data are also combined for both the seasons which may not be appropriate to do. However, this has been done in order to measure the marginal value product for all crops with respect to chemical fertilizers. Our fitted relationship turns out to be : (1961-62)

$$\frac{Y}{A} = \underset{(\cdot 4780)}{-\cdot 4446}\left(\frac{X_1}{A}\right) + \underset{(\cdot 1817)}{\cdot 4862}\left(\frac{X_2}{A}\right) + \underset{(\cdot 1051)}{1\cdot 1062}\left(\frac{X_3}{A}\right). \quad R^2 = .8119, \quad n = 36$$

(All variables are measured from their means)

The marginal value product with respect to chemical fertilizers is negative although statistically insignificant. Perhaps, the separate relationship for each season and crop might lead to meaningful results. However, this cannot be done as the number of observations are very few. Rainfall data indicated that 1961-62 was a normal year. The recorded actual rainfall in 1961-62 was 607 millimetres while the normal rainfall was 692 millimetres.

It may be stated that the response of chemical fertilizers on maize, wheat and many other crops is lower than that of paddy. Probably, the price of chemical fertilizers may be too high to obtain higher rate of return on chemical fertilizers in the districts growing mainly wheat, maize and other crops.

SURAT DISTRICT

This district is situated in the southern Gujarat and receives an annual rainfall of 1059 millimetres. Most of the rainfall is received during May to October. The percentage of net area irrigated to total net sown area of the district was 2.28 per cent in 1960-61. The Intensive Agricultural District Programme was started initially in 1962-63. The yield of paddy per acre by the Japanese method averaged 3,270 lbs. per acre. The extra yield obtained was 824 lbs. per acre. Net profit per acre on an average was Rs. 70.

Data on yield in value terms for demonstrations and controlled blocks are available. Disaggregate cost per acre data are also available for both controlled and demonstration blocks for five to six crops.

In the functional approach, additional yield over control is made a function of additional expenditure on chemical fertilizers over control and additional expenditure on other inputs over control. Results are shown in Table VII. R^2 is extremely low and therefore, most of the coefficients are statistically insignificant. For wheat crop of *Rabi* 1963-64 and *Rabi* 1962-63, the additional return on chemical fertilizers works out to be Rs. 1.25 and Re. 0.91 per additional rupee invested on chemical fertilizers over control. The lower coefficient for paddy crop of *Kharif* 1962-63 may be on account of scanty rainfall during that year. Actual rainfall in 1962-63 was 692 millimeters while the normal rainfall is 1059 millimeters in Surat. As paddy crop requires large quantity of rainfall, we might have obtained a lower return on chemical fertilizers for paddy as compared to cotton of the same year.

III

It may be worthwhile to mention the general limitations of the study and conclusions reached.

Limitations

(1) Data may be subject to large reporting and rounding-off (nearest to the fifth rupee) biases. The purpose of the IADP scheme to increase the agricultural production by promoting the use of chemical fertilizers may have led the investigators to over-emphasize the role of chemical fertilizers than it may be. However, the large errors of observation in reporting the use of chemical fertilizers could not be corrected. The direction and magnitudes remain unknown, so that its effect on yield cannot be examined. The recorded data regarding the expenditure on chemical fertilizers for a particular crop may not be the actual use of chemical fertilizers for that crop. Farmers might have used the chemical fertilizer for tobacco while the recorded expenditure may refer to paddy. This possibility severely brings down the rate of return for paddy.

(2) Rainfall effect cannot be considered as the block-wise data are not available. Inadequate rainfall results into poor crop both quantitatively and qualitatively. The years 1960-61 and 1962-63 were considered to be bad years for the country as a whole and the paddy yield between chosen blocks in a district may have been distorted. Residuals in per acre linear (untransformed) form (R^2 is higher in per acre linear form than in per acre double log form as found for West Godavari district) indicated that weather and/or other factors affected the output between blocks quite randomly. The direction and magnitude of residuals for IADP blocks between time-points are also random. However, it cannot be said conclusively that weather is the only factor affecting the yield between different blocks. It may be said on the basis of raw data and prior information of rainfall in the district that weather influences yield significantly. The different cultivation methods (Japanese method of paddy cultivation, U.P. method of wheat and barley cultivation and line-sowing method of cultivation) might be other important factors affecting the yield between blocks quite significantly.

(3) In this study, the interaction of soil and effect of fertilizer has not been considered. This is an important factor especially in the Thanjavur district where

certain demonstration plots failed to show results due to non-response of fertilizers used in alkaline or saline soils. Further, the response function is assumed to be linear.

Conclusion

(1) The inclusion of yield on controlled blocks as a proxy for the soil difference has improved the results considerably. In all the cases, the coefficient with respect to yield on controlled blocks is statistically significant. The correction factor for soil variability should be used on any study on IADP blocks.

(2) *Kharif* crops are dependent upon rainfall to a large extent. It is therefore necessary to examine the effect of excessive or scanty rainfall on the crop even in IADP blocks, where irrigation facilities are comparatively better. We have attempted to use the prior information of rainfall in explaining some of the results concerning the marginal value products. However, it is not possible to analyse the effect of scanty or excessive rainfall in lowering the yield between different blocks. It is suggested, here, that future reports on IADP should make an extensive examination of the effect of rainfall on crop. This will aid to establish the effectiveness of chemical fertilizers.

(3) For West Godavari district, our marginal rate of return was Rs. 5 approximately in *Rabi* 1960-61 while it was about Rs. 2 per additional rupee invested in *Rabi* 1961-62. For Thanjavur, the rate of return on paddy for *Samba* crop of 1962-63 was Rs. 2.46 per additional rupee invested while it was only Re. 0.79 per additional rupee invested for 1963-64 *Samba* crop. For paddy crop, the marginal value product is higher than that for wheat and other crops. Only in few cases, the marginal value product for fertilizers is statistically significant. It is very likely that the return on chemical fertilizers for crops like tobacco, sugarcane and cotton may be very high as compared to the food crops. Such a possibility combined with the errors in collection of data may have yielded statistically insignificant results.