EFFECTS OF TIME OF WEEDING AND PLANT POPULATION ON THE GROWTH AND YIELD OF CASSAVA

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SUMMARY

The critical period competition for cassava (*Manihot esculenta* Crantz) by weeds occurs between 60 and 120 days after planting. Weeds competing with cassava during the first 6- days reduced production by 50 percent. Cassava kept weed-free from the first 60 days produced 76 percent of yield of fully weed-free cassava and that kept weed-free for 120 days, 88 percent of the maximum.

The optimum plant density varied with the weed control practice used. Densities of 6000 to 8000 plants/ha were optimal for cassava kept chemically weed-free, whereas for cassava hand-weeded only once at 30, or twice at 30 and 60 days after planting, densities greater than 8000 plants/ha were necessary to obtain the maximum yield.

RESUME

Le période critique de concurrence entre le manioc (*Manihot esculenta* Crantz) et les mauvaises herbes se situe entre les 60 et 120 hours qui suivent le semis. La concurrence des mauvaises herbes avec la manioc pendant les 60 premiers jours réduit la production de 50 pour cent. Libére de la concurrence des adventices pendant les 60 premiers hours, le manioc donne 76 pour cent de manioc entièrement débarrassé d'adventices; dans les mémes conditions et pendant 120 jours, on obtient 88 pour cent du maximum.

La densité optimale de peoplement varie en fonction de la méthode de lutte contre les adventices. 6,000 à 8,000 plants à l'hectare représent les densités optimales quand les adventices sont maîtrisés par des produits chimiques, alors que des densités supérieures à 8,000 plants à l'hectare sont nécessaires quand le désherbage se fait à la main une fois à 30, ou deux fois à 30 et 60 hours après le semis pour obtenir un rendement maximum.

RESUMEN

En yuca, (*Manihot esculenta* Crantz), el périodo crítico de competencia de malas hierbas ocurre entre 60 y 120 días despues de la siembra. Las malas hierbas compiten con la yuca durante los primeros 60 días reduciendo la producción en un 50 porciento. La yuca que se mantiene libre de hierbas los primeros 60 días produce el 76 porciento de lo que produce un cultivo que se mantenga completamente des hierbado. La yuca que se mantega libre de hierbas 120 días, produce el 88 porciento del maximo.

La densidad de población óptima varió con la práctica empleada en el control de las malas hierbas. Las densidades de 6000 a 8000 plantas/ha fueron óptimas cuando la yuca se mantuvo libre de hierbas quimicamente, en tanto que los cultivos de yuca, donde se hizo un solo deshierbe manual a los 30 días o dos a los 30 y a los 60 días despues de la siembra, se requirieron densidades mayores a las 8000 plantas/ha, para obtener los rendimientos máximos.

INTRODUCTION

Relatively little is known about the losses due to weed competition in cassava (*Manihot esculenta* Crantz). For many annual crops, the critical period of weed competition is from 30 to 40 days after planting[2] This is the period during which these crops, if freed from competition, can completely shade the interrow area, thereby greatly reducing subsequent weed germination and growth. Cassava, on the other hand, due to its slow initial growth, may often require three months or longer to attain a closed canopy. The wide spacing usually used for cassava makes it more susceptible to losses from weed competition than the use of close spacing.

It was anticipated in planning our study that the initial growth period could be the most important one in which to keep cassava weed free, and that this period would be more prolonged than for annual crops.

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Completely weed-free cassava will be able to utilize all the available nutrients, light and water. Lower plant populations, which nevertheless attain a closed canopy, may be able to yield as much or more than higher ones under weed free conditions. However, when weeds are potentially competing with the crop, the plant density which produces the maximum competitiveness against weeds may yield better than more widely spaced plantings. Higher plant populations are expected to be more competitive against weeds than lower ones. Thus the optimum plant density may be expected to interact with measures to control weeds. This interaction has been studied in two cassava cultivars.

MATERIALS AND METHODS

Study of the critical period of competition

This experiment was designed to compare the production of two cassava cultivars CMC39 and CMC84, weeded at various times and frequencies with that of cassava kept completely free of weed competition by the use of herbicides (hereafter called 'chemically weed-free cassava'). Weeds were allowed to grow with cassava for varying periods at different growth stages of the crop.[2] Weeding times and frequencies are presented in Table 1. In the first four treatments weeds competed during the initial growing stages, and the crop was thereafter kept weed-free. In treatments five to eight, weeds were controlled initially and then weed control measures were stopped. Treatments of two weedings, at 30 and 60 or 15 and 45 days, were included as being typical of practices used by cassava growers. The unweeded check was included to measure the loss when no weed control measures were taken. The chemically weed-free treatment, included as well as complete hand weeding, indicated whether or not the soil disturbance which occurred during normal weeding affected root yield.

The competitive ability of the cultivar CMC39 (a tall and branched type) was compared with that of CMC84 (a shorter and less branched type). Cassava was planted in a clay soil containing 6.3 percent organic matter with a pH of 6.8. The crop population was 10,000 plants/ha. The experimental design was a split-plot with cultivar as the main plot and weeding as the sub plot treatment. Four one-meter wide rows comprised each subplot and ten plants were spaced one meter apart in each row. Four replications were used. Stem cuttings of 20 cm were planted. These were inclined and planted just below the soil surface on May 10, 1972. Missing plants were replaced three weeks later by cuttings propagated on the same date in polyethylene bags.

Fluometuron (3 kg/ha a.i.) was applied pre-emergence in the treatment of chemically weed-free cassava. Post-emergence applications of 0.5 percent v/v paraquat with 0.25 percent surfactant, were directed to the weeds as often as they emerged. A total of eight such applications were made.

The height of the cassava was measured 160 days after planting. Harvesting was carried out 9.3 months after planting and the fresh and dry weights were measured for the roots and aerial part of 16 plants per plot. Weed counts and the weights of weeds removed were recorded at each weeding.

Cassava density and competition

A systematic design was used to obtain plant populations ranging from 2380 to 13,850 plants/ha[1]. Twenty five stem cuttings were planted, inclined in ridges. Weed control treatments included one hand weeding at 30 days, two weedings at 30 and 60 days, a chemically weed-free treatment (fluometuron and alachlor pre-emergence at 2.0 + 1.5 kg/ha a.i. respectively, followed by a total of 12 directed post-emergence applications of a 0.5 percent solution of paraquat as needed), and a weedy check. The cultivars Llanera and CMC84 were used. Missing plants were replaced three weeks after planting with plants of the same age grown in polyethylene bags. The soil characteristics were similar to those of the previous experiment. The predominant weed species were *Cyperus rotundus* L. (purple nutsedge), *Cenchrus brownii* Roem & Shult, (sandbur), *Amaranthus spp.*, (pigweed), *Ipomoea* spp. (morning glory), *Leptochloa filiformis* (Lam.) Beauv. (springletop) and *Digitaria sanguinalis* (L.) Scop. (crabgrass).

Plant heights were taken 30, 90, and 180 days after planting. Soil moisture was determined at 100 days. Three central rows were harvested 8.4 months after planting and the data are expressed as three point moving averages.

RESULTS AND DISCUSSION

Critical period competition

Weed competition reduced the height of both cultivars 160 days after planting. Non-weeded cassava was less than half as tall as that kept chemically weed-free. Cassava free of weed for 60 days was as tall as that weeded for 120 days or more. Plant heights with two weedings at 30 and 60 days or 15 and 45 days were similar to those with four weedings. Waiting 120 days before beginning weeding gave cassava little

height advantage over the weedy check. No hand weeding system produced cassava as tall as that kept chemically weed-free. The two cultivars were similar in responses.

The fresh weight yield data show that the maximum production for each cultivar was achieved in the chemically weeded treatment (Table 2). CMC39 and CMC84 kept mechanically weed-free throughout the season produced 86 and 96 percent, respectively, of the yield of chemically weeded cassava. There was a more or less complete crop failure when no weed control measures were practiced as the yields were less than five percent of the chemically weeded cassava.

There was a yield reduction in CMC84 but not in CMC39 caused by weeds that germinated after 120 days (Table 2, treatments one and five.) The shorter stature of CMC84 makes it more susceptible to late season competition, especially in the presence of *Rottboellia exaltata* L.f. (itch grass), a weed which germinates throughout the season and grows and competes even under the reduced light conditions of the cassava canopy.

Weed competition occurring only during the first 60 days reduced the yield by 50 percent. Thus it is extremely important to control the weeds during the initial growth period. Starting the weeding operations at 120 days after planting proved less detrimental for CMC39, the taller cultivar, than for CMC84, the shorter one. By this time, CMC84 had already suffered severely from the competitive effects of the weeds.

Similarly drastic yield reductions occurred when only a single weeding was carried out at 15 days. Weeding twice at 15 and 30 days was also insufficient and yields were still reduced to 60 percent of the weed-free control.

In contrast, with two weedings performed at 30 and 60 days, yields were reduced only 10 to 15 percent compared with the hand weeded all season. Weeding at 15 and 45 days was less effective than weeding at 30 and 60 days (Table 2).

There was no effect of difference in the weeding system on root moisture content (Table 3). However, the harvest index (ratio of root dry weight to total plant dry weight) was lower in both the weedy check and the chemically weed-free treatment than the mechanically weeded treatments. Thus, under severe weed competition or in complete absence of this, there is proportionately a greater production of the aerial plant parts than of roots. This means that in the chemically weed-free cassava, there is not only greater root production, but also proportionately more aerial production. This would be beneficial in areas where the leaves are consumed and also where planting material is being produced.

Weeds present, in order of abundance, were purple nutsedge, itch grass, morning glory, and *Sorghum halepense* (L.) Pers. (Johnsongrass). Weed counts and weights are not presented due to the difficulty of data interpretation. The greatest confounding factor is the relative shortness of the weed life cycles in comparison to that of cassava. Several generations of weeds may be produced in the time it takes cassava to mature and also the weeding systems used gave a great diversity of stages of weed growth at any one time. To indicate the high degree of weed infestation, however, there were an average of 918 and 717 weed plants/m^2 in plots weeded for the first time at 30 and 60 days respectively. Over 90 percent of the total population was composed of purple nutsedge and due to this species the eight post-emergence herbicide applications were necessary in the chemically weed-free cassava.

Cassava density and competition

Plant heights in this experiment reveal some interesting trends. At 30 days after planting, both cultivars were the same height and the chemically weeded cassava was only slightly taller than that of the other treatments. At this early stage there was no response to differences in population density.

By 90 days after planting, the chemically weed-free cassava was two to three times taller than any other treatment and this was so for both cultivars. There is a tendency for cassava plants to be taller at higher populations in this treatment. The Llanera cultivar responded more to the hand weeding treatments than did CMC84.

The trend toward taller plants at higher plant populations was more marked at 180 days for the chemically weeded cassava, especially for CMC84. This indicates the existence of intra-specific competition between the cassava plants. When one or two weedings were performed, this tendency was less pronounced and it was completely lacking in the non-weeded treatment. Fresh root weighs 8.4 months after harvest for Llanera are somewhat variable (Figure 1). However, the maximum production for chemically weed-free cassava occurs at a lower plant population than for hand weeded cassava.

More marked differences are seen for CMC84 (Fig. 1). In the chemically weeded plots the maximum yield is reached with 6000 to 8000 plants/ha., and yield then decreases by 50 percent at 13,850 plants/ha. In contrast, for cassava hand weeded at 30 or 30 and 60 days, yield was continuing to increase even at the higher densities. This means that cassava in the presence of some weeds has a higher optimum density for yield than when grown in weed-free conditions. When no weed control was practiced, yields were close to zero for both cultivars.

Data on daily production of root matter lead to the same conclusions. Completely weed-free Llanera reached its maximum production between 6000 to 11,000 plants/ha, while the same cultivar weeded at 30

and 60 days yielded the maximum even at high plant densities. Yields for cassava weeded at 30 days was irregular for Llanera, but the same trend of higher yields at high plant densities was present in CMC84.

The harvest index for Llanera decreased as plant density increased regardless of the weeding system. This was also true for the chemically weed-free CMC84.

The trend was not consistent for the hand-weeded treatments. Thus there may be an interaction between cultivars and weed control measures. The yields of the weedy checks were so low that harvest index data provide no useful information other than that in general they are considerably lower than any other treatment. This supports the observations made in the previous experiment.

Percentage dry matter in harvested roots and in relation to soil moisture

Percent root dry matter was similar in all treatments with Llanera. However, in CMC84 at densities above 6000 plants/ha in the weedy checks, the percentage dry matter was nearly ten percent greater than in the chemically weed-free plants. Percentage dry matter in the hand-weeded cassava was intermediate. It is possible that by this time large vigorous plants in the chemically weed-free treatment had used up the available soil moisture and thus the roots were drier. In support of this suggestion, it was observed during harvest that the soil in plots with this treatment was noticeably harder and drier than in the others. Also, in the weedy check, the annual weeds matured several months earlier and by the time of cassava harvesting were serving as a mulch and so probably conserving soil moisture in comparison with bare soil beneath cassava.

However, this was not the case earlier in the season (Table 4). At 100 days after planting, the highest soil moisture contents occurred under the chemically weed-free cassava. At this time the cassava root system had not extended fully and in the absence of weeds probably there was less uptake by infiltration. The canopy had closed at densities of 5,530 plants/ha and above in the chemically weed-free cassava and hence shaded the soil surface. However, no difference in soil moisture between shaded and unshaded areas was detected. The weedy check had the least available soil moisture at this time. Plots weeded at 30 or 30 and 60 days were intermediate in soil moisture availability.

CONCLUSIONS

Cassava is seriously affected by weed competition. Even hand weeding throughout the crop period may not be sufficient to produce the maximum yield when heavy infestations of weed seeds are present. Weed competition occurring during the first 60 days reduced yields by 50 percent for both CMC39 and CMC84.

However, cassava kept weed-free during the first 60 days produced 76 percent of the yield of chemically weeded cassava. Weeding for the first 120 days gave 88 percent of the maximum and full-season weeding produced 91 percent of the maximum (averages over the two cultivars).

The harvest index was lowered by full-season weed competition or the complete absence of the same for both cultivars as compared to any hand-weeding practice. Root moisture content was not affected by any treatment.

The optimum plant density is related to the weed control system. For CMC84, populations of 6000 to 8000 plants/ha have maximum yield in the chemically weed-free treatment, but the maximum production for cassava weeded at 30 or 30 and 60 days was always produced at populations above 8000 plants/ha. Similar but less defined trends were observed for Llanera.

Harvest indices decreased with increasing plant populations and this was especially so for the chemically weed-free cassava. This means that proportionately less dry matter is being accumulated in the roots at higher populations. Root dry matter content was 10 percent higher for chemically seed-free CMC84 as compared to the weedy check. There was no such difference for Llanera.

REFERENCES

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2. Furtick, W.R. and Romenoski, R.R. Jr. (1971) *Weed Research Methods Manual.* Intl. Pl. Prot. Center, Oregon State University, Corvallis, 80 pp.

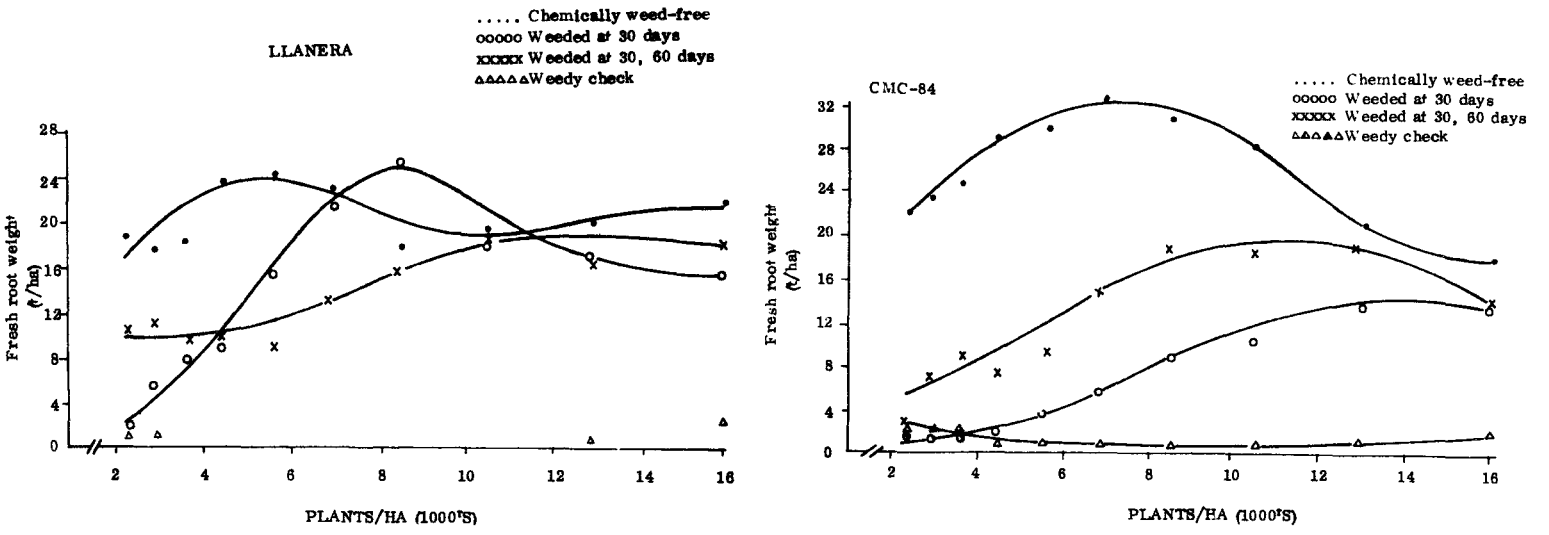

Figure 1. *Fresh root weight of Llanera (above) and CMC-84 (below) as affected by plant density and weed control practices 250 days after planting.*

TABLE 1

Number and timing of hand weedings for the cultivars CMC39 and CMC84

Treatment (see text)	No. of hand weedings	Days after planting when weeded				
1	4 + *	15	30	60	120	UH**
2	3 +		30	60	120	UH
3	2 +			60	120	UH
4	1 +				120	UH
5	4	15	30	60	120	
6	3	15	30	60		
7	2	15	30			
8	1	15				
9	2		30	60		
10	2	15	45			
11	0	Weedy check				
12	0	Chemically weed-free check				

* The plus sign indicates additional weedings were carried out to maintain the plants weed-free until harvest.

** UH = until harvest.

TABLE 2

Effects of varying the period of weed competition on the fresh root yields of cassava and percent yield as compared with chemically weed-free cassava 9.3 months after plant. CMC39 and CMC84 cultivars.

Treatment (see text)	No. of weedings	Frequency of weeding					CMC 39		CMC 84	
							f.w. (t/ha)	% yield*	f.w. (t/ha)	% yield*
1	4 + **	15	30	60	120	UH≠	18.05	85.7	19.32	96.3
2	3 +		30	60	120	UH	16.01	76.0	15.53	77.4
3	2 +			60	120	UH	11.00	52.2	9.47	42.2
4	1 +				120	UH	7.00	33.2	2.75	13.7
5	4	15	30	60	120		19.50	92.5	14.71	73.3
6	3	15	30	60			12.94	61.4	16.82	83.8
7	2	15	30				13.31	63.2	11.64	58.0
8	1	15					5.83	27.7	5.99	29.8
9	2	30	60				16.28	77.3	16.87	84.0
10	2	15	45				15.39	73.0	13.23	65.9
11	0	wd.ck.					1.40	6.6	0.96	4.8
12	0	chem.ck					21.07	100.0	20.07	100.0

* Yield is expressed as a percent of the chemically weed-free treatment.
** The + indicates weeding until harvest
≠ UH = until harvest

TABLE 3

Effects of varying weed competition periods on the harvest index and percent root moisture in cassava cultivars CMC39 and CMC84 at 9.3 months after planting.

Treatment	No. of weedings	Frequency of weeding	Harvest Index* CMC 39	Harvest Index* CMC84	% root moisture CMC39	% root moisture CMC84
1	4 +	15 30 60 120 UH	.52	.64	64.3	64.8
2	3 +	30 60 120 UH	.62	.68	66.0	64.5
3	2 +	60 120 UH	.57	.70	66.0	65.2
4	1 +	120 UH	.54	.62	66.2	65.5
5	4	15 30 60 120	.50	.68	68.2	63.6
6	3	15 30 60	.51	.62	64.6	62.1
7	2	15 30	.57	.70	63.3	61.2
8	1	15	.59	.70	63.7	60.0
9	2	20 60	.55	.61	63.8	62.3
10	2	15 45	.54	.65	64.1	64.0
11	0	wd. ck.	.49	.49	65.0	61.6
12	0	Chem.ck.	.48	.54	63.8	65.4
Mean:			.54	.64	64.9	63.4

* Harvest index = root dry weight/total plant dry weight.

TABLE 4

Soil moisture 100 days after planting the cultivars Llanera and CMC84

Weed control system	Soil moisture Llanera	Soil moisture CMC84
1. Chemically weed-free	13.0	13.4
2. Weeded at 30 days	10.4	11.1
3. Weeded at 30, 60 days	10.8	9.7
4 Weedy check	9.5	9.1