The new intercropping technology being developed at CIAT therefore is attempting to aleviate these constraints by selecting improved, well adapted crop cultivars, establishing optimum planting techniques with respect to timing, planting density, spacial arrangement and plant nutrition and developing a low cost, easy to handle pest management system. The development of new technology for multiple cropping is less advanced than that for monoculture, hence not only present practices but also likely future practices are reported.

SELECTION OF CROP SPECIES AND CULTIVARS.-

A) Cassava

There is a wide range of growth habits in cassava with respect to branching and early vigor, both being characteristics with potential influence on the companion crop. Varieties with high early vigor depress bean yields more than those with less early vigor but no relationship between early vigor and cassava root yield has been observed (Thung, 1978). Thus, the somewhat less vigorous types with late branching habit appear to be more suitable for intercropping as they impose little competition on associated legumes initially (Fig. 1). Furthermore, Cock <u>et al</u> (1979) have suggested that late branching cultivars have higher yield potential. Based on this data, a group of cassava varieties has been selected combining high yield with the desired plant type for intercropping (Table 1).

NEW TECHNOLOGY FOR CASSAVA INTERCROPPING[1]

DIETRICH E. LEIHNER[2]

INTRODUCTION.-

Cassava, an initially slow growing crop, lends itself to intercropping allowing a more efficient utilization of growth factors during its establishment phase. There is a number of possible crops to be combined with cassava, however, cassava intercropping research at CIAT has concentrated on cassava-grain legume associations for several reasons. Grain legumes such as field beans (*Phaseolus vulgaris*), cowpeas (*Vigna unguiculata*), peanuts (*Arachis hypogaea*), and others have a short growth cycle. They cover the ground quickly reducing loss of moisture, erosion and weed problems and reach maturity before cassava starts to close its canopy. The nutritional balance achieved by an associated cassava-grain legume production, the former providing energy and the latter protein, is essential for the small-scale and subsistance farming sector. Also, fast maturing legumes provide an early cash flow to the farmer who without the legume intercrop would have to wait 12 months or more for an income from cassava.

In traditional cassava-legume intercropping systems, the use of unimproved cultivars, low planting densities, low soil fertility and deficient or untimely pest control make cassava intercropping a system with low productivity.

---

[1] Paper presented at a workshop on pre-release testing of agricultural technology, held at CIAT March 19-23/79.

[2] Cultural Practices Specialist, CIAT Cassava Program.

B) Legumes

Initial cassava intercropping work at CIAT used field beans as companion crop since expertise on this species was available within CIAT's commodity programs. Research work with beans allowed the establishment of some of the physiological and agronomic principles of cassava-legume intercropping. Grain legumes should have a non-agressive (erect or prostrate) growth habit, cover ground rapidly and mature in less than 100 days for successful intercropping with cassava. Earliness is essential for the legume to reach pod filling stage before cassava starts to close rows and shading gets serious. Field beans fulfill these requirements, however they are not adapted to the low humid tropics and perform poorly on acid, infertile soil where cassava has the potential to yield well. Therefore, other species are now evaluated with regard to their adaptation to poor soil and suitability of plant type to be intercropped with cassava. Cowpea has the right growth habit, is early maturing and grows well on acid soils as shown by monoculture yields of 1.5 to 2 t/ha obtained at CIAT Quilichao on a soil with pH 4.1, low P and high Al levels (Table 2). When grown intercropped with cassava, a yield reduction of only 10% was observed (Table 2). Testing peanuts under these conditions, promising results were obtained with a yield of 1.5 t/ha of unshelled nuts in association with cassava. At this yield level, the crop would produce 365 kg/ha of protein and 461 kg/ha of oil, whereas 1.5 t/ha of common beans, if it were possible to produce them under the same conditions, would only provide about 375 kg/ha of protein but no oil. Several other grain legume species, among them lima bean (Phaseoulus lunatus), jack bean (Canavalia ensiformis), sword bean (Canavalia gladiata) and velvet bean (Stizolobium derringianum) are tested to collect information on their potential production under poor soil conditions. Some of these legumes have a climbing growth habit and could be intercropped with cassava at the end of its growth cycle using the cassava stalk as support. The feasibility of this system has been demonstrated at CIAT with climbing phaseolus beans (CIAT, 1978).

PLANTING TECHNIQUES.-

a) Relative planting time

The planting time of the intercrop relative to cassava has physiological and practical aspects. Cassava yields can be drastically reduced by early competition (Doll, 1976). Light seems to be the most critical factor followed by water and nutrients. (Thung, 1978). Competition for light is most serious when the intercrop is given a relative advantage in planting time and overgrows cassava. On the other hand, yield of the intercrop is seriously affected when cassava is planted ahead in time. In a relative planting time trial with cassava and beans at

CIAT, simultaneous planting of the two crops or sowing them with one week of difference (beans earlier than cassava) gave the highest biological yields (Fig. 2; Thung, 1978). This practice has been tested with a number of other intercropped species at different sites with the same results. Simultaneous planting is therefore a recommended practice from the production point of view and it also has the practical advantage of one single operation being necessary to establish the association. Even mechanized planting can be visualized provided the required adaptive development of present planting equipment is done.

b) Density and Spacial Arrangement.

A frequent characteristics of traditional intercropping practices is a low plant density which results in low yields. However, experimental results show that total system yield and Land Equivalent Ratios (LER)[1] can be increased just by changing planting densities. In trials conducted with cassava and beans at CIAT, increasing bean density from 10 to 40 plants/m^2 did not alter cassava yields significantly (Figure 3). Increasing cassava plant population depressed bean yield to some extent, but LER values were high and remained largely unaffected by cassava density (Figure 4). Although maximum cassava production was reached at the highest cassava density, highest LER values were obtained at much lower planting

[1] LER = Land Equivalent Ratio = the amount of land that would have been necessary to achieve the same production obtained from one hectare in intercropping, growing the associated crops in monoculture.

densities of cassava. The conclusion drawn from this data is that normal monocrop densities may be used in cassava-legume intercropping and yields will be close to the maximum obtainable (CIAT, 1977).

In Colombia, the spacial arrangement or planting pattern of cassava is usually not altered when another crop is interplanted. This is very much to the disadvantage of the interplanted crop since it suffers much earlier shading from cassava than if a wider row spacing of cassava is used. Trials at CIAT show no effect of planting pattern on cassava root yield, within the range of 1 x 1 to 2 x 0.5 m, when the same plant population is maintained (Fig. 5). Therefore, wider row spacings in cassava are feasible favoring the intercrop without sacrificing cassava yield. Data on the optimum spacial arrangement in intercropped legumes are in the way of being generated in our program. Preliminary results from a cassava-cowpea intercropping trial grown on acid, infertile soil at CIAT-Quilichao show that cowpea yields did not differ greatly in three arrangements, at three different planting densities (Fig. 6).

It is concluded that legumes are flexible in their yield response to spacial arrangement similar to cassava and that legume planting patterns can be arranged according to practical convenience.

SOIL FERTILITY CONSIDERATIONS IN CASSAVA INTERCROPPING.-

The intercropping technology we are developing at CIAT concentrates on crop combinations which have the ability to yield well with a limited nutrient supply but are able to respond to higher levels of fertility. The ability of cassava to yield well on poor soils and respond to fertilizer input is well documented (CIAT, 1976; CIAT, 1977; Howeler, 1976; Cock and Howeler, 1978). Among the legumes suitable to be intercropped with cassava, field beans is the best studied option with nutrient requirements well established through research in several Latin American institutions. They grow well together with cassava at intermediate elevations on fertile soil but do not thrive in the more difficult environments (high temperature, low soil fertility). Under these conditions cowpeas and peanuts, for example, seem to have a much higher yielding ability and nutrient requirements similar to cassava (CIAT, 1978, Leihner, 1978).

Assuming a high degree of competition for nutrient between two crops when grown in association, the individual requirements of each crop would have to be added up to give the total nutrient requirement of the system. However, Howeler (1978) found that the interaction in terms of plant nutrition between cassava and seven interplanted legume species was low; intercropped legumes neither increased the N level nor decreased the P level in cassava leaves suggesting that there was no immediate contribution of N from the legumes and competition for other nutrients may have been low.

In designing cassava-based intercropping patterns, long term nutritional requirements for stable yields and soil fertility maintenance have to be established. Presently, very little information is available in this area. One report from Indonesia shows how sustained production was achieved over five years on an acid, infertile soil in a relay-intercropping system involving cassava. Management included a moderate application of lime, NPK fertilizer and mulching with rice straw. Besides providing agronomic stability, several soil fertility parameters were reported to have improved after five years of cultivation (Tables 3, 4; Mc Intosh and Suryatna, 1978).

However, this system included cassava only as one of five crops. It is not known wether the same results can be obtained where cassava represents a greater portion of the cropping pattern. Investigation in our program is presently focused on generating information such as total nutrient extraction, efficiency of nutrient utilization in intercropping as opposed to monocropping, and management practices to stabilize yields and soil fertility in cassava-legume systems where cassava is the single major crop.

MECHANIZATION OF PLANTING AND HARVESTING.-

In both cassava and grain legume monocropping, machinery has been developed to fully mechanize the planting and harvesting process. Two-row and four-row cassava planters are presently in use in Brazil and other countries, with the disadvantage that planting position of stakes is horizontal. However, recently, the development of a two-row vertical planting cassava planter was reported (Odigboh, 1978). Also, implements of the vegetable or tobacco-transplanting types should be looked at for adaptive development of vertically planting cassava planters. Mechanization in grain legume planting has existed for a long time and cannot be considered as a technical problem. An intercrop-planter would simply have to combine the different elements of the single crop planters into one machine.

Similarly, machinery exists for the mechanical harvest of grain legumes and cassava. Since harvesting of the two associated crops occurs separately and grain legumes are harvested when cassava is still young, the only problem to be solved is the appropriate planting pattern to permit mechanical grain legume harvest. Once the legume is harvested, cassava grows as a monocrop and can be harvested as such without difficulties. Several suggestions for cassava-legume planting patterns facilitating mechanical harvest of the legumes are given in Fig. 7. The three suggestions show very distinct arrangements but they have in common the preservation of optimum planting densities per unit area. As was shown before, both cassava and legumes have a high degree of flexibility with respect to planting pattern whenever the right plant population is maintained.

PEST MANAGEMENT.-

It is a general belief that greater diversity of plant species in a cropping systems leads to more stability and lower pest incidence. Research data so far available confirm this view in general. Studying monoculture and mixed cropping systems involving cassava and grain legumes, Moreno (1978) found that both incidence and severity of major cassava and legume diseases were reduced in intercropped as opposed to monoculture stands (Table 5). Similar observations were made when insect populations of lacebug (Vatiga manihoti), whitefly (Aleurotrachelus sp.), shoot fly (silba pendula) and hornworm (Erinnyis ello) were counted in cassava monocrop and cassava/bean intercrop plots. Without insecticide, populations were 30 to 32 percent lower in the intercropped plots than in cassava monoculture (CIAT, 1977). Finally, weed incidence was shown to be drastically reduced in cassava intercropped with beans as compared to monoculture (Fig. 8).

The meaning of these observations for the practical management of pests in cassava intercropping is that pest control input can be reduced to some degree, according to the generally reduced seriousness of pest incidence. Where two or three applications of fungicides and insecticides are necessary to keep diseases and insects under control in monocrops, a single spray may do in intercropping. As an example, our experimental plots with cassava-cowpea and cassava-peanut at CIAT-Quilichao produced the high yields reported here with one single fungicide/ insecticide application. In a weed control systems trial, a single preemergent herbicide was sufficient to keep weeds at an economically unimportant level during the first half of cassava growth cycle when cassava was grown intercropped with beans whereas additional hand weeding was necessary in cassava monoculture (Fig. 8). This demonstrates the lower requirements for pest control input in the intercropping system.

CONCLUSIONS.-

Intercropping is a practice developed by the "primitive" farmer in an attempt to make a more efficient use of his land and other resources, increase, stabilize and diversify food production per unit land and time, and avoid the risk of total crop loss inherent to monoculture.

Applying modern technology to this system should further increase its production potential. With the simple and inexpensive practices for cassava-legume intercropping discussed in the previous paragraphs increased production is very likely to be achieved.

The suggested practices can be summarized as follows:

1.- Use high yielding cassava cultivars with appropriate growth habit to minimize intercrop competition (erect, late branching types)

2.- Use early maturing, rapid ground covering legume species with determinate growth habit (erect, non-climbing types).

3.- Plant each of the associated crops in its normal monocrop planting density.

4.- Plant cassava and legumes simultaneously

5.- Use an appropriate planting pattern to accommodate the associated crops. Both cassava and legumes are highly flexible with their yield response to changes in planting pattern, allowing variations of inter and intra row distances without reductions in yield.

6.- Control diseases, insects and weeds adequately. The intercropping system per se has pest suppressing potential therefore reduced input requirements can be anticipated. In the areas of plant nutrition and mechanization of the intercropping system, more research is needed to establish safe and easy to handle practices. Replacement of at least those nutrients which were removed with the harvest products of both crops appears to be advisable until more detailed recommendations based on long term studies are available. In the mechanization area, no serious attempts have so far been made to develop machinary for intercrop planting and harvesting, however, all the basic elements of mechanizing cassava and grain legume production do exist and only some adaptive development would be required to put these elements together. Intercropping mechanization is imperative if this system is to gain broader application.

REFERENCES

1.- Centro Internacional de Agricultura Tropical, CIAT. 1977. Annual Report for 1976. Cali, Colombia.

2.- Centro Internacional de Agricultura Tropical, CIAT. 1978. Annual Report for 1977. Cali, Colombia.

3.- Centro Internacional de Agricultura Tropical, CIAT. 1979. Annual Report for 1978. Cali, Colombia.

4.- Cock, J. H., D. Franklin, G. Sandoval and P. Juri. 1979. The Ideal Cassava Plant for Maximum Yield. Crop Science. In press.

5.- Doll, J. D. and C. W. Piedrahita, 1976. Methods of Weed Control in Cassava. Cali, Colombia. CIAT series EE-21. 12 p.

6.- Howeler, R. H., 1978. The Mineral Nutrition and Fertilization of Cassava. In: Cassava Production Course, Book I. Preliminary draft, CIAT, Cali, Colombia.

7.- J. H. Cock, and Howeler, R. H., 1978. The Ability of Cassava to Grow on Poor Soils. In: Crop Tolerance to Suboptimal Land Conditions. ASA - special publication.

8.- Howeler, R. H. 1978. Personal communication.

9.- Leihner, D. 1978. Agronomic Implications of Cassava-Legume Intercropping Systems. In: Proceedings of a Workshop on Intercropping with Cassava. Trivandrum, India, November 27 - December 1, 1978. In press.

10.- McIntosh, J. and E. Suryatna, 1978. Soil Fertility Implications in Cassava Intercropping Systems. In: Proceedings of a Workshop on Intercropping with Cassava. Trivandrum, India. November 27 - December 1, 1978. In press.

11.- Moreno, R. A. 1978. Crop Protection Considerations in Cassava Intercropping. In: Proceedings of a Workshop on Intercropping with Cassava. Trivandrum, India. November 27 - December 1, 1978. In press.

12.- Odigboh, E. U. 1978. A Two-row Automatic Cassava Cuttings Planter: Development, Design and Prototype Construction. I. Agric. Engng. Res. (1978) 23, 109-116.

13.- Thung, M. 1978. Multiple Cropping based on Cassava. Post Doctoral Report. CIAT, Cali, Colombia.

TABLE 1.- Seven cassava varieties selected for high yield and low competition with an associated crop, contrasted with a very vigorous early branching variety (Thung and Cock, 1978)

VARIETY	MONOCULTURE YIELD FOUR-YEAR MEAN AT CIAT t/ha	YIELD IN ASSOCIATION WITH FIELD BEANS ONE YEAR DATA, CIAT t/ha	YIELD OF FIELD BEANS IN ASSOCIATION RELATIVE TO MONOCULTURE %
Late branching, medium vigorous			
MCOL 1468 (CMC 40)	38.3	30.3	101
MCOL 1684	40.3	34.6	94
MMEX-11	42.4	31.8	93
MVEN 270	42.8	33.2	105
MECU 47	36.2	33.6	117
MPAN 70	42.0	30.5	99
M PTR 26	40.2	28.4	98
Early branching, very vigorous			
M MEX 59	32.8	25.8	89

TABLE 2.- Grain yield, growth duration, plant type and growth habit of twelve outstanding cowpea cultivars grown in monoculture on poor soil, and grain yield in monoculture and association with cassava of one promising cowpea cultivar grown at CIAT-Quilichao. (Hegewald and Leihner, 1979)

Cultivar designation	Grain yield kg/ha	Days to maturity	Plant Type
TVX 1193-059 D	2.074	82	Erect
TVX 1977-OD	1.963	84	Erect
TVX 1836-9E	1.889	80	Erect
TVN 2616-P-01D	1.736	79	Erect
TVN 3629	1.718	80	Semi erect
P - 18	1.671	81	Semi erect
TVX 289-4G	1.628	83	Erect
TVX 1193-7D	1.618	80	Erect
VITA 4	1.610	83	Erect
TVX 337-3F	1.599	83	Erect
TVX 1836-19E	1.557	77	Erect
TVX 1193-9F	1.554	74	Very erect
	Grain yield monoculture	Grain yield intercropped	
TVN-201-1D	2.156	1.945	

TABLE 3.- Five-year crop production with and without soil fertility management in a relay - intercropping system with cassava, Central Lampung, Indonesia. (McIntosh and Suryatna, 1978)

CROP	YEAR	ZERO-TREATMENT	LIME+NPK+MULCH
		Dry grain kg/ha	
Corn	1974	455	1.350
	1975	206	2.436
	1976	223	2.213
	1977	46	1.896
	1978	130	2.261
Upland rice	1974	769	2.724
	1975	862	3.222
	1976	653	1.820
	1977	538	1.490
	1978	153	2.146
Peanut	1974	222	567
	1975	467	763
	1976	229	490
	1977	-	-
	1978	224	584
Rice bean	1974	93	627
	1975	50	492
	1976	-	-
	1977	7	44
		Fresh root t/ha	
Cassava	1974	14.6	23.2
	1975	6.1	20.1
	1976	6.0	36.8
	1977	3.7	15.9
	1978	3.9	22.7

TABLE 4.- Soil characteristics in cassava row area after five years of cultivation with five crops per year with full soil fertility management, no management and uncultivated check. Central Lampung, Indonesia (Mc. Intosh and Suryatna, 1978)

SOIL PARAMETER TESTED	UNCULTIVATED CHECK	CULTIVATED ZERO TREATMENT	CULTIVATED LIME+NPK+MULCH
pH (KCL)	4.8	4.1	5.5
Ca meq/100 g	2.8	1.0	3.8
Mg	0.4	0.5	0.3
K	0.1	0.1	0.1
Al	0.0	0.21	0.0
CEC	6.6	5.6	6.4
Base Sat. %	50.0	29.0	66.0
P (Bray II) ppm	4.2	4.6	50.0
Organic Matter C %	1.23	0.96	1.15
N %	0.10	0.08	0.09
C/N	12.3	12.0	12.8

TABLE 5.- Effect of intercropping on incidence of cassava and bean/cowpea diseases in monoculture and intercropped stands (Moreno, 1978)

DISEASE	MAXIMUM INCIDENCE PERCENT CASSAVA MONOCULTURE	 CASSAVA AND BEANS INTERCROPPED
A. Cassava		
Oidium manihotis P. Henn	17.7	10.2
Sphaceloma sp.	37.0	34.0
Uromyces manihotis	67.7	56.6
	TRANSFORMED McKINNEY INDEX	
B. Legumes	BEAN MONOCULTURE	BEANS INTERCROPPED WITH CASSAVA
Isariopsis griseola Sacc (angular leaf spot)	10.23	10.81
Uromyces phaseoli before anthesis	5.39	3.39
anthesis	15.11	16.67
Green pod stage	17.16	20.41
	PERCENT INFECTED PLANTS 66 DAYS AFTER PLANTING	
CPMV & CCMV	COWPEA MONOCULTURE	COWPEA INTERCROPPED WITH CASSAVA
Early association	29.2	21.5
Late association	100.0	19.0

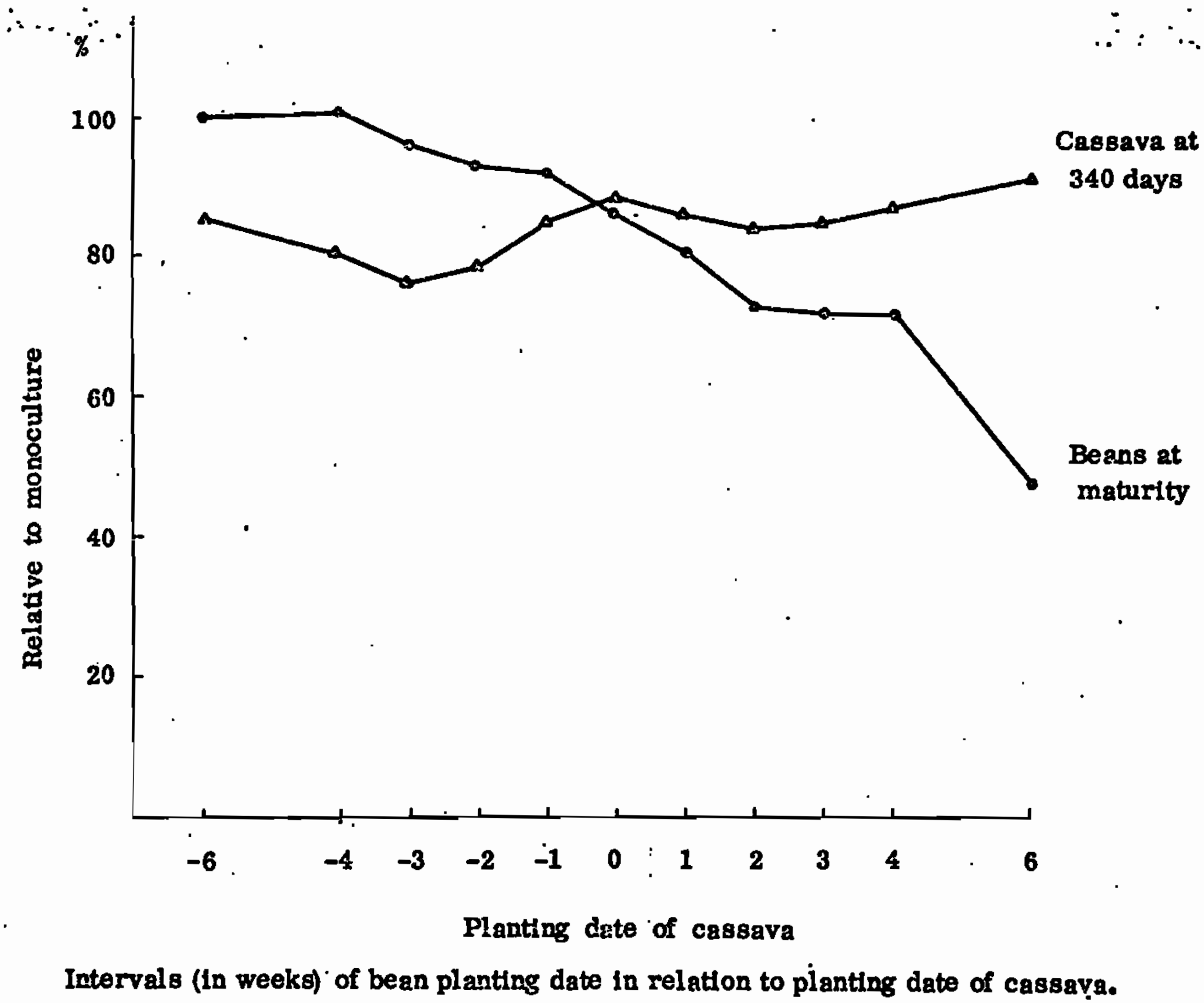


Figure 2.- Yield of cassava (root dry matter) and beans (14% moisture) at different relative planting dates (Thung, 1978)

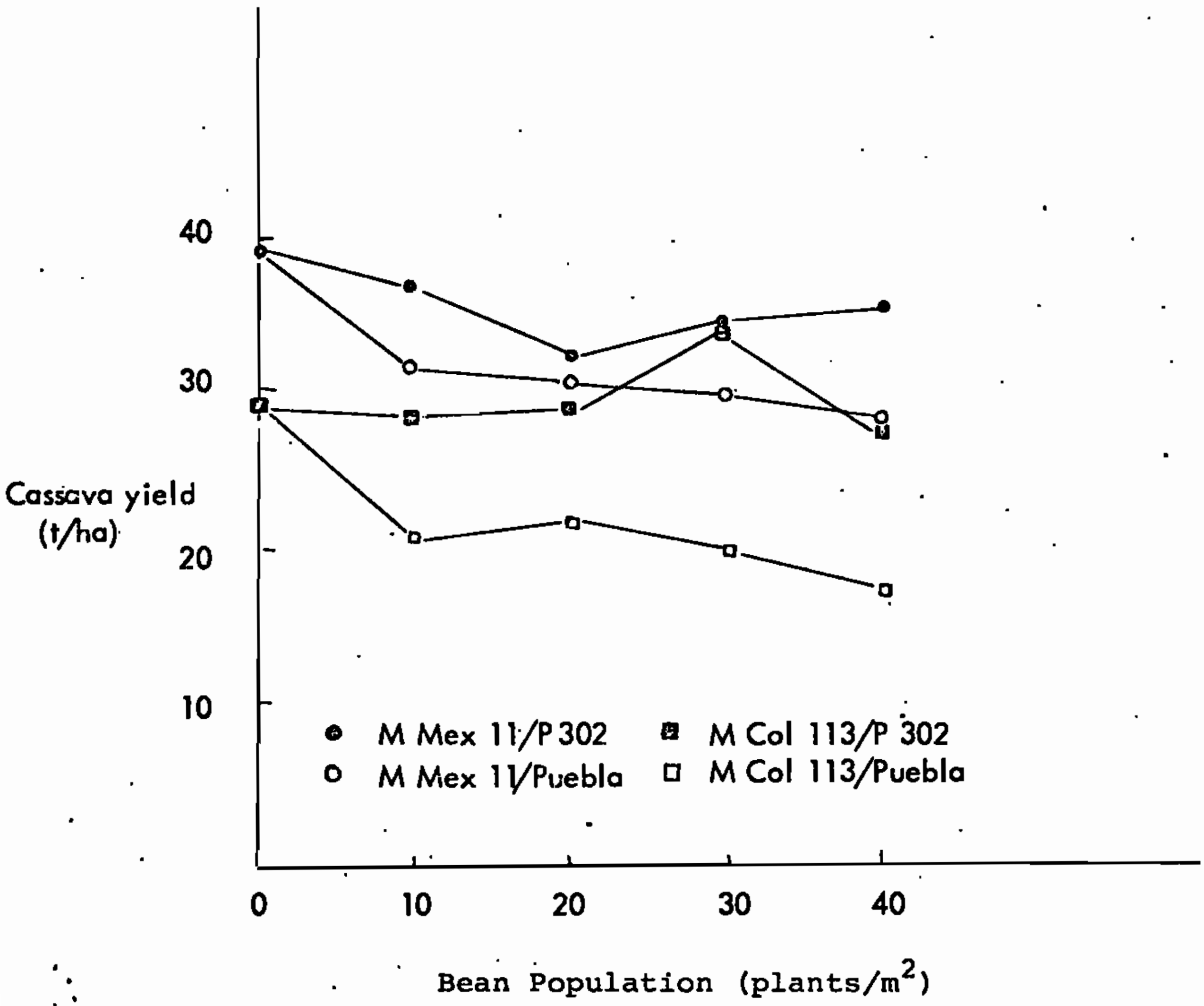
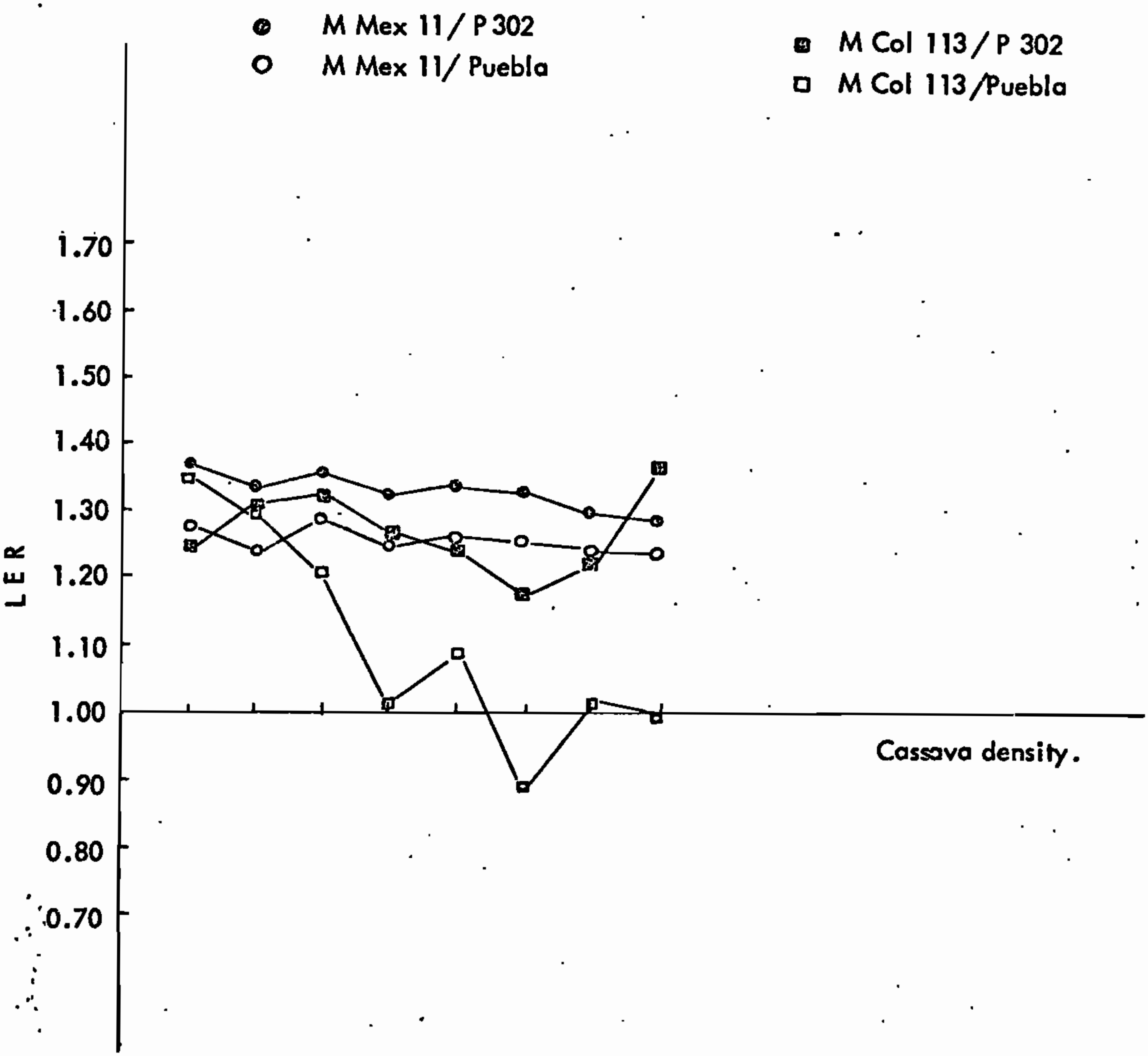


Figure 3.- Cassava yield as affected by bean population (Thung, 1978)

Figure 4.- Land equivalent ratio of different cassava-field bean combinations as affected by cassava planting density (Thung, 1978)



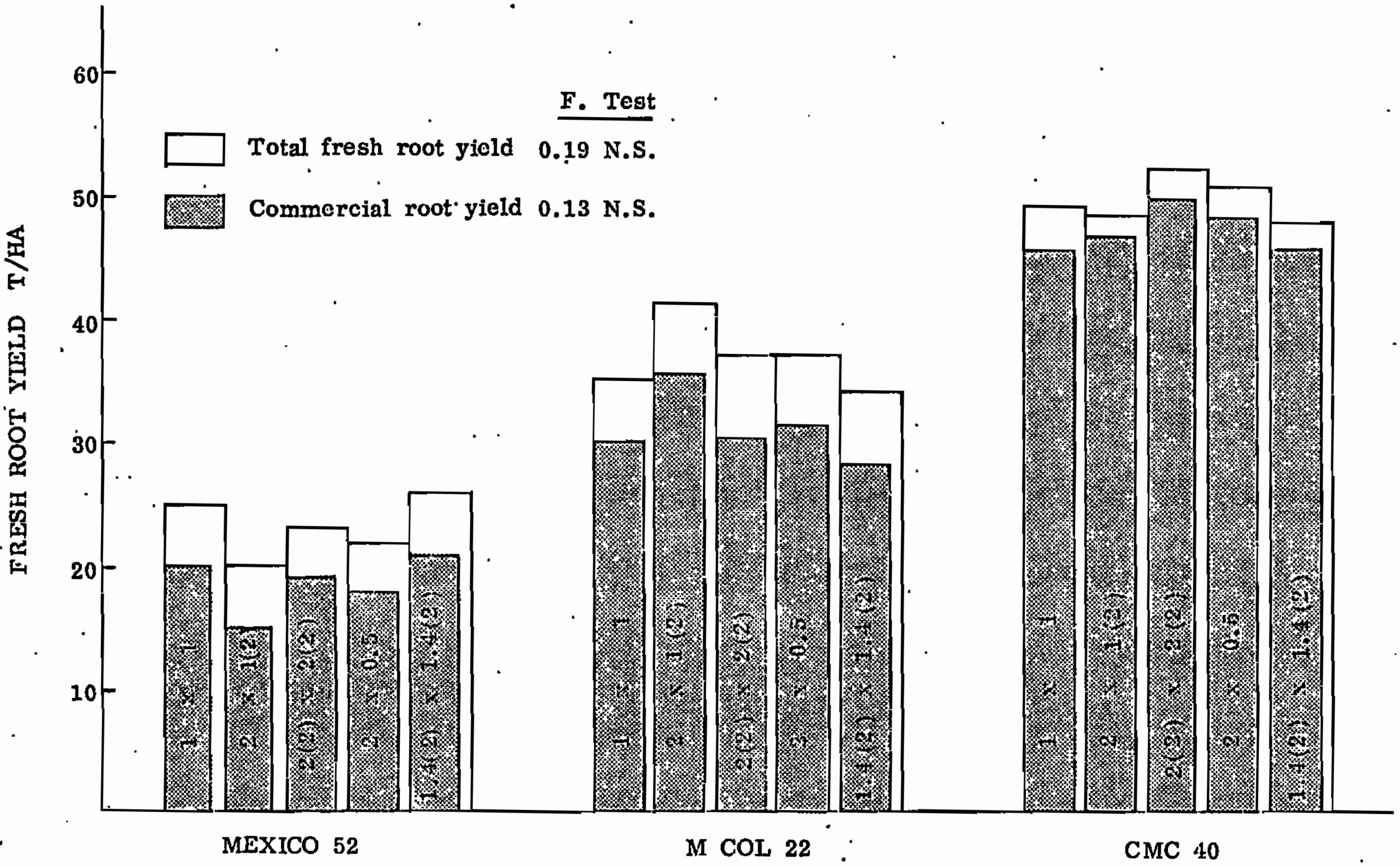


Figure 5.- Effects of planting patterns on total and commercial root yields of three cassava varieties at a standard density of 10.000 plants/ha, at CIAT, 1977. First figures in columns are distances (meters) between ridges, second figures are distances within ridges. Figures in parentheses are number of plants per site (Castro, 1977)

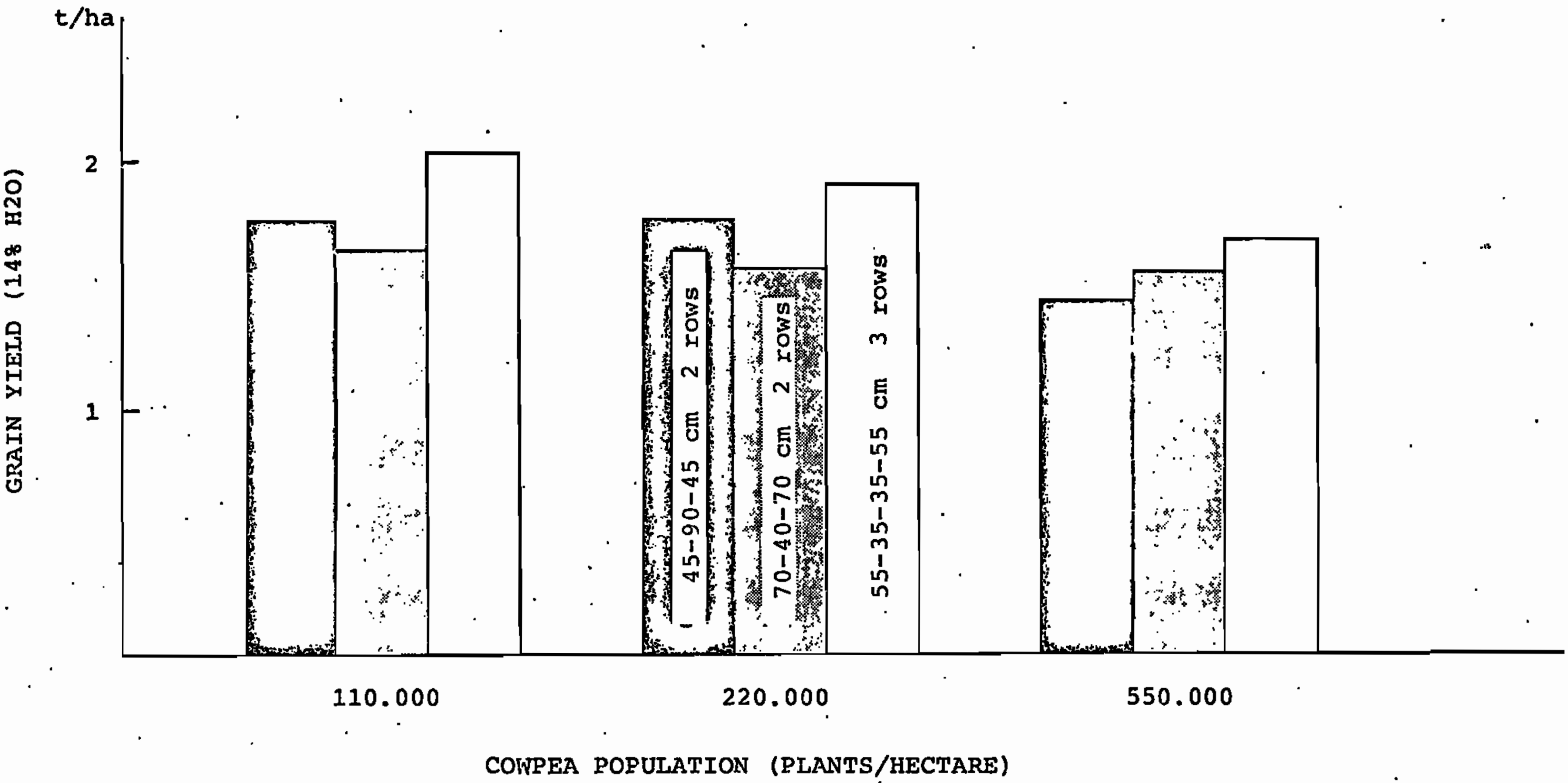
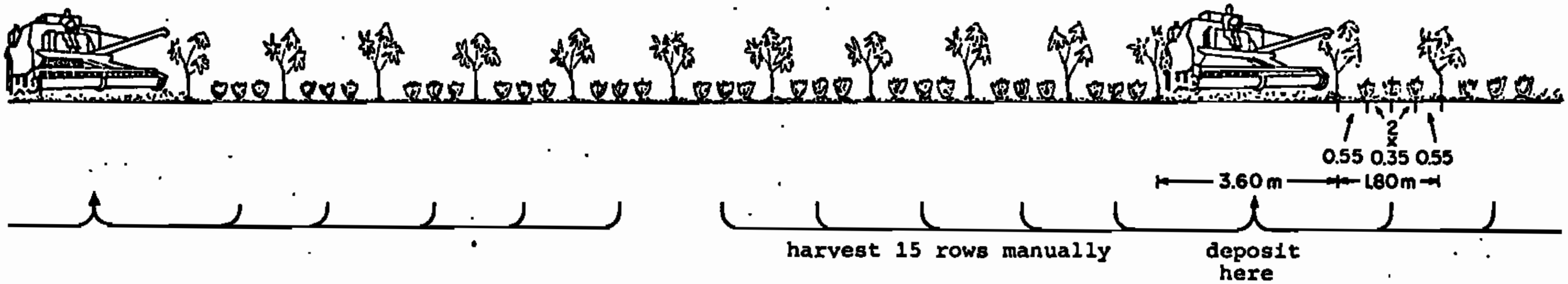


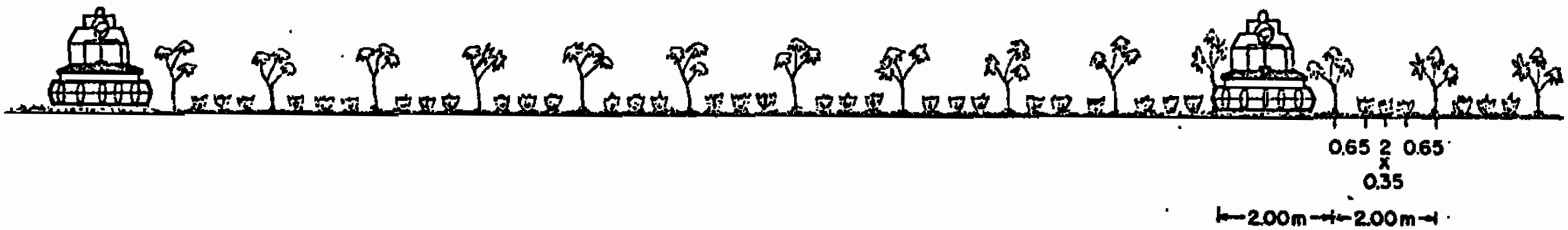
Figure 6.- Grain yield of cowpea in association with cassava as affected by different spacial arrangements of cowpea rows within the 1.80 m space between cassava. Three planting densities. CIAT Quilichao (Hegewald and Leihner, 1979).

Figure 7.- Mechanized harvest in cassava-grain legume intercropping (Leihner, 1979)

Manual-mechanical system, big combine
Cassava spacial arrangement, density = 1.80 x 0.60, 8.487 pl/ha (single row)
Grain legume arrangement, density = 0.60 x 0.15, 110.000 pl/ha (three rows)



Fully mechanized, mini-combine
Cassava spacial arrangement, density = 2.00 x 0.50, 10.000 pl/ha (single row)
Grain legume arrangement, density = 0.67 x 0.12, 125.000 pl/ha (three rows)



Fully mechanized, big combine
Cassava spacial arrangement, density = 1.80 x 0.60, 9.259 pl/ha (paired row)
Grain legume arrangement, density = 0.60 x 0.15, 110.000 pl/ha (six rows)

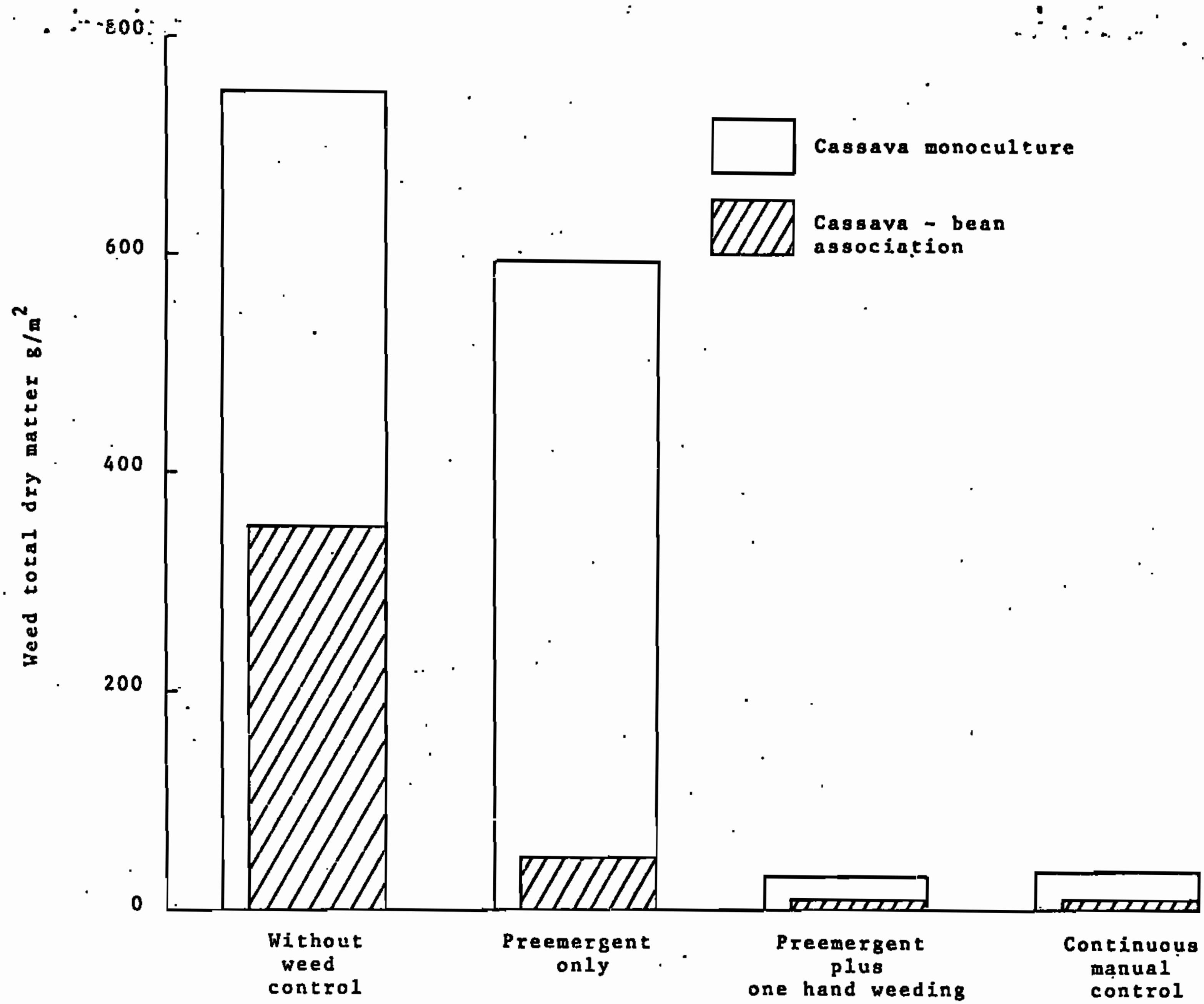


Figure 8.- Weed total dry matter in cassava monoculture and a cassava-bean association. Four weed control systems, 90 days after planting. (Leihner, 1978).