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WEEDS AND THEIR CONTROL IN CASSAVA

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ABSTRACT

Cassava (*Manihot esculenta* Crantz) is a major source of carbohydrate for more than 200 million people, mainly in Africa and to some extent in Asia and Latin America. In Africa, cassava is mainly grown in mixtures with other crops by subsistence farmers using unimproved methods of production. Root yields from farmers' fields are generally low, partly due to effects of weed competition. Hoe-weeding is the common practice among cassava farmers. The frequency and timing of weeding depend on such factors as climate, cultural practices, crop growth, soil fertility and weed species. Some common noxious weeds of cassava and their control by chemical, cultural and integrated means are discussed. Appropriate weed control methods for resource-limited cassava farmers, namely, cultural and biological, as well as an integrated system which combines two or more weed control methods at low input levels are suggested as ways of ensuring sustained production of cassava in developing countries.

Key Words: ***Manihot esculenta*, noxious weeds**

RÉSUMÉ

Le manioc (*Manihot esculenta* Crantz) est la principale source d'hydrates de carbone pour plus de 200 millions d'habitants, essentiellement en Afrique et dans une moindre mesure en Asie et en Amérique Latine. En Afrique, le manioc est surtout cultivé en association avec d'autres plantes dans le cadre d'une agriculture de subsistence qui utilise des méthodes de production peu élaborées. Les récoltes de tubercules en provenance des champs de paysans sont habituellement faibles ce qui est en partie dû aux effets de la compétition avec les mauvaises herbes. Le désherbage à la houe est la pratique habituelle des agriculteurs traditionnels. La fréquence et le calendrier des désherbages dépendent de facteurs comme le climat, les pratiques culturales, la croissance des plantes, la fertilité du sol et les espèces de mauvaises herbes. Le contrôle de quelques mauvaises herbes communes, nuisibles en culture du manioc, par des moyens chimiques, culturaux et intégrés, est discuté. Des méthodes de contrôle adaptées aux conditions des planteurs de manioc aux ressources limitées, comme les mesures de type cultural ou biologique, ainsi qu'un système intégré, qui combine deux ou plus de ces méthodes à faible intrant, sont suggérées comme des moyens permettant d'assurer une production satisfaisante de manioc dans les pays en développement.

Mots Clés: ***Manihot esculenta*, mauvaises herbes**

INTRODUCTION

In developing countries the demand for food far exceeds the present production levels, especially in Africa. This is due to many constraints, amongst which are inefficient management of inputs, poor technologies and retrogressive and unstable government policies. Weeds are among the major crop pests in the humid and sub-humid tropics where adequate rainfall, humidity and temperature favour their growth. These reduce yields by competing with crops for light, soil moisture and nutrients. Subsistence farmers in the tropics are often unaware of the magnitude of damage to their crops caused by weeds. This is so because their effect is less obvious compared to other pests and diseases.

African countries have, by and large, depended on abundant arable land, cheap family labour and inefficient manual weeding methods for food production. However, with the rapid rise in human population, paralled with increasingly limited and expensive farm labour and finite production inputs, improvement of food production technologies has become necessary. Cassava (*Manihot esculenta* Crantz) is an important crop in Asia, Latin America and especially in Africa, where it is the single largest source of calories produced throughout the tropics. It is estimated that cassava is the a major source of energy for more than 200 million people (IITA, 1988/90). It is considered to be a food security crop because yields are generally reliable. Cassava may be grown in pure stands but is commonly grown in mixture with other crops, especially maize (*Zea mays*); yam (*Dioscorea rotundata*); 'egusi' melon (*Colocynthis citrullus* (L.) 0. Ktze) and vegetables (Doku, 1967; Okigbo and Greenland, 1976). For many farmers in Africa, cassava is a dual purpose crop, namely a staple food and a source of income (IITA, 1990; Nweke, 1994).

Weed control is currently the cornerstone of increased casava production in the tropics. It is, by far, the most labour demanding field operation (Anon., 1972). Some current weed control practices are not sustainable and may lead to environmental degradation. Better weed control methods that satisfy the needs of both resource-poor and progressive farmers should be developed. The objective of this paper is to summarise the available information on cassava weeds and their control. Suggestions are made for sustainable weed management alternatives.

WEEDS OF CASSAVA

Information on the of weeds of cassava is very limited. Most lists of weeds that are available were not done on a crop basis. Doll *et al.* (1977) compiled a weed flora of cassava. According to them, the ten most important weed species in cassava fields in Colombia are: *Pteridium aquilinum* L. Kuhn, *Imperata cylindrica* L. Beauv., *Melinis ninutiflora* Beauv., *Sida acuta* Burm F., *Cyperus rotundus* L., *Commelina diffusa* Burm F. sub-species *diffuse* J.K. Morton, *Ageratum conyzoides* L. and *Portulaca oleraceae* L., among others.

In Nigeria the only available information on the weed flora of cassava was obtained in a field survey of monocrop cassava in four villages during the 1990 wet season (Table 1). Weed densities were estimated from quadrat (1 m x 1 m) samples taken systematically along diagonal transects. The area surveyed was at least 0.03 ha in each of 24 farms surveyed. Broad-leaved species were the most frequent weeds in all areas, averaging 71-78% of all the species recorded. Only 17-19% of the weed species present were grasses and 4-7% were sedges. Five weed species, namely, *Ageratum conyzoides* L., *Alternenthera sessilis* L. R. Br. ex Roth, *Mimosa invisa* Mart, *Digitaria horizontalis* Willd, and *Panicum maximum* Jacq occurred in the entire area surveyed. The other species varied from one village to the other. Most of the weeds recorded were among those regarded as "the World's worst" (Holm, 1969).

In similar studies in Colombia, Doll and Piedrahita (1976) recorded *Cyperus rotundus* L (purple nutsedge), *Rottboellia exaltata* (Lour) Clayton (Raoul grass), *Sorghum halepense* L. Pers (Johnson grass) and *Ipomoea* sp- (morning glory) to be the most noxious weeds in cassava fields. In south western Nigeria, Onochie (1975) observed that annual weeds, especially broad-leaved ones, were the most common in cassava. Shanna and Dairo (I 991), too, reported *Euphorbia hirta* L. and *Talinum triangulate* Willd as prevalent weed species in cassava in the same region.

WEED-CASSAVA COMPETITION

Data from several countries show conclusively that weeds compete strongly with cassava and can cause total yield loss if weed growth is unchecked (Table 2). The slow initial growth rate of cassava renders the crop particularly vulnerable to weed interference soon after planting. In Nigeria, an initial weed-free period of 12 weeks is

TABLE 1. The ten most common weed species in cassava fields in Umuahia, southern Nigeria[1] (Melifonwu, 1991, unpublished)

NDIORO	APUMIRI	OHOKOBE	UMUDIKE
Ageratum conyzoides	*A. conyzoides*	*A. conyzoides*	*A. conyzoides*
Calopogonium mucunoides	*Alternenthera sessilis*	*Alternenthera sessilis*	*Alternenthera sessilis*
Alternenthera sessilis	*Calopogonium mucunoides*	*Boreiria ocymoides*	*C. mucunoides*
Commelina erecta	*Chromolaena odorata*	*Chromolaena odorata*	*C. odorata*
Mimosa invisa	*Commelina benghalansis*	*Commelina benghalansis*	*C. benghalansis*
Tridax procumbens	*Mimosa invisa*	*Mimosa invisa*	*Mimosa invisa*
Brachiaria delfexa	*Platostoma africanum*	*Digitaria adscendens*	*Synedrella nodiflora*
Digitaria horizontalis	*Digitaria horizontalis*	*Digitaria horizontalis*	*Digitaria horizontalis*
Panicum maximum	*Panicum maximum*	*Panicum maximum*	*Panicum maximum*
Cyperus rotundus	*Cyperus esculentus*	*Cyperus esculentus*	*Cyperus rotundus*

[1]Weeds are listed in order of prevalence. Weeds were ranked based on plant stands m^{-2}

TABLE 2. Cassava yield losses due to uncontrolled weed growth

Country	% Yield loss	Source
Colombia	94	Doll and Piedrahita (1973)
Fiji	75	Piedrahita and Doll (1974)
Nigeria	95	Moody and Ezumah (1974)
Thailand	46	Harper (1973)
Venezuela	92	Barrios (1973)

required to avoid the adverse effects of weed competition on tuberous root yield (Table 3). This is the period when the crop is most sensitive to weed interference in the humid and sub-humid tropics. Weed should be controlled by cultural means at this time to prevent yield loss. Yields from plots maintained weed-free during this period are similar to those from plots kept weed-free throughout the season. This assumes optimum cassava plant population environmental conditions for plant growth. The most weed sensitive stage of cassava in Nigeria occurrs during the third month after planting when root tuberisation takes place. This suggests that if labour for weeding is limiting then weeding should be done during the third month after planting.

TABLE 3. Cassava root yield as affected by weed control practices at a site in Nigeria (Onochie, 1975)

Cultural operations	Mean yield (kg plot^{-1})
Free of weeds for the first:	
I month and Weed-infested UH	41.5
2 months "	45.5
3 months "	54.0*
4 months "	59.0*
5 months "	60.5 *
6 months "	66.7*
7 months "	59.5*
8 months "	59.0*
Control: Free of weeds UH	57.7
Weeds infested for the first:	
I month and Weed-free UH	47.7
2 months "	63.0*
3 months "	35.7
4 months "	50.5
5 months "	47.0
6 months "	43.2
7 months "	42.0
8 months "	36.2
Control: Weed infested UH	32.0
LSD 0.05	21.4
CV	30%

UH = Until harvest.
* Significant at 5% level of probability.

WEED INTERFERENCE STUDIES IN CASSAVA-BASED CROPPING SYSTEMS

A study was conducted at the National Root Crops Research Institute (NRCRI) at Umudike in the lowland rainforest zone of southern Nigeria to determine when and for how long a cassava/ maize intercrop should ideally be kept weed-free. Cassava (var- TMS 30211) and maize (Fartz 7) were planted at the onset of the rains. Cassava was planted on crest ridges 1 m apart. Concurrently maize was sown on both sides of the ridges also 1 m apart. Cassava and maize populations were 10,000 and 40,000 plants ha^{-1}, respectively.

Two treatment schemes were used. In one the plots were weeded fortnightly for different periods after planting to maintain weed-free conditions. The other plots were kept weed-infested for different periods before being weeded until maturity. As controls, one cassava-maize intercropped plot was kept weed-free from planting until crop maturity. The other control was weed-infested plots. Other mixtures were weeded at 3, 8 and 12 weeks after planting. Weed-free and weed-infested monocultures were included to evaluate the effects of intercropping on the yields of the two crops. NPK (15:15:15) compound fertilizer was applied at a rate of 400 kg ha^{-1}. Economic yield was assessed.

The first 4-8 weeks were found to be the most critical for weed control (Table 4). Weeds, especially those germinating late, were then controlled by the maize and cassava shade. Keeping the crop mixture weed-free for the first 8 weeks prevented subsequent adverse effects of the weeds. The differences in yield between 1981 and 1982 could be attributed to differences in rainfall and soil fertility. Uncontrolled weed infestation in the mixture reduced crop yields on average by 65%.

METHODS OF WEED CONTROL

Hoe-weeding. Manual weeding by hand and by hoe is the traditional method of controlling weeds in the tropics, but this is very uncongenial and labour intensive. Indeed, Nigerian farmers spend more time controlling weeds than on any other aspect of crop production (Table 5). Proper timing and frequency of the operation is essential and will enable a farmer to obtain yields similar to those from plots kept entirely weed-free until harvest. Earlier studies in Nigeria, showed that two or three properly timed hoe weedings resulted in effective weed control and higher tuberous

TABLE 4. Effect of duration of weed interference on maize grain and fresh tuberous root yields of cassava in a cassava-maize intercrop, at Umudike, in Nigeria (NRCRI, 1983)

Interference (weeks after planting)	Yields (t ha^{-1})			
	Maize[a]		Cassava	
	1981	1982	1981	1982
Weed-free				
Intercrop				
0-4	3.0	2.3	13.7	11.5
0-8	3.0	2.4	14.3	12.6
0-12	3.1	2.9	15.9	11.5
0-16	3.1	2.2	23.9	12.9
0-20	3.1	2.4	18.1	12.8
0-24	3.1	2.6	21.2	12.5
0-28	3.1	2.2	18.7	11.8
0-40	3.0	2.8	20.0	17.6
Sole Cassava 0-40	0.0	0.0	21.2	18.4
Sole Maize 0-16	3.4	3.8	0.0	0.0
Weed-infested				
Intercrop				
0-4	2.9	2.9	14.5	11.5
0-8	2.1	1.7	13.4	12.1
0-12	2.1	1.3	10.9	5.2
0-16	2.1	1.4	10.9	4.4
0-20	1.9	1.7	7.7	3.2
0-24	1.9	1.3	6.7	0.8
0-28	2.4	1.2	5.9	1.2
0-40	2.4	1.4	7.9	1.4
Sole Cassava 0-40	0.0	0.0	8.0	3.7
Sole Maize 0-40	2.4	0.0	0.0	0.0
Weeded				
3 WAP	2.6	2.7	10.7	8.5
3, 8, 12 WAP	2.9	2.3	18.9	12.9
CV. (%)	24.0	52.0	43.6	66.0

root yields (Akobundu, 1980), while in Colombia, four weedings were necessary for similar results to be obtained (Doll and Piedrahita, 1973, Table 6). Cassava may have to be hoe-weeded more than three times depending on plant type, plant population, cultural practices and whether or not the crop is left in the ground beyond 15 months (Moody, 1985). Hoe-weeding, however, has drawbacks as the operation is tedious and uncongenial. It is labour intensive (Anon., 1972) and is expensive, especially on commercial farms (Akobundu, 1980). Moreover, labour for weeding may not be readily available when most needed. Nevertheless, hoe-weeding may be economical, especially on small farms (Hahn *et al.*, 1979).

Cassava growth habit and plant population. Growth habit and plant population affect the ability of cassava to cover the ground early and shade out weeds (Leihner, 1980). Improved, early branching, vigorous cassava cultivars cover the ground quicker than the late, non-branching traditional ones. Akobundu (1980) reported that improved cultivars of spreading habit required less frequent hoe-weeding and low rates of herbicides than the non-spreading ones. Moreover, cassava at dense populations of more than 10,000 plants ha^{-1}, covers the ground earlier than at low densities.

A study was conducted in Colombia to determine the cultural weed control potentials of a vigorous cassava cultivar (MMEX59) and a non-vigorous one (MCOL 22) planted at 7,500 and 15,000 plants ha^{-1} under three weed control regimes:- complete control,incomplete control and no-control. Vigorous cultivars were less sensitive to lack of weed control than non-vigorous ones (Leihner, 1980). Vigorous cultivars were able to express their genetic potential fully at low population densities when weed control was either effective or intermediate, compared to the unweeded control. Without weeding, root yields were greatest at highest population density.

TABLE 5. Percent farmer's time spent on weeding in selected root crops in western Nigeria (Anon., 1972)

Crop	Including land clearing	Excluding land clearing
Cassava	32.2	41.0
Cassava/maize	31.9	41.2
Cassava/melon	30.5	37.7
Yam	28.0	32.4

TABLE 6. Effect of frequency of weeding on fresh weight of cassava in Colombia (Doll and Piedrahita, 1973)

Frequency of weeding	Timing (Days from planting)	Root yield (t ha^{-1})	(%Yield of check)
4+	15,30,60, 120,UH	18.1	86
2+	60,120, UH	11.0	52
3	15, 30, 60	12.9	61
l+	120, UH	7.0	33
1	15	5.8	28
Weeded check	-	21.1	100
Weedy	-	1.4	7

UH = Subsequently weeded as necessary until harvest

Soil covers. A study in Colombia assessed the cultural weed control potential of *Desmodium heterophyllum* (Willd) DC' (CIAT, 1979) with bean (*Phaseolus* sp.) as live legume green covers, and cane bagasse mulch as inert cover, compared to the effect of an unspecified pre-emergence herbicide mixture. Both legumes gave better weed control and root yields than the herbicide and mulch treatments (Table 7).

Stylosanthes guianensis (Aubl.) SW, too, has been used as a cover crop to suppress weeds in cassava (Nitis, 1977; Nitis and Suama, 1977). Legume and dry mulch covers are beneficial because they improve soil organic matter and nutrient status, prevent erosion (Lal *et al.*, 1979) and suppress weeds (Unamma *et al.*, 1986). The use of legume covers is, however, expensive because of the cost of seeds and labour for their establishment. It is important to use legume and other crop covers which will not compete with cassava for resources. Moreover, any crop cover used must directly benefit the farmer to facilitate adoption/acceptability of the practice.

Chemical weed control. Several herbicides have been evaluated for weed control in cassava in different parts of the world and with varying degrees of success. Their performance is influenced by climatic and edaphic factors as well as weed flora, rate of herbicide applied, cultivar grown and crop management practices. Field trials conducted in eastern and south-west Nigeria, showed that many herbicides can be used safely and economically (Tables 8, 9, 10).

Data from these experiments showed that metobromuron, prometryn, fluometuron, atrazine/metolachler (Primextra), diuron, and diuron + paraquat (gramuron) gave effective weed control in cassava and were economical. Similar results had been reported in Colombia with fluometuron, diuron, and diuron plus paraquat (Doll and Piedrahita, 1976); and in Brazil with fluometuron and diuron and their mixtures with alachlor (Carvalho, 1980). Good results have also been reported for diuron in Cuba (Nodals, 1980) and fluometuron in Venezuela (Barrios, 1973), Colombia (CIAT, 1973) and Nigeria (Onochie, 1975; IITA, 1977).

TABLE 7. Effect of weed control systems on cassava (Var. CMC-40) and bean yields in a trial in Colombia (CIAT) (Leihner, 1980)

Weed control system	Cassava fresh root yield (t ha^{-1})	Legume yield (kg ha^{-1})
No-weed control	12.9	-
Pre-emergent herbicide	23.4	-
Cane bagasse mulch	27.6	-
Green cover (annual legume)	26.8	1.95a
Green cover (perennial legume)	26.9	600b
Manual weeding	33.2	-
CV (%)	13.6	
S.E.±	1.5	

[a] = Seed yield (14% moisture) of black bean variety "Porillo Sintetico"
[b] = Fresh weight of *Desmodium heterophyllum* foliage produced under cassava

TABLE 8. Effect of weed control treatment on establishment and tuberous root yield of cassava in Nigeria (Akobundu, 1977)

Weed control treatment	Rate (kg a.i. ha^{-1})	Time	% Stand[1]	Fresh wt of roots (t ha^{-1})	% of weed-free check
Metobromuron	2.0	Pre	79	10.7	79
Metobromuron	2.5	Pre	72	12.5	92
Fluometuron	1.6	Pre	71	8.0	59
Fluometuron	2.4	Pre	79	10.3	76
Prometryn + Anetryne	1.0	Pre	86	11.1	82
Prometryn	1.2	Pre	79	12.2	90
Prometryn	1.6	Pre	71	9.4	70
Terbutryn	1.6	Pre	79	8.9	66
Terbutryn	2.8	Pre	71	7.2	53
Paraquat	0.3	Post	50	6.8	50
Weed-free check	-	-	86	13.6	100
Weedy check	-	-	36	5.2	38

[1] Average of 4 replications expressed as % total intended population per treatment
Pre = Pre-emergence;
Post = Post emergency

TABLE 9. Weed control rating in Cassava 1976 (IITA, 1977)

Treatment	Rate (kg a.i ha^{-1})	Time	Weed control rating					
			Broad leaved: WAP			Grasses: WAP		
			5	9	13	5	9	13
Fluometuron	2.0	P.E.[4]	98	81	72	99	84	68
Fluometuron	3.0	P.E.	99	83	77	100	79	67
Primextra[1]	2.5	P.E.	97	70	56	100	80	70
Tarbutryn + Metolachlor	1.5+1.5	P.E.	97	89	82	98	64	52
Gramuron[2]	2.8	21WAp[3]	100	78	59	100	87	82
Diuron	2.0	P.E.	95	59	34	96	64	70
Diuron	2.0	P.E.	99	85	74	100	85	84
Weed-free check	-	-	100	100	100	100	100	100
Weedy check	-	-	0	0	0	0	0	0

[1] Primextra + Trade name for the herbicide mixture containing atrazine + metolachlor
[2] Gramuron + Trade name for the herbicide mixture containing paraquat + diuron.
[3] WAP = Weeks after planting.
[4] P.E. = Pre-emergence.

TABLE 10. Effect of weed control methods on economic returns for cassava production in Nigeria (Akobundu, 1980)[1]

Weed Control Method	Rate (kg a.i. ha^{-1})	Cost of Weeding (N ha^{-1})[2]	Fresh wt roots (t ha^{-1})	Gross return (N ha^{-1})	Net return (N ha^{-1})
Atrazine + Metolachlor	2.5	46	29	1305	1258
Fluometuron	2.0	51	31	1395	1344
Diuron + Paraquat	2.8	46	30	1350	1304
Hand weeding 2X	-	200	30	1350	1150
Hand weeding 3X		320	1440	1140	

[1] Based on tables of yield data

[2] NI.0 = US$ 1.75. Cost of weed control includes cost of herbicide plus labour at I-man-day each for sprayer operator and assistant. Labour at N5.0/man/day. Cost of hand weeding is based on 20/man-day ha^{-1} and excludes cost of supervising staff.

3. Based on mean rural price of N300/t of garri. Garri recovery rate is 15%

4. Net return excludes other production costs and these are identical for all weeding methods.

The effectiveness of the herbicides depends on climatic and edaphic factors, weed flora, rate of herbicide applied, crop variety and management practices. Apart from being economical, chemicals are cheap, convenient and attractive, prevent early weed competition and can be used on commercial farms. However, adoption of herbicides is limited because farmers lack skill in their application. In addition, the supply of the chemicals is unreliable because of the dependence on foreign exchange for imports. Coupled with this, the herbicide may be hazardous to the operator and to inter-crops, apart from causing pollution. Also, resource-limited farmers may not be able to afford the cost.

Integrated weed management. Integrated weed management combines aspects of two or more control methods at low input levels to keep weed competition in a given cropping system below an economic threshold. This approach to weed control is particularly appropriate for cassava production in the tropics where the farmers generally have limited resources (Hahn *et al.*, 1979). It is also environmentally sound. In Nigeria, Unamma *et al.* (1986) used low-growing egusi melon (*Colocynthis citrullus*) and cowpea (*Vigna unguiculata* (L.Walp.) at 40,000 plants ha^{-1} to suppress weeds effectively in a cassava/maize intercrop (Table 11). Also, Ibedu *et al.* (1990) using simazine herbicide at pre-emergence and egusi melon at 40,000 plants ha^{-1} for weed control obtained the highest economic returns from a cassava, yam, maize, cocoyam (*Colocasia antiquorum* L.W. Cocoindia) crop mixture (Table 12). Similar results were obtained in a yam, maize and cassava intercrop by using egusi melon alone or egusi melon at 40,000 plants ha^{-1} plus hoe-weeding 12 weeks after planting (WAP). Cowpea at 80,000 plants ha^{-1} was less effective (Table 13). In all plots, intercropping was combined with additional weed control method(s) to suppress weeds effectively. Cassava intercropped with early maturing cover crops or other crops requires less weeding than when it is grown as a sole crop, provided soil fertility is adequate (Akobundu, 1981). However, it is necessary to identify compatible crops and determine their correct spatial arrangement, sequence and population in intercrop systems, so as to minimise inter-plant competition and enhance the crops competitive ability with weeds.

Control of *Imperata cylindrica*. A study was begun at IITA, Ibadan in 1983 to determine the long-term effectiveness of chemical, mechanical, biological and integrated methods of controlling *Imperata cylindrica* P. Beauv (Spear grass) in fallow vegetation. Results (Table 14) indicate that 67 weeks after the treatment spear-grass was suppressed most thoroughly by *Mucuna utilis*. *Psophocarpuspalustris* and *Pueraria phaseoloides* (Robx) Benth cover crops also reduced spear grass stands by 42 and 46%, respectively. *Mucuna utilis* was the only treatment that reduced spear grass rhizomes. Glyphosate at 1. 8 kg ha-1, followed by tillage one week after treatment application, was more effective than delaying tillage by four weeks and was as good as glyphosate at 3.6 kg ha-1 (Poku and Akobundu, 1984).

Other trials on weed management of fallow vegetation were conducted at IITA, Ibadan from 1982 to 1984, to identify suitable herbicides for the control of perennial cassava weeds. Paraquat at 1.0 kg/ha-1 gave excellent control of *Chromolaena odorata* R M King and Robinson and *Panicum maximum* Jacq throughout the cropping season, resulting in maize yields comparable to those in plots treated with glyphosate at 3.6 kg ha-1. The *C. odorata and P. maximum* stands controlled with paraquat originated from seeds and not stumps. Only Glyphosate at 1.08 kg ha-1 followed by 2.4-D at 1.5 kg ha-1 gave excellent control of *C. odorata* and *P. maximum* (Poku and Akobundu, 1984). In Colombia, Doll and Piedrahita (1976) controlled

TABLE 11. Effect of weed management techniques and intercropping on weed control in cassava and maize at Umudike, Nigeria 1982/83 (Source: Unamma *et al.*, 1986)

Weed management	Dose kg a.i ha-1	Time*	Weed control (%) 8 WAP		Crop yield (t ha-1)	
			Weeds	Grasses	Cassava	Maize
Cowpea	-		35	40	9.8	2.7
Egusi	-		47	70	9.6	2.7
Groundnut	-		53	62	7.5	2.2
Sweet potato	-		20	20	7.1	1.9
Chloramben	3.4		82	85	7.1	2.4
Fluometuron	2.5		72	67	7.5	1.9
Cowpea-alachlor	2.0		88	88	7.6	2.8
Egusi-alachlor	2.0		45	81	7.2	2.1
Groundnut-alachlor	2.0		57	68	6.2	2.1
Sweet potato-	1.0+2.0	P.E.	75	85	9.1	2.0
Alachlor+chloramben	2.0					
Sweet potato+ chloramben	3.4		60	45	5.5	1.7
Cowpea+chloramben	3.4		72	75	8.9	1.7
Egusi+chloramben	3.4		77	80	4.9	2.9
Groundnut+alachlor+chloramben	1.0+2.0		55	82	5.0	2.3
Egusi+alachlor+ metolachlor	2.0		83	87	5.2	2.3
Alachlor+	2.0+2.5					
fluometuron			77	57	6.0	2.8
Chloramben+	3.4+2.5					
fluometruen			65	77	7.3	2.3
Altrazine/metolachlor	2.5		75	85	6.4	2.4
Hoe-weeding	2X	3+8WAP	80	88	7.3	2.8
Hoe-weeding	12X	2 &				
		every 4			control	
		weeks	85	75	7.5	2.5
Unweeded check	0	-	0	0	3.5	1.4
Sole cassava hand-hoed	12X	Every 4				
		weeks	100	100	9.6	-
Sole cassava unweeded	0	-	0	0	3.9	-
Sole maize hand-hoed	5X	2 &				
		every 4				
		weeks	100	100	-	2.6
L.S.D. (P=0.05)			-	-	2.5	0.4
LER						1.743

P.E. = Pre-emergence
WAP = Weeks after planting
*Relative to cassava/maize

TABLE 12. Yield of component crops in a cassava, maize, cocoyam intercrop using different weed management methods at Ogoja, Nigeria, in 1988 (Ibedu *et al.*, 1990)

Treatment combination	Weed control	Mean yield ($t\ ha^{-1}$) C	M	CY	Eg	Total gross income (I,000 N)	Total variable cost (N)	Net return ($N\ ha^{-1}$)
C/M/CY + Manual weeding at 3+8+12WAP	79	13.7	0.66	4.7	-	14.3	14,000	282
C/M/CY+chloramben + egusi at 20,000 pl ha^{-1} AP	81	11.6	0.71	4.1	0.37	13.5	4,110	9,421
C/M/CY+egusi at 40,000 pl ha^{-1} AP	72	8.7	0.60	3.3	0.11	10.1	535	9,518
"+ simazine P.E.	78	6.4	0.67	6.0	-	13.7	3,377	10,372
"+ butachlor P.E.	80	13.8	0.71	3.5	-	12.2	3,407	8,794
"+ Linuron P.E.	78	13.7	0.76	3.7	-	12.6	3,449	9,146
"+ Diuren P.E.	75	7.3	0.66	3.7	-	10.0	3,413	6,566
"+ Unweeded check	0	2.1	0.13	2.3	-	5.1	-	-
Sole cassava	76	5.2	-	-	-	6.1	-	-
Sole cocoyam	75	-	-	4.7	-	8.4	-	-
Sole maize	77	-	1.40	-	-	0.8	-	-
LSD = $^{(0.05)}$	-	4.1	0.12	1.4	-	-	-	-

P.E. = Pre-emergence; AP = At planting; WAP=Weeks after planting; C =Cassava; M = Maize, CY=Cocoyam; Eg = Eguis melon;
Cassava = N400 t^{-1} -; Maize = N600 t^{-1}; Cocoyam = NI,800 t^{-1}; Egusi melon = N3,000 t^{-1}; Approximate currency exchange rate at the time 22 N = 1 US$; N=Nigerian Naira

TABLE 13. Combined energy value (Kcal) and economic analysis of a Yam/Maize/Cassava intercrop as influenced by different weed control measures in Ogoja, Nigeria (Anuebunwa, 1991)

Weed management altemative	Energy value (Kcal) 1988	Total variable cost 1989	Gross yield costs (I,000N)	Net benefit (I,000N)	Benefit: benefit (I,000N)	Cost ratio
Egusi @ 40,000 ha^{-1}	60c	50c	10.3	14.9	4.6	0.45:1
Egusi @ 40,000 ha^{-1} + weeding at 12WAP	79b	64b	10.8	19.5	8.7	0.81:1
Egusi @ 40,000/ha + weeding at 12WAP fb Cowpea @ 40,000 ha^{-1}	75b	65b	91a	19.1	8.1	0.74:1
Egusi @ 40,000 ha^{-1} + weeding 12WAP fb cowpea @ 80,000 ha^{-1}	91a	78a	I I.e	23.5	12.4	1.11:1
Hand weeding @ 4+8+12WAP	77b	65b	11.9	19.8	7.9	0.67:1

fb = Followed by: WAP = Weeks after planting
22 Nigeria Naira = 1 US$

TABLE 14. Response of *Imperata cylindrica* to different control practices (UTA, 1984). All herbicides were applied before planting.

Control	Herbicide rate (kg ha^{-1})	Imperata stands m^{-2}		
		12DBT[4] in 1983	67 WAT	Reduction%
Glyphosate	1.8	101	42	59
Glyphosate fb[1] tillage I WAT[2]	1.8	133	27	80
Glyphosphate fb[1] tillage 4 WAT[2]	1.8	78	40	60
Glyphosphate CDA[3]: no-tillage	1.8	101	55	33
Glyphosate: no tillage	3.6	86	21	76
Psophocarpus cover	-	101	58	42
Pueraria	-	114	41	46
Mucuna cover	-	101	1	98
Ridging	-	78	78	0
Slashing	-	85	79	12
LSD 5%				18

[1] fb = Followed by
[2] WAT = Weeks after treatment
[3] CDA = Controlled droplet application
[4] DBT = Days before treatment

Cyperus rotundus L. effectively with butylate herbicide at 4-8 kg a.i. ha^{-1}.

CONCLUSIONS

There is an urgent need to characterise the weed flora associated with cassava in different regions and ecological situations. Broad-leaved weeds appear to be of major importance in cassava. A few sedges and grass weeds may also be important. Some problem weeds of cassava include: *Imperata cylindrica*, *Panicum maximum* and *Cyperus rotundus*. Cassava grown as a monocrop requires a weed-free period of twelve weeks after planting to prevent weed competition from decreasing root yields. Moreover, cassava-maize as intercrop requires a weed-free period of eight weeks to prevent the adverse effects of weeds.

Cultural methods of weed control in cassava include choice of cultivar and plant population, live and dead mulch covers, especially legume cover crops and low-growing egusi melon and cowpea. Vigorous early branching cassava varieties should be grown which require less time to cover the ground fully and suppress weeds than non-vigorous types. Plants that soon cover the ground require fewest times of hoe-weeding. Cassava should be grown at optimum populations to facilitate development of a closed canopy cover and gain a competitive advantage over, weeds. Optimum populations are not less than 10,000 plants ha^{-1} combined with about 2-3 hoe-weedings. The number of hoe-weedings may have to be increased if cassava is left longer than 15 months in the ground.

Chemical weed control in cassava is economical compared to hoe-weeding. Promising herbicides are: diuron, fluometuron, atrazine and their mixtures with alachlor and metolachlor. However, their use is environmentally unsound.

Combinations of weed control methods such as intercropping, use of low-growing cover crops, herbicides and hoe-weeding give economical weed control in cassava-based intercrops. Each of these methods should be used at low input levels. Biological and integrated weed control methods are ecologically sound and can be practised by subsistence farmers who grow cassava.

Farmers in Africa largely depend on hand-weeding to produce cassava. This practice is tedious, labour demanding and is not always carried out in time to prevent the detrimental effect of weed competition on cassava yield. It may also lead to soil erosion. In additon, labour for weeding may not be available at peak periods of demand. There is, therefore, an urgent need to develop recommendations for how to improve the efficiency of manual weeding and reduce the labour involved.

Current weed control recommendations have seldom been adopted, partly because they are not appropriate to the farmers' level of development, and due to the fact that such results are not developed in conjunction with farmers in order to make them meaningful.

Chemical weed control in cassava is not currently sustainable because subsistence farmers have limited education and lack the skill to use this approach. Furthermore, herbicides may not be readily available because of heavy dependence on scarce foreign exchange to import them. Farmers with limited resources may be unable to afford the cost. However, chemical weed control may be used in situations where other control methods have failed, as with perennial weeds. They are also appropriate in commercial farms. In such situations, farmers should first be equiped with correct skills of application to minimise health hazards and damage to crops and the environment.

It is necessary to work out the socio-economics of weed control measures and assess farmers' perceptions of weeds before recommending such technologies to them.

Since some weeds are hosts of cassava pests and pathogens as well as the natural enemies of arthropod pests, there is need for a better understanding of the inter- relationships between the various components of the cassava ecosystem. Effective collaboration is required among scientists of different disciplines to determine possible relationships between weed control systems and the incidence of other cassava pests and diseases. For example, viruses may influence canopy development and the ability to withstand weed competition or mealybug/green mite infestations. Another possibility is that herbicides may influence populations of natural enemies of mealybug/green mite.

Where cover crops are used as intercrops, they should provide direct benefit to the farmer in order to justify their adoption and use in an overall weed control package. For intercropping as a means of weed control, there is need to use compatible crop mixtures, correct plant populations, spatial arrangements and appropriate sequences of planting to minimise interplant competition and achieve ground cover for a prolonged period. Where early branching cassava varieties are used in intercropping, there is a need to identify and use companion crops that have fast growth rates to escape the adverse effects of cassava shade. Cultural, biological and integrated weed management systems are ecologically sound, economically feasible and are acceptable to subsistence farmers even though they are labour demanding.

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