Centro Internacional de Agricultura Tropical

CASSAVA PROGRESS REPORT

Cassava/Swine Advisory Committee

March 19-21, 1973

Centro Internacional de Agricultura Tropical

CASSAVA PROGRESS REPORT

Cassava/Swine Advisory Committee

March 19-21, 1973

CASSAVA PRODUCTION SYSTEMS TEAM

James H. Cock, Assistant Physiologist, Leader
Carlos Lozano, Assistant Pathologist
Robert Booth, Visiting Pathologist (TPI)
Kazuo Kawano, Associate Breeder
Aart van Schoonhoven, Assistant Entomologist
Jerry Doll, Assistant Weed Scientist
P. P. Andersen, Associate Ag. Economist
Fernando Monge, Associate Communication Scientist
Fernando Fernandez, Coordinator, Plant Sciences Training

CASSAVA PROGRAM

General Introduction

In 1972 the Cassava Program began to build up to its full strength which will be reached in 1973. At the same time multiplication of planting material went ahead rapidly so that new trials could be planted

The germplasm bank, consisting of some 2,000 collections has now been freed of bacteria using a green shoot propagation method This system promises to give a simple system to rapidly propagate clean seed for release

A new disease that causes superelongation was reported and is being investigated It has been found in most areas of Colombia where cassava is grown extensively, but as yet has not been reported elsewhere

Preliminary observations suggest that under dry conditions thrips may be a very serious pest, however, there are lines that show a quite striking resistance to the insects

On the experimental farm acceptable yields in the region of 30 ton per hectare can be obtained in less than one year with little problem The search for higher yielding types is intensifying.

The optimal plant spacings and fertilizer levels are being investigated The optimal spacing on CIAT soils appears to be between 2 and 10 thousand plants per hectare Above this level yield drops off rapidly. On relatively fertile soil we have gained no response to N, P, or K However, on more impoverished soil fertilizer response will certainly occurr.

Studies on the losses caused by weeds and ways of preventing these are underway A large number of herbicides have been tested on a small scale Some of these appear particularly promising

The development of simple on-farm techniques of fresh root storage is progressing rapidly and the possibilities of using a soil and straw storage unit appear very good Progress has also been made in the description of the drying characteristics of cassava so that simple solar driers can be designed in the future

A study of world production figures suggest that cassava production is increasing at a rate equal to the population increase Productivity per hectare has not, however, increased Efforts are being made to study the alternative markets of cassava so that an excess, if produced, can be used

The collection of cassava literature continues and work on a comprehensive bibliography is well advanced

The Cassava Program has not been in a position to train many new people, however, as our knowledge and experience increases we are taking more trainees from different countries so as to extend knowledge of this neglected but important crop

Growth cycle of the plant

CMC 84, a bitter variety, was planted in the ICA farm at Palmira at 1 x 1 m spacing, using 25 cm stem cuttings inclined to the horizontal Missing plants were replaced by transplants one month after the original planting At planting 100 kg/ha of N, P_2O_5 and K_2O were applied A severe hailstorm 3 1/2 months after planting severely defoliated the plants and damaged some of the apical buds

Fresh weight root yield after three months was less than 3 ton/ha but thereafter increased rapidly to 26 ton/ha after 8 2 months (Fig 1) The percentage dry matter of the roots increased during the same period from 18 to 38 percent (Fig 2) Consequently, the yield of root dry matter increased from less than 0 5 ton/ha to 10 ton/ha after 8 2 months (Fig 3) This is equivalent to an annual production of more than 14 ton/ha of root dry matter

The increase in yield from 3 to 8 2 months was not due to a large increase in the number of swollen roots but due to an increase in their size (Fig 1)

The crop growth rate (CGR) during the first three months was extremely slow (19 g m^{-2} wk^{-1}), while leaf area was being formed (Fig. 4). Later, the CGR stabilized at about 60 g.m^{-2} wk^{-1} which is small compared with the crop growth rates achieved by many crops The level of CGR may be low for two reasons, firstly, the low leaf area index (1.4-2 2) during the period and secondly, because no attempt was made to assess the dry matter lost in the leaf fall, which might have been considerable.

Figure 5 shows the proportion of total dry matter that accumulated in the roots during the period between each harvest During the final two months the plant diverted 86 percent of its dry matter production into the roots, demonstrating a remarkably efficient partition of dry matter.

The nitrogen content of the various plant parts is shown in Figure 6). The nitrogen content of the leaves decreased form 4 7 percent at 3 months to about 3 5 percent at 6 months when apparently it became stable The percentage of nitrogen in the roots decreased steadily from 0 95 to 0 40 percent at 8 2 months The nitrogen content of the stems (without leaves and petioles) stayed almost constant at about 1 percent after 4 5 months

Transplanted plants had less thick roots and yielded less than regular plants, suggesting that this method of replacing missing plants is not effective.

Precocity

In the germplasm bank there are many varieties whose local name is "Tempranita" meaning early. Fifteen varieties* (ten of them called Tempranita) were planted as spaced plants (2 x 2 m) and harvested at 76, 100, 164 and 220 days to investigate variation in the time the plant begins to store carbohydrates in the roots, a process called rootbulking. By 76 days none of the varieties had produced a substantial root yield but by 100 days most of the varieties had started to produce root yield (Fig 7). None of the varieties showed a delay

*Two collections were later lost because of severe bacterial infection in onset of root bulking followed by a rapid rate of bulking

These results suggest that there is little if any difference in the onset of root bulking, however, some varieties appear capable of producing acceptable yields after seven months' growth Strain M Colombia 137 will be propagated and tested further

Germination of cuttings under field conditions

Stem cuttings 15 cm long of CMC 71 and CMC 64 were planted vertically, inclined horizontally and inverted (with the axillary buds pointing downwards) Germination was assessed by counting the number of buds that broke the soil surface. The soil conditions were dry during the measurament period The vertically planted cuttings emerged most rapidly in both varieties (Fig 8), while those planted upside down emerged most slowly In CMC 71 the final germination for all treatments was similar In CMC 64 the inverted cuttings never reached the level of the other treatments. This experiment is being continued to give final yield figures

Two node cuttings of Llanera and M Colombia 375 were planted in the field either treated with 4,000 ppm of NAA or IBA absorbed on talc or as untreated controls Germination was more than 90 percent in all treatments, and no improvement in germination was associated with the treatments These results suggest that, under good management, two node cuttings can be used in the field when there is a shortage of planting material, and that hormonal treatment does not improve germination.

Farmers frequently plant cuttings which previously bore side branches.

Simple and branched cuttings of CMC 84, Llanera and M Colombia 1080 were cut to 25 cm The branched cuttings were as shown in Fig 9 Germination was both slower in branched cuttings than in simple ones (Table 1) Hence, where-ever possible, plant simple cuttings

Lead angle and stomatal resistance

Leaf angle is important in considering the interception of light in a crop canopy The angle from the horizontal of an expanding leaf, the upper-most fully expanded leaf and a lower leaf were measured on two varieties on a clear day (total radiation 462 gcal/cm) The lower leaf of both varieties remained horizontal during the day (Fig 10) The first fully expanded leaf of M Ecuador 44 also remained almost horiztontal during the day However, the leaf angle of M Colombia 114 increased from about 10° at 9 00 to maximum of 45-50° at midday before declining to a 10° in the late afternoon The expan-ding leaves of both varieties changed their leaf angles in a similar manner, reaching a maximum of 60° and 70°, respectively, for M Col 114 and M Ecu 44

At the same time, stomatal resistance was measured using a diffusion resistance meter The readings varied In M Ecuador 44 the resistance ten-ded to decrease until 10-11 a m and then to increase The mean resistance of the lower leaf was much greater (7 0 seconds/cm) thant the expanding (4 6) and the first expanded leaf (4 4). In M Col 114 the stomatal resistance of the expanding and first expanded leaf remained nearly constant throughout the day (mean figures of 4 5 and 4 1, respectively) while the lower leaf resis-tance increased from about 6 to about 14 sencond/cm during the day (mean value of 10 7)

7

Table 1. Germination of branched and un-branched stakes

Variety	Days after planting	Simple	Branched
Colombia 1080	16	71	38
	21	97	86
	25	100	87
CMC 84	16	80	62
	21	97	92
	25	99	97
Llanera	16	47	16
	21	73	51
	25	83	61
Mean	16	66	39
	21	89	76
	25	94	87

There was no apparent relationship between leaf angle and stomatal resistance, suggesting that the change in leaf angle is not associated with midday wilting. This may be important in selecting varieties with high dry matter production because it appears possible to select varieties that have inclined leaves at midday, which is beneficial to uniform light interception, without having a detrimental effect on stomatal aperture and hence, dry matter production of the canopy

Effects of different spacings

Three varieties of cassava, CMC 84, CMC 39 and Llanera, were shown in a systematic fan design at plant populations ranging from approximately 2,000 to 80,000 plants per hectare Harvest had been taken at 3,5 and 7 months After 5 months, lodging became progressively more pronounced in CMC 84 and CMC 39, and the latter variety had almost completely lodged at all plant populations after 7 1/2 months (Fig 11). Up to seven months there was no lodging in Llanera.

At three months, yield in all varieties was less than 4 ton/ha at the optimum plant populations (Figs. 11, 12, 13) which were not clearly defined. At five months all varieties showed marked optimum plant populations for yield between 5,000 and 9,000 plants per hectare. By seven months, CMC 84 produced its maximum yield of about 18 ton/ha between 5-9 thousand plants per hectare while CMC 39 also produced a maximum yield of about 18 tons/ha at between 2-5 thousand plants pere hectare Llanera at seven months produced a maximum yield of about 24 ton/ha between 3-7 thousand plants per hectare These results indicate that 1) in cassava there is an optimum planting density and 2) this optimum varies with variety

The decrease in yield of these varieties at higher than optimum plant densities is because of a decrease in thick root number per hectare ~~(Fig. 15).~~ In all varieties thickened root number per hectare appears to be reaching a plateau at about 80-90 thousand roots per hectare (Fig 15).

The decrease in yield at high plant populations is because of a market decrease in weight per thickened root as plant population increases (Fig 16)

The total dry matter production did not show an optimum plant population (Fig 17) At five months it increased from about 7 ton/ha at 2.5 thousand plants per hectare and reached a plateau of about 12 ton/ha However, the proportion of the total dry matter found in the roots showed a marked decrease as plant population increased (Fig 18)

The relationship between crop growth rate and leaf area index between 3-5 months was extremely variable unless an allowance was made for the weight of leaves and petioles lost through senescence. This was estimated by multiplying the mean leaf loss per week by the mean leaf weight from 3-7 months In CMC 84 GCR increased with leaf area index (LAI) up to about 4 giving a CGR of about 150 g m^{-2} wk^{-1} while in CMC 39 CGR increased with increasing LAI up to about 3 and reached a plateau value of about 110 g m^{-2} wk^{-1} (Fig 19)

These results are somewhat surprising in view of the light transmission data collected for these two varieties (Fig 20). Light transmission was measured on a clear day at midday when the plants were approximately 3 months old CMC 39 absorbed less light per unit LAI than CMC 84, suggesting greater light penetration This should in turn lead to a greater critical LAI but does not The reason is not clear but may be related to the leaf angle changes reported above

Preliminary varietal observation

The work previously described suggests that growth rate of the cassava plant increases as plant population increases but that the proportion of this growth found in the roots decreases, in some varieties, as plant population increases To select for high-yielding varieties that can withstand high populations and fertility levels, ~~more than 30~~ 28 varieties were sown at 70 x 70 cm spacing (about 20 x 10^3 plants per hectare) with 100 kg/ha of N, P_2O_5 and K_2O These varieties will be harvested at 4, 6, 8 and 10 months.

After 120 days, M Colombia 22 had the highest yield, 12 4 ton/ha There was a close relationship between harvest index and yield, a loose relation between yield and total dry matter production, and no relation between yield and percentage dry matter of the root (Figs. 21, 22, 23) Thus, it seems that higher yielding varieties can most easily be selected by choosing those with highest harvest indices, and that high yielding varieties can be selected which also have a high root dry matter content

Of the 14 varieties, so far harvested at both 4 months and 6 months, there is a close correlation between yield at the two periods suggesting that 1) the breeder can use young plants to select for final yield and 2) there is little difference in the time at which varieties start bulking (Fig 24)

So far, there does not appear to be any obviously superior plant type The three highest yielding varieties at 4 months were respectively short, branched with fine leaves, tall unbranched with broad leaves and medium height, branched with broad leaves

Varietal Selection

Five promising varieties were chosen from the germplasm bank and planted as two node stem cuttings (treated with NAA) in red acid soil and three weeks later transplanted at 1 x 1 m spacing for planting material multiplication plots Ten plants, all surrounded by at least two border rows, were harvested 7 1/2 months after planting Details of the yield data are presented in Table 2 M Colombia 22, a short variety from the North Coast of Colombia, showed a remarkable yield potential producing 29 ton/ha after 7 1/2 months which is equivalent to 46 0 ton/ha year The production of root dry matter is equivalent to 17.8 ton/ha year The root shape of this variety is short, almost conical, and hence it is easy to harvest Further evaluation of this variety is underway

Table 2 Yield and root characters of five varieties 7 1/2 months after planting

Variety	Yield ton/ha (Fresh material)	Yield ton/ha dry matter	Percent moisture of root	Root number per plant	Weight per Root ~~(Kg)~~
M Panama 64	17	4.9	29	16	0 11
M Colombia 65	22	8 2	38	21	0 10
M Colombia 645	14	4 5	32	14	0 10
M Colombia 463	14	4 5	32	13	0 11
M Colombia 22	29	11 2	39	18	0 16
Mean	19	6 7	34	16.4	0 12

PROPAGATION

Techniques for propagation, storage of cuttings and the influence of agronomic practice on cutting production are being studied as a doctoral thesis by Douglas W Wholey, a research fellow supported by CIAT, and a graduate student of the University of the West Indies

Small size propagules

Cassava research is repeatedly slowed because of the lack of planting material, hence, rapid propagation methods are being studied Although preliminary investigations demonstrated that cuttings with a single node from mature stems can be rooted under greenhouse conditions, poor results were obtained under field conditions Two node cuttings have given highly acceptable rates of emergence and establishment and are now used to plant in the field, where, because of a shortage of planting material, normal size stakes, i e 15-25 cm, are not available.

For success, two node cuttings need to be of excellent quality and must be grown under intensive care during the rooting and establishment phase. Well-prepared soil is required as well as attention to both drainage and irrigation. Protection must be provided against pests which damage the buds and emerging shoots Crickets, centipedes and cut worms are problems at CIAT but have been controlled by applying Aldrin powder to the soil surface, around the young shoots

A bamboo lath house has facilitated experimental evaluation of rooting media, methods of planting and the effects of rooting hormones and fungicides on emergence and establishment of two node cuttings.

* These studies are being made by Mr Douglas W Wholey, a research fellow supported by CIAT, on this doctoral thesis and a graduate student of the University of the West Indies.

Rooting media

Six locally available rooting media with pH's ranging from 4 9-7 3 and organic matter from 0 6-5 2 percent were prepared as raised beds Soils were kept constantly at or near field capacity The CIAT soil, probably because of its higher water retention properties, supported a more rapid rate of emergence of two node cuttings Differences in final establishment values were not statistically significant Figure 24 shows the rates of emergence from the two most contrasting media All the other treatments fell in between the two curves

Rooting method

Rate of emergence with two node cassava cuttings was more rapid with inclined cuttings than with those horizontally placed Vertically placed stakes produced intermediate results (Fig 25) The initial advantage of inclined or vertical over horizontally placed cuttings is rapidly lost, and all planting methods yield similar establishment percentages after four weeks

Rooting green cuttings

Two node cuttings of Llanera were prepared from green stems with leaves still attached An experiment to compare the rooting of this type of cutting with mature wood cuttings showed that more than 90 percent success can be achieved with both types of cutting, but diseases result in the subsequent loss of a high proportion of these green stem cuttings

Disease problems in propagation

Three weeks after planting, symptoms of "damping off" began to appear on the green stem cuttings. Diseased cuttings were examined by the pathologist and isolates of <u>Fusarium</u> sp, <u>Sclerotinium</u> sp, <u>Pythium</u> sp and <u>Alternaria</u> sp obtained However, while these fungi are known to be common soil borne pathogens, the causal relationship between these fungi and the reported disease of cassava cuttings has not been established

Dipping green cuttings in 1 percent Manzate D fungicide increased the rate of establishment from 51 to 72 percent and may be recommended as a protective measure against soil borne pathogens

<u>Rooting hormones</u>

The application of naphthalene acetic acid (4,000 ppm absorbed on talc) to the base of each cutting increased rate of rooting in green cuttings (Fig 25) and the number of roots produced from the callus at the basal cut in both types of cuttings

<u>Rapid propagation methods</u>

Preliminary studies demonstrate that high humidity plays an important role in both shoot and root production Mature stem cuttings rooted horizontally in vermiculite under high humidity produce shoots from a high proportion of the nodal buds The excised shoots may be rooted allowing further shoot production from the same nodal growing point. Six mature stem cuttings (a total of 60 nodes) produced more than 180 shoots in 42 days using this technique, a three-fold incease over single node propagation methods The methods of maximizing production and rooting of these green shoot cuttings, using mist propagation are being studied further

Tip cuttings

Green shoot cuttings produced under high humidity and shoot tips from young plants grown in the field can be successfully rooted This technique has enabled the production of plants free from disease organism harbored in the old cutting piece

A humidity chamber has been designed and constructed enabling large scale rooting of tip cuttings for pathological screening Under constant mist it has been found that fine gravel provides a better rooting medium than a mixture of sand and gravel or sand alone.

Storage of cuttings

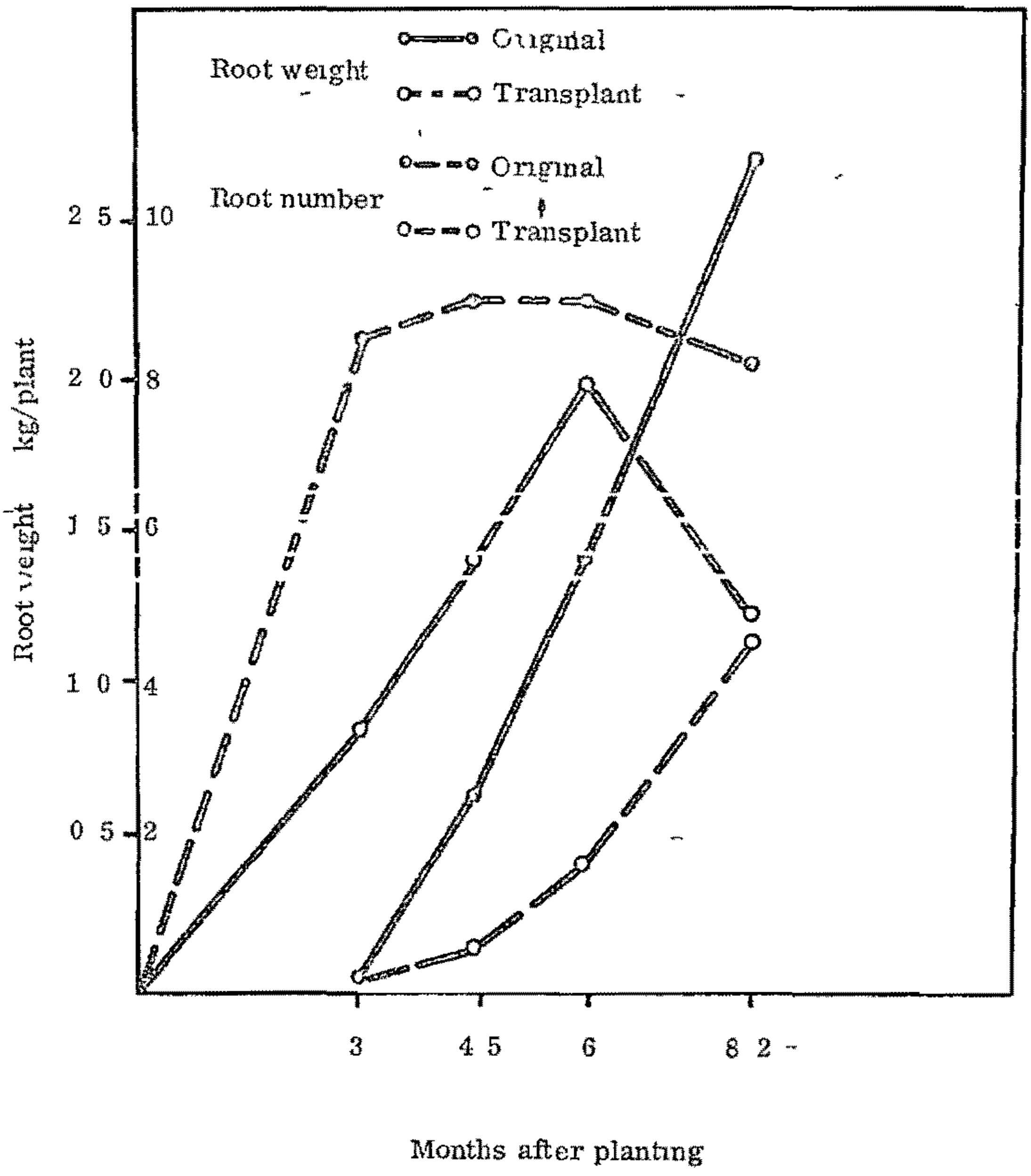
Long cuttings (i e greater than 1 m) have been kept for up to 3 months with the central portion viable, however, short cuttings (less than 25 cms) rapidly deteriorate.

Groups of cuttings with paraffin waxed ends were compared with non waxed cuttings in an experiment to investigate moisture loss (Fig 27) Waxing did not reduce loss of fresh weight at the 5 percent level of probability.

Storage attitude did not affect overall storage behavior, however, it was noted that bud breaking was delayed when cuttings were stored in the inverted position, and a larger proportion of nodal buds developed into shoots in horizontally stored cuttings than either vertical or inverted cuttings

The moisture content of the cuttings fell from 67 to 46 percent after 50 days storage in a room at ambient conditions Waxed cuttings deteriorated rapidly after the twentieth day in storage because of a fungus (Glomerella sp) which developed under the wax.

After 50 days 48 percent by length of the waxed planting material had to be dicarded because of the fungus Only 16 percent of the unwaxed material had deteriorated Non-diseased cuttings from both treatments showed more than 90 percent germination, there being no differences between treatments Waxing is not presently recommended as a stake storage method



Root weight and number per plant original and transplanted plants of CMC 84

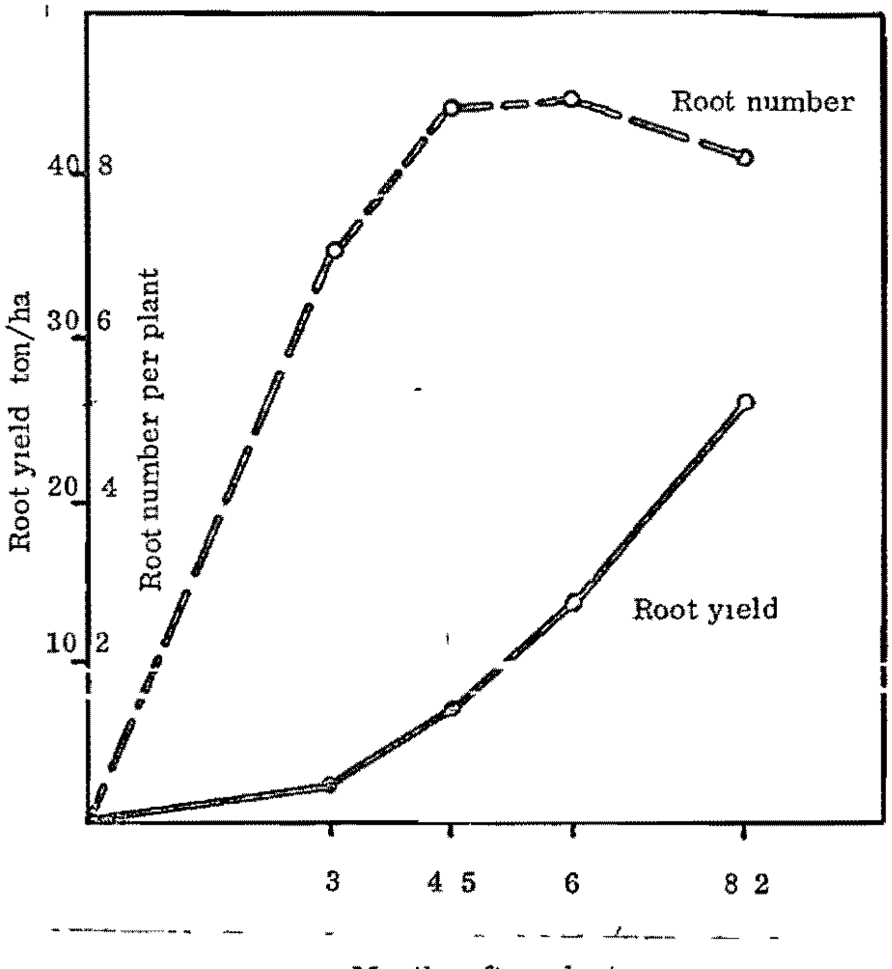


Fig 1 Yield and root number of variety CMC 84

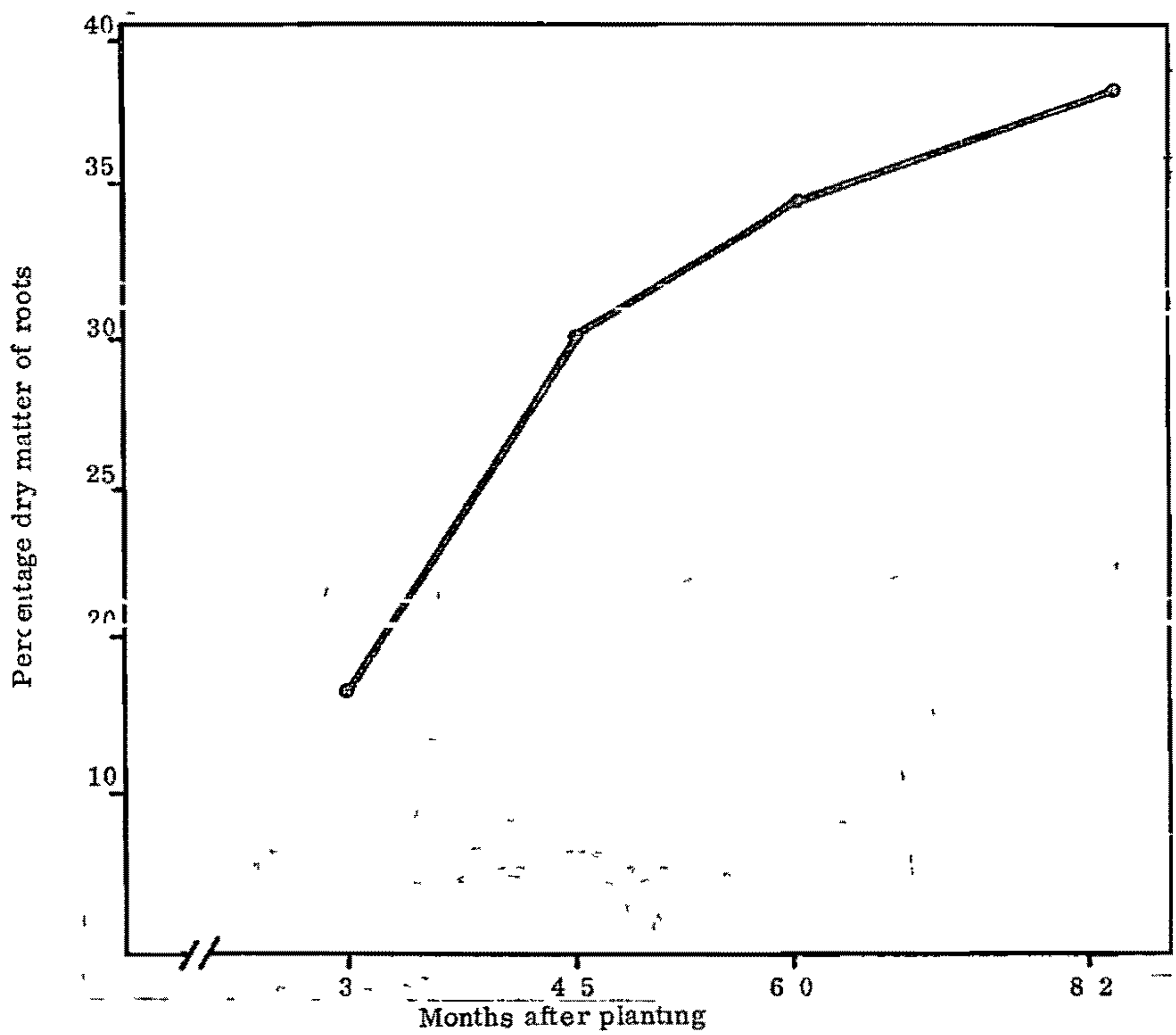


Fig 2 Dry matter contents of roots of variety CMC 84

Fig 3 Dry matter production of whole plant and roots and Leaf Area Index (LAI) in variety CMC 84

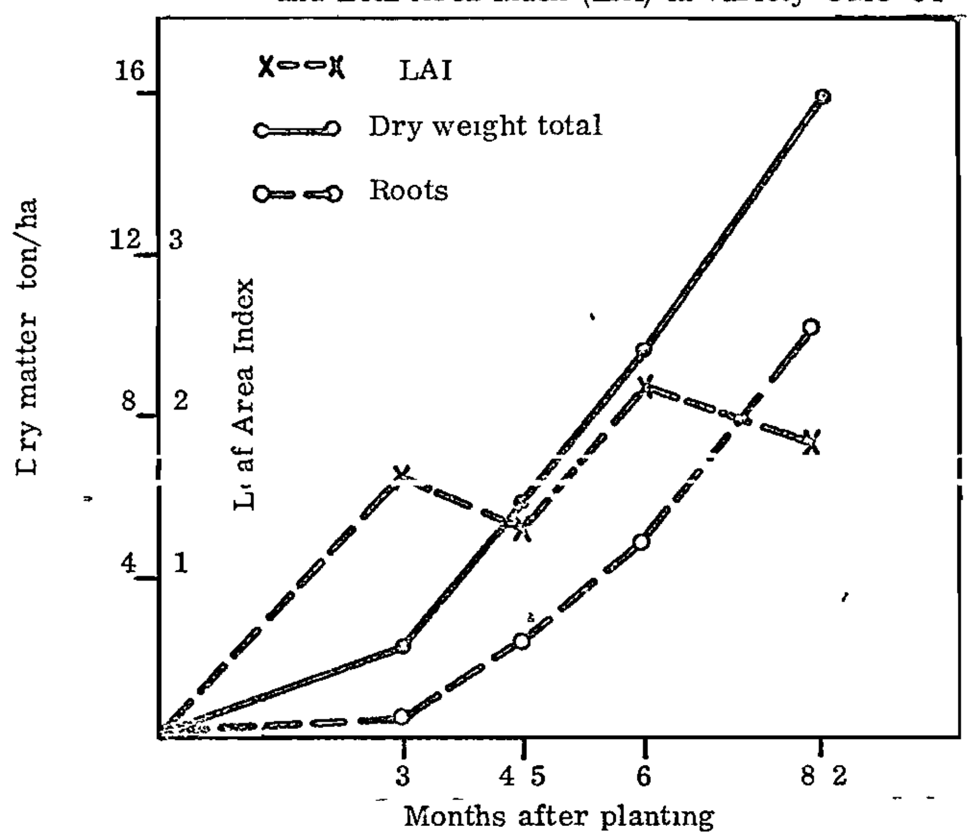
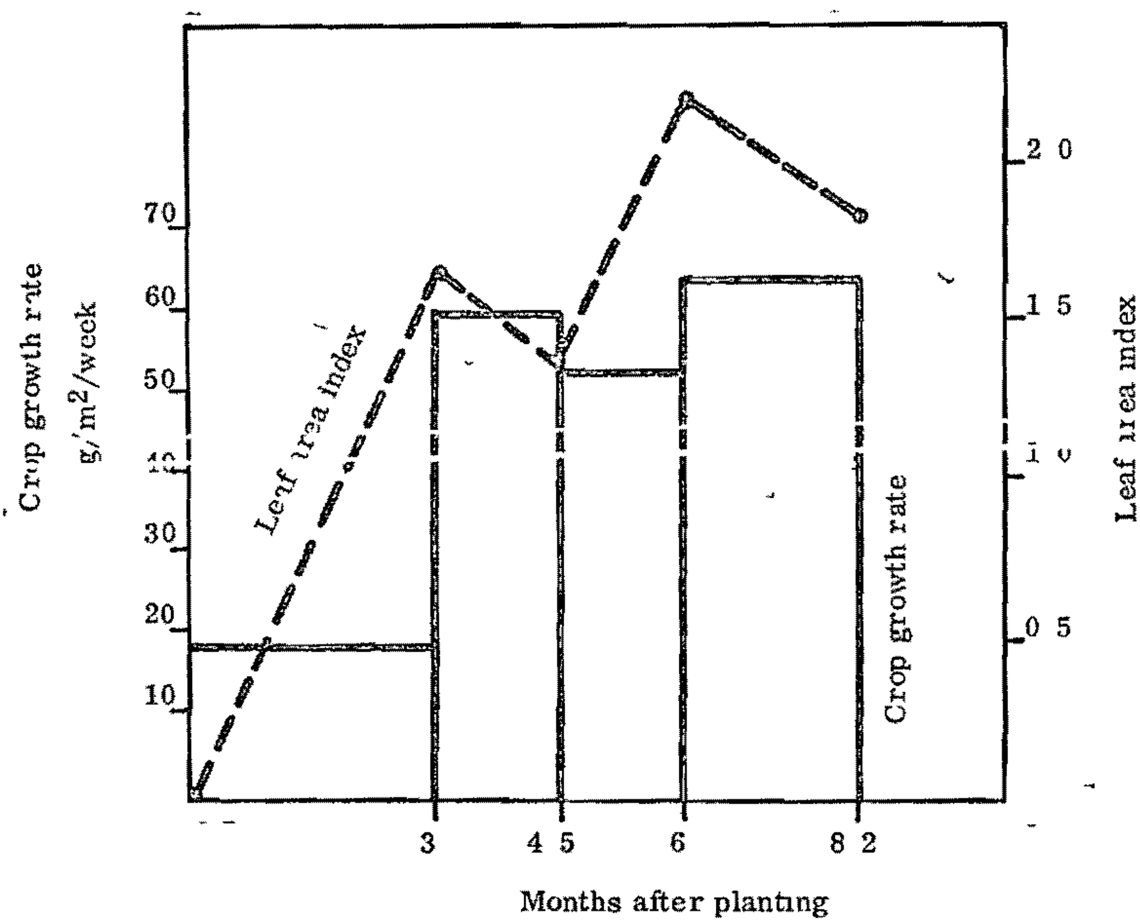


Fig 4 Crop growth rate and leaf area index of variety C M C 84



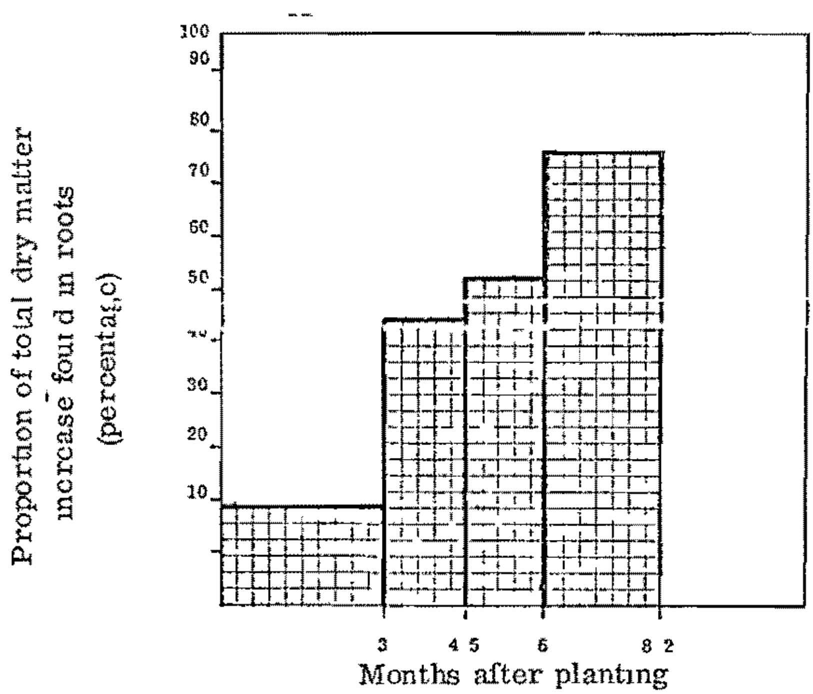


Fig 5 Distribution of dry matter in variety CMC 84

Fig 6 Nitrogen content of various plant parts

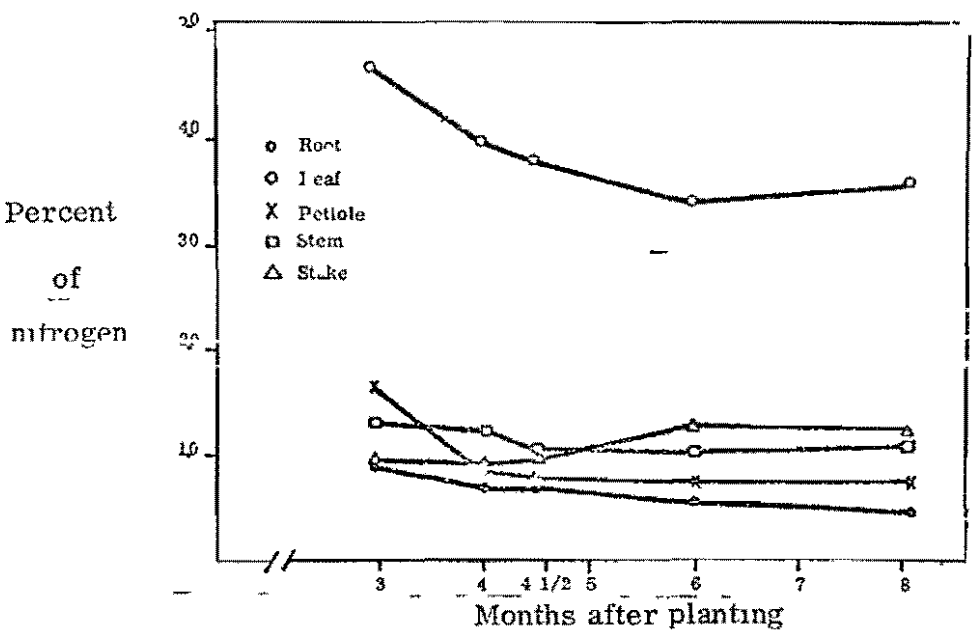
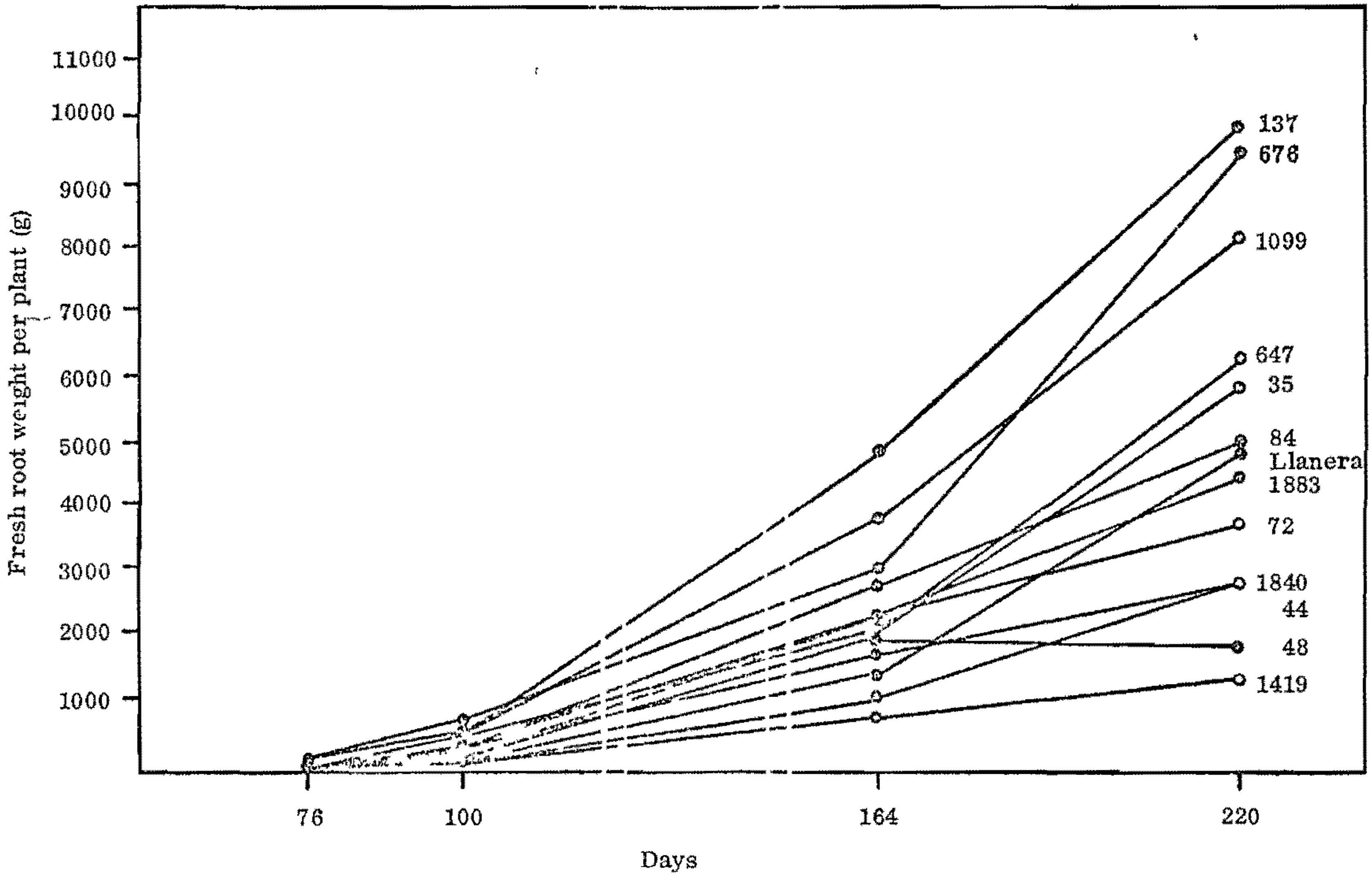


Fig 7 Increase in fresh root weight of 13 cultivars of cassava grown as spaced plants (numbers refer to M Colombia material)



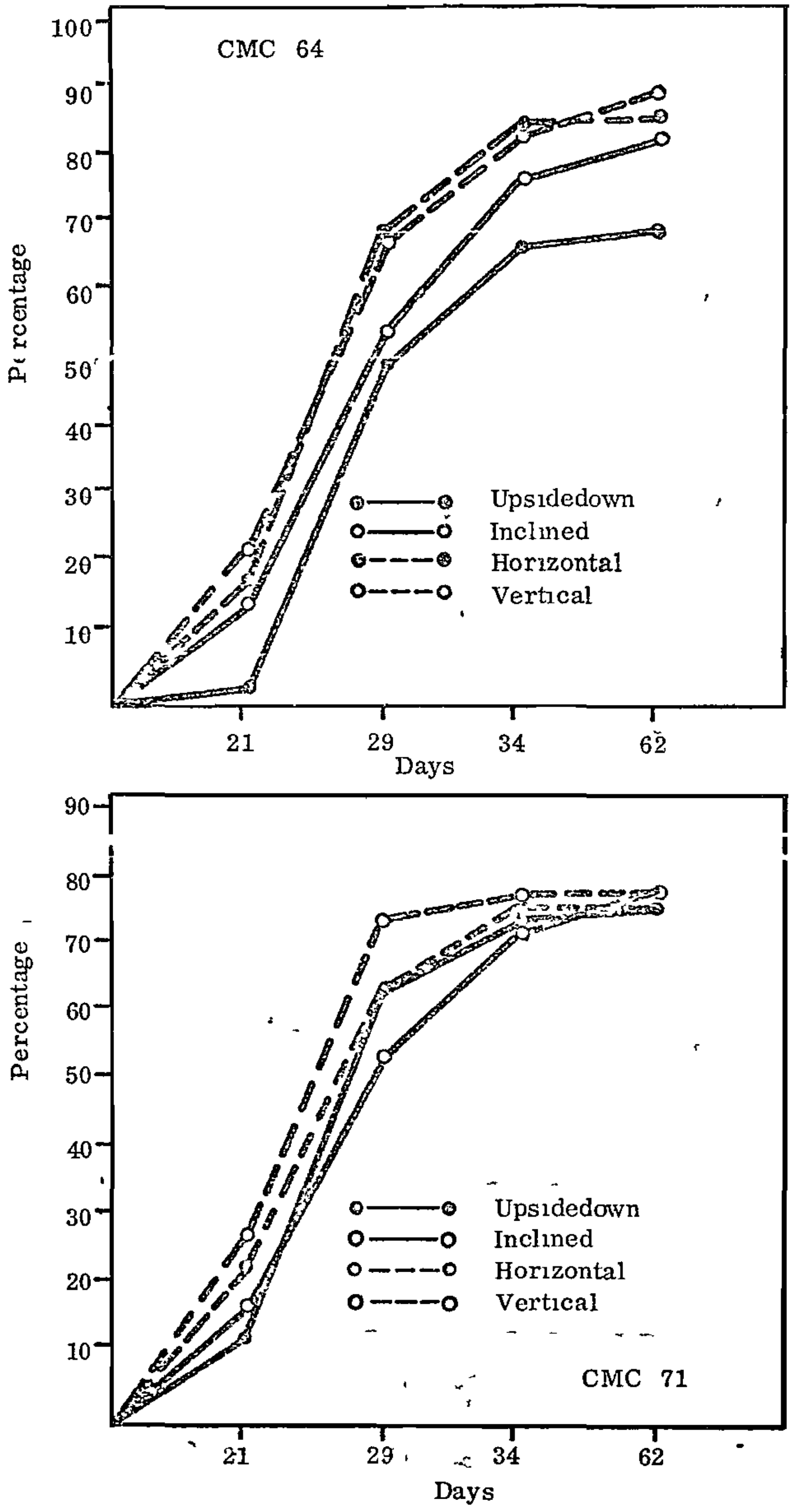


Fig 8 Germination of stakes planted with four different placements in varieties CMC 64 and CMC 71

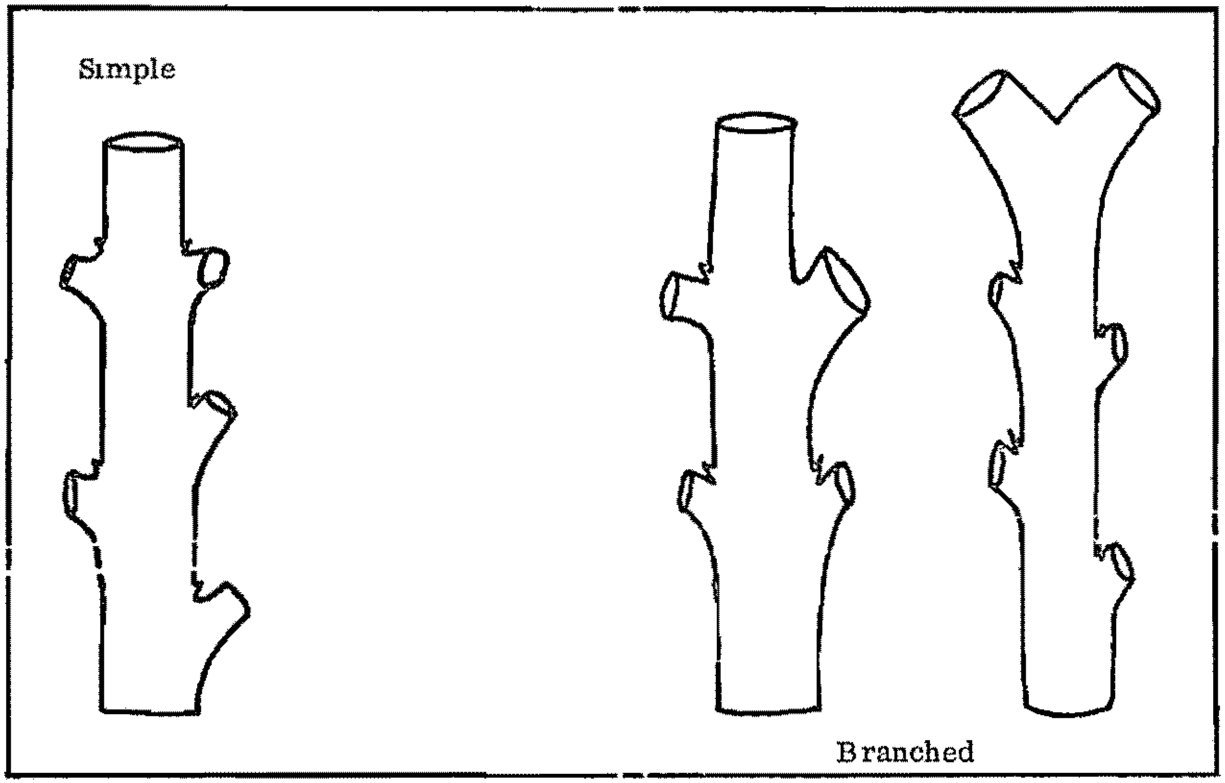


Fig 9 Simple and branc ied stakes of cassava

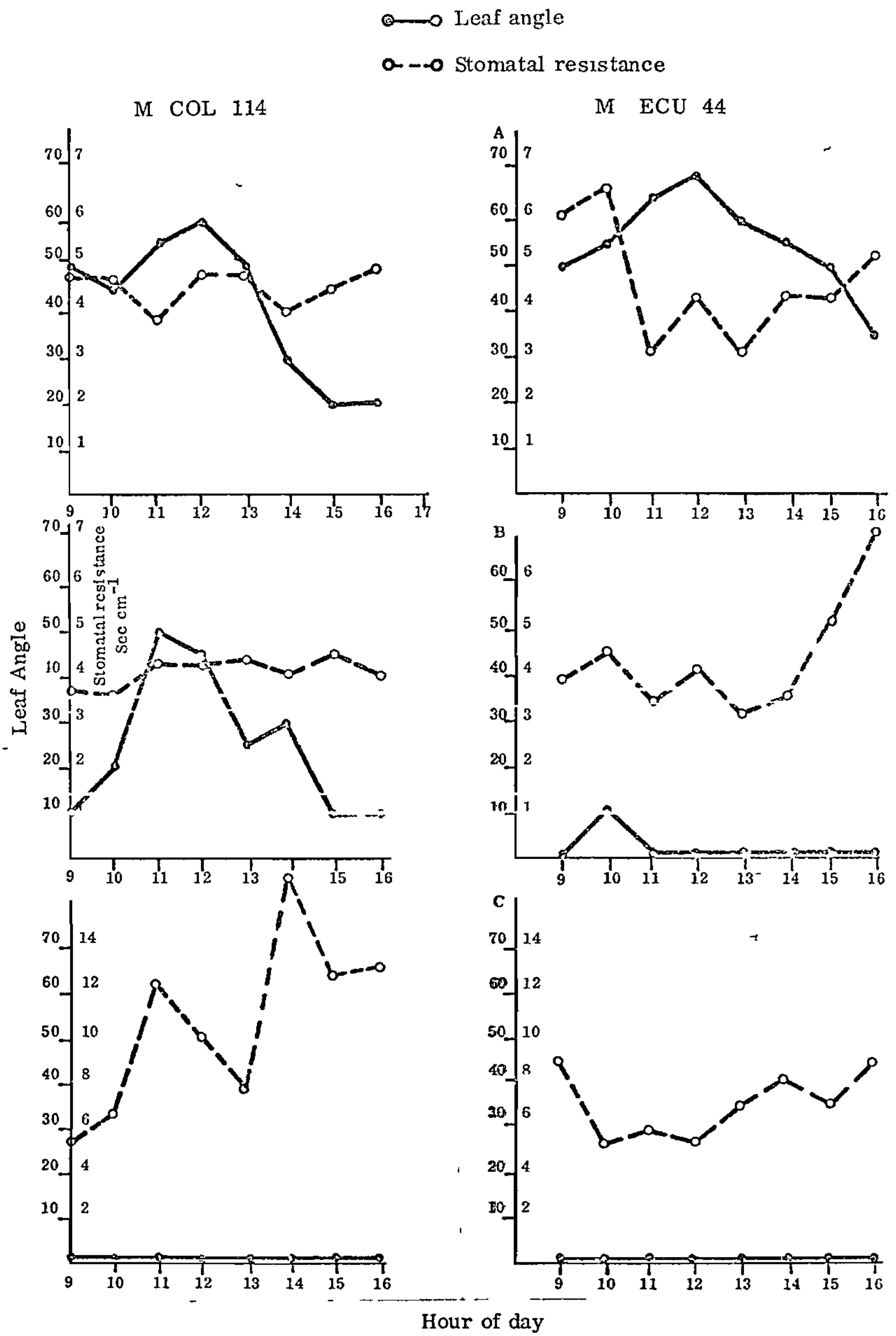


Fig 10 Leaf angle changer in two cassava varieties

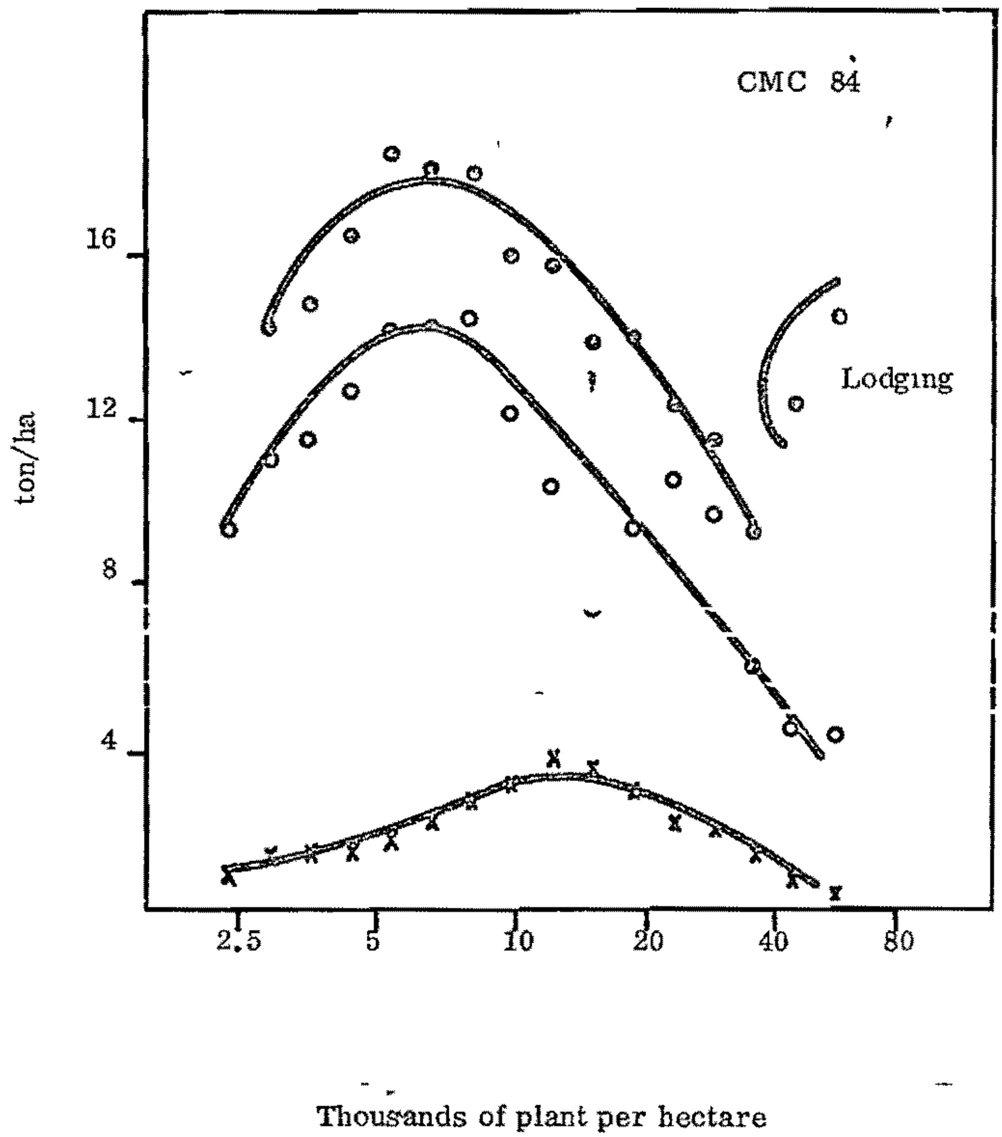
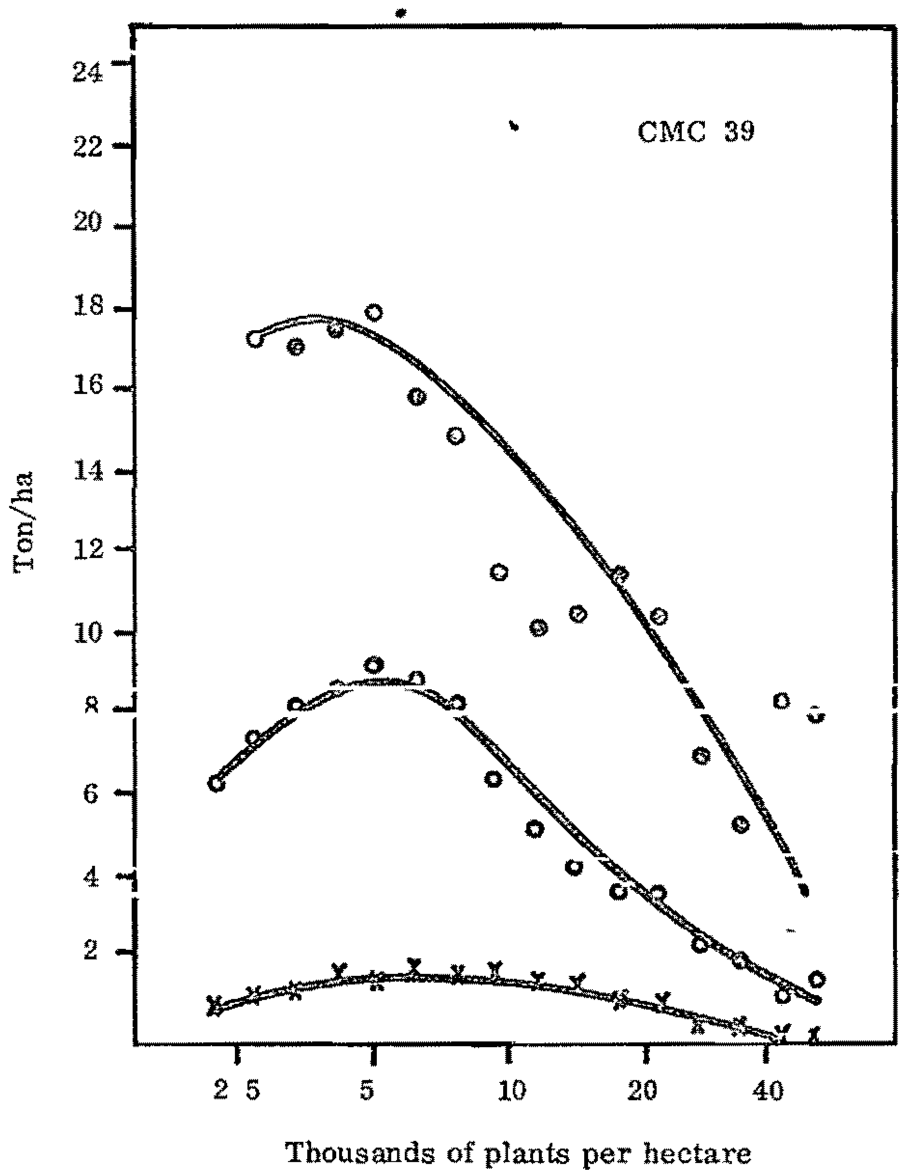


Fig 11 Yield at three months (x—x), 5 months (o—o) and 7 months (o—o) in variety CMC 84

Fig 12 Yield at 3 months (x—x), 5 months, (o—o) and 7 months (o—o) in variety CMC 39



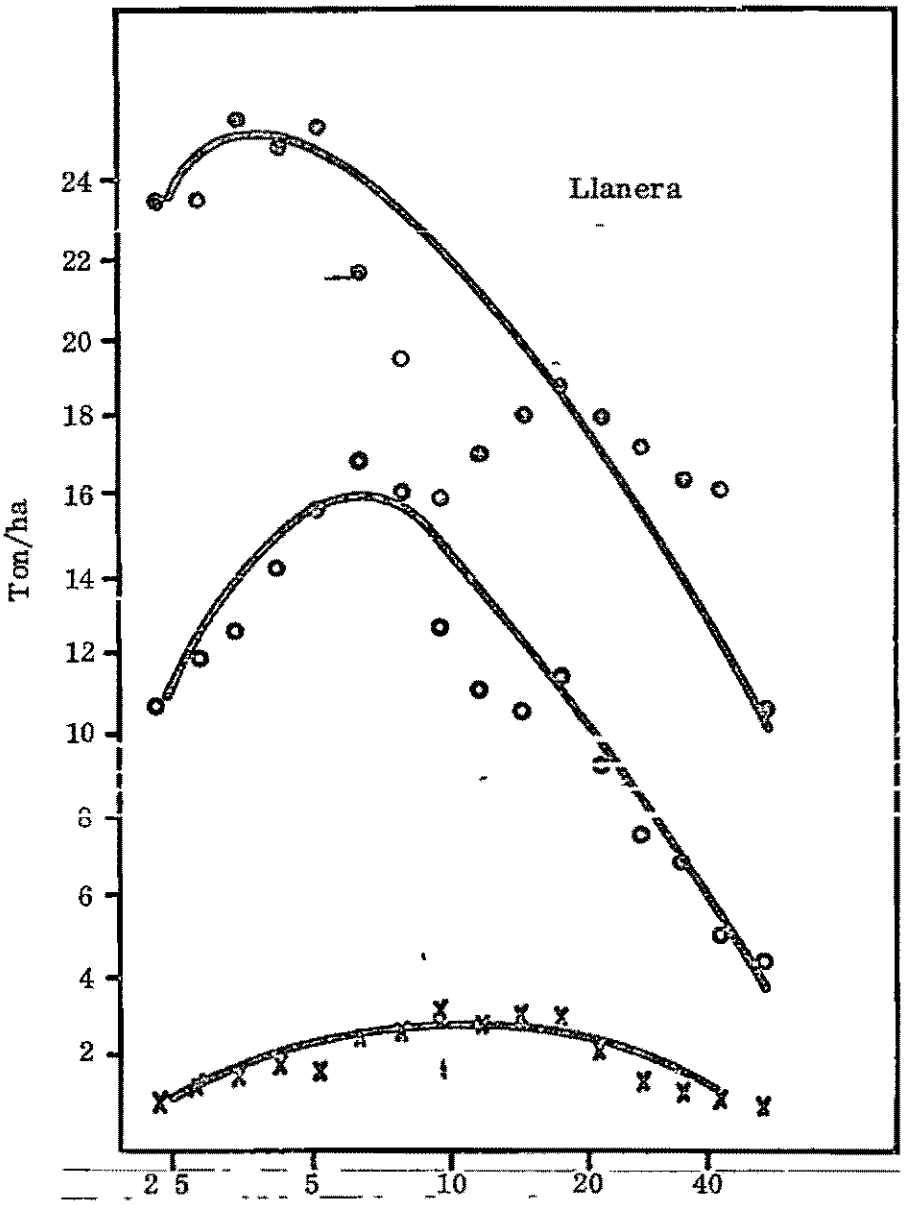


Fig 13 Yield at 3 months (x-x), 5 months (o-o) and 7 months (⊙-⊙) in variety Llanera

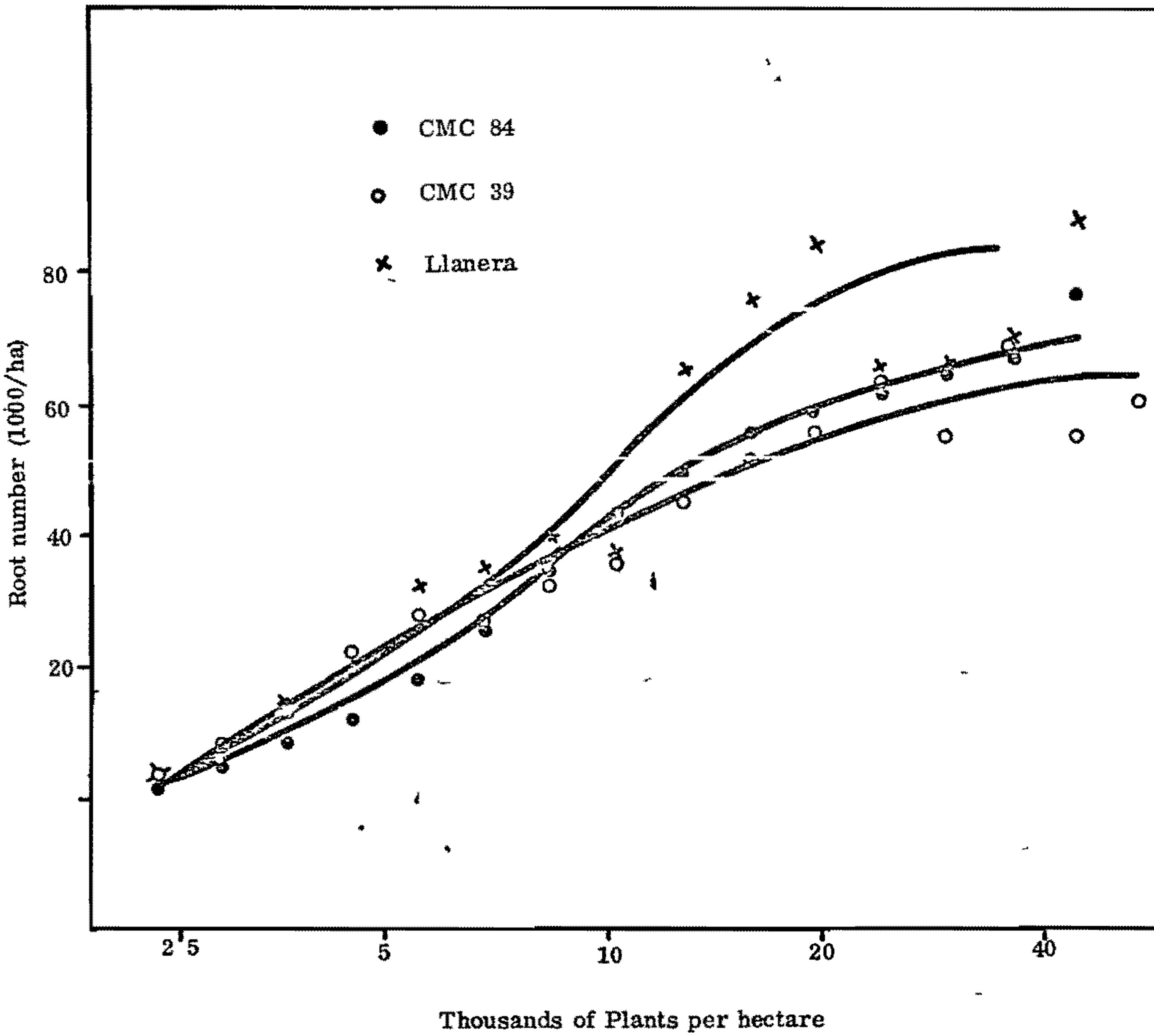


Fig 14 Root number per hectare at 7 months

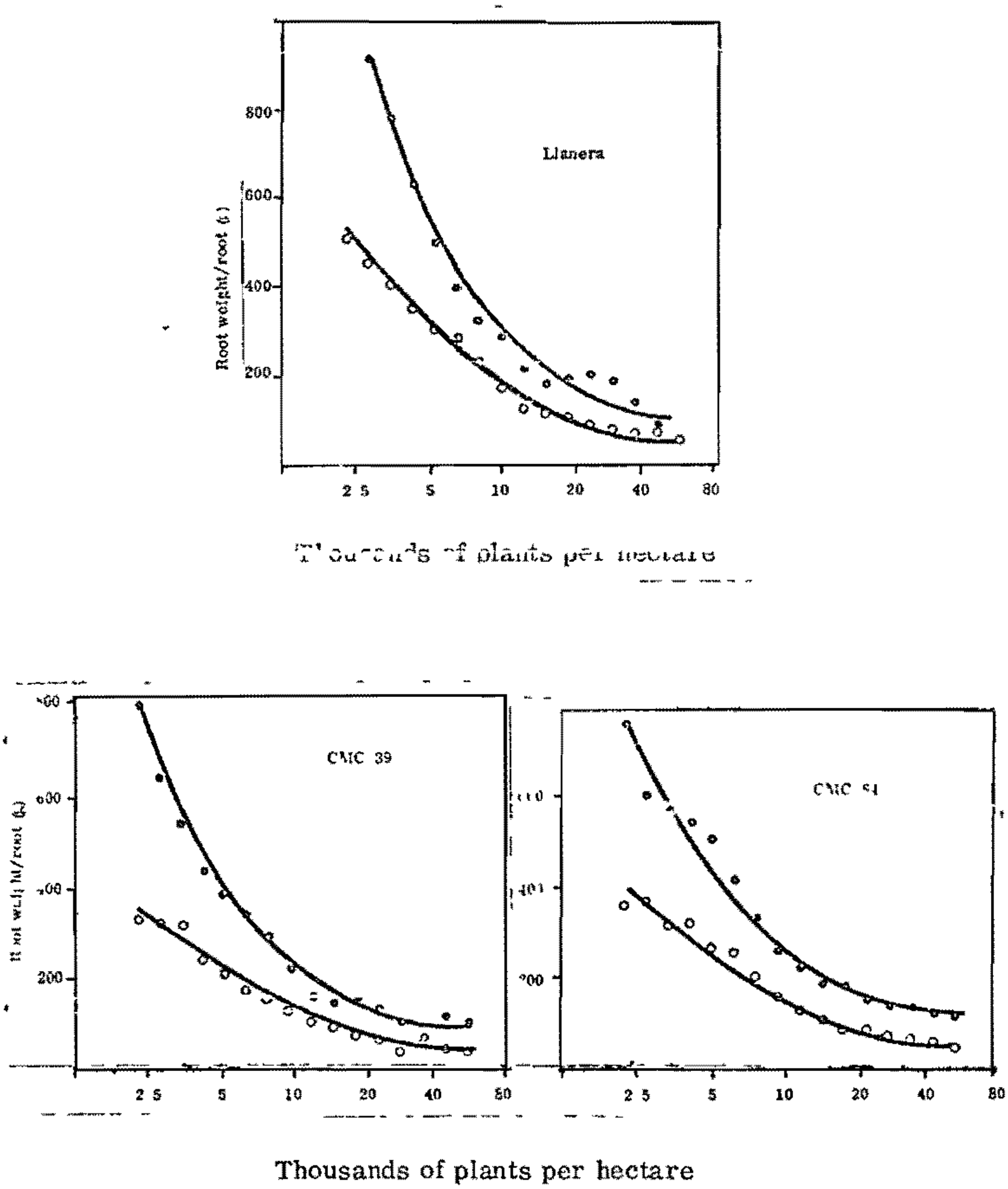


Fig 15 Root weight/root at seven months (o—o) and five months (o—o)

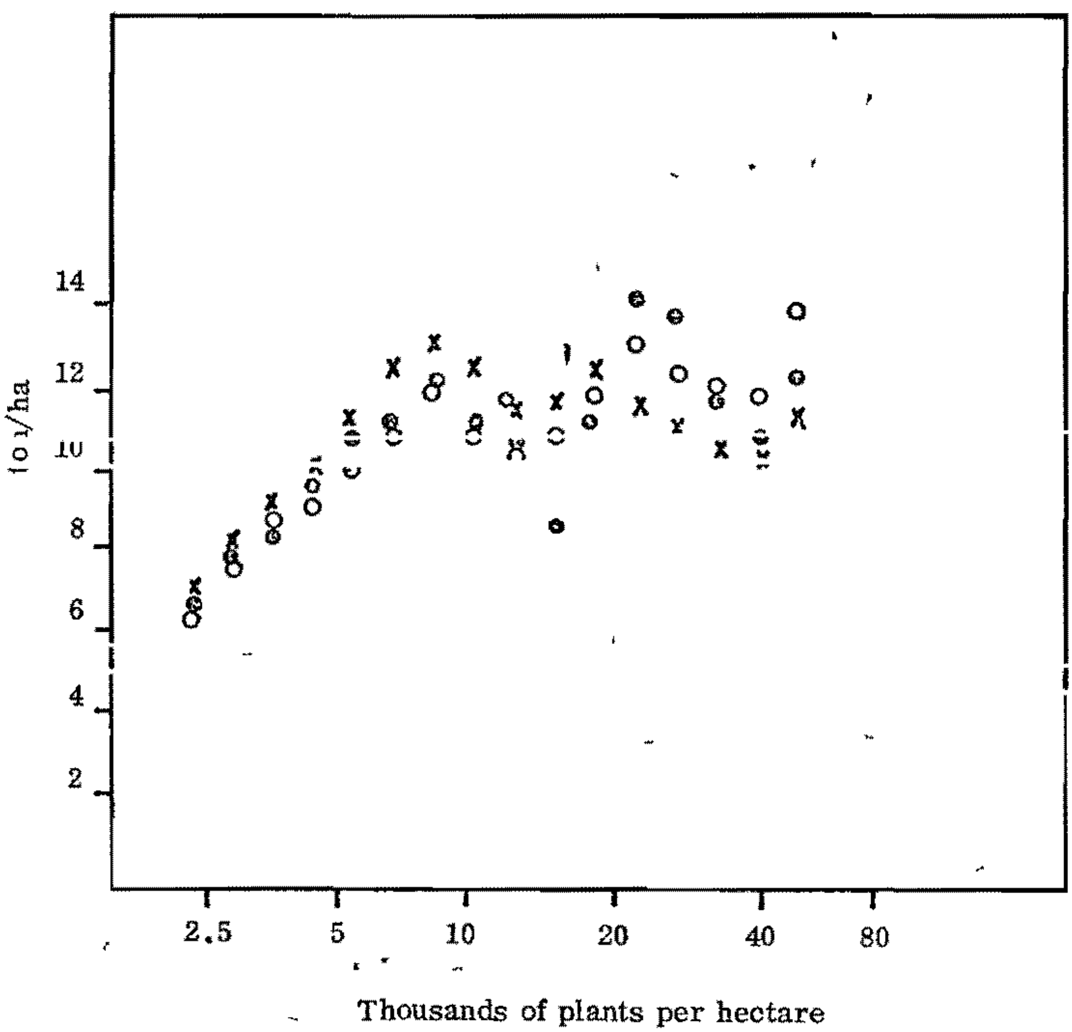


Fig 16 Total dry matter production after five months

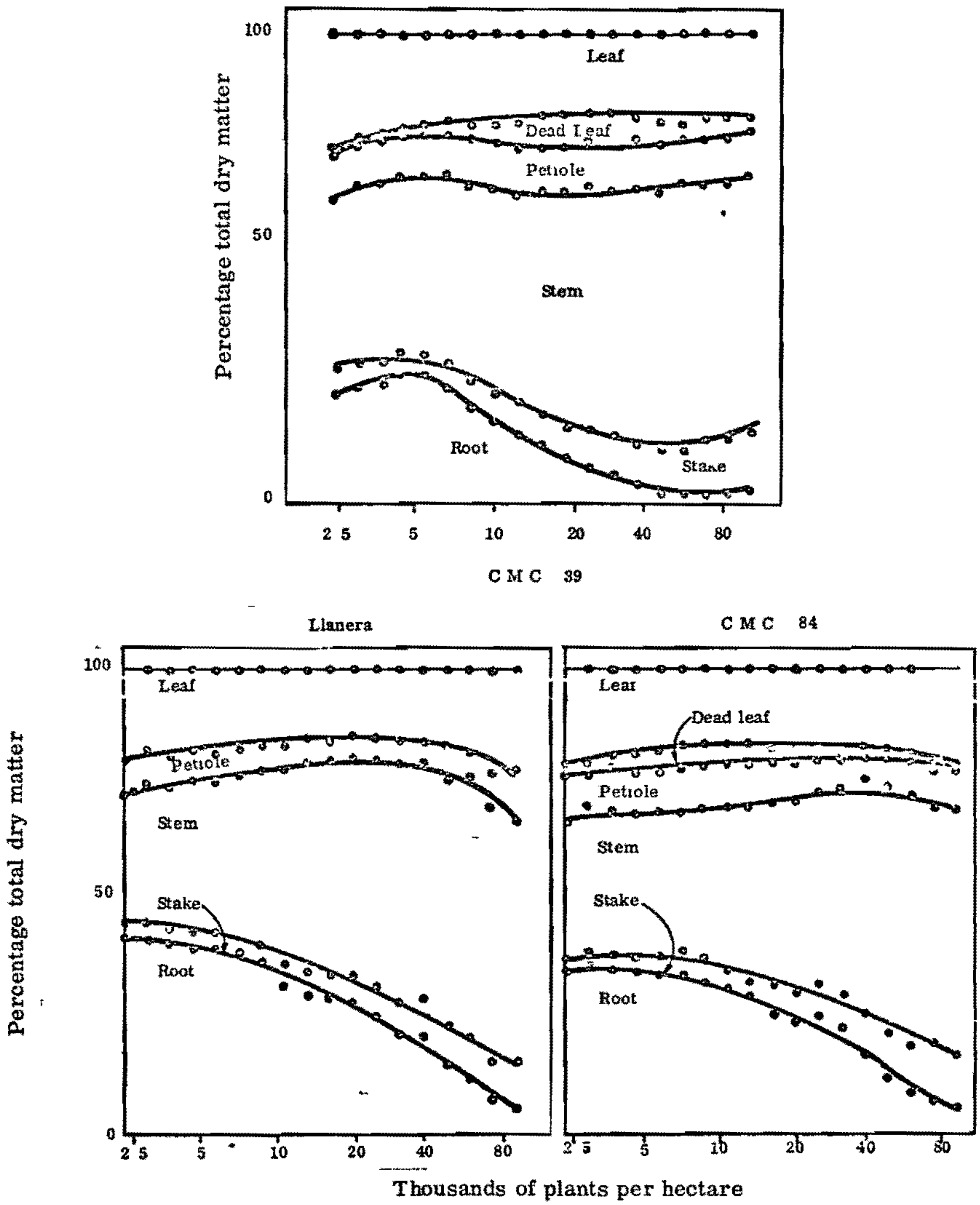
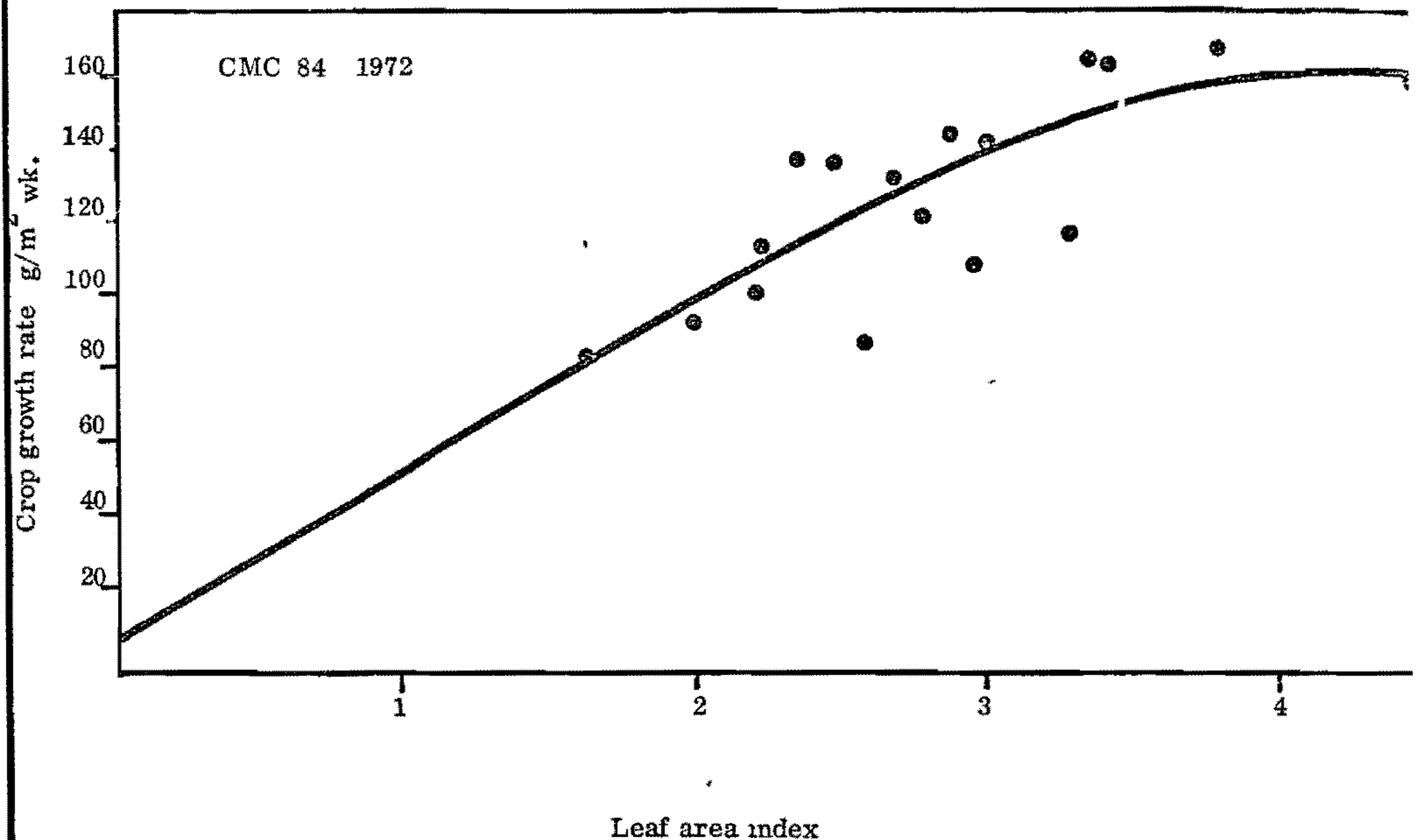


Fig 17 Distribution of dry matter after five months at different plant populations (varieties CMC 84, CMC 39 and Llanera)



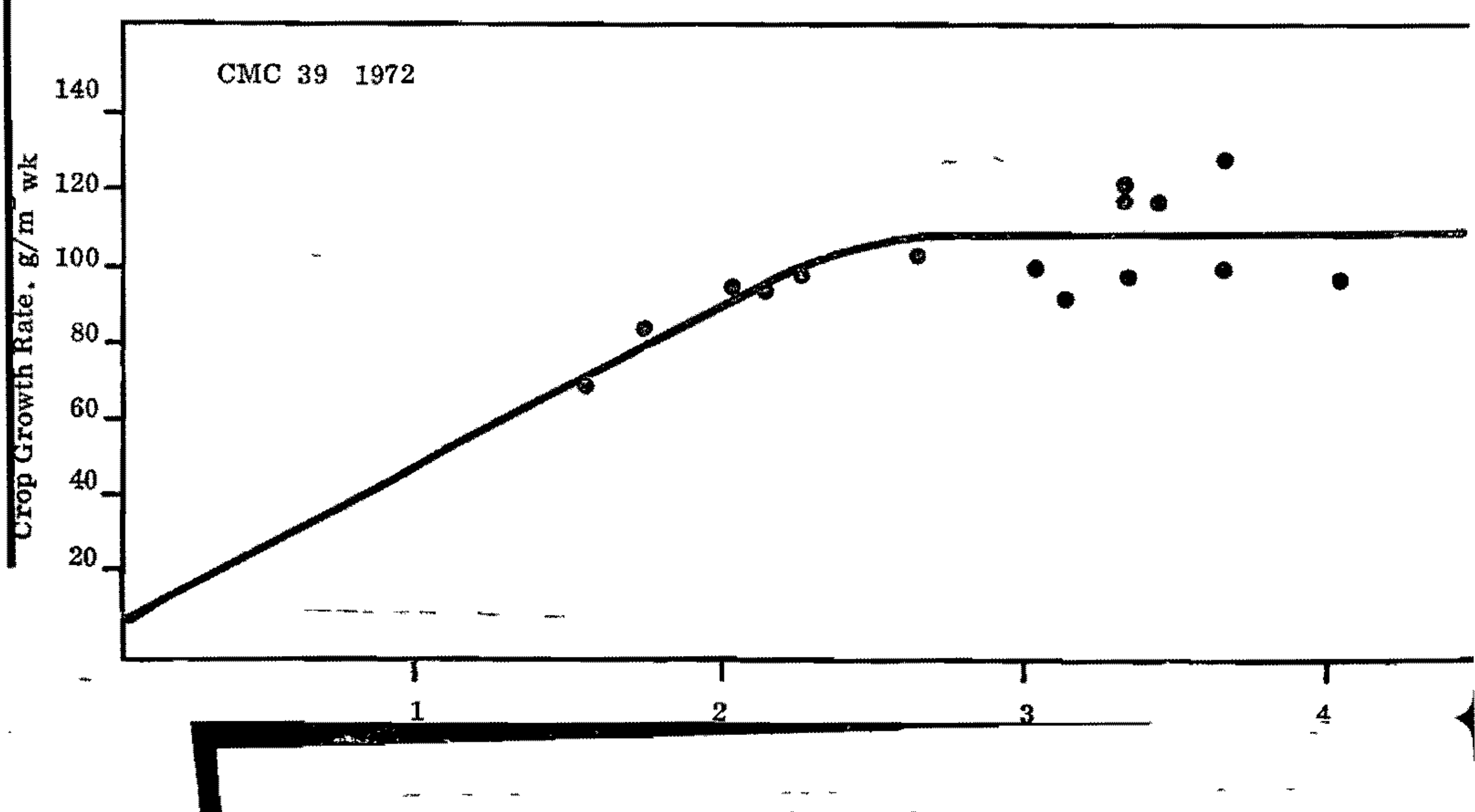


Fig. 18 Crop Growth Rate (3-5 months) as a function of leaf area index making an estimation of dry weight loss due to leaf fall.

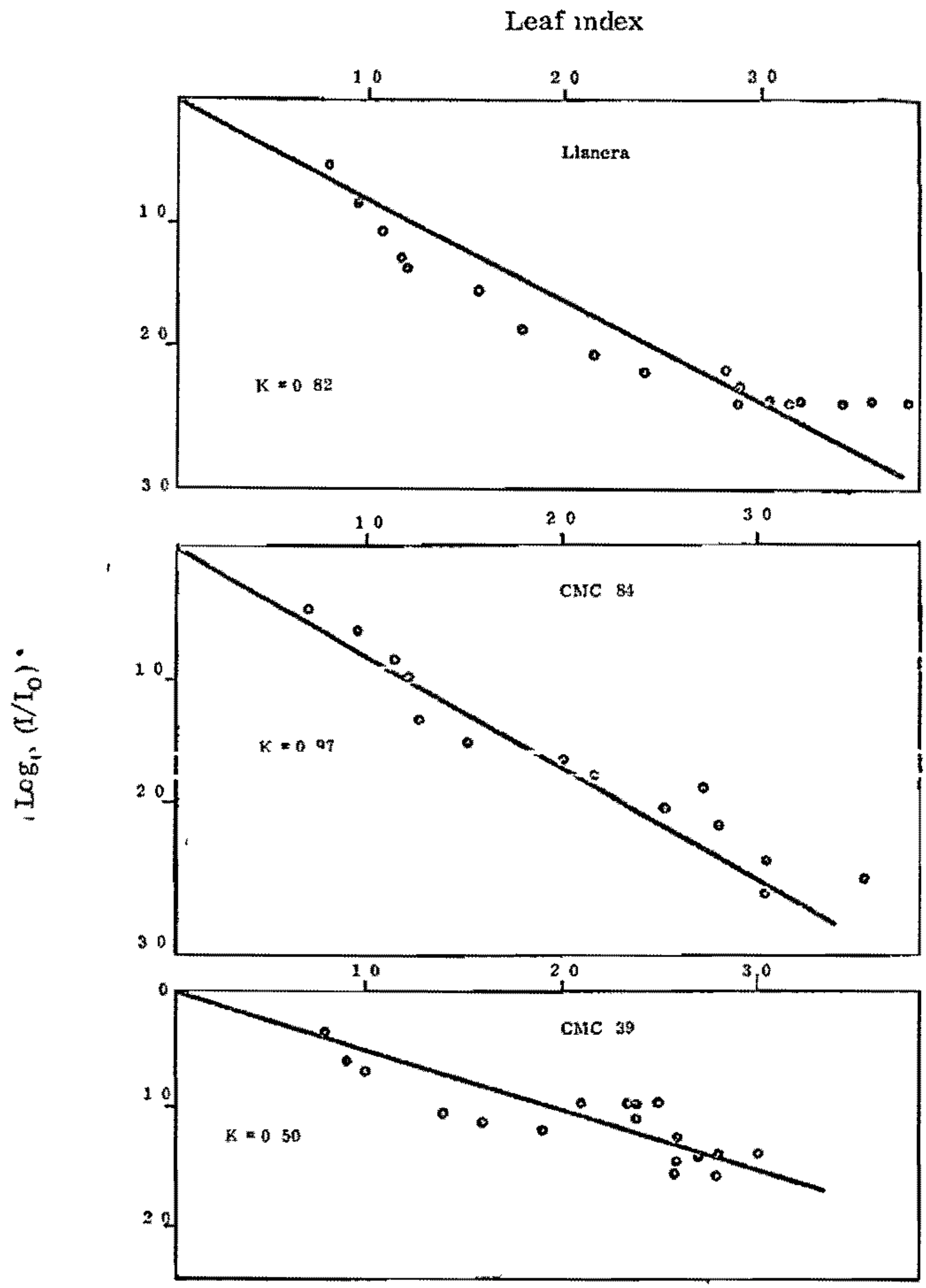
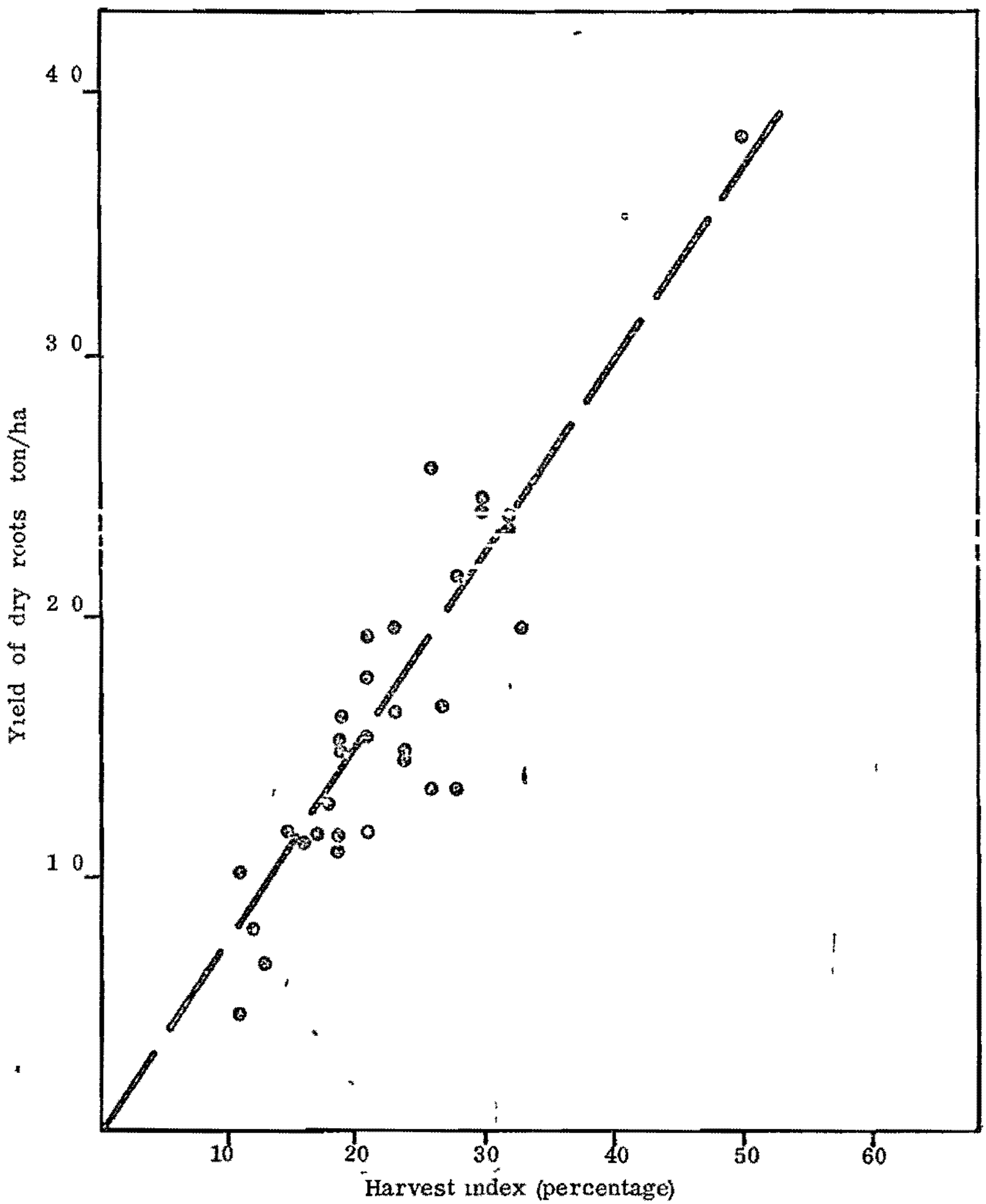


Fig 19 Relation between radiation at the bottom of the canopy and leaf area index in CMC 84, CMC 39 and Llanera varieties.

Fig 20 Yield of dry roots of 28 varieties at four months as a function of harvest index (Llanera repeated four times)



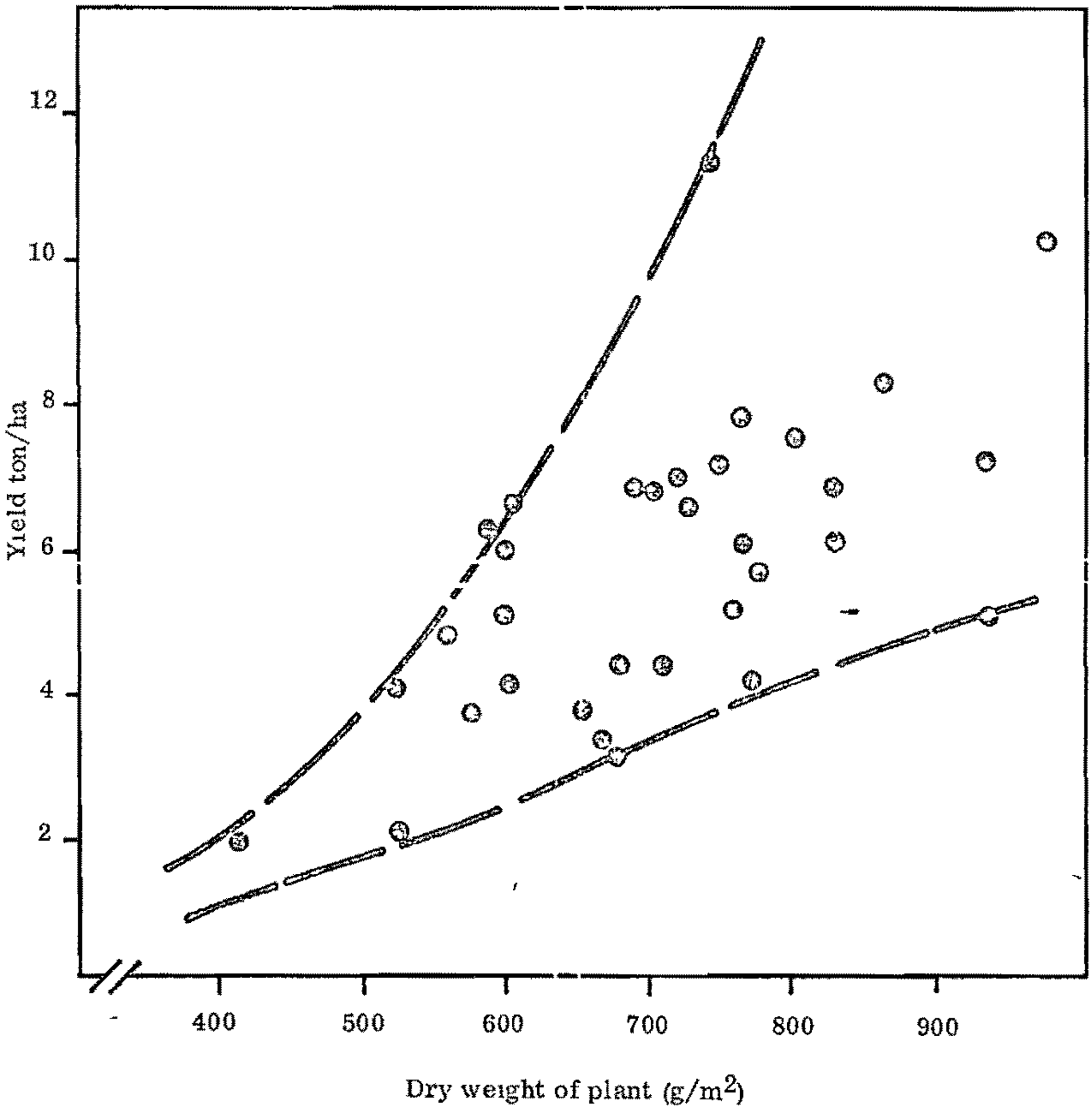


Fig 21 Yield as related to dry matter production of 28 varities at 4 months (Llanera repeated four times)

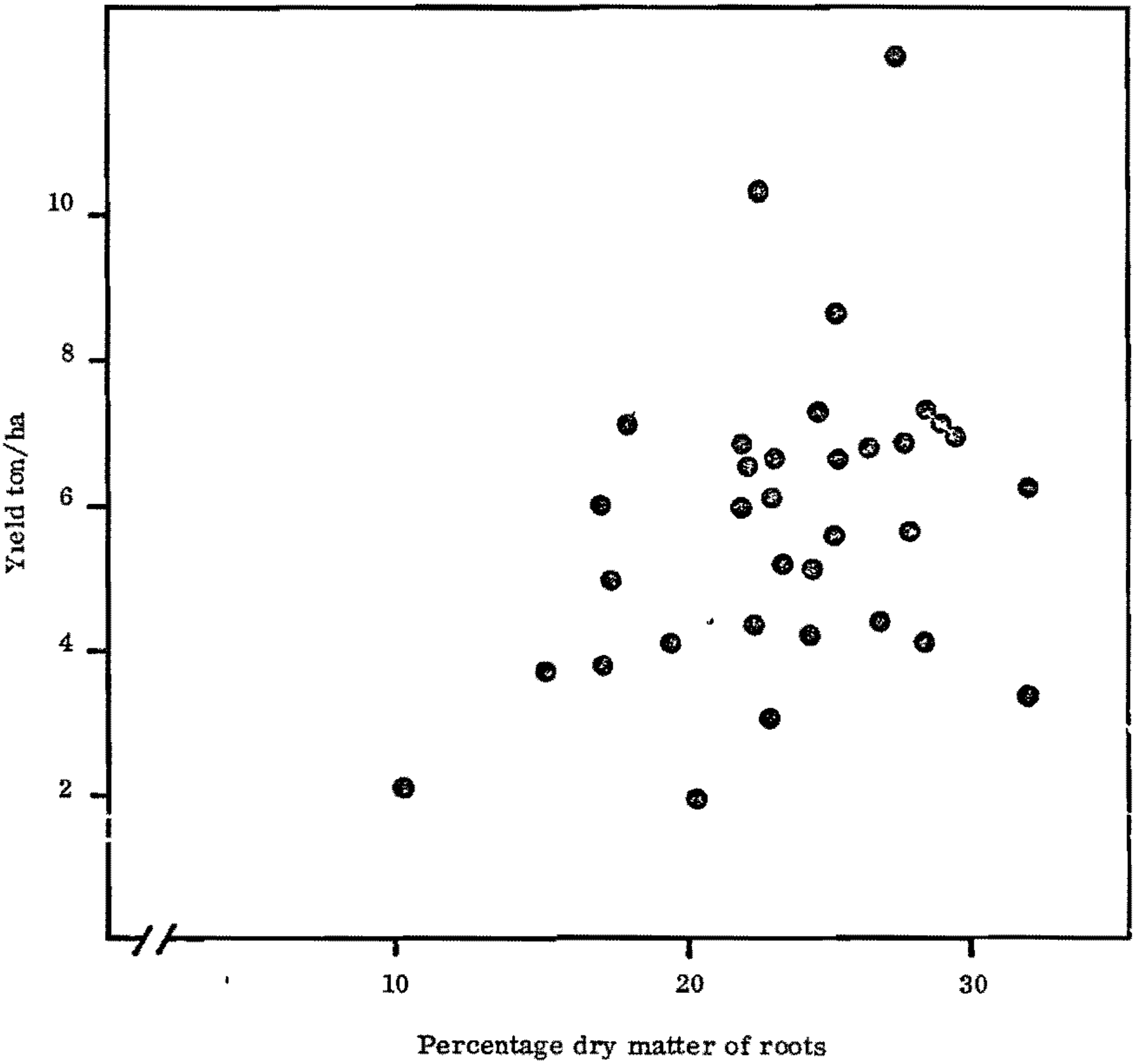


Fig 22 Scatter diagram of yield and dry matter content of the root at 4 months of 28 varieties (Llanera repeated 4 times)

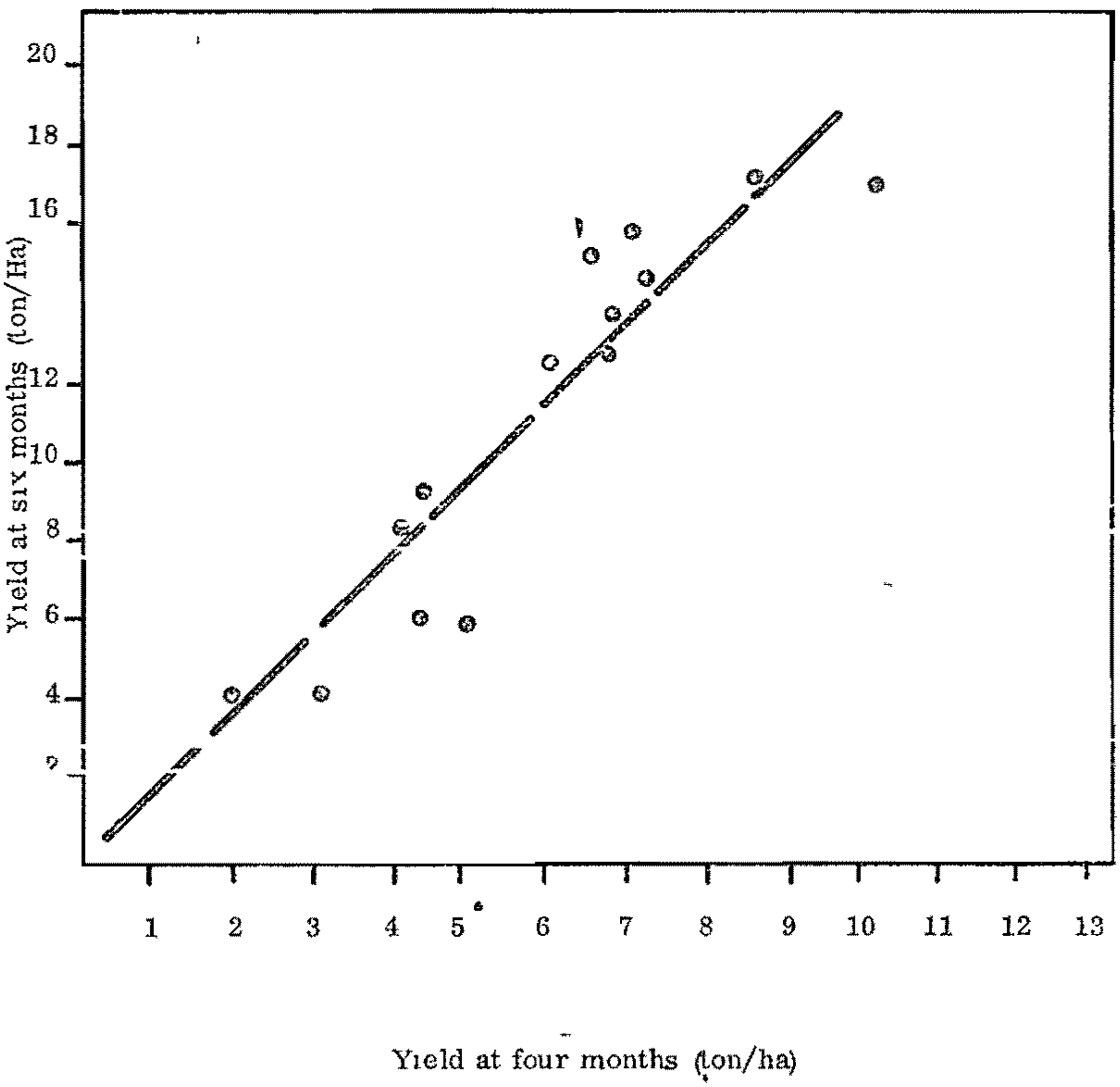


Fig 23 Yield at six months as related to yield at four months of 14 varieties

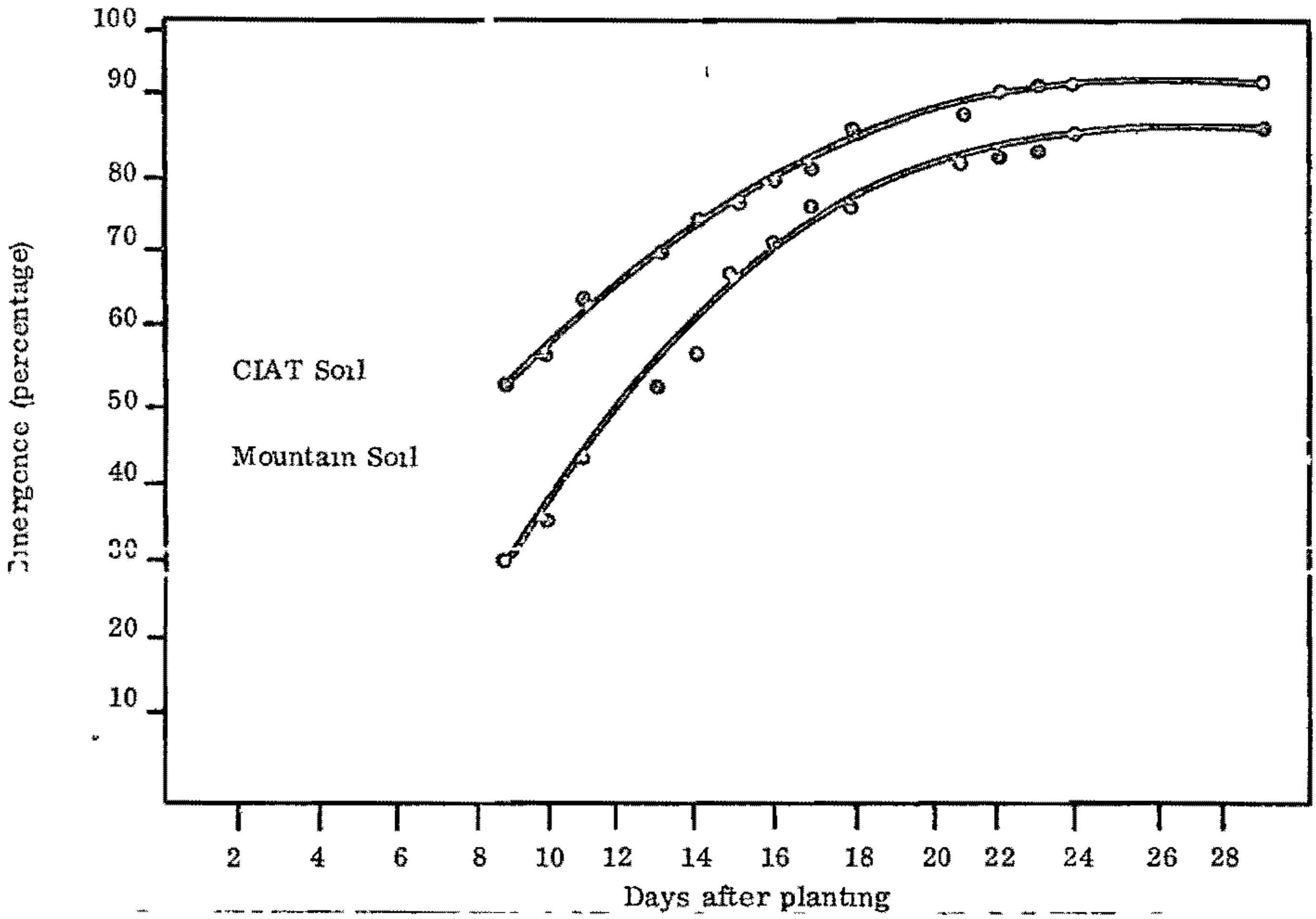


Fig 24 Rate of emergence from two rooting media

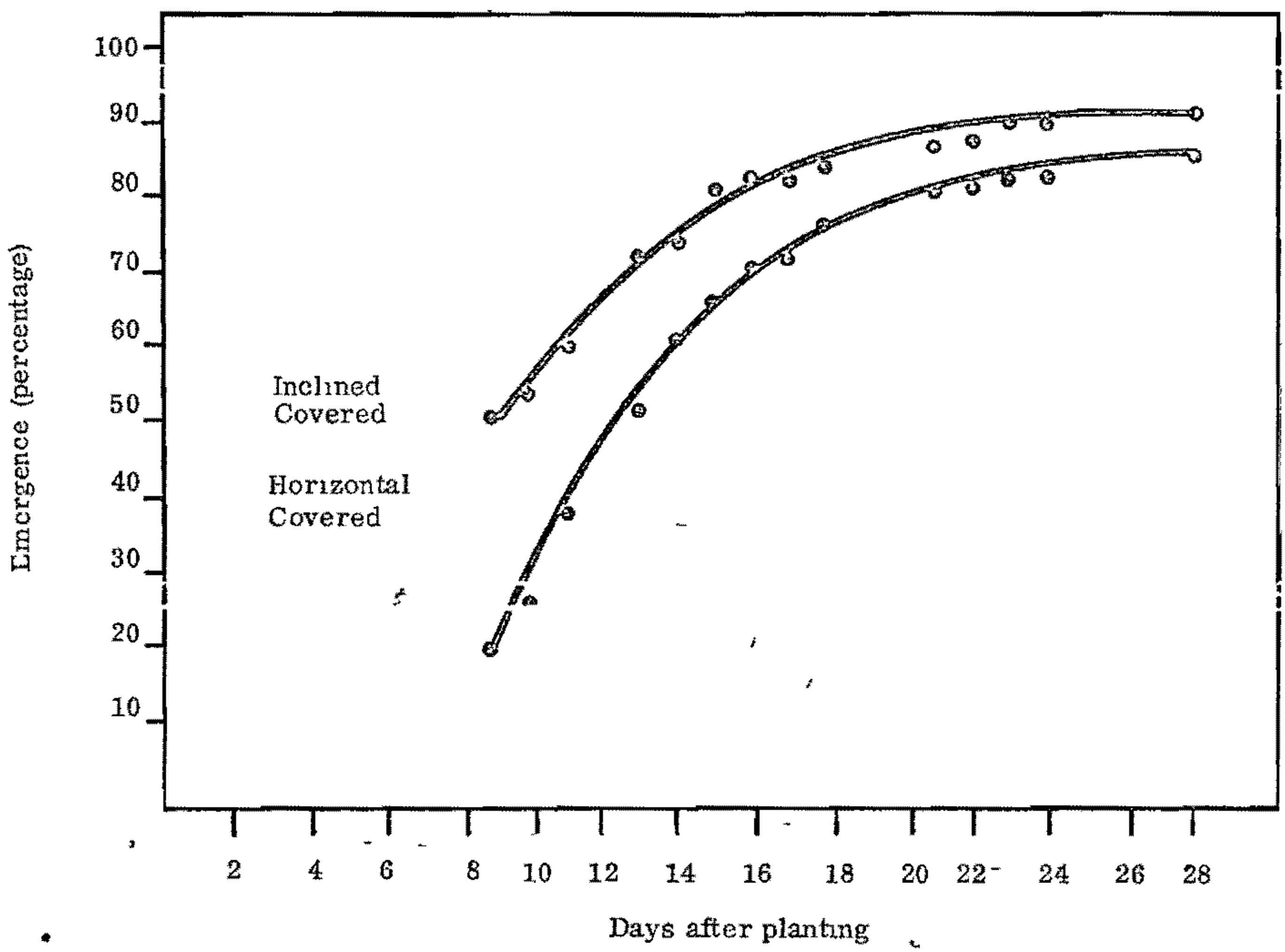


Fig 25 Rate of emergence of horizontal and inclined cuttings

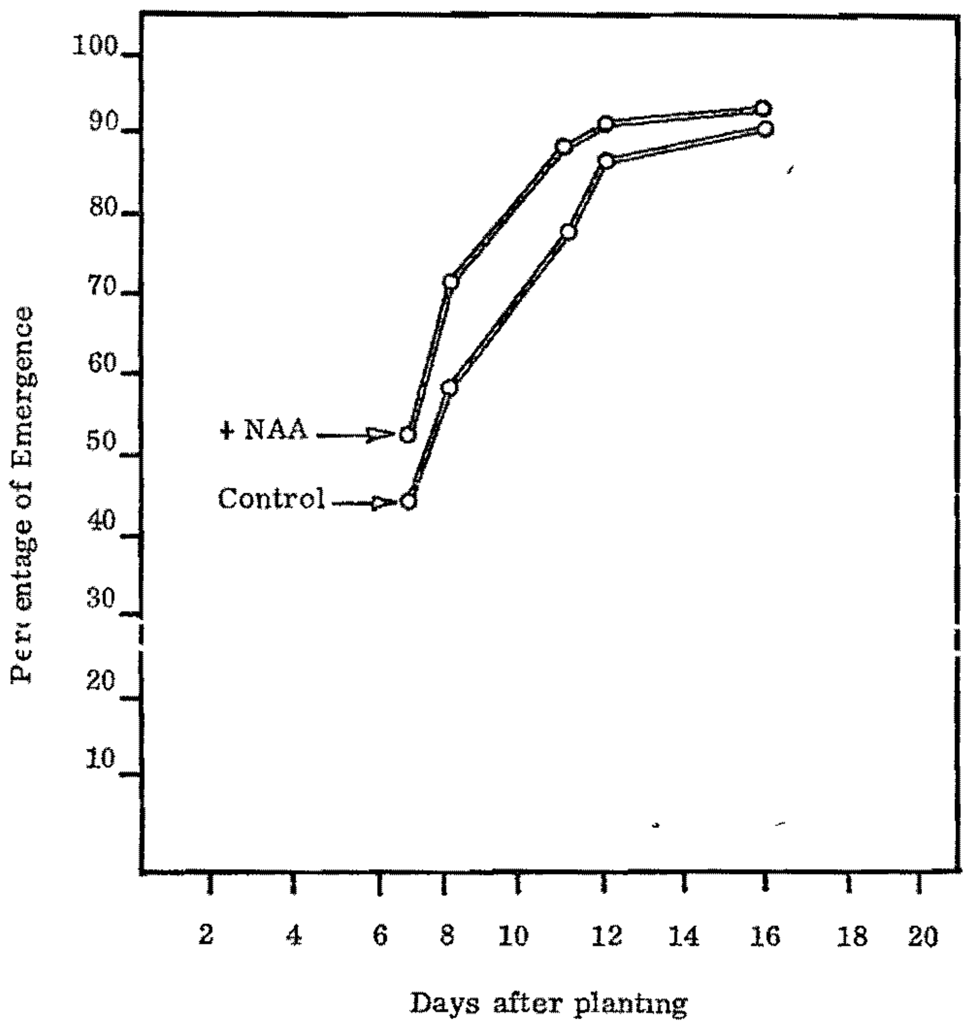


Fig 26 The effect of NAA on rate of emergence of green stem cuttings

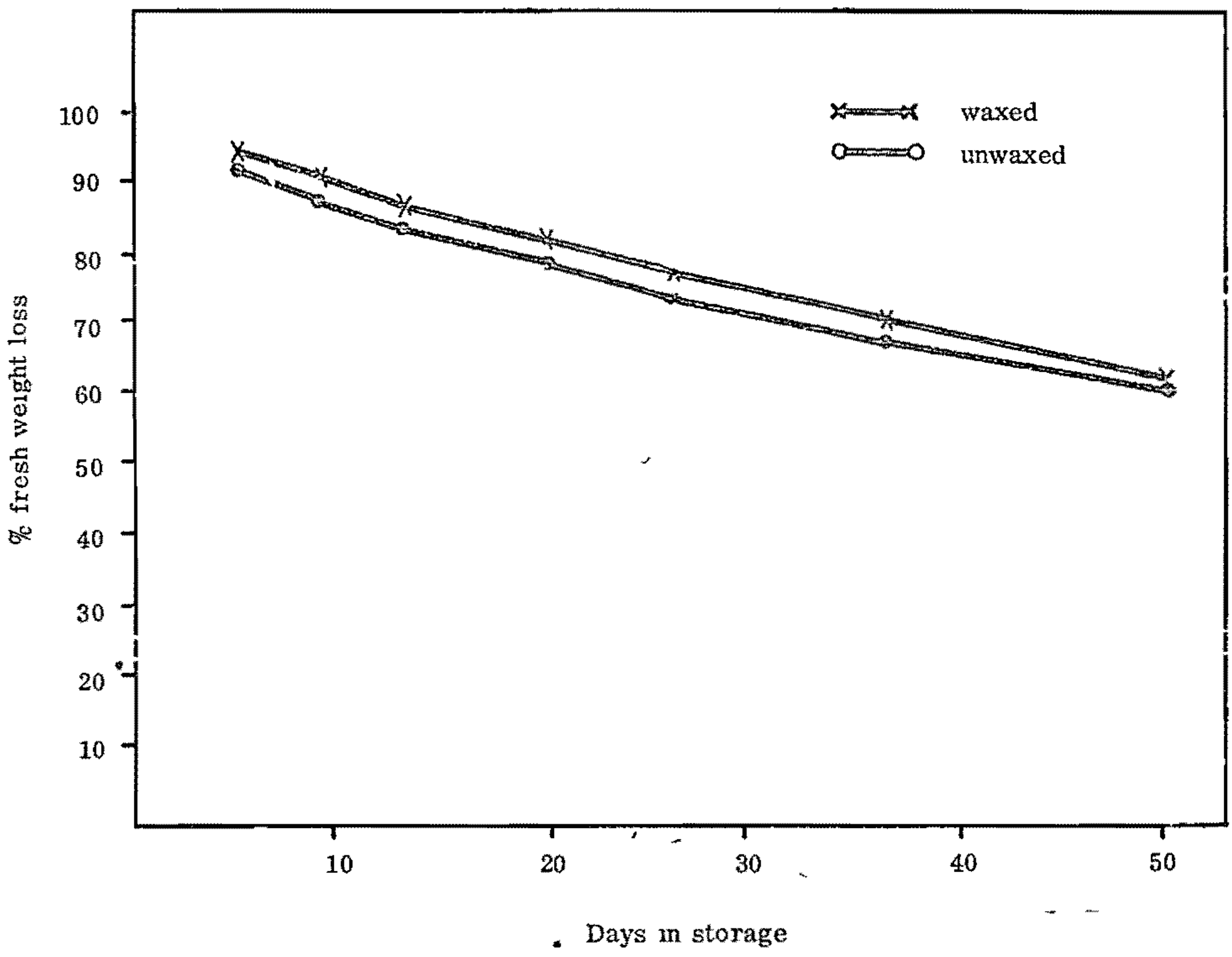


Fig 27 Effect of waxing cuttings on fresh weight loss

Bacterial Blight

This disease has been associated with considerable losses in several Latin American countries and Africa In Colombia, epidemics have been recorded in the most important cassava-growing areas, and the disease has been disseminated widely during the past few years

Symptoms of the disease are characterized by spotting and blight of leaf tissues, wilting, dieback and exudation of gum on young shoots and vascular discoloration and necrosis in mature, old stem portions, and roots of susceptible cultivars.

These symptoms are similar to those reportedly induced by *Xanthomonas manihotis* (Arthaud-Berthet) Starr, but studies of the morphology, physiology, serology, and phage susceptibility of the bacterium isolated in Colombia, Brazil, and Venezuela suggest that it is sufficiently different from *X manihotis* to be considered a distinct strain or even species The cassava blight bacterium (CBB) also differs from *X manihotis* in pathogenicity Using serological and phage-typing methods CBB can also be distinguished from species of *Erwinia*, *Pseudomonas* and *Xanthomonas* A *Bdellovibrio* sp causes lysis specifically on CBB and can be used to distinguish CBB from other plant pathogenic bacteria.

Isolates of CBB from distinct geographical areas could not be grouped on the basis of differences in virulence or biochemical characteristics Using serological and physiological characteristics, different groups could be identified, but these differences could not be correlated with geographical origin

Cassava leaves can be inoculated by spraying with aqueous suspensions of CBB cells, and maintaining the plants under high moisture conditions for six hours after inoculation (Table 3) Addition of Tween 20 (0.01%) increased the effectiveness of this procedure (Table 4) Wounding epidermal tissues of leaves and stems with infested implements also proved an effective method of inoculation (Table 5)

CBB normally penetrates the host via stomatal openings and wounds and eventually invades the vascular tissues and results in extensive breakdown of parenchymatous tissue in leaves and young shoots In mature, highly lignified old stems or roots the bacteria remain restricted to the vascular tissue CBB moves systematically into vascular strands of roots of susceptible cultivars, in susceptible cultivars, bacteria have been found in roots four months after leaf spray inoculations.

Results of controlled inoculations in the field suggest that dissemination in cassava plantations is the result of rain splashing A high correlation between total rainfall and the number of infected plants in successive 15-day periods has been recorded (Figs 23 & 24) Studies on dissemination from an inoculum source to plants located at different distances from it revealed that spread only occurred over 10 m during a 60-day period No infection was observed on plants growing 15 m or more distant from the inoculum source (Table 6) During this 60-day period, the total rainfall was 207 mm and dissemination was observed to occur in the directions of the prevailing winds.

20

Table 3

TABLE

Effect of moist chamber exposure period on infection of cassava plants following inoculation with CBB at 10^9 cells/ml (isolate 5 27L)

Moist chamber period (hr) incubation	Number of leaf spots/leaf[1] 25 days after inoculation
0	0 3
6	14 2
12	15.6
24	17 4
36	16 7
48	15.5

[1]The data are averages of three trials, each treatment consisted of 10 leaves from three plants

Table 4

TABLE 1 Effectiveness of various materials added to a bacterial suspension (3×10^9 cells/ml of CBB isolate 5 27L) used as inoculum sprayed on cassava plants*

Bacterial suspension in distilled water plus	Mean number of spots*
None	6 0
Carborundum (0.1 g/liter)	5 6
Agar (0 2%)	3.3
Gelatin (0 2%)	3 0
Dextrose (0 2%)	2.3
Tween 20 (0 01%)	10.0

*Number of spots on each lobe from each of six leaves from five plants Averages of three replications Readings were taken 25 days after inoculation

LSD 0 5% = 1.8

LSD 0 1% = 2 6

Table 5 Infection by CBB following wounding of epidermal tissues of leaves and stems of cassava cultivar M Col 1 with infested microneedles or infested knives

Tissue wounded	Number inoculated*	Number infested**	%
Leaves	56	54	97
Young stems	27	27	100
Mature stems	32	9	28
Old stems	82	9	11

*Average of three replications.

**Disease readings were recorded 3 months after inoculation as leaf spots (on leaves) or wilting (on stems). Control plants inoculated with distilled water showed no infection

23

Table 6. Dissemination of CBB on cassava plants located at different distances from the inoculum source

Distance (m) from inoculated source	Number of plants/plot	Number of infected plants per plot**	%
5	20*	12	60
10	20	5	25
15	20	0	0
20	20	0	0

*Number of plants in each of four plots, each plot located on one side of an inoculum source

**Incidence of disease 60 days after planting.

Dissemination from one area to another can occur by means of infected vegetative planting material (Fig 30). This methods of dissemination is particularly important in Colombia because there is no restriction in the movement of vegetative cuttings throughout the country or any certification scheme for cassava.

Dissemination of CBB by means of infested tools is also probable A high incidence of infection has been shown to result from cuts made with infested knives (machetes) (Table 6) This method of dissemination may be most important during harvesting when planting material stakes are obtained These operations require extensive cutting in localized areas. Because wounds are portals of entry for CBB, dissemination may be caused by man, animals, insects and may also occur during environmental conditions that lead to extensive wounding

The following methods for controlling this disease have been investigated

1 -Field experiments in which infected plants were heavily pruned showed that only 6 percent of those pruned had symptoms on the young sprouts one month after pruning but after two months an additional 2-3 percent showed disease symptoms. Each of these infected plants were uprooted and destroyed, and by six months after pruning no additional diseased plants had appeared The control unpruned plot was 100 percent infected.

   In a further experiment, pruning was carried out in infected plots of different cultivars Within the very susceptible cultivars, 76 percent of the new sprouts were infected six months after pruning as compared with 36 percent of the susceptible cultivars, 16 percent of the moderately susceptible, and 9 percent of the resistant ones (Fig 3) These results indicate that the effectiveness of the control methods depends, to a large extent, on the level of resistance of the cultivar

2 -Tip indexing -Experiments on rooting tip cuttings showed that it is possible to erradicate CBB from diseased plants by propagating from young shoot tips free from disease symptoms. About 95 percent success in rooting and a 100 percent elimination of CBB was obtained when young cuttings were planted in fine gravel in small waxed paper pots. Rooting cuttings were kept in a humidity chamber under mist produced from an electric humidifier at a temperature of 25-33°C After 12 to 15 days rooted tip cuttings were transplanted into sterile soil and maintained in a greenhouse for two months before transplanting to the field.

To eradicate CBB from CIAT's cassava collection, about 80 percent (approximately, of the 2,200 clones) have been indexed by this method

3.-Varietal resistance -The response of 1,400 cassava cultivars to CBB has been determined using artificial inoculations with several isolates of the pathogen collected in Colombia. Disease indices of the 21 most resistant cultivars are presented in Table 7 Of these, M Col 647 and M Col 667 were the most resistant Even those cultivars listed here as susceptible (M Col 282, M Col 707 and M Col 803) had few leaf spots per leaf as compared with the susceptible control cultivar Popayan

Generally, the performance of cassava cultivars in the field appears to be well correlated with the resistance ranking calculated from die-back wilting, gum exudation and leaf spotting indices obtained following artificial inoculation In general, leaf spotting alone appeared to be as good an index of resistance as all the other characteristics combined, but the resistant cultivars M Col 647 and M Col 667 had a relatively high number of leaf spots per leaf These spots remained small, suggesting a hypersensitive response.

While other control methods based on knowledge of the epidemiology of the disease are being investigated, the use of clean planting material and resistant cultuvars are the best known methods for practical control of bacterial blight.

Superelongation disease of cassava

A new disease of cassava has benn found inducing epidemics in several cassava growing areas of Colombia The disease is characteristically recognized by an exagerated elongation of the internodes of young stems of infected plants As a consequence, the stems become thin and weak, and are considerably taller than those of healthy plants. The youngest part of stems, petioles of young leaves and leaf midribs are frequently distorted, resulting in stem, petiole and leaf deformation Frequently, leaflet are not completely developed and leaf lamina not fully expanded

Portions of the epidermis of young stems show, on occasions, scratching damage which is characteristic of the damage known to be inflicted by thrips. However, the epidermis of infected stems commonly bear cankers of different sizes usually located on the youngest and the least lignified parts of the stem Mature stem parts look normal, but thery are generally brittle. These symptoms vary according to cultivar from mild to severe distortion, elongation and leaf deformation These general symptoms have not previously been reported in the literature on cassava diseases.

A fungus has been found to be associated with the stem cankers usually observed on the infected plants The relationship of this fungus to superelongation disease is being studied.

Cercospora leaf spot

Three Cercospora spp. (C caribea, C henningsii, and Cercospora sp) have been found inducing leaf spots in most of the cassava-growing areas of Colombia Their incidence and relative importance varied according to the environmental conditions prevailing in the areas as well as the susceptibility of the growing cultivars (Fig 32)

As a preliminary necessity to the screening of varieties for resistance to Cercospora spp , studies have been undertaken on methods of inducing artificial cultures to sporulate and on inoculation techniques.

The different Cercospora species differ in their growth rates on different agars None of the species sporulated well when incubated in the dark Sporulation of C caribea and C henningsii was enhanced by periodic one-hour exposures to black-light or by continuous exposure to flourescent light

A good infection (3-5 spots per leaf) has been obtained with spray inoculations of spore suspension of C henningsii Inoculated plants were kept in a moist chamber for 48 hours at 28°C, following inoculation and disease symptoms appeared 10 to 12 days after inoculation

Soft rot of cassava roots

A Phytophthora sp. has been isolated from roots with severe soft rot and also from seedlings showing severe damping-off symptoms The soft rot disease was reported by the Federación Nacional de Cafeteros, with losses up to 80 percent on certain plantations Observations indicate that the disease is associated with wet soil conditions either in poorly drained areas or near drainage canals. A similar condition was experienced on the CIAT farm in mid-1971 when some areas under cassava cultivation became water-logged because of excessive rain fall.

Present studies indicate that the Phytophthora sp isolated is similar to the fungus (P drechsleri) reported to cause a similar disease in Brazil A Fusarium species was also isolated from a number of rooting-roots The role of this fungus in the epidemiology of this disease is also being investigated

Phyllosticta leaf spotting

This disease has been found predominantly in high altitude areas of Colombia (more than 1,000 m) Infection results in severe leaf spotting, defoliation and die-back, with a subsequent decrease in yield Spots are characterized by the presence of concentric rings on the necrosed areas and tiney brown dots, which are the fruiting structures Picnidia of this fungus

Successful isolation from diseased plant tissues is relatively simple, but spore production by the fungus in artificial culture is only induced by incubation under continous flourescent light

Powdery mildew leaf spot

This disease has been found to be present in most of the cassava-growing areas of Latin America Its incidence is particular important during the dry season when the pathogen attacks mature and fully expanded leaves, inducing yellowish spots and rarely necrosis

Field observations and evaluations of about 2,200 cassava cultivars of CIAT's cassava collection have revealed a good source of varietal resistance About 220 cultivars were rated as resistant and 1,350 as susceptible

Gloeosporium disease

This pathogen appears only to attack young leaflets and shoots inducing blight and die-back The occurrence and severity of this disease appear to be closely related to air moisture conditions Artificial inoculation (by spraying aqueous spore suspension - 10^5 spores/ml) was only successful when plants were kept for 60 hr at 100 percent relative humidity

Other diseases

An *Armillariella* sp has been found associated with a stem-base and root rot of mature cassava plants.

Isolates of *Sclerotium* sp , *Sclerotinia* sp, *Pythium* sp and *Fusarium* sp have been obtained from young rooted cuttings which showed symptoms of damping-off during propagation experiments

Table 7. Disease severity indices of 21 cassava cultivars 30 days after spary - and stem-inoculation with CBB isolate 4 26L (10^7 cells/ml)

Cassava cultivar	Disease indices				Total index	Number of leaf spots/leaf	General evaluation
	Die-Back	Wilting	Gum exudation	Leaf spot			
M Col 282	15	15	15	20	65	4 0	SS[1]
M Col 350	11	10	10	17	48	6 6	MS
M Col 353	8	8	10	15	41	10 1	MS
M Col 558	10	11	10	20	51	3 8	MS
M Col 642	0	6	0	15	21	3 1	RR
M Col 647	0	5	0	5	10	20 2	HR
M Col 667	5	5	0	5	15	11 0	HR
M Col 707	17	15	15	25	72	5 0	SS
M Col 800	10	13	10	20	53	5 2	MS
M Col 803	15	17	15	20	67	4 0	SS
M Col 808	0	7	5	15	27	4 4	RR
M Col 853	13	15	10	20	58	5 8	MS
M Col 866	11	10	15	20	56	8 5	MS
M Col 952	10	10	10	25	55	6 4	MS
M Col 1060	10	11	10	20	51	5 4	MS
M Col 1073	5	8	5	15	33	2 4	RR
M Col 1079	5	7	5	15	32	4 2	RR
M Col 1080	6	10	10	15	41	5 6	MS
M Col 1137	10	10	10	20	50	5 8	MS
M Col 1155	5	9	5	20	39	3 0	RR
M Col 1184	6	5	5	20	36	8 4	RR
Popayan (CK)	25	25	25	25	100	139 3	VS

[1] VS = Very susceptible, SS = susceptible, MS = moderately susceptible, HR = highly resistant, RR= resistant.

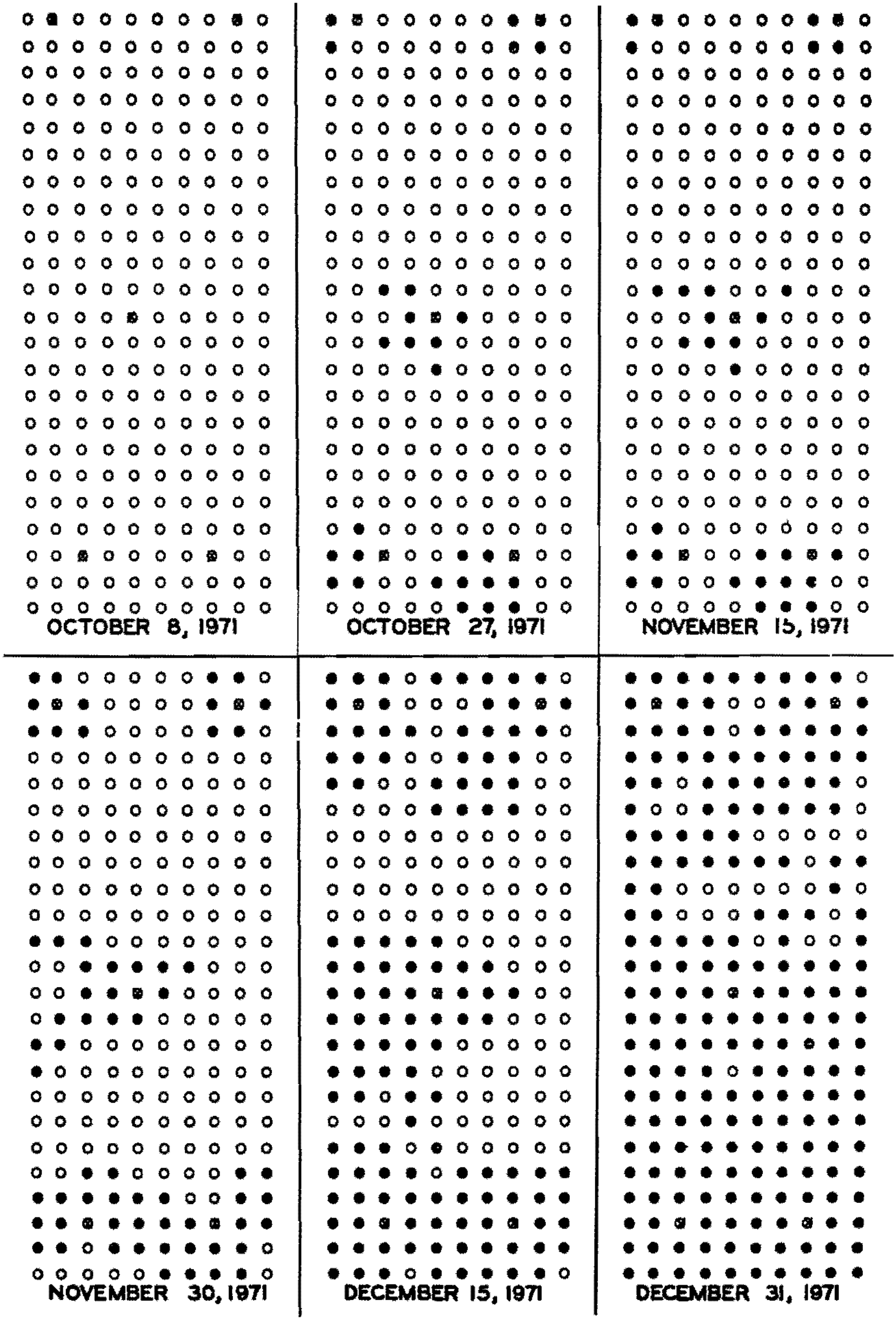


Fig 28 Spread of CBB in the field from initial sources of infection in experiments conducted between September 15 and December 31, 1971 Results were recorded as number and position of plants infected at 15-day periods after inoculation

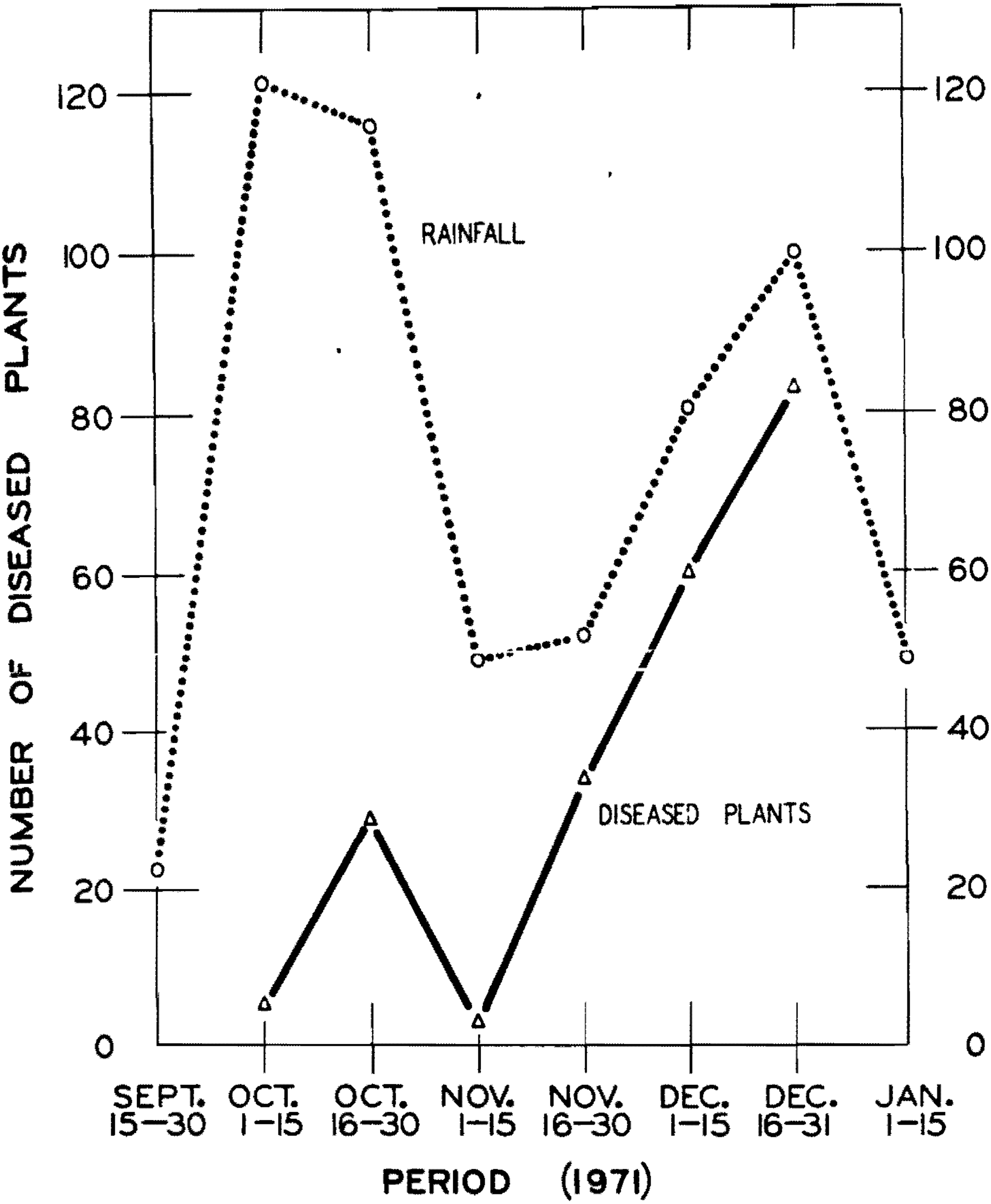


Fig 29 Spread of CBB in the field from initial sources of infection in experiments conducted between September 15 and December 31, 1971 Relation of total rainfall (mm) and number of diseased plants in each 15-day period

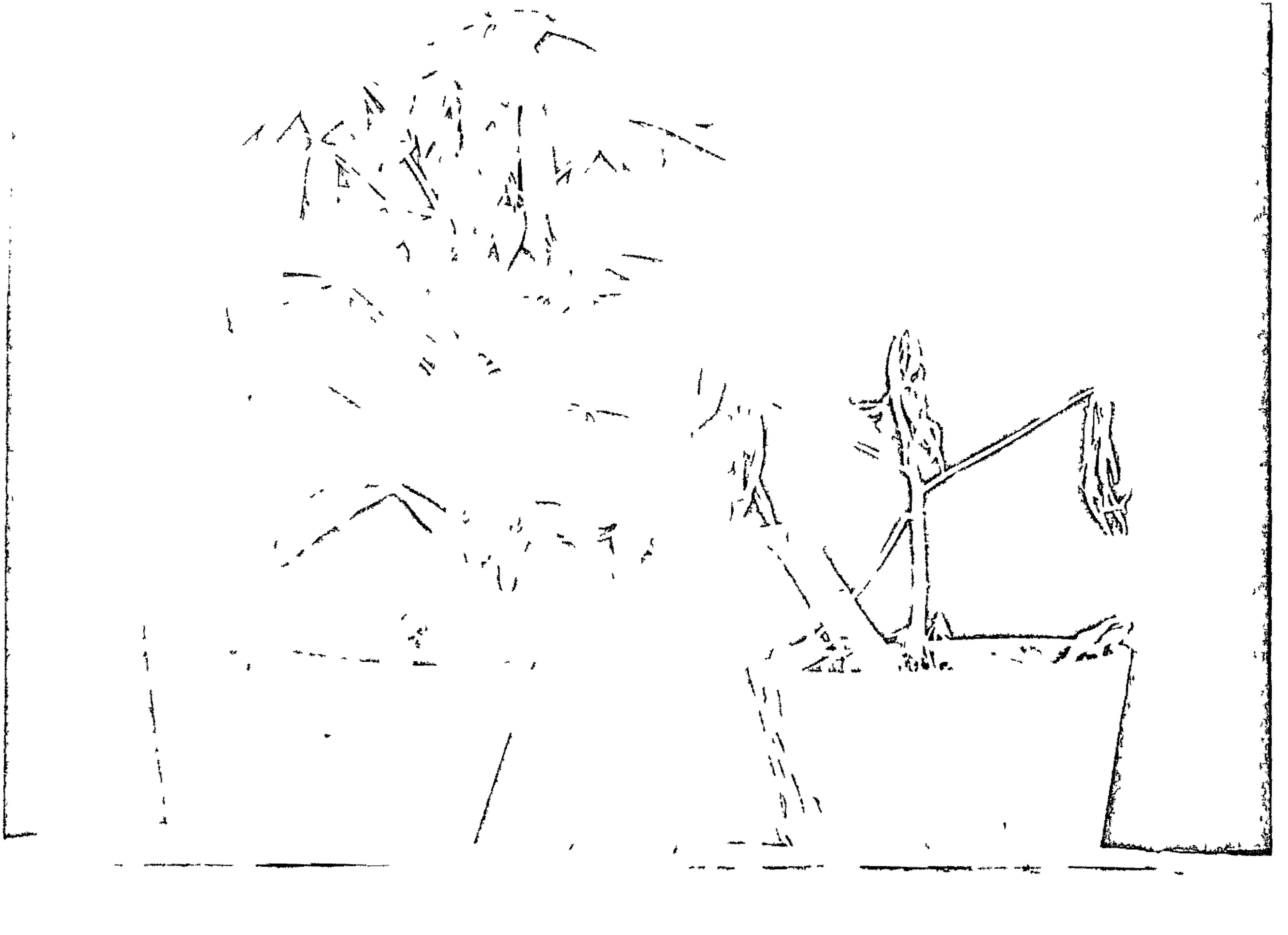


Fig 30 Dissemination of CBB by infected vegetative "seed" Left healthy sprout from a healthy stem cutting [illegible]

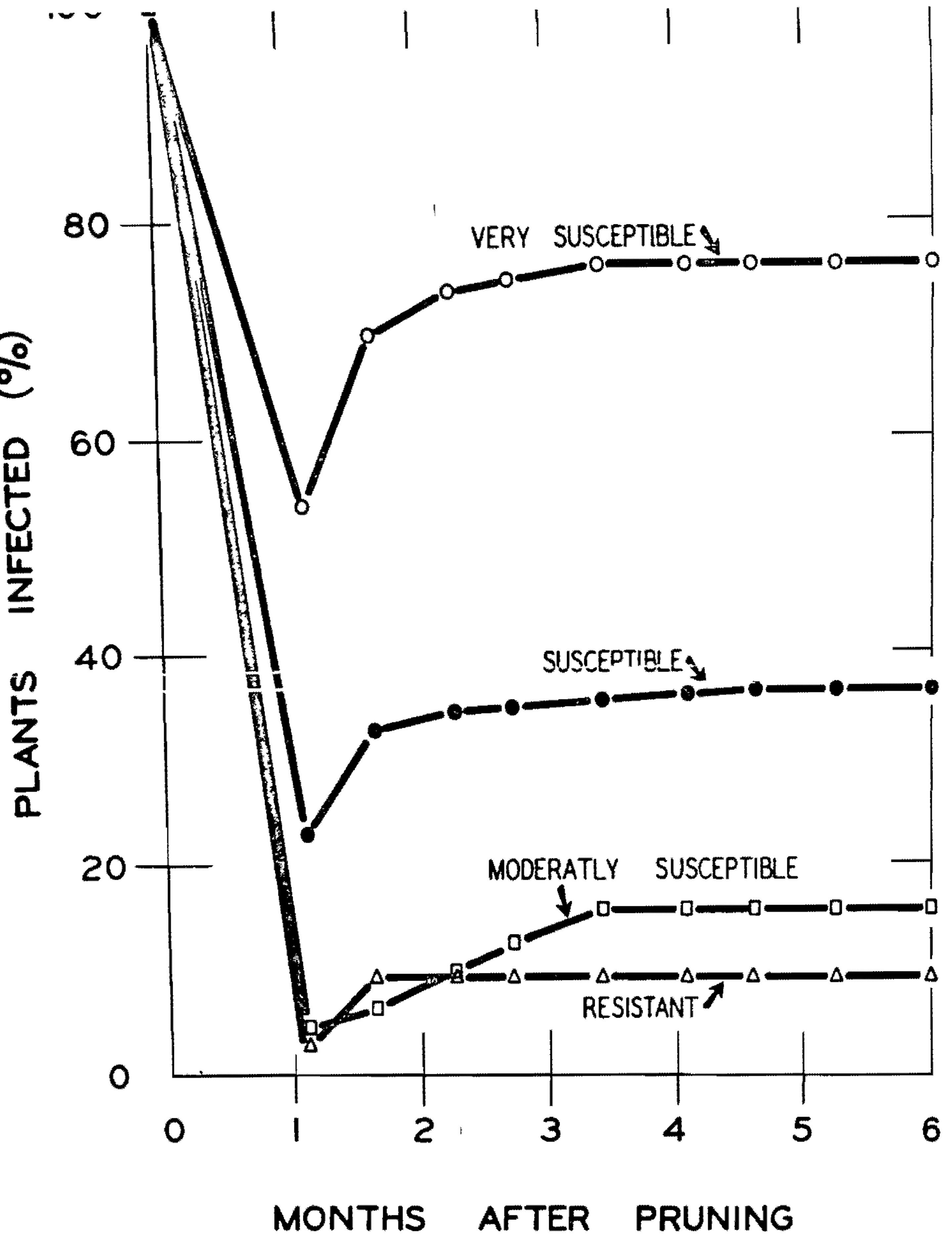


Fig 31 Effect of pruning infected cultivars having different levels of resistance to CBB. Plants were pruned 6 months after they were spray-inoculated with a bacterial suspension (10^9 cells/ml) of isolate 4 26L

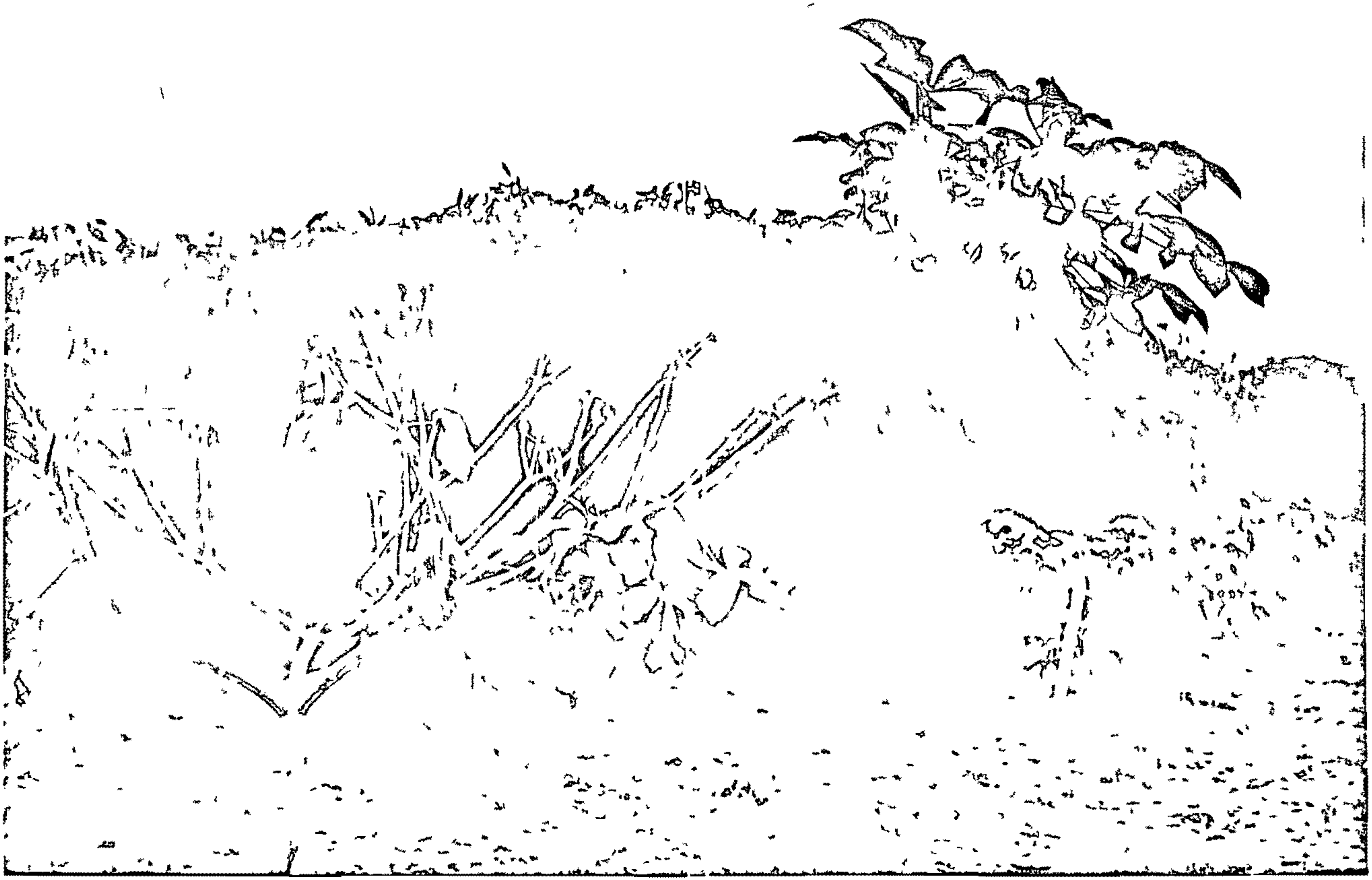


Fig 32 Cercospora leaf spot

ENTOMOLOGY

Shoot fly

Nineteen varieties were screened for resistance to shoot fly (Silba pendula) at 20, 40 and 60 days after planting using natural populations in the field Damage was estimated by counting the percentage of the total shoot number that had been attacked by the shoot fly. None of the varieties had a high level of resistance, but the level of damage after 60 days varied between 25-78 percent showing that there are differences in susceptibility Young plant showed little damage, and it is suggested that plants should not be screened at less than 60 days.

Observations on more than 5 000 larvae of Silba spp. in different states of development did not identify any parasites that could be used for control

To screen varieties for resistance to Silba spp under controlled conditions, it is necessary to breed flies artificially Promising results have been obtained using a diet containing ground cassava roots, yeast and sorbic and ascorbic acid Larvae collected in the field have been successfully grown on this diet

Thrips

Thirty varieties were planted in the field and were rated by eye for resistance to thrips At the same time, the number of thrips per shoot was counted There was no relationship between the two methods because some other insects (especially spider mites) can cause damage similar to that by thrips

Several varieties had no thrips, suggesting that there is a high level of resistance to be exploited

Horn Worm

Natural parasitism of the eggs of Erynnis ello by Trichogramma spp produce good biological control under most conditions When this control breaks down, applications of aresenic insecticides (5-6 lbs/ha of lead arsenate) have given good control These should not be used when the leaves are to be eaten by animals or humans

Vatiga Manihotae (Hemiptera Tingidae)

These lace bugs can produce symptoms similar to these produced by th spider mite It oviposits in the leaf tissue itself and because of its feeding habits is considered to be a possible virus vector

SOILS

Acid soil tolerance

Cultivars from ICA were screened on plots having 0, 05, 2 and 6 ton/ha of lime The effect of lime on the pH and aluminium levels is shown in Fig 33 The soil is extremely infertile (Table 8)

The entire field was very seriously affected by Superelongation and bacteriosis However, in the first three months the plants were not seriously affected by diseases and the following observations were made

Most varieties showed visual response to lime up to 2 ton/ha

Some cultivars appeared similar to 0, 05, 2 ton/ha of lime

Some varieties were adversely affected by 6 ton/ha lime, probably because induced micronutrient deficiencies

After 8 months the plots were harvested The yield figures are indications of varietal difference, not a measure of possible yields to be obtained on a large scale Eight varieties yielded more than 1 2 kg/m^2 at 0, 05 and 2 ton/ha The maximum yield was 2 6 kg m^{-2} in CMC 172 at 0 5 ton/ha CMC 172 was one of the highest yielding clones at 0 and 2 ton/ha lime CMC 143 and 110 were among the best varieties in all treatments These results suggest that cassava is extremely resistant to acid soils and is potentially important in these areas

In two other trials there was marked visual response to phosphorus, nitrogen and potasium

35

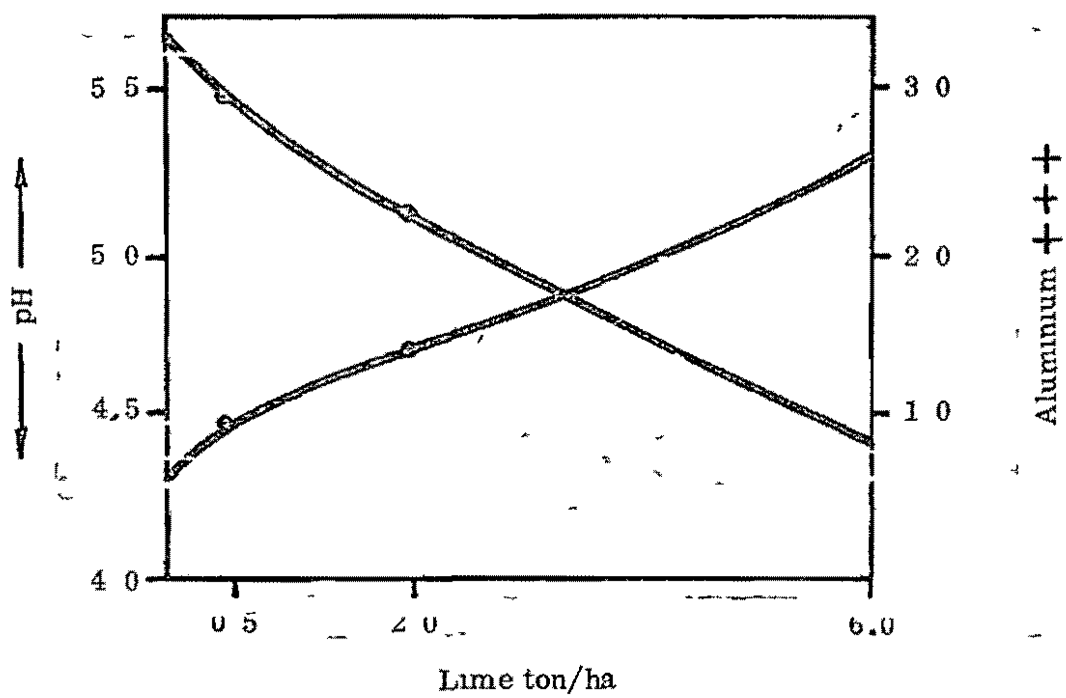
Tab 2

Table Soil characteristics of a Carimagua soil used to compare ~~I C A~~ cultivars of cassava

pH	4 5	P C	meq/100 gm	4 5
O M % (0-20 cm)	5	Al^{+++}	"	3 5
P ppm (BRAY II)	3	Ca^{++}	"	0 5
TEXTURE		Mg^{++}	"	0 3
. . CLAY LOAM		K^{+}	"	0 08

Mantenerlo

Fig 33 Effects of lime on pH and aluminum levels in a Carimagua soil in which several ICA cassava cultivars were compared



J6

WEED CONTROL

Research objectives in weed control were to determine the safe compounds and recommended rates for cassava, and to determine the critical period of weed competition

Selectivity of herbicides

A herbicide selectivity trial was done at CIAT where soils are relatively heavy The results, consequently, are valid only for soils equally as heavy and can not be transfered to lighter soils areas without an initial screening test Three rates were used for the 27 herbicides tested the recommended one for other crops on similar soils, twice that and quadruple the recommended rate Thus, it was possible to determine not only which chemicals are selective but also what the margin of selectivity

Two special conditions exist for cassava planting which are not common in other crops and these also were taken into consideration Normally, a pre-emergence herbicide is applied to the soil after the crop has been planted Sometimes cassava is planted leaving a portion of the seed piece exposed and a herbicide application will bring the product into direct contact with the seed piece On the other hand, if the herbicide is applied before planting, the seed piece is pushed through treated soil, also bringing it into direct herbicide contact To determine which system caused the least toxicity, half of each plot was planted before the herbicide application and the other half afterwards

The practice of ridging before planting also presents a problem Several excellent herbicides are only effective if soil-incorporated after being applied If ridges are formed after such chemicals have been incorporated, the product is accumulated within the ridge and the furrows are left with little or no product Applying and incorporating after the ridges have been made is impossible without damaging the ridges Thus, if such chemicals are to be used, ridging may have to be eliminated

To study the possible interaction between ridging and herbicide toxicity, half of each plot was ridged after applicationwhile the other half was planted directly in non-ridged soil The variety used in the test was CMC 64 and it was planted in rows 66 cm wide with 50 cm between plants Observations were made at 30, 45, 60, 90 and 110 days, after which time the trial was terminated Surface irrigation was applied after herbicide application to provide adequate soil moisture

Herbicides which showed an extremely wide range of selectivity in this trial were (Tables 9, 10, 11). Linuron, Norea, Fluometuron, Chlorbromuron, Diuron, Fluorodifen, Nitrofen, Pronamide and Nitralin Even at four times the recommended rate, only slight or initial injury was observed for a few of these products, the majority being completely selective

Those herbicides which were selective only at the recommended rates were Ametryne, Prometryne, Terbutryne and Butylate, and the ones which were phytotoxic at the recommended rate were Atrazine, Bromacil, Karbutilate, Vernolate and EPTC In general, the herbicides of the triazine, carbamate and uracil families presented the greatest injury to the cassava plant No differences were found between planting either before or after pre-emergence herbicide application or between ridging and not ridging for the preplant incorporated herbicides (Table) It appears that the pre-emergence application can be made either before or after planting and that there is no increased injury when ridges are made after applying preplant incorporated chemicals

Critical competition period

Because of cassava's slow initial growth and traditionally wide plant spacing, it is thought to be susceptible to early weed competition Once the foliage has "closed", that is, formed a complete ground cover, weed control practices are normally not needed However, most varieties delay 3 to 4 months in closing and thus may be affected by weed competition over relatively long periods

To determine the exact period that weed competition is most serious, a series of hand weeding treatments is being carried out with two cassava varieties, CMC 84, a short growing plant and CMC 39, more vigorous and taller It is logical to expect that there will be different critical weed free periods for each variety to produce the maximum yield in relation to its particular vigor and growth habits

The weeds present are *Cyperus rotundus*, *Sorghum halepense*, *Rottboellia exaltata*, and *Ipomoea* spp Rows are 1/m wide and plants are spaced 1/m apart in the rows Yield data are not yet available but the cassava heights at 160 days after planting in relation to the number and timing of hand weedings compared to the chemically weed free treatment offer some striking information (Fig 3)

It was impossible to obtain cassava plants as tall as those in the chemically weeded plots (fluometuron, 3 kgai/ha pre-emergence and paraquat, 0.5%, v/v, in directed-postemergence applications as needed) with hand weeding A minimum of two weedings will be needed to obtain maximum growth and early weedings (15 days) may be more harmful to the young plant than those done at later times (30 or 60 days).

Injury ratings in cassava at 30, 45, 60, 90 and 110 days for the preemergence herbicides

	Herbicide	Rate kgai/ha	Injury rating *				
			30	45	60	90	110 days
1	linuron	1.5	1 0	1 0	1 5	0 0	0 0
2	"	3 0	1 0	1 0	2 5	0 0	0 0
3.	"	6 0	1 2	1 0	3 5	1 8	2 5
4	norea	2 5	1 2	0 2	0 0	0 0	0 5
5	"	5 0	1 2	0 8	0 8	0 0	0 5
6	"	10 0	1 5	1 2	2 8	2 5	0 0
7	fluorodifen	3 0	1 2	0 5	1 8	0 0	0 0
8	"	6 0	1 5	0 8	1 8	0 0	0 0
9	"	12 0	2 8	0 2	1 0	1 0	1 5
10	DNBP	1 5	1 0	0 2	0 2	0 0	0 0
11	"	3 0	2 0	0 2	0 5	0 0	0 0
12	"	6 0	1 5	0 8	1 5	0 0	0 0
13	pronamide	1 5	1 0	1 2	1 5	0 0	0 0
14	"	3 0	1 5	0 8	1 2	0 0	0 0
15	"	6 0	2 5	1 5	2 2	1 0	0 0
16	methazole	2 0	1 8	1 5	1 8	0 0	0 0
17	"	4 0	1 0	1 0	1 0	0 0	0 0
18	"	8 0	1 5	1 2	2 0	1 0	0 0
19	nitrofen	3 0	1 0	0 8	1 0	0 0	0 0
20	"	6 0	1 8	1 2	1 5	0 0	0 0
21	"	12 0	1 0	1 0	1 8	0 0	1 0
22	butachlor	2 0	1 8	1 0	2 0	0 0	0 0
23	"	4 0	1 5	1 2	1 5	0 0	0 0
24	"	8 0	1 8	0 8	0 5	0 0	0 0
25	atrazine	2 0	1 8	1 5	4 2	2 5	1 5
26	"	4 0	3 0	2 5	8 5	7 8	8 0
27	"	8 0	1 8	3 2	8 8	5 0	10 0
28	alachlor	2 0	1 5	1 0	1 0	0 0	0 0
29	"	4.0	1 8	1 0	1 5	0 0	0 0
30	"	8 0	3 0	1 2	3 5	1 0	0 0
31	fluometuron	2 0	1 8	1 0	2 8	2 5	0 0
32	"	4 0	1 0	0 5	1 2	0 0	0 0
33	"	8 0	1.8	1 5	1 8	0 0	0 0
34	chlorbromuron	1 5	1 0	1 0	2 5	0 0	0 0
35	"	3 0	1 0	1 2	3 0	0 0	1 0
36	"	6 0	1.5	2 2	2 5	3 0	0 0
37	bromacil	0 5	1 0	1 0	1 5	0 0	0 0
38	"	1 0	2 5	1 5	3 5	2 0	0 0
39.	"	2 0	2.0	2 0	5 5	6 8	5 0

	Herbicide	Rate l gal/ha	Injury rating * 30	45	60	90	110 days
40	chloramben	2 0	1 5	1 0	2 5	0 0	0 0
41	"	4 0	1 0	0 8	0 8	1 0	1 0
42	"	8 0	1 0	0 2	1 5	2 5	2 0
43	norea + diuron	1 11 + 0 5	1 0	1 5	2 8	0 5	0 0
44	" + "	2 22 + 1	1 0	1 5	3 5	2 0	1 5
45	" + "	4 44 + 2	1 0	1 8	4 5	2 5	2 0
46	ametryne	2 0	1 5	1 5	2 5	0 0	0 0
47	"	4 0	2 0	1 2	2 0	0 0	0 5
48	"	8 0	0 8	1 5	4 2	5 0	4 0
49	cynazine	2 0	3 2	1 5	1 8	0 0	0 0
50	"	4 0	1 5	1 5	2 0	0 0	0 0
51	"	8 0	1 8	1 0	3 0	0 0	0 8
52	benthiocarb	3 0	2 0	0 8	2 0	0 0	0 0
53	"	6 0	2 5	1 5	3 0	0 0	0 0
54	"	12 0	3 3	1 5	3 5	0 0	0 0
55	karbutilate	2 0	1 5	2 2	7 2	6 8	6 0
56	"	4 0	1 0	2 5	8 0	9 0	8 0
57	"	8 0	2 0	3 8	9 0	10 0	9 8
58	terbutryne	1 0	1 0	0 3	3 2*	0 0	0 0
59	"	2 0	1 2	1 2	3 8	4 0	1 8
60	"	4 0	1 5	2 2	4 8	4 5	0 5
61	prometryne	2 0	1 0	1 8	3 5	1 8	0 5
62	"	4 0	1 5	2 0	4 0	2 0	0 5
63	"	8 0	1 8	2 8	5 5	5 5	4 8
64	diuron	1 5	1 2	1 0	1 0	0 0	0 0
65	"	3 0	1 8	0 8	1 5	0 0	0 0
66	"	6 0	1.5	1 5	3 5	2 5	0 0
67	control	-	1 0	0 8	1 8	0 0	0 0
68	control	-	1 0	0 5	0 5	0 0	0 0

* 0 = No injury , 10 = complete kill

Injury ratings in cassava at 30, 45, 60, 90 and 110 days on the pre-plant incorporated herbicides

	Herbicide	Rate	Injury rating *				
			30	45	60	90	110 days
		kg ai/ha					
1	butylate	3.0	2.0	1.2	2.2	0.5	0.0
2	"	6.0	3.0	2.8	4.5	4.8	4.0
3	"	12.0	3.5	2.6	6.0	6.5	5.0
4	vernolate	3.0	2.5	1.2	3.0	3.5	3.0
5	"	6.0	4.5	2.0	5.5	4.2	3.8
6	"	12.0	7.8	9.0	9.0	7.2	7.5
7	EPTC	3.0	3.0	1.0	3.5	2.5	3.0
8	"	6.0	3.2	2.2	4.0	4.2	4.0
9	"	12.0	6.2	8.2	7.8	6.8	5.0
10	trifluralin	1.5	2.2	0.8	1.0	0.0	0.0
11	"	3.0	4.5	0.8	2.0	0.0	0.0
12	"	6.0	6.0	2.0	3.0	0.8	0.0
13	nitralin	1.5	1.2	0.8	0.2	0.0	0.0
14	"	3.0	0.2	0.8	0.8	0.0	0.0
15	"	6.0	1.0	0.8	1.8	0.0	0.0
16	control		1.0	0.5	1.5	0.0	0.0

* 0 = No injury, 10 = complete kill

TABLE 3 Plant injury at 90 days and per cent reduction in germination at 30 and 90 days, when planting either before or after preemergence herbicide application, and when planting with or without ridges for the preplant incorporated products (averages for all treatments)

Method		Injury rating[1] at 90 days	Germination reduction[2] %	
			30	90 days
1	Preemergence			
a	Before planting	2 7	6 0	12 3
b	After planting	3 0	5 0	14 5
2	Preplant Inc			
a	With ridges	2 8	22 2	7 9
b	Without ridges	2 4	24 0	13 0

[1] 0 = No injury , 10 = complete kill

[2] With respect to the control

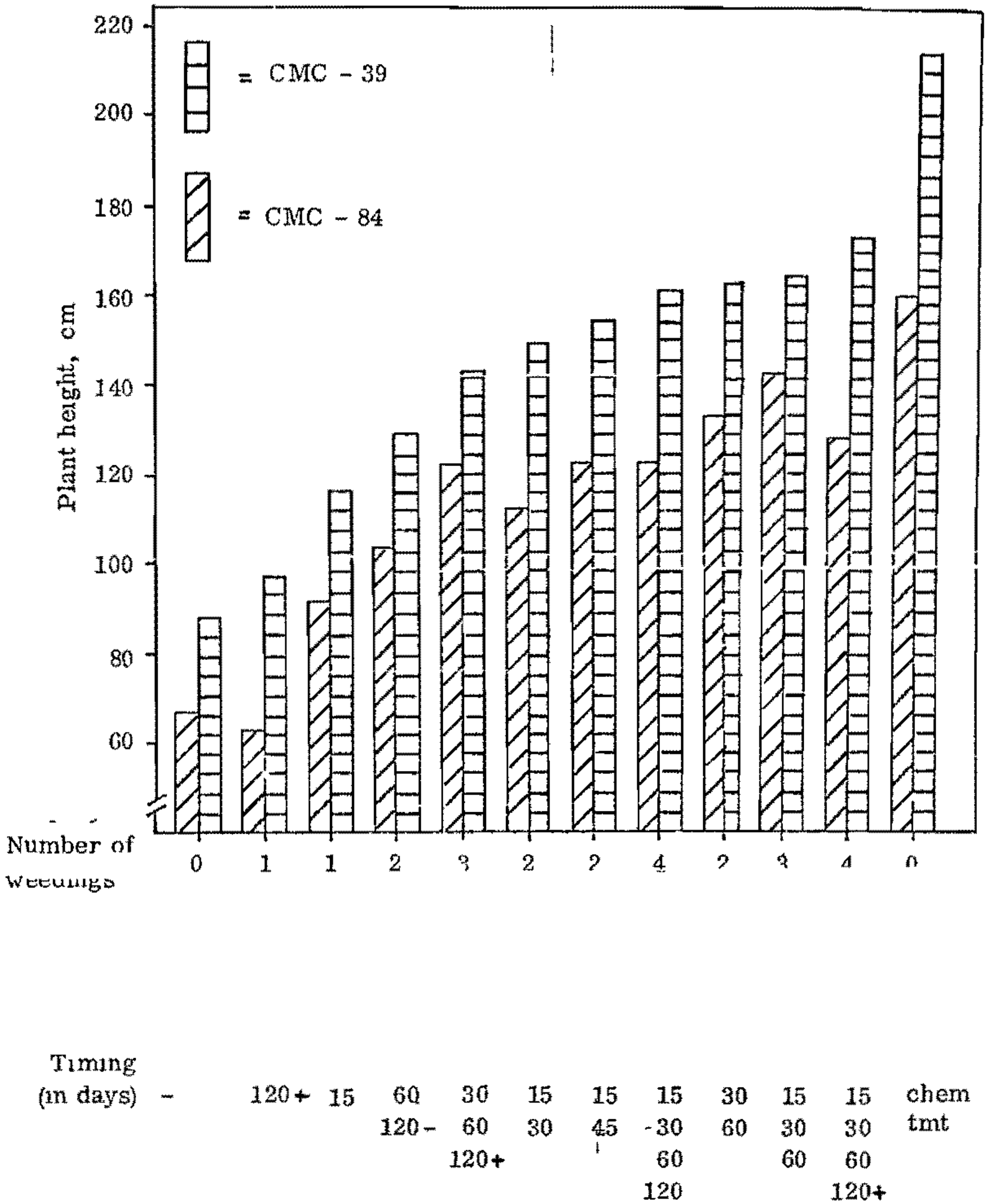
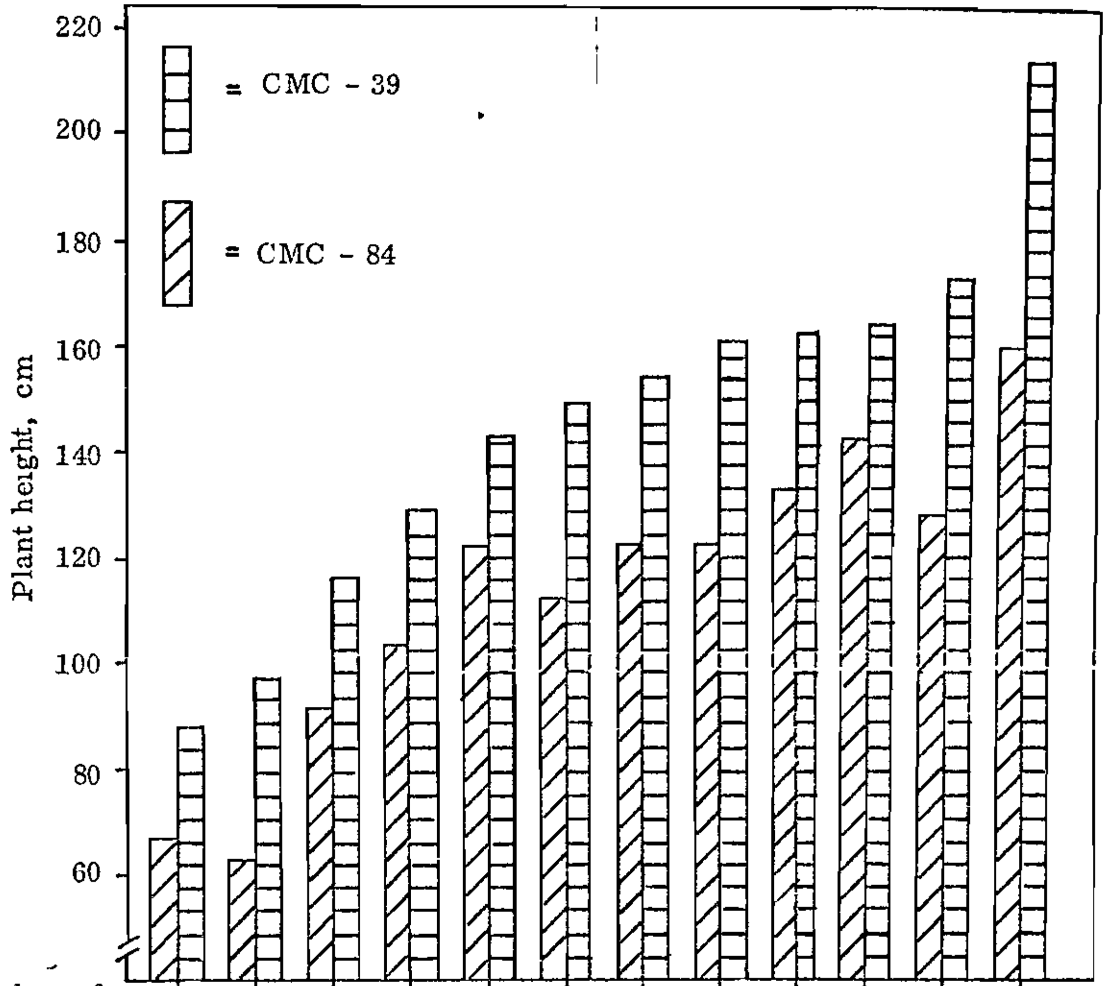


Fig 34 Effect of number and timing of hand weedings on cassava height 160 days after planting the varieties CMC-39 and CMC-84 as compared to chemical weeding (the "-" indicates weedings were continued until harvest time)



Number of weedings	0	1	1	2	3	2	2	4	2	3	4	0
Timing (in days)	-	120+	15	60	30	15	15	15	30	15	15	chem
				120-	60	30	45	30	60	30	30	tmt
					120+			60		60	60	
								120			120+	

Fig 34 Effect of number and timing of hand weedings on cassava height 160 days after planting the varieties CMC-39 and CMC-84 as compared to chemical weeding (the "-" indicates weedings were continued until harvest time)

STORAGE

Fresh root storage*

Post-harvest behavior of cassava roots is being investigated in the hope of devising techniques for extending the storage life of fresh cassava roots While it is realized that such techniques as refrigeration and waxing can satisfactorily extend the storage life of fresh roots, the present investigation is directed to find simple, inexpensive, "on-farm" methods

A detailed study was made of the nature, occurence, symptoms, and progress of the post-harvest deterioration that occurs in fresh cassava roots Resulting from this investigation a key for the assessment of deterioration has been prepared (Fig 35)

The effect of various chemicals on the retardation of deterioration has been examined using a root slice technique in addition to whole roots Results indicate that surface sterilants may significantly delay deterioration (Fig 36) Observations on deteriorating roots indicates a close association between various kinds of mechanical damage and the onset of deterioration

The possibility of storing cassava roots in simple potato "clamp" like structures is being examined (Fig 37) To date roots have been stored by this method for five weeks without any deterioration and possibility of longer term storage looks promising

---

*This work is being done by Dr R Booth, of the Tropical Products Institute, London, while spending a year at CIAT

Observations suggest the possibility that the rapid root deterioration that occurs after harvest is the result of invasion by epiphytic organisms naturally present on the root surface after injury These organisms, at present uncharacterized, do not normally invaae the roots, but when roots are damaged they stimulate vascular streaking, discoloration and necrosis but do not cause any decay

The success of "clamping" in preventing deterioration suggests that either the conditions within the clamp prevent the invasion of wounds or that the wounds heal and so prevent any deterioration

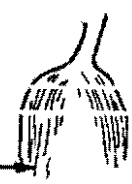
Should the use of "clamps" be repeatedly found to control deterioration, then this technique would proveide a simple, inexpensive method of "on-farm" storage of fresh cassava roots

Fig 35 Key for the assesment of deterioration in whole cassava roots

- The assesment is made by surface and numerous cross-sectional observations on peeled roots

- Typical symptoms

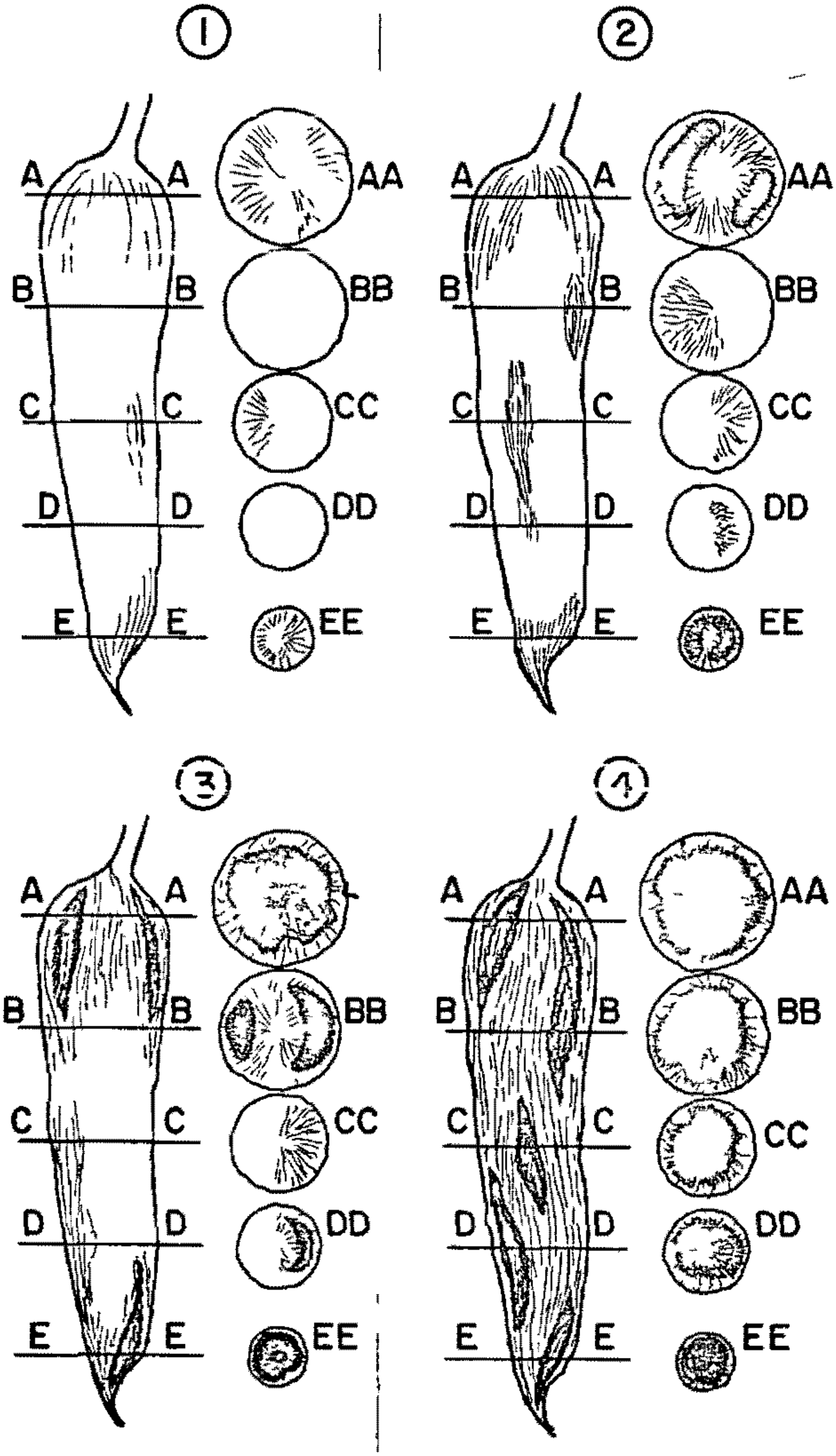
  A Streaking

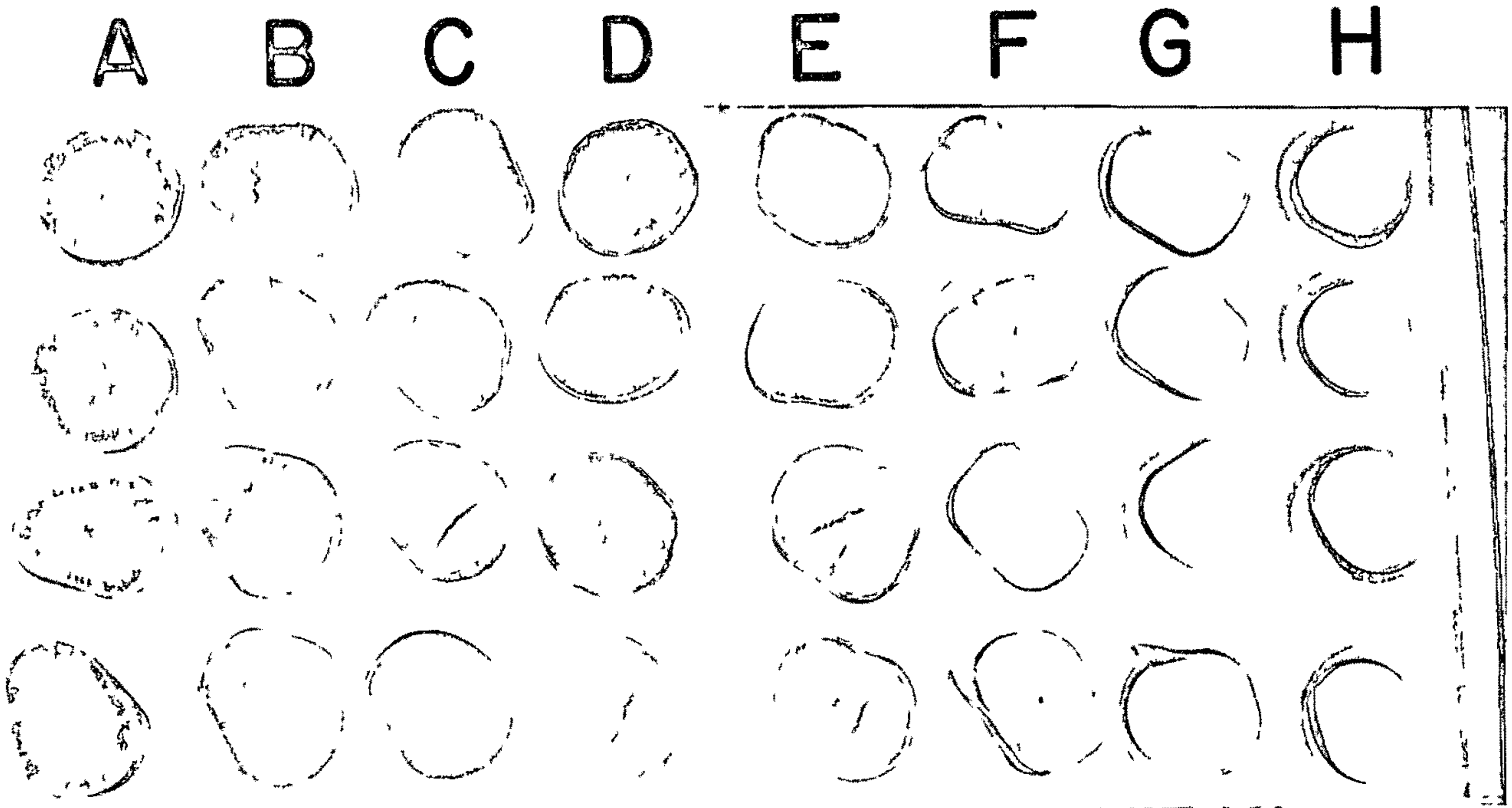


  B Necrotic "lesions"

- $$\text{Deterioration Index} = \frac{\text{Total score of sample} \times 100}{(\text{No roots in sample} \times 4)}$$

Fig. 35 (A)





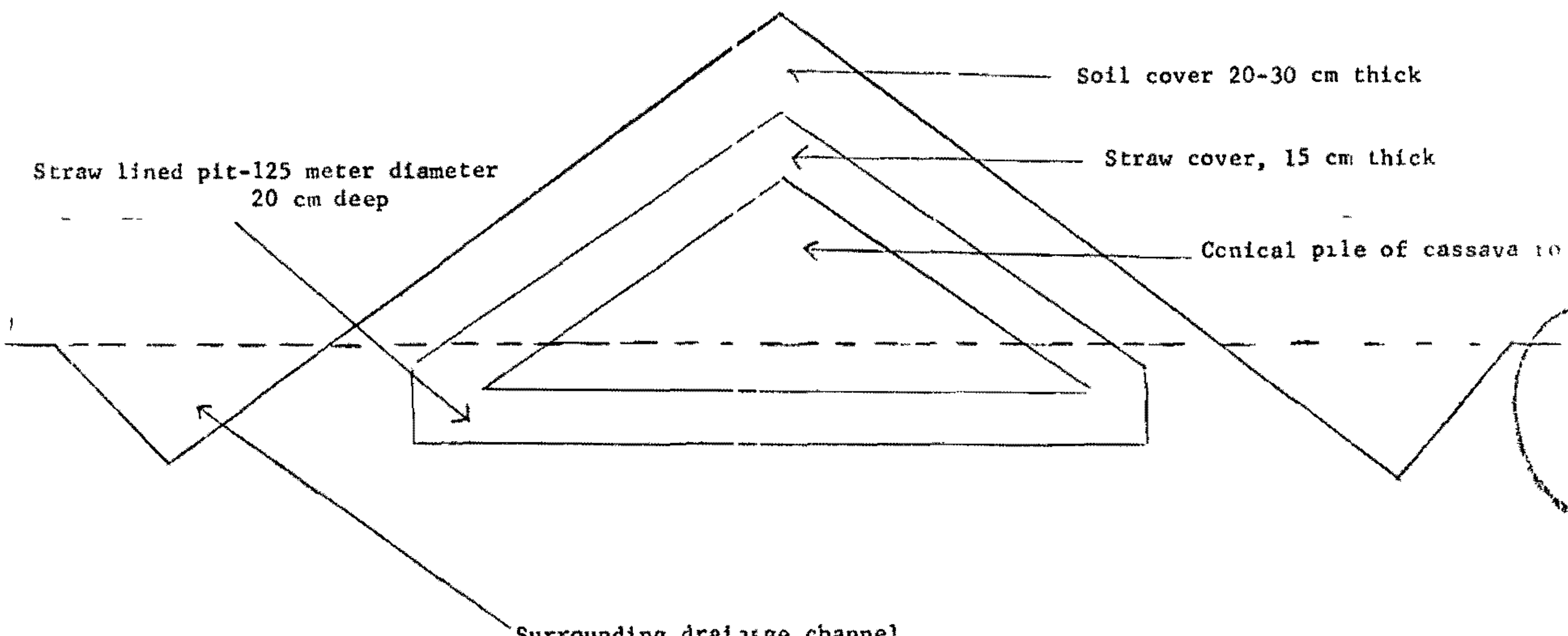
COMMERCIAL ALCOHOL

Fig 36 The effect of alcohol on the retardation of deterioration of cassava root slices, onde day after treatment

<u>Treatments</u>

A ________________ E ________________
B ________________ F ________________
C ________________ G ________________
D ________________ H ________________

Fig. 7 -SECTION THROUGH CASSAVA "CLAMP"



Solar drying*

Research was conducted to estimate quantitatively the basic physical mechanisms that control the drying of cassava particles with emphasis on drying under natural ambient conditions Existing theroretical principles of drying of biological products were successfully applied to design the experiments and to explain mathematically the influence of the independent variable in the desorption characteristics of cassava particles This knowledge is applicable now to give practical recommendations to dry cassava naturally at low cost obtaining a high quality product with excellent drying, storing and handling properties

A manual cutting press was built to produce rectangular bars of one square centimeter of section and variable length The device cut about 30 kg per hour but could be modified to obtain higher yields if required A disc cutter machine, widely used in some cassava producing countries, was modified to experiment with different type of chips (non-uniform slices with variable thickness and length, uniform slices and a geometry similar to the rectangular bars) This machine produces yields of 300 kg per hour when operated by a man using a bicycle pedal mechanism or 600 kg per hour operated by the power take-off of a tractor or by a gasoline motor

The field tests consisted of drying cassava particles in horizontal wire trays elevated from the floor during drying experiments Two types of solar driers were tested, and a preliminary bin drying of cassava chips with unheated

*This work forms part of the PHD thesis of Gonzalo Roa, at Michigan State University forced air was performed

A simple thin layer equation which express the drying rates (changes in moisture content per unit time) proportional to the removable moisture content, see equation (1), was fitted to the experimental data,

$$\frac{dM}{dt} = - K\ (M - M_{eq}) \qquad (1)$$

~~Same level~~

Where

M, moisture content, dry basis

t, time, hours

K, proportional constant

M_{eq}, equilibrium moisture content, dry basis

A multiple linear regression indicated that drying of cassava is sensitive mainly to changes in air temperatures (dry bulb) and wind to a lesser extent Solar radiation does not influence natural drying of cassava directly because of its highly refectant surface Absolute humidity had small influence because of the relatively low air free movement of the air between the particles in natural drying (under the experimental conditions absolute air water content varied from 0 012 to 0 019 g/g and, in more humid areas it may be important) The results of regression are summarized in the equation

$$\frac{M - M_{eq}}{M_i - M_{eq}} = e^{-Kt} \qquad (2)$$

~~Same level~~

$$K = 0.01\,\bar{M}_i - 48.8 + 1.51\,D - (4.07 - 3.38 \times 10^{7}\,D^{-8})\,W + 6.54\,D^{-0.654}\,\bar{T} \quad (3)$$

where

$\bar{M}_i$, initial moisture content, dry basis

D, fresh cassava weight per unit area, kg/m^2

W, average wind velocity, m/sec

T, average air dry bulb temperature, °C

This equation allows calculation of values of moisture content of 1 x 1 x 5 cm unselected rectangular bars when the average independent variables are known or can be predicted

When the moisture content is expressed in the form of equation (2), the desorption equation and curves are not effected by the initial moisture content (Fig 38) when the moisture contact is above twenty percent wet basis This fact was particularly useful during the desorption curve analysis where differences of initial moisture content were of the order of ten percent, wet basis, because of differences in cassava age, variety and position of the particle along the root

The influence of ambient conditions in the drying rates are shown in Fig 39 The bottom section shows the recorded ambient variables The experimental K Value, calculated using equation (1) in its finite form are indicated in the upper section

The experimental K values and those calculated using the expression (3) are compared in Fig 40 The standard deviation of these observations is 0 03 and a mean value of 0 20 The estimated error in the experimental K value due to field measurements is 0 02 These figures allows moisture content, wet basis, after 8 hours of natural drying to be estimated to within ±4 percent

It was possible to dry safely 20 kg/m^2 of fresh cassava in wire trays elevated from a floor at an average air temperatures of 30°C and wind velocity of 1 m/sec The drying process to moisture content of 15 to 13 percent w g , takes two to four days Some drying also occurs overnight when the moisture content of the root pieces is about 20 percent or higher

Rectangular bars of 1 x 1 x 5 cm were from a practical point of view the best geometry among those tested in the study The relatively high void space between the particles, about 65 percent, allows the natural air to circulate removing the saturated air Also the dry bars do not break easily producing the undesirable fines Other geometries tested were small chips (non-uniform slices, 1 to 12 cm long and 0 1 to 0 17 cm thick), big chips (non-uniform slices 1 to 12 cm long and 0 2 to 1 2 cm thick), slices (uniform 0 3 cm slices)

Hourly stirring of the product does not acelerate the drying of cassava particles significantly if appropriate natural drying conditions exist. The reason for this is the high solar reflectivity value of the white cassava surface

The tested solar driers are not recommended to dry cassava because they have advantages over natural drying only when the radiation intensity is very high

Drying of cassava particles in bins, with forced ventilation is a difficult process if low air flows are used because of big differences in static pressures caused by the non-uniformity of the product and by the shrinkage (about 30 percent of the initial volume) that occurs when drying cassava from 65 percent to 14, w b This results in non uniform drying and rotting of the product

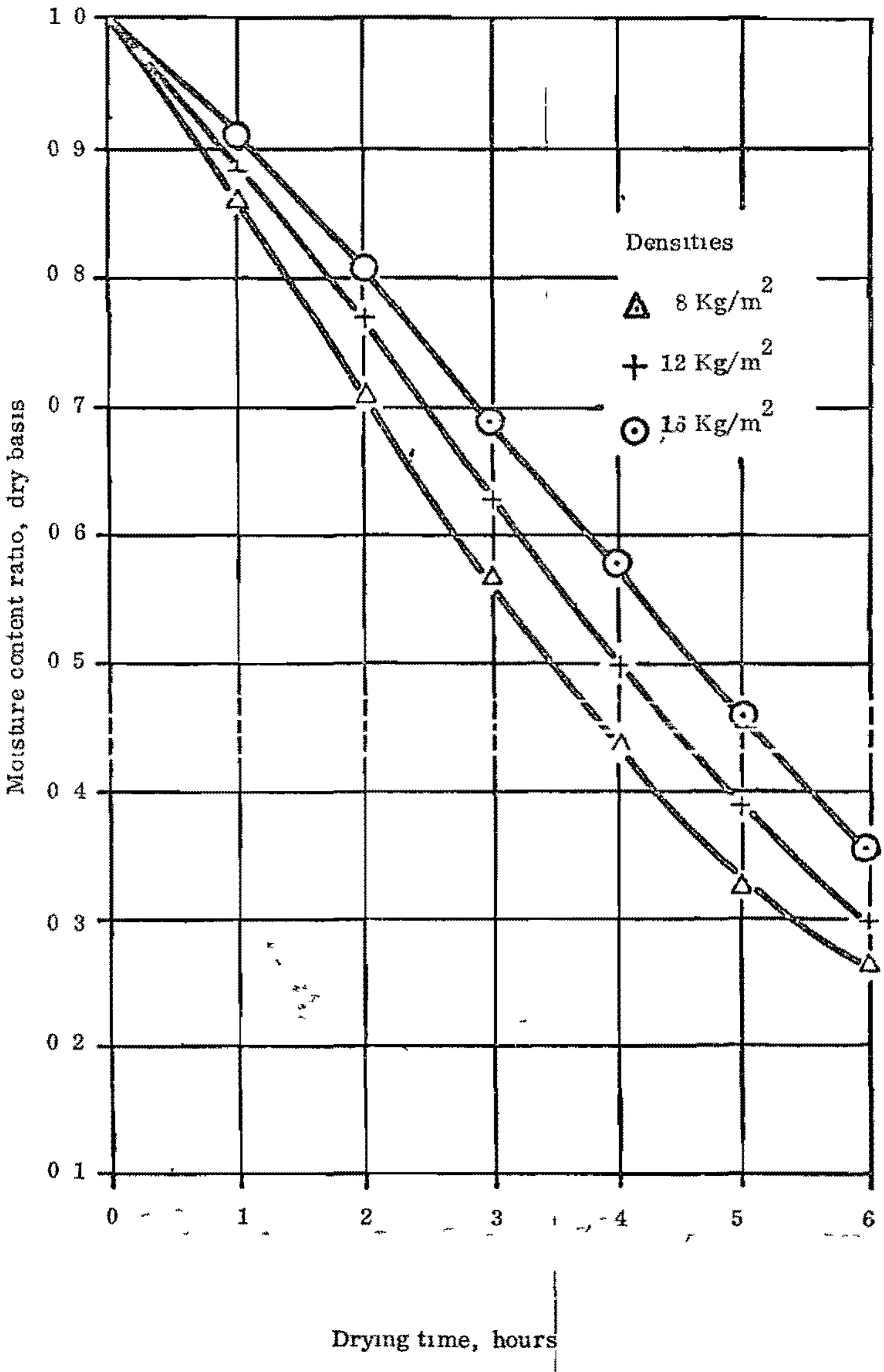


Fig 38 Desorption curves of natural cassava drying

Fig 39 Influence of ambient conditions on natural cassava drying

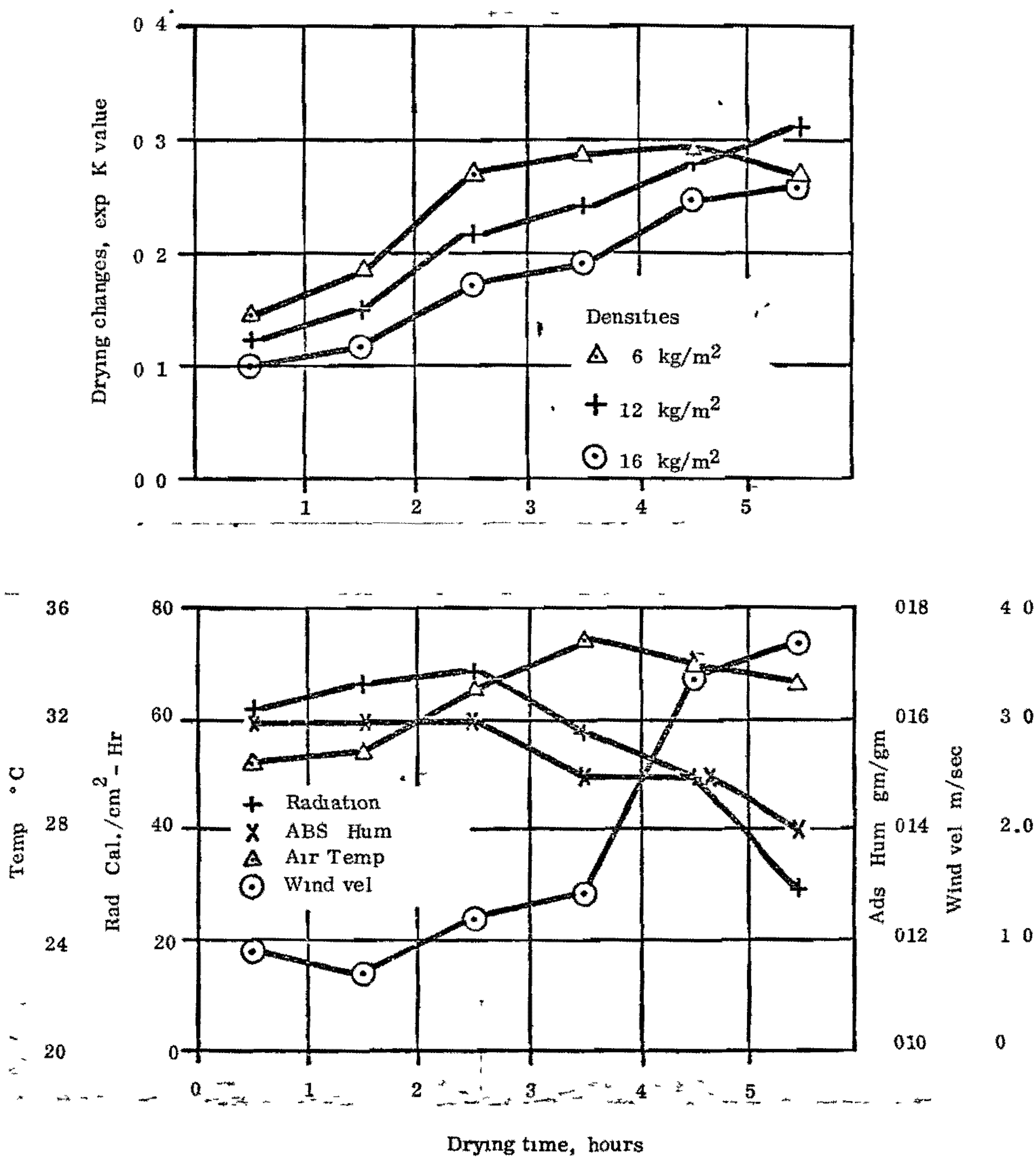
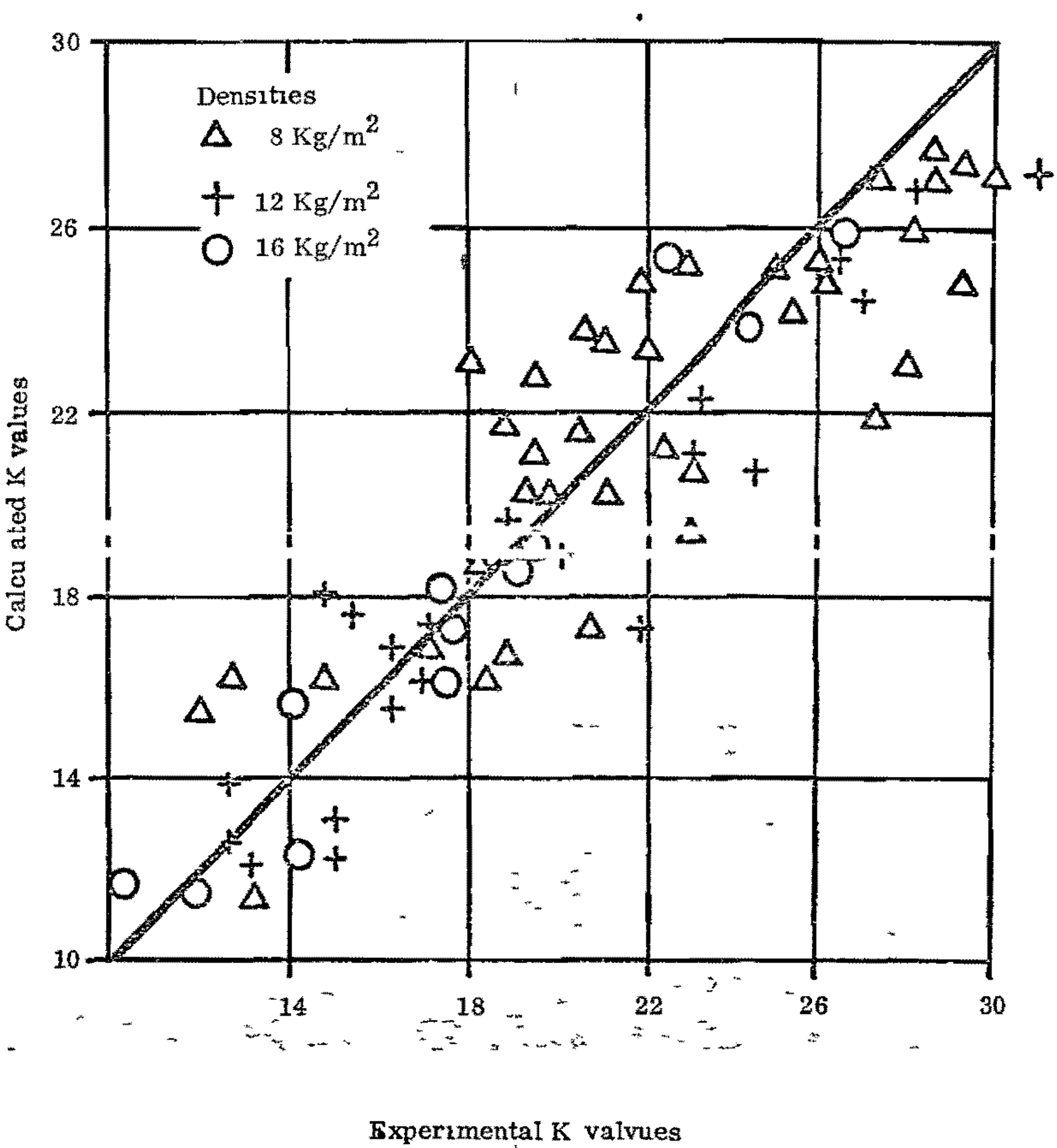


Fig 40 Comparison of experimental and calculated K values



(52)

AGRICULTURAL ECONOMICS

The work carried out during 1972 focused on (1) a description of existing cassava production systems in Colombia and the cost of production under these systems, and (2) the economics of utilization of cassava

Description of production systems

A farm survey was carried out among 330 cassava producers in various regions of Colombia A stratified sampling procedure was used in an attempt to obtain information expected to be representative of the various Colombian production systems The objectives of the survey were to describe present production systems and to estimate costs of production and labor use by production activity for the various production systems Although the analysis of the data has not been completed, some preliminary results may be reported

Almost one-half of the cassava producers included in the survey had less than two hectares of cassava, while only 13 percent had more than 10 hectares Slightly more than one-half of the farmers grew cassava mixed with other crops Maize was the crop most frequently found together with cassava, followed by plantain, yams, coffee and beans. A large proportion of the farms (22 percent) grew cassava together with more than one other crop

A large variation was found in plant population per hectare The majority of the farmers producing cassava on flat lands outside the North Coast Region maintained a population of 10,000-15,000 plants per hectare, while the farmers in the North Coast Region maintained a much lower plant population (4,000-12,000) and the farmers producing on sloping lands were found to maintain a plant population of 6,000-12,000 in most cases The length of the crop cycle varied from one region to another The most common crop cycle was found to be 12-14 months

The use of purchased inputs was low Only five percent of the farmers interviewed used fertilizers and 31 percent used insecticides About two-thirds of the farmers used only manual labor for land preparation, six percent used animal traction and 27 percent used a more mechanized form for land preparation On all farms the planting and harvesting was done exclusively by manual labor None of the farmers used chemical weed control Most of the farmers weeded the cassava field three times during the crop cycle.

The data are presently being analyzed with respect to labor utilization and production costs by production activity and farm size It appears that present production costs run from 400 to 700 Colombian pesos/ton of cassava These figures are tentative, however, and subject to revision

Cassava utilization

The potential demand for cassava for direct human consumption, industrial starch and animal feed is presently being analyzed jointly by the University of Guelph, Canada, and CIAT

Tentative results from an analysis of the economic feasibility of partial substitution of wheat in bread in Colombia suggest that such substitution would not be economically sound given present prices of wheat and cassava If the wheat price remains constant, the price of cassava flour would have to drop by approximately 50 percent to make the substitution economically sound for the bread producer If the present cost of marketing and processing per ton cannot be reduced, the price of fresh cassava would have to fall from the present $1 700/ton to around $190/ton It is likely,however, that the cost of processing will be reduced if the quantity of cassava flour increases The extent to which processing costs can be reduced is not clear at present, however, they are a major portion of the total cost

Given the large outflow of foreign exchange associated with wheat import, a pratial substitution of wheat in bread might considerably influence the foreign exchange balance The economic feasibility of partial replacement of wheat imports by other Latin American countries and the implications of such replacement on foreign exchange, farm sector revenues and domestic employment are presently being analyzed

The economic feasibility of using cassava as an energy source for swine is being studied Tentative results are reported under Swine Production Systems

Recent trends in cassava production and yields

An analysis of the world cassava production and yield trends during the period 1960-68 was carried out on the basis of secondary data The analysis suggests an increasing production trend of about two million tons annually during the period The increasing production was because of an increase in cassava acreage of about 200,000 hectares annually Average world yields of approximately 9 tons/ha show no significant change during the period

The largest production increases took place in Africa and South America The increase in total world production of cassava just kept pace with population increase in the cassava producing countries leaving per capita cassava consumption in these countries constant

TRAINING

Before 1972, training in the cassava program had been available to few (two interns and two research fellows) mostly because of limitation in numbers of senior staff and an outbreak of bacteria disease Soon after the appointment of a full-time program co-ordinator, the cassava production systems team was established. This team sought and identified qualified candidates for training In 1972, nine post-graduate interns, two doctoral candidates and two special trainees were appointed or continued training

In addition, three trainees in plant protection dealt with cassava as part of their training Colombia, Perú, USA, and the United Kingdom have been so far represented in the above groups Additional professionals have already been selected from Ecuador and Venezuela for training in early 1973