Studies in Agricultural
Capital and Technology

Economics and Sociology
Occasional Paper No. 210

FERTILIZER RESPONSE FOR ANNUAL CROPS IN BRAZIL

by

Charles L. Wright
Richard L. Meyer
Joaquim Jose de Camargo Engler

November, 1974

Department of Agricultural Economics and Rural Sociology
The Ohio State University
2120 Fyffe Road
Columbus, Ohio 43210

FERTILIZER RESPONSE FOR ANNUAL CROPS IN BRAZIL

by

Charles L. Wright
Richard L. Meyer
Joaquim Jose de Camargo Engler*

Expansion of chemical fertilizer use has been a major part of Brazil's agricultural policy since 1966. Although fertilizer use has increased roughly four times since that date, average farm yields of annual crops which are the principle users of fertilizers have not shown dramatic increases. The present paper examines Brazil's fertilizer policy in light of research on empirical data from fertilizer experiments and surveys of farms in the Ribeirao Preto region of the State of Sao Paulo. This research suggests limited yield response to fertilizers and the need for additional agronomic research into the issue.

BRAZIL'S FERTILIZER POLICY

Large scale use of chemical fertilizers in Brazil is a relatively recent phenomenon. Historically, Brazil has expanded its agricultural production primarily by bringing new areas of land under cultivation. It has become one of the world's major producers of several agricultural

---

*Charles L. Wright is a Graduate Assistant and Richard L. Meyer an Associate Professor, Department of Agricultural Economics and Rural Sociology, The Ohio State University. Joaquim Jose de Camargo Engler is currently chairman of the Department of Rural Social Sciences, ESALQ-USP, Piracicaba, Brazil. Several topics discussed in this paper are treated in greater detail in Charles L. Wright, "Analise Economica de Adubacao em Culturas Anuais, Regiao de Ribeirao Preto, Ano Agricola 1971-72," M.S. Thesis, Departamento de Ciencias Sociais Rurais, ESALQ-USP, Piracicaba, 1973.

commodities by virtue of the sheer size of its cultivated area, in spite of comparatively low yields for most of its principal crops.

In the last decade, the need to increase yields has come to the forefront. On the supply side, there is a growing scarcity of good farm land with the gradual recession of the agricultural frontier, while the demand for agricultural products has expanded greatly as a result of rapid population growth, increasing real incomes and improved foreign markets. In 1972 and 1973, Brazil applied more stringent export controls in an effort to avoid large increases in domestic prices of food and industrial raw materials produced in agriculture. Thus, there are clear economic reasons for encouraging a shift from a traditional, extensive agriculture to a more modern and intensive pattern of cultivation.

In the mid-1960's, Brazilian policymakers began a conscious effort to accelerate this process through greater fertilizer production and use. The national fertilizer industry received subsidies and other support for its expansion. The importation of fertilizers was also encouraged through favorable exchange rates, duty and tax reductions, and special port and rail rates. These measures plus a decline in fertilizer prices on the international market resulted in a 35 percent reduction in the real price of fertilizer in Brazil between 1961 and 1969.[1/]

Fertilizers, however, continued to be relatively expensive in Brazil. In 1967, the wholesale price of nitrogen in Sao Paulo was 36 cents per kilogram (going up to 89 cents in some other states) compared with only 18 cents

---

1/ Otto Lohmann, Ltda., "The Brazilian Fertilizer Market, 1969," Sao Paulo: Otto Lohmann, 1970, Vol. 2 (Mimeograph), p. 76.

to 27 cents in many other countries.2/

Subsidized agricultural credit has been the chief means used to stimulate utilization of fertilizers, first in 1966 with the creation of FUNFERTIL (Fundo de Estimulo ao Uso de Fertilizantes e Suplementos Minerais) and since 1970 by its successor FUNDAG (Fundo Especial de Desenvolvimento Agricola). Through these funds, loans to farmers for fertilizer purchases were made at interest rates that were less than the rate of inflation resulting in negative real rates of interest. A zero nominal interest rate was charged under FUNFERTIL, while under FUNDAG farmers have paid a 7 percent annual nominal rate. Inflation, on the other hand, was approximately 38 percent at the beginning of this period and gradually fell to around 15 percent by 1972.

However, the influence of the FUNDAG program has been even greater than suggested by the subsidies. Following official guidelines aimed at expanding use of modern inputs, banks give preference in granting loans to farmers who adopt "integral finance plans" including the allocation of 15 percent of the loans for the purchase of "modern inputs." Loans to farmers who do not plan to use fertilizers, improved seeds, insecticides etc. have been restricted as part of governmental policy.3/ Such farmers have difficulty obtaining credit from the banking system. In fact, many banks will not make operating loans at all unless a minimum

---

2/Louis F. Herrmann, "Changes in Agricultural Production in Brazil, 1947-65," Washington: Economic Research Service, USDA, Foreign Agricultural Economic Report No. 79, 1972, p. 41.

3/Escritorio de Analise Economica e Politica Agricola (EAPA), "Identificao e Avaliacao Preliminar de Politica de Estimulos a Producao e Uso de Fertilizantes," Brasilia: Ministerio da Agricultura, Secretaria Geral, Subsecretaria de Planejamento e Orcamento, Primeiro Relatorio (segunda tiragem), 1972, pp. 1-46.

of 15 percent of the loan is spent on "modern inputs."4/

These subsidies are characterized by Smith as part of the recent Brazilian attempt to expand and modernize agriculture through reliance on market incentives.5/ From such a viewpoint, the success of an input subsidy depends on: (1) the input's elasticity with respect to lower prices; (2) the excess of marginal social productivity of the input over marginal social costs; and (3) a shift in the input demand function arising from experience with the input. Under favorable conditions, subsidies will increase the use of fertilizer, there will be a positive social payoff from its use and by discovering its benefits farmers will continue to use fertilizer when the subsidies are withdrawn.

Smith argues that these conditions were met in the 1950-66 period. The basis for such a conclusion is an estimated elasticity of total output of 0.04 with respect to fertilizer (as compared with 0.10-0.11 and 0.18 estimates for the U.S and Sweden, respectively, all with Cobb-Douglas functions) and the negative correlation of prices and quantities during the period. The demand function for fertilizers appeared to have shifted since purchases did not fall to their previous levels when prices increased substantially in the 1961-66 subperiod.6/

Such an analysis, however, cannot be easily applied to the post-1966 period, when subsidized credit for fertilizer users became widely avail-

---

4/Based on interviews conducted in banks in Piracicaba by Charles L. Wright and in the Ribeirao Preto region by Zezuea Pereira da Silva in 1973.

5/Gordon W. Smith, "Brazilian Agricultural Policy, 1950-1967," in H.S. Ellis, The Economy of Brazil, Berkeley and Los Angeles: University of California Press, 1969, p. 213.

6/Ibid, pp. 226-233. The estimated elasticity although positive indicates a low response to fertilizer for Brazilian crops.

able, resulting in a fourfold increase in purchases estimated at 1,278,000 metric tons in 1973.[7/] Prior to 1966, profit maximizing would have encouraged fertilizer use only if the value of increased yields exceeded the costs incurred with its application. Since 1966 farmers could have been encouraged to use uneconomic levels of fertilizer in order to obtain subsidized credit.

Chemical fertilizers have traditionally been used in large amounts on a few crops produced with a reasonably advanced agricultural technology: irrigated rice and wheat (Rio Grande do Sul), sugarcane (Sao Paulo and the Northeast), coffee, cotton, and vegetables (Sao Paulo).[8/] However, increased fertilizer consumption since 1966 has been due largely to an increase in the number of farms using fertilizer and the number of crops on which substantial amounts are applied. The financial costs of stimulating such increases are high both in terms of foreign exchange spent on imports (domestic production is only one-fifth of Brazil's consumption) and the cost of subsidies for agricultural loans (estimated at Cr. $52.9 million or about U.S. 9 million for 1971 alone).[9/]

Research and extension programs, however, have not kept pace with the resultant expansion in fertilizer sales. Very little soil mapping has been done and there has been almost no research on micro-nutrient soil deficiencies. There are few guidelines available as to what levels and types of fertilizer will bring best results for specific regions and crops. When agronomic studies have been made, economic issues are frequently neglected. The following section summarizes some of the most

---

7/Otto Lohmann, op. cit., Vol. 2, pp. 2-33.

8/Herrmann, op. cit., p. 41

9/EAPA, op. cit., pp. 17-22; p. 43.

relevant research on fertilizer response.

Experimental Fertilizer Response: A Brief Summary

Studies based on experimental data have given mixed results for fertilizer use in Brazil. An analysis of research findings compiled by Nelson showed the number of significant positive responses to fertilizers to be approximately the same as the number of null, insignificant or mixed responses.10/

Research by Knight indicated that nitrogen application on wheat and rice in Rio Grande do Sul resulted in only one-eighth to one-fourth the additional yields obtained on wheat in India and rice in the Philippines. The marginal products of phosphate and lime were positive, but there was no significant response to potash.11/ Lanzer also found positive but low responses to fertilizer and lime on wheat in Rio Grande do Sul with the marginal value product of lime inferior to the input's cost.12/

Economic analysis of experimental trials on corn in the Ribeirao Preto region of Sao Paulo led researchers to the conclusion that the variability in the results made it impossible to establish optimum application levels and that nitrogen was the only nutrient which could be

10/William C. Nelson, "An Economic Analysis of Fertilizer Utilization in Brazil," unpublished Ph.D. dissertation, Columbus (Ohio): The Ohio State University, 1971, p. 29.

11/Peter T. Knight, Brazilian Technology and Trade: A Study of Five Commodities, New York: Praeger Publishers, 1971, pp. 144-197.

12/Edgar A. Lanzer, "Analise Economica de Um Grupo de Experimentos de Fertilizacao e Calagem do Solo na Cultura do Trigo--Rio Grande do Sul," Porto Alegre: IEPE/FCE/UFRGS, 1970, pp. 101-104.

economically recommended. Other research showed that recommendations could be greatly altered by varying fertilizer and product prices.[13/]

Cotton research at the Instituto Agronomico de Campinas resulted in more optimistic fertilizer recommendations. Some experiments, however, used labor intensive application techniques which would probably be uneconomical at the farm level and in another set of trials, 148 of 320 tests could not be used for analysis due to extremely low yields or unacceptable variation coefficients.[14/]

Fertilizer response has been very low for peanuts and edible beans. Seven trials with peanuts produced only four cases of favorable response to nitrogen and phosphate, and only two for potash. Only one of four trials with lime was favorable. For edible beans, only 30 percent of 300 trials showed a favorable response to nitrogen, 50 percent for phosphate, and a mere 5 and 10 percent for potash and lime, respectively.[15/] For another major crop, coffee, extensive trials revealed positive but low response ratios.[16/]

13/Humberto de Campos, "Aspectos de Aplicacao das Superficies de Respostas a Ensaios Fatoriais 3^3 de Adubacao," Piracicaba: Departamento de Matematica e Estatistica, ESALQ/USP (tese de livre-docencia), 1967, p. 43; Sonia Vieira, et. al. "Estudo Comparative de Tres Funcoes na Analise Econometrica de Experimentos de Adubacao," Piracicaba: Convenio ESCO/MA/ESALQ/USP 1971, p. 35. H. de Campos. P.F.C. de Araujo and H.V. de Arruda, "Aspectos Economicos da Adubacao em milho," Agricultura em Sao Paulo, Ano XX, Tomos I e II, 1973, pp. 149-183.

14/Nelson Machado da Silva, "Estudo Preliminar do Emprego de Torta de Mamona Associada a Adubacao Mineral do Algodoeiro," Campinas: IAC, Projeto BNDE/ANDA/CIA, 1971, pp. 1-2; Milton Geraldo Fuzatto, et. al., "Estudo Tecnico-Economico da Adubacao do Algodoeiro no Estado de Sao Paulo," Campinas: Projeto BNDE/ANDA/CIA, 1970.

15/Euripedes Malavolta, em O Estado de Sao Paulo: Suplemento Agricola, Ano 19, No. 939, May 25, 1973, p. 3.

16/Herrmann, op. cit., p. 43.

Other research has shown that low physical response to fertilizers may make them uneconomical in regions of Brazil with unfavorable climatical conditions, given normal price relations. Frederick asserted that plant disease problems along the humid Northeastern coast (Zona da Mata) make sugarcane the only crop on which fertilizer can be profitably used, while the uncertain rainfall in the Northeastern interior also makes chemical fertilizers uneconomic.[17/]

These results suggest that although there are positive physical responses to fertilizer in many experiments, such responses are often small and extremely variable, raising doubts about the economic value of fertilization for a number of crops and areas in Brazil. One of the chief difficulties with interpreting these results is that the experimentation has not always been conducted in a highly structured and controlled manner, and there has been little interaction between agronomists and economists to obtain necessary data for economic research.[18/] Little research has been done on yield response under actual farming conditions in order to determine the extent to which the lack of control over other production factors reduces the impact of fertilization.

Farm Level Fertilizer Response

Two recent studies have investigated the use of and response to fertilizers on the farm level in one of Brazil's most modern agricultural

---

17/Kenneth D. Frederick, "Revolution Red or Green: An Examination of the Rural Northeast," unpublished manuscript prepared for USAID, 1971, pp. 4-22.

18/Campos, et. al., op. cit., p. 149.

areas: the Ribeirao Preto region of the State of Sao Paulo. The farms in the municipios (counties) included in the survey have some of Brazil's best soil (latosol roxo or purple latosol being the principle type), are highly mechanized and specialize in annual crops. Both studies used data based on interviews from a random stratified sample of farmers in the region. The first study was undertaken by Nelson with data on the 1969/70 agricultural year for 174 farms.[19/] The second study, by the authors of the present paper, used data collected for the 1971/72 agricultural year from 120 of the same farms.

1969/70 Agricultural Year

Nelson used Cobb-Douglas and quadratic functions to test physical response to fertilizer on four annual crops: corn, cotton, dryland rice and soybeans. He concluded that although the farmers were using less fertilizer than recommended by area agencies, they were using excessive amounts from an economic point of view, since the marginal value products were less than the costs of the nutrients. Nelson raised the hypothesis that the results could have been caused by a negative response to nitrogen, and suggested that there might be a critical minimum level of application necessary for good fertilizer response.[20/]

1971/72 Agricultural Year

The second study tended to support Nelson's general conclusion of a lack of fertilizer response but differed on a number of specific points.

19/Nelson, op. cit.

20/Nelson, op. cit., p. 95, pp. 255-293.

For the 1971/72 agricultural year, all the sample farms used fertilizer on cotton and soybeans, while only two farmers did not fertilize corn. Two-thirds of the sample farmers fertilized rice, but the weighted average of rice yields on unfertilized plots was actually higher than on those farms where fertilizer was used. Fertilizer, however was not always used in conjunction with soil analysis and liming. Only a third of the farmers ran soil tests within the two preceding years and only two-thirds used lime within the last five years.

There was little variation in the fertilizer formulas used on the sample farms. The most common were 3-15-15 and 4-14-8. The principal difference among formulas used was in their potash content.

Levels of fertilizer use in the 1969/70 and 1971/72 agricultural years are shown in Table 1 for the sample farms, as well as the recommendations for the State of Sao Paulo. Current usage is above the minimum statewide recommendations (made for "new soils") for all crops except rice. For this crop, the farmers that used fertilizer applied it at levels near the minimum recommendations. These averages, however, are only about 50 percent of the quantity recommended for "medium" and "tired" soils as well as the levels frequently suggested from experimental data. Fertilizer use in this region is relatively high for all crops in comparison with general Brazilian levels, but with the exception of soybeans is considerably below that commonly used in other countries.

The changes in general levels of use between the two years studied are consistent with expectations based on Nelson's conclusion that aggregate fertilizer use was excessive for maximum profit. Average fertilizer use was reduced for three of the crops with a substantial reduction for soybeans (25 percent). The exception was a 15 percent increase in fertilizer applications on corn. It is interesting to note that between the two years, average yields went down for corn and up for soybeans. Rainfall in both years was adequate and well spaced throughout the growing season.

The fact that farmers increased their use of nitrogen for corn, cotton and rice between the two years, and reduced it for soybeans is not consistent with Nelson's hypothesis that the marginal value product of nitrogen was negative for all crops except soybeans. From an agronomic standpoint, it seems unlikely that the low rates of nitrogen application on corn, rice and soybeans would have any significant effect on yields. Farmers reduced phosphate usage in relation to potash and this change may be considered technically advisable since there may be some potash deficiencies in latosol roxo soils while their high iron and aluminum content may result in phosphate fixation.

Cobb-Douglas and quadratic functions were used to evaluate factors affecting yields for the four crops. In general, the Cobb-Douglas function is better adapted to the analysis of multiple inputs, including labor and capital.[21/] The quadratic model, however, provides a better mathematical description of the commonly accepted biological relationship between crop response and fertilization, since it can have a non-zero intercept and

---

21/ The Cobb-Douglas function was also used to test if location, soil testing, the time of fertilizer application and other variables not analyzed in this paper had significant effects on productivity. The estimated coefficients were not statistically different from zero. See Charles L. Wright, op. cit. pp. 73-153.

TABLE 1

Recommended and Actual Use of Fertilizer--1969/70 and 1971/72 Agricultural Years

Nutrient and Crop	Recommendation a/	Level Used on Sample Farms		Usage in 1971/72 as a Percent of Recommendation	
		1969/70 b/	1971/72 c/	Minimum	Maximum
	(Kilograms per Hectare)			(Percent)	
Corn					
(1) N	9-71	14	17	191	25
(2) P	45-90	33	36	80	40
(3) K	9-18	21	25	273	136
Total	63-179	68	78	124	44
Cotton					
(1) N	12-66	18	33	279	51
(2) P	60-120	76	54	90	45
(3) K	12-120	47	50	417	42
Total	84-306	141	138	164	45
Rice d/					
(1) N	12	7	10	83	--
(2) P	60	31	24	41	--
(3) K	12	13	15	128	--
Total	84	51	50	59	--
Soybeans					
(1) N	9-12	9	6	64	48
(2) P	45-60	46	39	87	66
(3) K	9-60	33	21	236	36
Total	63-132	88	67	105	50

a/ ANDA, Manual de Adubacao, Sao Paulo: Editora Ave Maria, Ltda., 1971, pp. 176-183. Maximum recommendations include side dressing. Here and throughout the paper "nutrients" refer to N, P as P_2O_5 and K as K_2O.

b/ Nelson, op. cit., p. 59. Numbers rounded to nearest integer.

c/ Mean of the rates of application on the sample farms including the cases of zero usage for rice. Numbers rounded to nearest integer.

d/ No maximum recommendation for dryland rice, the type encountered in the region.

is capable of representing the second and third stages of production[22/]

Due to the limited variation in formulas and resulting multicolinearity, an attempt to analyze yield response to individual fertilizer nutrients was discarded. Placing the highly correlated nutrient variables N, P, and K in the same regression produced large and opposite errors in the estimation of the parameters.[23/] Typically, two of the estimated coefficients and "t" tests would have approximately the same magnitudes but opposite to the estimated coefficient with the largest absolute value.[24/] Since levels of fertilization varied widely, however, regressions were used to test yield responses to aggregate fertilizer use and to lime applications.

Cobb-Douglas Function[25/]

The variables were defined as follows for the Cobb-Douglas function:

Y = Yield in units of 60 kg/alqueire for corn, rice and soybeans, and 15 kg/alqueire for cotton (alqueire = 2.42 hectares).

X_1 = Number of alqueires of land in the specific crop. This variable was included to permit evaluation of associations

---

22/For a more complete description of these models, see Charles L. Wright, op. cit. pp. 74-78.

23/Such results in the presence of high multicolinearity are described by J. Johnston, Econometric Methods, New York: McGraw-Hill Book Company, 1972 (2nd edition), pp. 160-169.

24/The negative coefficients for nitrogen obtained by Nelson may have been due to similar problems. Correctly constructed one-tailed tests of the hypothesis would, of course, eliminate any possibility of accepting the significance of such estimates.

25/The Cobb-Douglas functions used here have fewer, and in some cases slightly different variables than those reported in Wright, op. cit. The results are essentially the same for all functions used.

between yields and farm size or specialization.

X_2 = Man-days of labor used per alqueire on the specific crop.

X_3 = Number of kilograms of lime applied per alqueire.

X_4 = Number of kilograms of nutrients (N, P_2O_5 and K_2O applied per alqueire`,

X_5 = Cruzeiros of capital per alqueire. This variable includes actual expenditures on seed, insecticides etc., plus 12% of machinery inventories.

All variables except (X_1) were hypothesized to have positive effects on yields. One tailed "t" tests were therefore used for X_2 + X_5 and a two tailed "t" test for X_1.

The results are given in Table 1. The "F" test for the regressions was significant only in the case of cotton. The adjusted coefficient of determination ($\overline{R}^2$) is low for corn and cotton, and negative for rice and soybeans. The estimated coefficient for X_4 was not significant in any case. Capital is the only variable whose estimate was statistically significantfor more than one crop (corn and cotton).

Quadratic Functions

Several formulations of the quadratic function were used to carefully test yield response to fertilizers, and insecticides. The results for the Cobb-Douglas model suggested that ignoring other variables should not introduce significant bias, except in the possible case of cotton. For these regressions, the variables were defined as follows:

Y = Yield in units of 60 Kg/alqueire for corn, rice and soybeans, and 15 Kg/alqueire for cotton (alqueire = 2.42 hectares).

TABLE 2

Cobb-Douglas Regression Estimates for 4 Annual Crops. Jardinopolis and Guaira, 1971/72 Agricultural Year

Estimates of Parameters ("t" tests in parentheses)								
Parameter	Corn		Cotton		Rice		Soybeans	
A (constant)	1.26	(5.00)	0.225	(0.39)	1.34	(4.25)	1.66	(0.81)
b_1	0.044	(1.07)	0.129	(2.12)*	0.010	(-0.14)	0.066	(0.96)
b_2	0.109	(1.40)	0.317	(2.53)*	-0.034	(-0.39)	-0.045	(-0.50)
b_3	0.015	(0.97)	0.007	(0.42)	-0.035	(-1.13)	0.009	(0.62)
b_4	0.032	(0.52)	0.044	(0.27)	0.031	(1.07)	0.074	(0.57)
b_5	0.187	(2.04)	0.428	(2.82)*	0.149	(1.35)	-0.011	(-0.06)
R^2	0.16		0.37		0.08		0.06	
$\bar{R}^2$	0.09		0.28		-0.02		-0.10	
F	2.22		4.33 *		0.78		0.38	
N	66		43		53		34	

* denotes significance at .05 level

X_1 = Kilograms of lime applied per alqueire at the beginning of the agricultural year.

X_2 = X_1^2

X_3 = Estimate of the cumulative affect of lime applied over time, with linear depreciation over five years (Kg/alq).

X_4 = X_3^2

X_5 = Total number of kilograms of nutrients (N, P_2O_5 and K_2O applied per alqueire).

X_6 = X_5^2

X_7 = X_1X_5

X_8 = X_3X_5

X_9 = Cruzeiros of insecticides applied per alquire.

X_{10} = X_9^2

X_1 and X_2 were not put in the same models with X_3 and X_4 since they are alternate measures for lime (the same holds for the interaction terms X_7 and X_8).

Lime was included as a variable to test both its direct effect as a macro-nutrient (Ca) and its indirect effect through reduction of soil acidity. The variables for insecticides (X_9 and X_{10}) were included only for cotton. Although insecticides are not directly productive, they may result in increased output by reducing insect damage. If output is greater on farms using more insecticides because of decreased losses, this input may be considered to have a positive "marginal product."

Due to the characteristics of the quadratic function and the postulated nature of the biological phenomena under study, right-sided one-tailed "t" tests were used for the linear and interaction terms (X_1, X_3, X_5, X_7, X_8, X_9) and left-sided one-tailed tests for the quadratic terms

(X_2, X_4, X_6, and X_{10}).

The results of the regressions are presented in Table 2 through 5. The $\bar{R}^2$ values were quite low or even negative and many of the "F" tests for the regressions are not significant at the 5 percent level. Estimates of coefficients for fertilizers were not significant at the 10 percent level in any regression and they frequently had signs opposite from those expected.

In the cases of corn and soybeans, a significant coefficient was obtained for lime, but the interaction term between lime and fertilizer had a negative coefficient. This may be due to high correlation between these variables which would tend to force the estimates of the coefficients (also the numerators of the "t" tests) in opposite directions. In both cases, the linear coefficient estimate for fertilizers had a negative value.

Thus, the hypothesis that fertilizer did not increase productivity on farms surveyed for the 1971/72 agricultural year cannot be rejected. Inability to reject the null hypothesis does not mean that response to fertilizer is actually zero. There may be a residual effect of increasing or maintaining soil fertility over time, or some differential effect on productivity which may have been hidden by variations in soil fertility or other factors which the regressions did not pick up.

CONCLUSIONS

These results need to be interpreted with considerable caution. A more detailed study of farm level yield response to fertilizer is required before definite conclusions can be drawn. Such a study should carefully account for initial soil fertility; rainfall during the growing season; variety and quantity of seed; formulas, quantity, timing and method of fertilizer application; and careful measurement of yields.

TABLE 3

Quadratic Function Regressions for Corn. Jardinopolis and Guaira--
1971/72 Agricultural Year

Parameter	Estimates ("t" Tests in Parentheses)				
	Model 1	Model 2	Model 3	Model 4	Model 5
b_o[a/]	94.01	88.76	92.26	92.45	93.33
b_1	0.023846 (1.92)**	0.013301 (1.34)*	---	---	---
b_2	-0.000002 (-1.10)	-0.000002 (-1.01)	---	---	---
b_3	---	---	0.004936 (0.75)	0.001281 (0.22)	---
b_4	---	---	0.000000 (0.43)	-0.000000 (-0.13)	---
b_5	-0.197750 (-1.04)	-0.071834 (-0.42)	-0.180413 (-0.98)	-0.112598 (-0.65)	-0.107210 (-0.64)
b_6	0.000846 (1.65)	0.000408 (1.00)	0.000884 (1.70)	0.000540 (1.28)	0.000533 (1.34)
b_7	-0.000047 (-1.39)	---	---	---	---
b_8	---	---	-0.000033 (-1.12)	---	---
N	66	66	66	66	66
R^2	0.1652	0.1382	0.1228	0.1043	0.1031
$\bar{R}^2$	0.0957	0.0818	0.0498	0.0457	0.0747
F	2,3747**	2.4456**	1.6802	1.7763	3.6212**

a/ Yields in units of 60 Kg/alqueire (one alqueire = 2.42 ha.).

** Significant at .05 level for the specified one-tailed "t" tests and the "F" tests.

* Significant at .10 level for the specified one-tailed "t" tests.

TABLE 4

Quadratic Function Regressions for Cotton. Jardinopolis and Guaira--
1971/72 Agricultural Year

Parameter	Estimates of Parameters ("t" Tests in Parentheses)				
	Model 1	Model 2	Model 3	Model 4	Model 5
b_o [a/]	136.20	151.96	146.78	146.64	176.63
b_1	-0.021404 (-1.01)	0.006091 (0.51)	---	---	---
b_2	-0.000001 (-1.28)	-0.000000 (-0.54)	---	---	---
b_3	---	---	0.004539 (0.28	0.008326 (0.97)	---
b_4	---	---	-0.000001 (-0.86)	-0.000000 (0.82)	---
b_5	0.160818 (0.44)	-0.061837 (-0.18)	-0.053432 (-0.15)	-0.086597 (-0.26)	0.038181 (0.11)
b_6	-0.000323 (-0.64)	0.000177 (0.45)	0.000110 (0.22)	0.000201 (0.54)	0.000132 (0.33)
b_7	0.000088 (1.54)*	---	---	---	---
b_8	---	---	0.000012 (0.27)	---	---
b_9	0.134286 (1.11)	0.123122 (1.00)	0.122240 (0.99)	0.123515 (1.01)	---
b_{10}	0.000011 (0.13)	0.000017 (0.19)	0.000016 (0.17)	0.000012 (0.13)	---
N	43	43	43	43	43
R^2	0.3308	0.2849	0.2992	0.2976	0.0557
$\bar{R}^2$	0.1970	0.1658	0.1591	0.1806	0.0085
F	2.4716**	2.3906**	2.1350	2.5432**	1.1806

a/ Yields in units of 15 Kg/alqueire (one alqueire = 2.42 ha.).
** Significant at .05 level for the specified one-tailed "t" tests and the "F" tests
* Significant at .10 level for the specified one-tailed "t" tests

TABLE 5

Quadratic Function Regressions for Rice. Jardinopolis and Guaira--
1971/72 Agricultural Year

Parameter	Estimates of Parameters ("t" Tests in Parentheses)				
	Model 1	Model 2	Model 3	Model 4	Model 5
b_o a/	65.56	65.04	66.58	60.22	63.81
b_1	-0.002457	0.001306	---	---	---
	(-0.11)	(0.07)			
b_2	-0.000001	-0.000001	---	---	---
	(-0.24)	(-0.30)			
b_3	---	---	0.002285	0.010022	---
			(0.23)	(1.18)	
b_4	---	---	-0.000001	-0.000002	---
			(-0.72)	(-1.06)	
b_5	0.075606	0.082183	-0.033589	0.057652	0.080058
	(0.95)	(1.08)	(-0.33)	(0.74)	(1.06)
b_6	-0.000066	-0.000075	0.000057	-0.000036	-0.000068
	(-0.54)	(-0.63)	(0.42)	(-0.29)	(-0.58)
b_7	0.000029	---	---	---	---
	(0.35)				
b_8	---	---	0.000060	---	---
			(1.44)*		
N	53	53	53	53	53
R^2	0.0588	0.0563	0.1041	0.0642	0.0364
$\bar{R}^2$	-0.0412	-0.0223	0.0089	-0.0137	-0.0021
F	0.5883	0.7171	1.0927	0.8239	0.8464

a/ Yields in units of 60 Kg/alqueire (one alqueire = 2.42 ha.)
* Significant at .10 level for the specified one-tailed "t" tests.

TABLE 6

Quadratic Function Regressions for Soybeans. Jardinopolis and Guaira--
1971/72 Agricultural Year

Parameter	Estimates of Parameters ("t" Tests in Parentheses)				
	Model 1	Model 2	Model 3	Model 4	Model 5
b_o a/	79.82	95.39	59.82	96.30	97.87
b_1	0.015744 (2.25)**	0.006024 (0.99)	---	---	---
b_2	-0.000001 (-1.28)	-0.000001 (-1.12)	---	---	---
b_3	---	---	0.019206 (2.84)**	0.003915 (0.94)	---
b_4	---	---	-0.000001 (-2.36)**	-0.000001 (-1.07)	---
b_5	-0.337674 (-1.55)	-0.450598 (-1.97)	-0.252328 (-1.11)	-0.510498 (-2.25)	-0.488705 (-2.21)
b_6	0.001404 (2.35)	0.001481 (2.31)	0.001357 (2.33)	0.001673 (2.66)	0.001615 (2.62)
b_7	-0.000061 (-2.33)	---	---	---	---
b_8	---	---	-0.000068 (-2.71)	---	---
N	34	34	34	34	34
R^2	0.3857	0.2659	0.4152	0.2611	0.2314
$\bar{R}^2$	0.2761	0.1647	0.3109	0.1593	0.1819
F	3.5166**	2.6267	3.9765**	2.5626	4.6679**

a/ Yields in units of 60 Kg/alqueire (one alqueire = 2.42 ha.)
** Significant at .05 level for the specified one-tailed "t" tests and the "F" tests.

There are several logical explanations, however, as to why these farm level results may correctly identify a problem of low yield response to fertilizer on annual crops in Brazil. First, some seed varieties created in Brazil have been developed for high levels of production on unfertilized land and as such they may not respond well to fertilizer. Secondly, timing and method of application are important as demonstrated by experimentation in other countries. Thirdly, farmers may have been encouraged to use inappropriate levels or formulas in the absence of soil analysis to identify recommended usage for specific farm needs. Fourthly, the present levels of nitrogen application may not be sufficient if heavy rainfall and the porous soils in the region cause rapid leaching of nutrients. Fifth, the absence of crucial micro-nutrients may reduce the effect of macro-nutrient application. Sixth, the frequently alleged poor quality of fertilizer and wide ranges in actual nutrient content of mixed fertilizers may explain low response in some cases. Finally, soil analysis as presently conducted may not provide accurate recommendations on quantity and nutrient content of fertilizers.

These results suggest that past evaluations of fertilizer policies may have overestimated the benefits. The economic implications are obvious. Farmers should be encouraged to use only that amount of fertilizer which is actually economic for their conditions. Credit resources are scarce and should not be used to stimulate farmers to adopt uneconomic quantities or formulas of fertilizer. Recent increases in fertilizer prices make the problem even more acute.

Brazil may eventually decrease its dependency on imports as new plants come into production, but fertilizers will only become an important element in increasing agricultural production if yield response is improved for major annual crops. For a country of such size and heterogeneous production conditions, this is a difficult task. Yet carefully controlled agronomic research could produce a greater long term payoff than subsidies to stimulate fertilizer production and use.