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Fertilizer Use and Agricultural Development in Brazil

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During the past eight years a number of different policies have been used to stimulate Brazilian agricultural growth. One important set of policies has been aimed at sharply expanding the use of chemical fertilizers. This has included the building of fertilizer plants, an expansion in fertilizer marketing facilities, promotion of fertilizer use by extension services, and providing substantial amounts of credit for fertilizer purchases at concessional interest rates. The net result of these policies has been a sharp expansion in the use of chemical fertilizer, especially in the southern part of the country. Surprisingly little research, however, has been done on this subject at the farm level. Little information is available in Brazil as to the characteristics of farmers who do or do not use fertilizer, their intensity of fertilizer use, and the profitability of chemical fertilizer application. Even more important, little is known about the extent towhich current fertilizer users are

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efficiently applying plant nutrients.

The following discussion attempts to shed some empirical light on these issues. The discussion begins with a brief summary of recent agricultural policy in Brazil, especially those segments of policy which have affected fertilizer use. This is followed by information on the productivity of fertilizer use in Brazil derived from experimental research, secondary sources reporting on farm level use of fertilizer, and farm level interviews carried out by the authors in the Ribeirao Preto, Sao Paulo region. The paper concludes with some suggestions for policy consideration as well as topics for future research.

Agricultural Policy and Fertilizer Use

Brazil, probably as much as any other country, has relied on price incentives, fiscal policy, and credit programs to stimulate agricultural production. In large part this has been aimed at inducing farmers to apply new technology (6, p. 17). It has been widely assumed that high payoff technologies were available, and that once farmers were introduced to these technologies they will forsake traditional methods of production.

Fertilizer policies have followed this overall pattern very closely. It has been generally assumed that fertilizer use is highly profitable to the farmer, but that some special incentives must be given to initiate the adoption process. Some of the policies have been

Table 1

Fertilizer Use and Manufacture in Brazil
1950-1970

Year	Metric Tons (1,000)	Percent Imported Into Brazil
1950	88.5	85
1952	72.8	77
1954	123.5	89
1956	165.3	85
1958	249.7	77
1960	298.7	65
1962	236.8	59
1964	255.4	58
1966	281.1	68
1968	601.7	78
1970	820.0	80

Source: Nelson, William C., "An Economic Analysis of Fertilizer Utilization in Brazil," unpublished PhD dissertation, Department of Agricultural Economics and Rural Sociology, The Ohio State University, 1971, pp. 206-210.

favored the importation of resources for agricultural production. Fertilizer was imported free from direct duties at a favorable exchange rate. After August, 1957, domestic fertilizer producers were subsidized. From 1950 to 1960, fertilizer consumption grew at an annual rate of approximately 15 percent and the use of fertilizer per hectare doubled. As can be noted in Table 1, total consumption nearly reached 300,000 tons in 1960.

Policies, modified in 1961, led to a decline in fertilizer use. The subsidy to national manufacturers was suspended and the profitability of fertilizer use declined due to unfavorable product price tendencies and a marked decline in availability of agricultural credit (in real terms). Fertilizer use fell to 80 percent of its 1960 level by 1962 and did not again reach the 1960 figure until 1966. The continued increase in cultivated area reduced consumption per hectare in 1966 to 75 percent of the 1960 level. It is estimated that only 5 percent of Brazilian farmers used chemical fertilizer in 1964 (2, pp. 65-185).

There was a rapid expansion in fertilizer use after 1966 when credit and product pricing policies were adjusted. Fertilizer use doubled by 1968 and nearly tripled by 1970 to 820,000 tons (3). Fertilizer use per cultivated hectare advanced to 18 kilograms in 1968, and by 1970 average use in Sao Paulo rose above 50 kilograms of nutrients per hectare.

Over the years relative fertilizer prices appear to be closely related to fertilizer use trends. The relative fertilizer price gradually decreased during the 1950's. The ratio of the fertilizer price index to the product price index (1948-52 = 100) decreased from 0.86 in 1950 to 0.67 in 1959, then rose to 1.66 in 1965. In 1967 it fell to 1.14 and has averaged 1.01 from 1968 to 1970 (7).

Credit policies also appear to be closely related to fertilizer use. This has had two dimensions: interest rates as well as amount of credit available. Throughout the last two decades Brazil has maintained nominal interest rates on institutional rural credit which were lower than the rates of inflation. In an economic sense agricultural credit borrowers were subsidized to use credit through these negative real rates of interest. Beginning in 1966 a special fertilizer program was set up which offered credit at zero nominal rates of interest, FUNFERTIL (Fundo do Estimulo Financeiro ao Uso de Fertilizantes e Suplementos Minerais). In 1968 FUNFERTIL financed 40 percent of the national use. In 1970 a new credit program, FUNDAG (Fundo Especial de Desenvolvimento Agricola), replaced FUNFERTIL. It provided concessional nominal interest rates of 7 percent for rural credit used to buy modern inputs, including fertilizer. This rate was well below the 12-18 percent charged for regular agricultural credit.

In addition to providing strong incentive for fertilizer use through concessional interest rates, Brazil also sharply increased the overall availability of institutional agricultural credit during the 1960's. The real value of the institutional agricultural credit portfolio more than quadrupled from 1960 to 1970 (1, p. 50) This huge increase in credit availability plus the very attractive interest rates appear to have been key factors in stimulating fertilizer use.

Previous Research on Fertilizer Response

As was already pointed out, Brazilian fertilizer policy was built on the assumption that fertilizer use at the farm level is highly profitable. Policy makers have concluded that the recent rapid increase in fertilizer use is proof of this assumption. In the following, data from several different sources are presented which indicate that this conclusion may not be well founded.

A significant number of researchers in Brazil have treated fertilizer response questions. Crop and soils specialists have tested various seed varieties, soil types, levels of fertilization and application techniques. These research activities, however, have tended to be fragmented, carried out on very small scale, often lacked an economic interpretation, and have not been integrated into any overall research design. Only a handful of studies have addressed the question of the economies of fertilizer use under

actual farming conditions. The results of the most prominent and recent of these studies in Brazil are summarized in Table 2.

Although only very crude measures are used in Table 2, an overview of the results suggest conclusions contrary to policy makers expectations. It appears that in some cases plant nutrients did not produce a clear positive yield response. In other cases, although the fertilizer response was positive, it frequently was not sufficient to generate an increase in net farm income. In the few cases where the profit maximization level of fertilizer use was calculated, the level was generally low in comparison with those experienced in other more developed countries. Especially perplexing were the mixed results reported for the use of nitrogen. Several of the studies showed negative or insignificant production responses to nitrogen use even at relatively low levels of application (8, 9).

Too little research has been done on fertilizer response in Brazil to justify drawing firm, broad policy conclusions. It is apparent, however, that two important questions at the farm level need to be addressed by research: (1) are the marginal products of various fertilizer nutrients positive at present levels of use? and (2) are there strong economic justifications for farmers who are currently using fertilizer to expand their usage?

Table 2. Summary of recent findings on fertilizer response research.

Research Source	Location of Research	Crop	Crop Response to [a]			
			Nitrogen	Phosphate	Potash	Total
Agri-Research	Sao Paulo	Corn	±	+	+	
		Cotton	±	+	+	
		Rice		+		
		Soybeans	+	+		
Steitieh	Rio Grande do Sul	All Crops				0
Frederick	N. E. Brazil	Sugar Cane				+
		Other Crops				0
Fuzetto	Sao Paulo	Cotton	±	±	±	
Knight	Rio Grande do Sul	Rice	+	+	0	
		Wheat	±	±	0	
		Corn	+	0	0	

TABLE 2--Continued

Research Source	Location of Research	Crop	Crop Response to:[a]			
			Nitrogen	Phosphate	Potash	Total
Santos	Minas Gerais	Corn	+	+	0	
Streeter	Rio Grande do Sul	Soybeans		+		
		Wheat		+		
Vieira	Sao Paulo	Corn	+	0	0	
Lanzer	Rio Grande do Sul	Wheat	+	+	+	

[a]Positive response to fertilizer is signified by +, insignificant or no response by 0 and mixed responses by $\pm$.

Source: Nelson, William C., "An Economic Analysis of Fertilizer Utilization in Brazil", unpublished PhD. dissertation, Department of Agricultural Economics and Rural Sociology, Ohio State University, 1971, p. 29; and Lanzer, E. A., "Analise Economica de Um Grupo de Equipamentos de Fertilizacao e Calagem do Solo na Cultura do Trigo-Rio Grande do Sul," unpublished M.S. thesis, Porto Alegre, 1970.

A Study of Fertilizer Productivity at the Farm Level

Additional light on these questions was provided by a study of 383 farmers in municipios (counties) in the Ribeirao Preto region, state of Sao Paulo, carried out by the authors in July of 1970.[1] This region was selected because of the production of a variety of annual crops, a high percent of crops marketed, extensive use of fertilizer and credit, progressive nature of the farmers and a highly developed infrastructure. In many respects this is one of the best agricultural regions in Brazil. It was presumed that the farmers would be well advanced in the fertilizer adoption process and that it would be possible to estimate reliable production functions from this farm data.

Characteristics of Sample

Each farm in the sample was chosen randomly from the list of farms assembled by IBRA (Instituto Brasileiro de Reforma Agraria), and subjected to the following criteria: (1) the farm contained from 10 to 3,000 hectares, (2) more than 50% of the farm land was operated in crop production or forage; (3) more than 50% of the operated land was used in the production of annual crops, sugar cane, coffee or beef cattle, and (4) more than 50% of the land was operated by the owner. The farm interviews provided information on resource use, cultural practices, cash and credit flows and farm expense for the 1969/70 agricultural year. In December of 1970, interviews were

also carried out with 62 persons in extension offices, banks, statistical authorities and fertilizer merchants to obtain basic information on the region and on the fertilizer marketing system.

A total of 174 of the 383 farm interviews were selected for fertilizer analysis based on the criterion that each had more than 50% of cultivated land in annual crops. One hundred and thirty of these farms were located in three muncipios of Guaira, Jardinopolis and Sales de Oliveira; the other forty-four were distributed among the other seven municipios. Guaira is located in the extreme northern part of the state of Sao Paulo, on the border with Minas Gerais south of Uberaba. About 80% of the gross product of the municipio originates from agriculture. In 1948, the region began changing from coffee and beef cattle to annual crops. The topography is gently rolling which facilitates mechanization. The municipios of Jardinopolis and Sales de Oliveira border Ribeirao Preto and still have considerable perennial crops and livestock. The topography is more hilly and the farms are smaller and less mechanized than Guaira

The 174 farms had an average of 56 alqueires (335 acres) of cultivated land with nearly 80% allocated to the production of four crops: corn, rice, cotton and soybeans. The majority of these farms did not specialize in any one of these crops [2]

Fertilizer Use

The actual use of fertilizer was greater than expected. An average of 200 kilos per alqueire (74 pounds per acre) of nutrients was used by these farmers. This was substantially higher than reported by previous studies in Brazil which indicate use levels of 25 to 120 kilograms per alqueire (9 to 44 pounds per acre). Only two of the farmers did not use fertilizer during the 1969/70 agricultural year and 56% bought more than ten metric tons. Utilization rates were not high, however, when compared to recommended rates.

Fertilization of cotton and soybeans was 102 to 140 percent of minimum recommendations, respectively (see Table 3), while rice and corn received only 60% of the minimum. The use of nitrogen was particularly low: only 24% of the recommendation for corn; 56% for cotton and rice; and 94% for soybeans. The use of phosphate was low for rice and corn, but exceeded the minimum for cotton and soybeans. Potash was used at levels equal or above the minimum recommendations for cotton and rice and exceeded maximum levels for corn and soybeans (4).

About 75% of the farmers use credit to purchase fertilizer, but less than half obtained bank credit. There was a tendency for medium sized and large farms to obtain bank credit while the major proportion of small farmers obtained credit from commercial firms and

Table 3. Comparison of fertilizer recommendations to actual use by farmers in the Ribeirao Preto Region, 1969/70[a]

Fertilizer and Crop	Recommendation[b] (kg/alq.)	Actual Use (kg/alq.)	Actual Use as % of Minimum Recommendation
Cotton			
Nitrogen	78-192	43.96	56
Phosphate	144-288	183.51	127
Potash	115-288	114.47	100
Total	335-768	341.95	102
Rice			
Nitrogen	30-77	16.84	56
Phosphate	144-230	74.47	52
Potash	30-150	31.79	106
Total	204-457	123.11	60
Corn			
Nitrogen	142-164	34.10	24
Phosphate	108-216	80.47	74
Potash	22-44	51.48	234
Total	272-424	166.07	61

TABLE 3--Continued

Fertilizer and Crop	Recommendation[b] (kg/alq.)	Actual Use (kg/alq.)	Actual Use as % of Minimum Recommendation
Soybeans			
Nitrogen	22-44	20.65	94
Phosphate	108-144	111.67	103
Potash	22-44	80.00	364
Total	152-232	212.32	140
All Crops			
Nitrogen	83.60	30.14	36
Phosphate	126.05	111.86	89
Potash	44.21	58.41	132
Total	253.42	199.41	79

[a]Fertilizer expressed in nutrients.

[b]Associacao Nacional para Difusao de Adubos, "Sugestoes Gerais de Adubacao," unpublished paper, Sao Paulo, 1970, p. 13.

Source: Nelson, William C., "An Economic Analysis of Fertilizer Utilization in Brazil," unpublished PhD. dissertation, Department of Agricultural Economics and Rural Sociology, Ohio State University, 1971, p. 59.

cooperatives.

The fertilizer retail marketing system expanded rapidly in this region during the 1960's. Only six of the 16 interviewed dealers sold fertilizer in 1960, and only nine were in operation in 1966. The number of formulas offered for sale, 74, appeared to be excessive when in reality only a small percentage of these were regularly bought. Many of the formulas have only one to two percent differences in nutrient value, and this apparently complicated the farmer's process of computing real nutrient prices. Although the number of retailers in the region indicates a competitive situation, large price differences were found for fertilizers of identical formula. This was partially explanable as some dealers furnish valuable services to farmers such as credit, transportation, technical information, and soil analysis (10).

Production Function Analysis

Production functions of Cobb-Douglas and quadratic form were employed to analyze the productivity of resources on the farms surveyed. The Cobb-Douglas form yielded better results in terms of significance of regression coefficients, standard error of estimate and coefficient of multiple determination. The dependent variable used was crop yield. The independent variables included lime, nitrogen, phosphate, potash, all fertilizer, labor, seed and

chemicals, machinery, labor and machinery, all operating costs except fertilizer, a management index, percent of total cultivated land in the specific crop (degree of specialization) and total cultivated land. Product prices used in the analysis were based on the average price received by farmers in the Ribeirao Preto region during the second half of the 1969/70 agricultural year.[3]

Several analyses were made with the data. The first included all observations treated jointly and separately for corn, rice, cotton and soybeans. Secondly, each of these classes was divided by three regions: Guaira, Jardinopolis and Sales de Oliveira, and the other municipios. Third, the observations were separated by high and low levels of fertilizer use for each crop.

The results of the aggregate function of all observations were similar to those found by Steitieh, who used data from Rio Grande do Sul (12). Lime, fertilizer, seed and chemicals, labor and machinery and the management index produced positive cofficients in relation to yield while cultivated land was negative. The fertilizer variable was statistically insignificant, however, and the regression coefficient was approximately zero, indicating nearly no response to fertilizer. All variables except seed and chemicals had values of marginal product less than the input prices, which suggests that the use of these factors should be reduced. When the fertilizer variable

was separated into its nutrients, nitrogen yielded a high negative production response while phosphate and potash were generally positive. The values of the marginal products are given in Table 4.

When observations were divided into three sets based on areas, the only significant results were that the response of cotton to potash was high in Guaira, and in Jardinopolis-Sales de Oliveira, the production of cotton and rice exhibited positive responses to nitrogen and negative to potash.

The division of observations into groups of high and low levels of fertilizer use produced some interesting results. The criteria used for inclusion in the high group varied by crop. For corn, rice and soybeans, observations were included if the application of nitrogen exceeded 50 kilos/alqueire (18 pounds per acre) or phosphate or potash exceeded 100 kilos/alqueire (37 pounds per acre). For cotton, the two limits were raised to 200 kilos/alqueire (74 pounds per acre). All observations with fertilizer utilization less than these quantities were included in the low group. The results show that the response to all fertilizers was higher (more positive or less negative) in the high level sample than in the regional or low level samples for each crop except soybeans. Although the reponse to nitrogen was still negative in the high group, it was less negative than in the other group for three of the four crops. The high group

Table 4. Value of the marginal product of fertilizer nutrients, by level of use and crop

Sample	Value of Marginal Product in Cruzeiros/kg.[a]			
	Nitrogen	Phosphate	Potash	All Fertilizer
Ribeirao Preto Region				
Corn	-2.80	0.46	1.22[b]	0.11
Rice	-12.42	-3.84	4.85[b]	-1.94
Cotton	-3.88	0.93	0.71[b]	0.14
Soybeans	1.88[b]	-0.70	2.94[b]	0.19
All Crops	-5.36	0.33	1.90[b]	0.03
High Group				
Corn	-2.04	0.18	3.16[b]	1.15[b]
Rice	-9.12	-1.55	3.38[b]	1.40[b]
Cotton	-0.75	2.37[b]	1.13[b]	1.63[b]
Soybeans	-15.17	0.93	0.52[b]	0.03

TABLE 4--Continued

Sample	Value of Marginal Product in Cruzeiros/kg.[a]			
	Nitrogen	Phosphate	Potash	All Fertilizer
Low Group				
Corn	-4.46	1.38[b]	0.71[b]	-0.09
Rice	-22.13	-11.84	18.79[b]	-3.76
Cotton	-6.07	-0.62	-3.35	0.44
Soybeans	-72.42	-13.05	23.38[b]	-2.34

[a]Value of marginal product calculated at geometric means based on coefficients from Cobb-Douglas type equations using prices given in text.

[b]Value of marginal product is greater than the price per unit of fertilizer.

Source: Nelson, William C., "An Economic Analysis of Fertilizer Utilization in Brazil," unpublished Ph.D. dissertation, Department of Agricultural Economics and Rural Sociology, The Ohio State University, 1971, p. 59.

also exhibited a higher response to phosphate for three of four crops and to potash for two of the four.

Although the results have some limitations due to several statistically insignificant variables and low coefficients of multiple determination, one conclusion is consistent throughout the analyses: use of fertilizer does not always produce a positive yield response. The results were negative in some cases, and in others, the coefficients were approximately zero.

Returning to the question of profitability the conclusions are still more disconcerting. Although positive values of the marginal product were obtained, the marginal income could still be negative when the cost of fertilizer is subtracted. As seen in Table 4, the marginal income from fertilizer use was generally negative. In the regional analysis, there are no cases where the net marginal income of all fertilizer (NPK) was positive, i.e., where the value of marginal product exceeds the cost of fertilizer.[4] The net marginal income of each crop with respect to potash was positive as was the use of nitrogen in soybean production.

The response to fertilization differed in some respects between the high and low application groups. Positive net marginal income values were derived for corn, rice and cotton with respect to all fertilizer for the high group while none were found for the low group.

Analysis using individual nutrients also revealed some major differences in the responses to nutrients, however, the net marginal income of each crop with respect to nitrogen remained negative.

Factors Affecting the Lack of Response to Fertilizers

Results of this study raise two questions: (1) What factors inhibit a profitable response to fertilizer; and (2) Why are farmers presently using non-profitable quantities and/or combinations of fertilizers?

The research project did not collect data which could completely respond to these questions. Several suggestions, however, offered by other reseachers aid in understanding the problem. One limitation could be the soil. The predominant soil in the region was terra roxa (red soil). It is normally acidic with high levels of iron and bauxite. Nitrogen applied in the form of ammonium sulfate can produce sulfuric acid which will increase the soil acidicity Phosphate fixation can also occur in this soil type, making the nutrient unavailable to plants. The porous quality of the soil may permit "leeching" of fertilizer if heavy rains occur soon after application.

A second possibility is that the present combination of nutrients is inadequate to correct soil deficiencies and/or perhaps there are deficiencies in micronutrients which prevent response to the application of macronutrients.

A third possibility is the application of fertilizer in the wrong time period or applied in an improper location relative to seed.

It is also possible that the Brazilian plant varieties do not efficiently respond to chemical fertilizer. Given the local conditions, present varieties may produce relatively less yield per unit of fertilizer than new varieties associated with the "Green Revolution".

A final explanation is suggested by the difference observed between the high and low groups. The rate of fertilizer application by the low group may not be sufficiently high to generate a significant yield response. Perhaps a minimum critical rate is necessary to compensate for the limitations mentioned previously and application above this rate produces an increasing response per unit over a limited range.

It is not entirely clear why farmers are apparently using uneconomical levels of fertilizer. One explanation is that farmers are still experimenting to determine optimum fertilization levels. They appear to be oriented toward economical fertilizer use in spite of existing fertilizer recommendations. As pointed out earlier, the average use of potash is relatively high and this nutrient consistently demonstrated a positive yield response. Nitrogen yielded a negative response and its average use is much below recommended levels. These factors suggest that recommendations may need to be

revised in light of research results at the farm level. Another possible answer is that a major portion of fertilizer used in Sao Paulo is premixed. Although there are many formulas, there are limited nutrient combinations from which farmers can chose. Banks often require that farmers use recommended formulas and application rates as a qualification for obtaining credit. Thus farmers are forced to use fertilizer practices which may not be appropriate for their specific conditions. With the very favorable credit situation, farmers have been encouraged to use large quantities of fertilizer without sufficient attention to real needs and correct application.[5]

Some interviewed farmers claimed that the quality control in manufacture and distribution of fertilizer was inadequate. Although there were instances of false or inaccurate labeling, it is not expected that this has been responsible for a significant part of lack of response to fertilizer.

Conclusions and Policy Recommendations

Brazil is a huge, complex, diverse, dynamic country. The handful of fertilizer studies reported on in this paper, therefore, may not necessarily represent conditions common to the whole country. Most of the studies were, however, carried out in some of the best agricultural regions in Brazil. The major portion of Brazilian fertilizer consumption is used by farmers in these regions.

On an apriori basis, one might expect these farmers who had already entered the fertilizer adoption process and were closely tied into the fertilizer marketing system to be the most logical candidates for absorbing major increases in fertilizer in the near future. The relatively low levels of fertilizer usage and the low marginal returns to fertilizer applications, especially with regard to nitrogen, suggests that even some of the best farmers in Brazil have a low profile fertilizer production function. The fact that fertilizer use has spread so slowly outside of the southern part of the country despite aggressive extension activities, credit programs, and seemingly reasonable price relationships hints that farmers in other regions of Brazil may face even more serious technical constraints which limit profitable fertilizer use.

The above mentioned information is very fragmentary. Much more research is needed on this issue. We feel, nevertheless, that Brazil ought to reassess its fertilizer promotion policies. The current emphasis on concessional credit, attractive product-fertilizer price relationships, and aggressive fertilizer extension work may have rather limited possibilities to further expand fertilizer use in Brazil. We hypothesize that many farmers in Brazil face technical conditions which sharply limits the average as well as marginal returns to chemical fertilizer use. Until these technical constraints

are identified and effectively overcome, market interventions in favor of fertilizer use will realize only limited success.

Some insights into how Brazil might address its apparent fertilizer-productivity problems can be drawn from recent experience with agricultural research centers initiated under the leadership of the Rockefeller Foundation: e.g. The Rice Reasearch Institute in the Philippines, the Corn and Wheat Research Institute in Mexico, and research centers in Nigeria and Columbia. In these centers a multi-disciplinary group of highly trained scientists have been provided with ample funds to address a handful of technical agricultural problems. Efforts are concentrated on these problems until they are solved. A research strategy with specific goals is used in each case.

Brazil is fortunate in having some very able soil scientists, plant breeders and other scientists needed to staff such a research center. As pointed out previously, current research by these scientists is very fragmented, under financed, and not part of a significant research strategy with specific, socially important goals. Drawing some of these people together and providing them with ample funds to treat fertilizer productivity problems may yield ample dividends to Brazil.

FOOTNOTES

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[1]Part of a joint research effort carried out by the Ohio State University and Escola Superior de Agricultura "Luiz de Queiroz", Universidade de Sao Paulo. More detail is presented in Nelson (9).

[2]Additional information on regional characteristics, interviewing procedures and farm descriptions can be found in : Wessel and Nelson (14, pp. 1-38); Perroco, L. R., et al (11, pp. 1-49), and Nelson (9, pp. 47-67).

[3]Prices used were: Cotton, Cr$ 10.70/15 kg.; rice, Cr$21.15/60 kg.; corn, Cr$10.00/60 kg.; and soybeans, Cr$27.80/60 kg.

FOOTNOTES CONT.

3 cont. Fertilizer prices were: nitrogen, Cr$1.08/kg, phosphate, Cr$0.96/kg.; potash, Cr$0.43/kg.; and aggregate fertilizer, Cr$0.83/kilograms. Fertilizer prices were based on an average price in 1969/70 of Cr$226.90/ton of ammonium sulfate (21%N), Cr$192.95/ton of superphosphate (20%P_2O_5) and Cr$257.10/ton of potassium chorate.

[4]Valdeci (13) used 124 of these same interviews to test the marginal revenue of inputs in corn production in Guaira and Sale de Oliveira. Using a Cobb-Douglas production and regressing the value of fertilizer against the total value of corn per farm, he concluded that the use of fertilizer was approximately at optimum levels. Nevertheless, he reported the results of other models, based on value per hectare, with small or negative fertilizer coefficients, suggesting the use of fertilizer at other than optimum levels.

[5]Some interviewed farmers claimed that the quality control in manufacture and distribution of fertilizer was inadequate. Although there were instances of false or inaccurate labeling, it is not expected that this has been responsible for a significant part of lack of response to fertilizer.

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