The long-term objective of the Economics section is to analyze the potential impact of improved cassava technology in Latin America. This objective defines a relatively broad research program, since the adoption potential of new technology is determined both by the characteristics of the technology and the access of increased production to markets. Output price becomes a key parameter in the analysis. On one hand, it determines the profitability of the technology at the farm and, on the other hand, it determines cassava's competitiveness (and thus its potential) in alternative markets. For most of the other crops within the mandate of the Consultative Group for International Agricultural Research (CGIAR), demand is not a critical factor influencing technology adoption; in the case of cassava, both economic research on production and demand are essential inputs into the Cassava Program's research strategy.

Production Economics

Media Luna on-Farm Trials

Last year cassava production systems in the Media Luna zone were described and results were reported from farm trials comparing the local variety with introduced cultivars (CIAT Cassava Progr. 1979 Ann. Rept.). Among the issues raised was that of root quality; while yields between the cultivars did not differ substantially, the local variety produced higher quality roots.

Given cassava's perishability and indeterminate harvest period, storage in the ground is a principal means for regulating market supplies, especially if there is a critical planting period. Since cassava cannot be stored after it enters urban fresh market channels, consistent flows of the product onto the market through the year depend on staggered harvesting. If farmer risk is to be minimized and farmers are to be assured access to the fresh market, yield and quality must be maintained throughout this storage period.

To evaluate potential future hybrid introductions and to develop a methodology within the farm trials for evaluating cassava storage, the local variety Secundina was compared to three new lines at an early stage of selection. Trials were established in the primary planting season and harvested monthly from 10 to 15 months of age. This harvest period extended from the dry season through initiation of the rains and through three months of high rainfall. This duplicated the actual pattern of the local area for about 70% of all cassava produced over the seasons. Results of the trial are shown in Table 1.

Data for Secundina confirm why this variety dominates in the Media Luna area. First, it matures early but still continues to yield when left in the ground for several more months. Secondly, it maintains its high quality, especially in terms of starch content and low fiber, over the storage period. Finally, it resists root rotting well. These characteristics minimize production and marketing risks, insure farmer access to markets and provide an adequate return to land and labor.

Results for the other lines suggest that a single evaluation for yield and quality characteristics will often be misleading, for example, in the case of CM 391-2 after 12 months. Such evaluations should be based on how the farmer adapts his farming system to requirements of the market, the rainfall pattern and, in some areas, to temperatures, since evidence suggests starch content is inversely correlated with temperature (CIAT Ann. Rept. 1978).

Mondomo on-Farm Trials

Farming System. Environmental and economic characteristics of the farming system in Mondomo, Departament of Cauca, Colombia, differ completely from those in Media Luna. Rainfall averages about 400 mm annually and is relatively well-distributed. There is no critical planting season, and time of planting is determined by labor availability and market requirements. The 1500 m altitude and average temperature of 19°C result in a significantly longer growing season of 14 to 18 months.

Table 1. Yield characteristics of four cassava lines as a function of different harvesting times, at Media Luna, 1979-80[1].

Yield characteristics	Harvest period (months after planting)					
	10	11	12	13	14	15
	Rainfall in harvest month (mm)					
	0	3	50	170	240	180
Dry matter content (%)						
Secunona	36.6	33.1	32.3	32.2	41.4	35.5
CM 323-375	28.5	22.5	23.6	23.1	25.6	23.7
CM 305-38	28.9	27.3	25.9	24.6	28.0	22.7
CM 391-2	29.8	26.8	27.2	21.1	33.2	30.2
Root rotting (% of total roots)						
Secundina	0.8	1.0	0.7	0.3	1.1	0.4
CM 323-375	4.1	13.3	6.3	2.8	4.5	4.5
CM 305-38	4.8	10.4	10.9	4.1	3.0	5.6
CM 391-2	2.2	18.3	14.1	5.8	4.3	1.0
Fiber content (%)						
Secundina	2.8	2.6	4.8	na	3.4	4.0
CM 323-375	3.1	3.6	5.3	na	3.9	3.3
CM 305-38	3.2	4.1	na	na	4.4	6.4
CM 391-2	3.3	3.4	6.4	na	4.5	3.3

[1] Cassava was planted in May 1979.

Soil factors are the principal constraints on the system. Phosphorus (Bray II) varies from 0.8 to 2.7 ppm, well below critical levels; potassium also varies substantially, from 0.10-0.78 meq/100 g. Soils are very acid with levels of Al reaching 4.7 meq/100 g. Fertilizer use is increasing but still is not widespread.

For cassava cultivation, farmers manage soil fertility through a fallowing system with variety selection based on relative responsiveness to fertility conditions. Optimally, farmers fallow for at least six years and then plant three or sometimes four successive cassava crops. This system is, however, dependent on farm size (ranging from 4 to 40 ha and averaging 15 ha) and farmers with smaller areas must reduce their fallow period. Four cassava varieties are commonly planted and each responds differently to existing soil fertility.

Although its yields are rather low, coffee is the only competing crop as it produces adequately under the local conditions. The average cropping pattern is 2.1 ha of coffee, 3.6 ha of cassava, 1.6 ha of other crops (principally plantain), and 8 ha in fallow. Critical labor demand peaks for the two coffee harvests determine scheduling of cassava activities. The amount of labor devoted to weeding is lower than in other zones due to this competition for labor.

Market restrictions are not so severe as in the Media Luna case. Cassava goes almost exclusively into a small-scale starch industry which, in turn, sells exclusively to the bakery industry. Prices received are slightly lower than those from the wholesale urban market; however, the high-quality variety suitable for the urban market does not yield well under the low fertility conditions. Supply continuity is maintained by staggered plantings. Starch content determines prices received and the market discriminates between local varieties as follows: Valluna, Col.$7.3/kg; Americana, $5.0/kg; and Algodona, $4.0/kg. Farmers claim yield potentials of the three varieties are inversely related to starch content.

Farm Trials. A complete factorial fertilizer treatment involving 500 kg/ha of lime and 500 kg/ha of 10-30-30 fertilizer was utilized on the two local varieties Algodona and Americana and a hybrid introduction CM 323-375. The latter had yielded consistently high across the regional trial sites at somewhat lower altitudes, and produced 19 t/ha under similar soil conditions at CIAT-Quilichao. Local average yields in the Mondomo area were about 6.7 t/ha.

Table 2 shows results of the trials. Algodona yielded more than either of the other two varieties, which is consistent with its local dominance. On the other hand, varieties did not differ significantly in dry matter content. This was inconsistent with the price discount applied to Algodona, unless another factor is causing differences in starch extraction rates between the two varieties. Such a factor, called simply latex, has been reported in Australia.

Table 2. Fresh root yield and dry matter contents for cassava tested in on-farm trials, at Mondomo, 1979-80.

Yield parameter and fertility treatment [1]	Cassava variety		
	Algodona	Americana	CM 323-375
Fresh root yield (t/ha)			
Lime + fertilizer	10.3	6.3	5.5
Fertilizer only	10.4	4.9	6.2
Lime only	9.3	4.8	4.7
Control	9.1	4.9	3.1
Dry matter content (%)			
Lime + Fertilizer	36.8	35.9	37.6
Fertilizer only	36.6	33.7	36.2
Lime only	36.1	35.1	36.4
Control	35.4	34.3	37.5

[1] Lime treatment was 500 kg/ha; fertilizer treatment was 500 kg/ha of 10-30-10.

Differences between fertilizer treatments were not significant but differences between farmers were, that is, variations between farms (replications) were greater than between treatments. This is not unusual and, as was the case in Media Luna, confirms the substantial micro-variation between farm trial sites. Table 3 gives average yields for Algodona on each farm along with the plot cropping histories.

A crop rotation index was also calculated. While somewhat arbitrary, the index is basically adapted from the proportion within the farmers' normal rotation scheme of six years of fallow and three successive crops of cassava. Remarkably, the index gives a virtual exact ordering of yields.

The sample was stratified according to the rotation index with 6 used as the dividing point, i.e., the implicit point in the rotation system at which soil fertility was declining. Table 4 shows that for all three varieties, yield and dry matter content differed significantly between the two groups (except for dry matter of CM 323-375).

There was also a significant and economic response to fertilizer in the case of Algodona on critical fertility plots and no significant response on plots where a sufficient rotation period was being maintained (Table 5).

The critical influence of the fallow system, and the differential response to a fertilizer based on how much the fallow system was shortened, define the requirements for new technology in this zone.

Table 3. Yields of two local cassava varieties on individual farms, as related to plot history and farm size, at Mondomo.

Farm size (ha)	Previous	Rotation index[1]	Fresh root yield	
			Americana (t/ha)	Algodona (t/ha)
44.8	1 year cassava, 15 years fallow	13	8.5	16.6
12.6	2 years fallow, 1 year cassava, 10 years fallow	10	[2]	13.7
19.2	10 years fallow	10	[3]	11.4
4.5	8 years fallow	8	6.6	8.7
5.8	6 years fallow	6	6.2	6.9
15.1	2 years fallow	2	3.5	6.5
5.0	2 years cassava, 8 years fallow	4	4.6	4.7
12.6	2 years cassava, 2 years fallow	-2	2.7	[2]

[1] Rotation index=number of years in fallow minus 2 times number of previous years in cassava.

[2] Sam[illegible] but different plot histories for the two varieties

[3] Plot [illegible]

Table 4. Fresh root yield and dry matter content of three cassava varieties, in relation to length of previous fallow period, at Mondomo[1].

Rotation strata	Cassava variety		
	Algodona	Americana	CM 323-375
Fresh root yield (t/ha)			
Adequate rotation	11.5	7.1	7.3
Shortened rotation	5.6	3.6	2.5
Dry matter content (%)			
Adequate rotation	37.2	37.5	37.6
Shortened rotation	34.0	32.[illegible]	36.6

[1] Except in the case of dry matter content of CM 323-375, there were significant differences at the 5% level between the two rotation groups for all other values.

Table 5. Yield response of the cassava variety Algodona to fertilizer treatments, in relation to the length of the rotation period, at Mondomo.

Fertility treatment [1]	Fresh root yield (t/ha) according to rotation strata	
	Adequate	Shortened
Fertilizer + Lime	11.3 a [2]	7.7 a
Fertilizer	11.1 a	8.9 a
Lime	12.1 a	2.5 b
Control	11.0 a	4.2 b

[1] Lime treatment was 500 kg/ha; fertilizer treatment was 500 kg/ha of 10-30-10.

[2] Values within columns followed by the same letter are not significantly different at the 5% level.

Cassava Intercropping Trials

Cassava is grown principally by small farmers, for whom land is usually a constraining resource and cash flow through the crop year is a principal concern. Intercropping permits intensifying land use and, where different maturity crops are used, can help stabilize income flows. Cassava is well suited to multiple cropping, but given its wide ecological range, the best potential intercrop will vary across ecological zones. On-farm intercropping trials were done in two locations by the Cultural Practices section; budgeting analyses of these trials are reported.

Media Luna. In Media Luna maize is the principal crop associated with cassava (for a discussion of environmental conditions and farming systems, see CIAT Cassava Progr. 1979 Ann. Rept.) Maize has no marketing problems; it is a short-season crop, and, while it has low productivity under existing conditions, it provides an adequate return on investment when grown with cassava. Farmers in the zone use a low-plant population system which seemingly minimizes light competition between the tall maize and slower growing, shade-sensitive cassava (Fig. 1). A trial was designed to compare the farmer's system using the local variety Secundina in both monoculture and intercropped, with an improved system in which plant densities of both cassava and maize were increased while the spatial arrangement of the cassava was modified (Fig. 1). An N treatment was added as one additional component, primarily to benefit the maize.

Four conclusions are evident from the yield results (Table 6): a) changing either the plant population or the spatial arrangement in monoculture, cassava did not increase yield; b) under the farmer system, maize did not suppress cassava yields; c) the higher maize population in the improved system produced a slight decline in cassava yields but almost tripled maize yields; and, d) there was no economic response to fertilizer.

Net income calculations (excluding land and management costs) at varying cassava:maize price ratios (Table 6) demonstrated that the improved intercropping system without fertilizer was the most profitable up to the very highest price ratio (Col. $4.0/kg for cassava: $5.0/kg for maize). At low cassava prices, the income gain was substantial, with only very marginal increases in costs. The experiment will be continued at least three years to evaluate the stability of the systems, especially those without applied fertilizer.

Caicedonia. Compared to the marginal agricultural conditions of Media Luna, Caicedonia is prime coffee land where cassava must compete with high-value crops. In this case, beans — the highest value intercrop — was selected for study. Cassava can compete economically due to the very high yields obtained, because of the preferential price received for the high-quality variety grown in the zone (usually more than double farm prices on the North Coast), and due to the generally high level of prices for cassava nationally.

Three basic agronomic changes were made in farmers' cassava-bean intercropping systems. First, plant populations of both crops were increased (beans by a factor of 10). Secondly, a preemergent herbicide was used instead of two hand weedings and fertilizer (100-100-80 kg/ha of N-P-K) was applied. Finally, changing from horizontal to vertical planting of cassava stakes allowed both crops to be planted simultaneously because cassava germinated faster and thus minimized interspecies competition.

Table 6. Yields and net incomes from various cassava and maize intercropping systems, at Media Luna.

Crop system and (spacing)	Mean yields (t/ha)		Net income per hectare; cassava price in $Col/kg[1]			
	Cassava	Maize	1.0	2.0	3.0	4.0
Farmer system						
Cassava monoculture (1.2 x 1m)	14.3	-	1944	16,244	30,544	44,844
Cassava (1.2 x 1m)/maize (2 x 1.2m)[2]	15.7	0.7	5256	20,956	36,656	52,356
Improved system without fertilizer						
Cassava monoculture (1 x 1m)	15.0	-	2644	17,644	32,644	47,644
Cassava monoculture (1.6 x 0.6m)	14.1	-	1744	15.844	29,944	44,044
Cassava (1.6 x 0.6m)/maize (1.6 x 0.3m)	13.9	1.9	9506	23,406	37,306	51,206
Improved system with fertilizer						
Cassava (1.6 x 0.6m)/maize (1.6 x 0.3m)	13.6	1.9	8661	22,261	35,861	49,461

[1] Maize price was held constant at $Col 5.0/kg.

[2] Maize population was determined by planting pattern and number of plants per hill (farmer: 3; improved: 2)

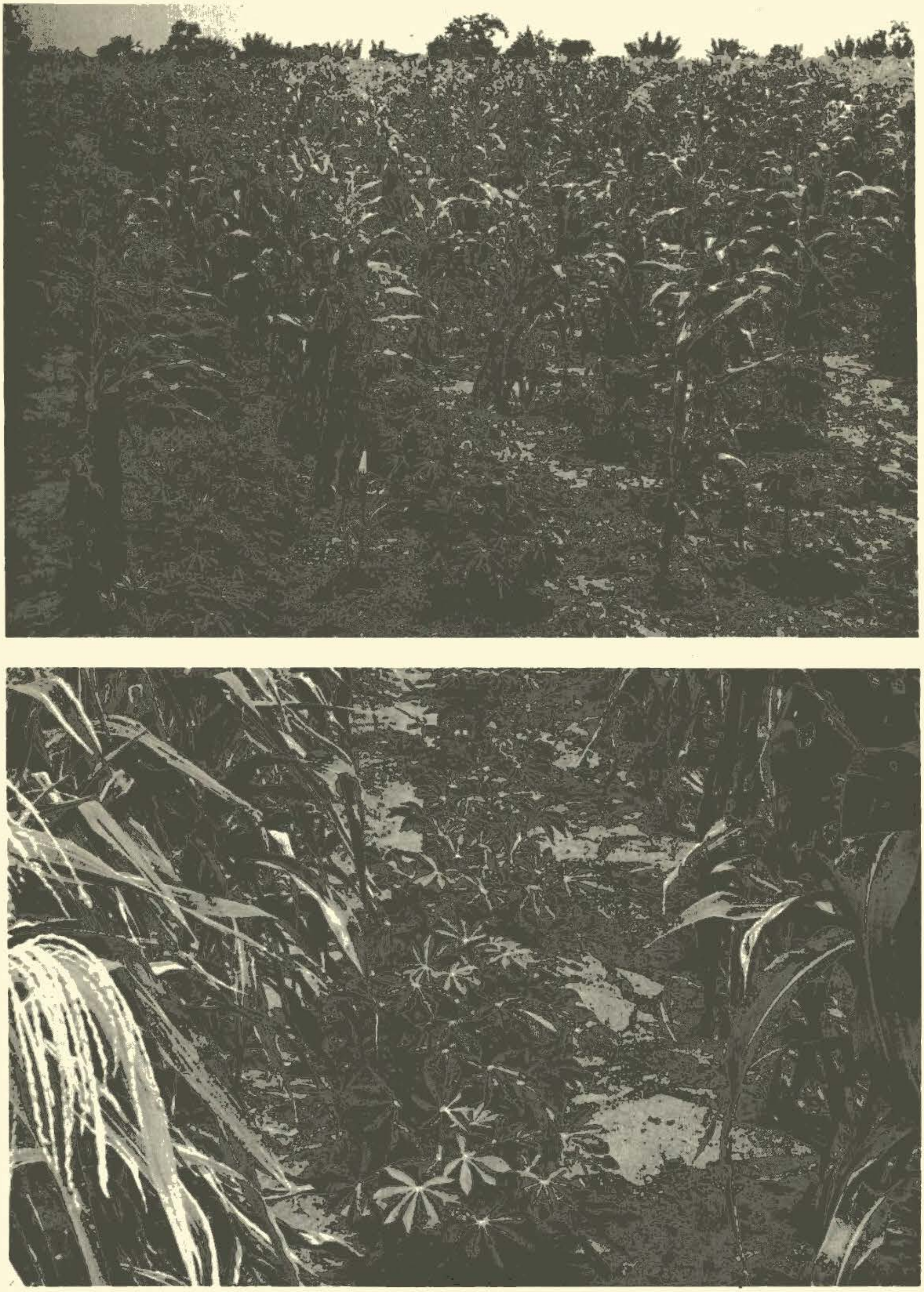

Figure 1. *(Above) typical farmers' cassava/maize intercropping system employed in the Media Luna zone. (Below) improved system developed by CIAT.*

As in Media Luna, there was no apparent competition in the intercropping system, and even some tendency was evident for increased cassava yields (Table 7). There was no apparent response by cassava to fertilizer, with the impact on beans being inseparable from the impact of increased density. Again, as in the Media Luna case, the improved system's principal advantage was in improved yields of the intercrop, with bean yields increasing fivefold.

A simple budgeting analyses of the results revealed that the intercropping systems were more profitable than monoculture and that the improved system was most profitable (Table 7). Nevertheless, cassava dominates in the economics of the association, and the beans only contribute marginally to total profitability of the system. Returns to land and management in Caicedonia were larger than returns to cassava systems in Media Luna by a factor of 10. If such profit differentials are necessary to bring prime agricultural land into cassava production, such zones will continue to supply only preferred, high-priced markets like the fresh cassava market of Bogotá.

Table 7. Yields and net income from various cassava and bean intercropping systems, at Caicedonia.

Crop system	Mean yields		Net income from system ($Col/ha)			
	Cassava	Beans	Gross income[1]		(Variable cost)	Net income
			Cassava	Beans		
	(t/ha)	(kg/ha)				
Farmers' system						
Cassava monoculture	31.7	-	253,600	-	(11,090)	242,510
Cassava/beans	37.5	210.0	300,000	6300	(14,727)	291.573
Improved system						
Cassava monoculture	36.0	-	288,000	-	(14,920)	273,080
Cassava/beans	37.4	1022.0	299,200	30,660	(20,499)	309,361

1 Prices received were cassava, $Col 8.0/kg and beans, $Col 30/kg.

Demand and Marketing Economics

Successful diffusion of new agricultural production technology is critically dependent upon the increased output reaching profitable markets. While in the past cassava has performed well as a basic food crop in many zones of Latin America, future yield-increasing technology will be adopted only if the additional production can be readily marketed.

Cassava is suitable for use in several distinct markets of which five are outstanding: a) fresh for human consumption; b) processed for human consumption; c) as an animal feed; d) as an industrial starch; and, e) as a feedstock in the distillation of fuel. Knowledge of the price at which cassava must be sold in order to compete in each of these markets not only indicates which markets cassava is most likely to enter, but also gives an estimate of the level of productivity which new production technology must attain if cassava is to compete in each market.

Colombian Case Study

Because CIAT's mandate emphasizes increasing the availability of food supplies, primary focus is placed on analyzing cassava markets where it is used directly or indirectly as a food. The poultry industry in Colombia was selected for study because of the extremely rapid growth rates in this and the related feed concentrate industry. Cassava might well find an important market in this latter industry as a substitute for one or more feed grains. It is also thought that any results from this industry-wide model could be adapted easily to other countries of the region.

A linear programming model was constructed for the poultry feed industry to provide a least-cost feed ration for broilers. Two levels of increased cassava production were assumed — a 15 t/ha low-input technology suitable for production regions with moderate stresses, and the other a 24 t/ha model for the same production regions but employing higher fertilizer levels and appropriate weed control measures.

Percentage cost reductions in the least-cost, nutritionally adequate rations are shown in Table 8, for cassava produced at three technology levels. The model assumes cassava is available at prices associated with these potential technologies and that alternative feed materials are available at prices prevailing at the time of study. Given the high national price for sorghum (about double world market prices), cassava completely replaced that grain in the least-cost ration calculated. Although the economic optimum where cassava could be substituted for other grains was at 43% of the broiler diet, poultry performance on cassava meal at that high level has yet to be fully defined. Therefore, the cassava level was also constrained to form no more than 10 and 20% of the rations.

The impact of reduced prices for feed concentrates on consumer welfare can be traced through a supply and demand model of the poultry sector. This influence was calculated for this case study and the results, in terms of gross benefits derived at the different technology levels and cassava substitution levels, are shown in Table 8. The magnitude of these benefits in Colombia alone compares favorably with total research expenditures being made on cassava.

It is also important to note that the benefits from the 15 t/ha techonology are about two-thirds those from the 24 t/ha technology although the yield increase required to attain 15 t/ha is only 40% that involved in reaching 24 t/ha, using current Colombian national average yields for comparison. This pattern of benefits tends to support the research strategy of the CIAT Cassava Program which emphasizes low input technology.

While the gross benefits indicated in this study are only those attributable to the increased consumption and lower price for poultry, when cassava substitutes for other feed ingredients, other social and political benefits would also accrue. For example, if cassava completely replaced sorghum in poultry rations, Colombia could realize an annual foreing exchange saving of US$12.7 million, based on 1979 prices and the average level of sorghum imports. Moreover, at the 20% inclusion level and with 15 t/ha technology, an additional 4.2 million mandays of employment would be created in producing the additional cassava required.

Table 8. Estimated percentage cost reductions and gross benefits from substituting cassava produce at three technology levels into commercial poultry feed concentrates, in a Colombian industry model.

Cassava substituted into concentrate (%)	Percentage reduction in feed costs, at cassava production of:			Gross benefits (US$ '000) realized by substitution, at cassava production of:		
	12 t/ha	15 t/ha	24 t/ha	12 t/ha	15 t/ha	24 t/ha
10	0.4	1.3	1.9	208	658	973
20	0.7	2.6	3.8	353	1320	1941
43 [1]	1.06	5.5)	8.2	808	2795	4151

[1] Economic optimum at all levels of technology.

Errata

Page	Columm	Element	Printed:	Should be:
6	1	Figure 2	M Col 59	M Mex 59
6	2	Figure 3	M Col 59	M Mex 59
6	2	Figure 3	LSD (P<0.05)	LSD (P<0.05)
7	1	Figure 4	M Col 59	M Mex 59
60	2	Second para., line 8	more to growth	more top growth
61	2	Line 1	and K contents	and K concentrations
20	1	Figure 1	I - Tolerant III - Tolerant V - Tolerant	I - Intermediate-resistant III - Intermediate-resistant V - Intermediate-resistant
62	1	Figure 3	Stems □	Stems △
64	1	Figure 5	5.0 4.0 % N	5.0 4.0 % N 3.0
66	1	Figure 8	Figure 44	Figure 8
93	2	Footnote	*Left during 1979.	*Left during 1980.