AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch 72

1. SUBJECT CLASSIFICATION

A. PRIMARY: Food production and nutrition — AF60-0000-GG50

B. SECONDARY: Weeds--Tropics

2. TITLE AND SUBTITLE

Weed control in major tropical root and tuber crops, a review

3. AUTHOR(S)

Moody,K.; Ezumah,H.C.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1974	9p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS

IITA

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)

(In IITA j.ser.21)
(In Pans,v.20,no.3,p.292-299)

9. ABSTRACT

10. CONTROL NUMBER

PN-AAE-622

11. PRICE OF DOCUMENT

12. DESCRIPTORS

Aroids
Cassava
Root crops
Sweet potatoes
Tropics
Yams
Weed control

13. PROJECT NUMBER

14. CONTRACT NUMBER

AID/ta-G-1185 GTS

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

AID/[illegible] 1185 GTS
IITA
PN-AAE-622

reprint series

Weed Control in Major Tropical Root and Tuber Crops – A Review

by K. Moody and H. C. Ezumah

References:
IITA Journal Series 21
PANS Vol. 20 No.3, September 1974

INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE
PMB 5320 IBADAN, NIGERIA

Reprint from

PANS

PEST ARTICLES & NEWS SUMMARIES

CENTRE FOR OVERSEAS PEST RESEARCH

Weed Control in Major Tropical Root and Tuber Crops – A Review

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Summary. The present status of weed control in the major tropical root and tuber crops is reviewed. The importance of early weeding is emphasised and summaries of the results obtained with herbicides are given. **PANS 20: 292–299, 1974.**

Introduction

The production of tropical root and tuber crops as a whole is hindered by a general lack of research especially in the area of weed control. At the present time, the cheapest means of weed control is by hand weeding or other physical means but in areas where labour is scarce, chemical weed control is rapidly becoming the most promising alternative to the techniques presently being used.

In no place is there a greater urgency for the development of effective means of weed control than in the tropical regions of the world. Crop losses are two to three times greater than in the temperate zones (Ashby and Pfeiffer, 1956), for example in Nigeria where yield losses due to weeds in food crops range from 30% for maize to 100% for upland rice (Moody, 1973), the Philippines where yields of rice were increased 50% by chemically controlling weeds (Matsunaga, 1967) and Colombia where the timely application of herbicides resulted in an average yield increase of 19% over the local farmers practices (Furtick, 1970).

The subsistence farmer of the tropics spends more time and energy on weed control than on any other aspect of crop production. The greatest proportion of cropped land in the tropics is still weeded with hoes and cutlasses. This is a slow business and usually starts after weeds begin to exert a depressive effect on crop yield. The necessity for weeding has also limited the size of tropical farms, which rarely exceed 2–3 ha (Terra, 1959).

Chemical weed control has a considerable potential in the growing of crops in the tropics. Herbicides can be applied before the crop and weeds emerge from the ground and remain active until the critical period of weed competition has passed. Labour is relatively expensive and often in short supply especially during the early stages of crop growth when weed competition is the greatest. A man using a knapsack sprayer can cover at least ten times the area that a man can hoe weed.

Unfortunately the use of herbicides by the small farmer in the tropics is limited by cost and availability, the mixed cropping pattern the farmer uses and the scarcity or absence of water in which to apply the chemical. However, with the lack of labour when weeding is most critical, the farmer may be forced to use chemical weed control methods. In areas where water is limiting, granular or low volume applications may be called for.

This paper reviews the present status of weed control in the major tropical root and tuber crops, discussing each individually.

Yams (*Dioscorea* spp.)

There are about 600 species in the genus *Dioscorea*, only a few of which are of any value to man (Coursey, 1967). More than two-thirds of the world's yam crop is produced in the eastern part of West Africa with Nigeria producing almost half the global figure (Coursey, 1967).

Yams are generally interplanted with crops such as maize, cowpeas, upland rice and vegetables on newly cleared forest land (Waitt, 1963; Enyi, 1970). Yams are decreasing in importance because the labour requirement is greater than that for the production of cassava while the yield is lower (Irvine, 1969).

According to Phillips (1964), hand cultivation of yams requires 370 to 590 man-days/ha but a recent study in Western State of Nigeria determined that only 190 to 250 man-days were required to produce a crop of yams including land clearing before planting (Anon, 1972d). Coursey (1967) reported work of Bray who found that on well run yam farms in Ghana, 30% of the total labour expended in the farm operation, excluding land clearing, was devoted to weeding while the least efficient farmers devoted only 13% of their labour to this operation. Western Nigerian yam farmers also devote about 30% of their time to weeding (Table 1). In Trinidad, farmers may weed as many as seven times in the life cycle of the crop (Newhouse and Wilson, 1969 in Ferguson, 1970).

TABLE 1. AVERAGE PERCENTAGE OF FARMER'S TIME SPENT WEEDING IN VARIOUS ROOT CROPS IN WESTERN STATE OF NIGERIA (ADAPTED FROM ANON 1972e)

Crop		Percentage of time spent weeding	
		Including land clearing	Excluding land clearing
Yam	(EM)*	28.1	32.4
Cassava	(EM)	33.2	41.0
Cocoyam	(EM)	18.0	28.3
Cassava/maize	(EM)	31.9	41.2
Cassava/melon	(EM)	30.5	37.7
Yam/maize	(EM)	33.0	37.8
Yam	(IM)	24.2	27.6
Cassava	(IM)	36.9	43.2
Cocoyam	(IM)	25.8	28.7
Cassava/maize	(IM)	31.3	38.8
Cassava/melon	(IM)	29.7	35.7
Yam/maize	(IM)	36.1	40.6

*EM- existing management

IM- improved mangement- the present level of technology achieved by a very small number of good farmers.

Coursey (1967) states that frequent and effective weeding is one of the first essentials of successful yam cultivation. However, weeding late in the growth cycle of the crop may be unnecessary and could be detrimental to the crop.

At the International Institute of Tropical Agriculture (IITA), a yam crop kept free of weeds for three months yielded only slightly less than one that was kept weed free until harvest (Anon, 1973a) but in the West Indies weeds continued to depress yields for a longer period; yams weeded one, three and six months after planting yielded almost as much as those weeded monthly (Kasasian and Seeyave, 1969). If yams receive a pre-emergence herbicide treatment which can control weeds for three months, or a post-emergence treatment applied about one month after planting having two months residual effect, minimal yield depression should occur (Anon, 1973a) and little subsequent weeding should be necessary (Kasasian and Seeyave, 1967).

Hahn (pers. comm.) reported considerable (more than 70%) rotting of yam tubers in a crop that was weeded continuously from planting to harvesting. Kang (pers. comm.) has suggested that this may have been due to increased soil temperature and reduced soil moisture losses caused by removal of weeds late in the growing cycle of the crop, an operation which removes the mulching effect of the weeds.

As with other root and tuber crops grown in tropical countries, little herbicide research has been conducted for weed control in yams. In mechanised yam culture, chemical weed control is the only method of weed control that can be used (Renaut and Merlier, 1973). Chemical weed control has a double advantage in that fewer weedings are necessary and cost per weeding is cheaper (Ferguson, 1970).

In the Caribbean, atrazine at 1.5–3 kg/ha* will give 8–16 weeks weed control and is recommended as a pre-emergence treatment (Kasasian and Seeyave, 1968). Grass control will be improved without significantly affecting yield on clay soils by the addition of 5 kg TCA but on light permeable soils yield reductions are likely to occur (Kasasian and Seeyave, 1967). If weeds have emerged at the time of treatment, paraquat should be added to the atrazine (Kasasian and Seeyave, 1969). In Fiji, atrazine at 3.4 kg applied post planting pre-emergence is also recommended for weed control in yams (Patel, 1971). This herbicide when applied alone has performed poorly in Nigeria (Onochie, pers. comm.) but good results have been obtained when it was mixed with TCA (Anon, 1973a) and alachlor (Anon, 1973a; Onochie, pers. comm.).

Diuron applied pre-emergence at 3.3 kg either alone or in combination with TCA at 5.6 kg has given good weed control and not damaged the crop in Trinidad but in Antigua these herbicides affected growth and yield adversely (Anon, 1969b). These treatments have also performed well in Nigeria (Anon, 1973a).

In the Ivory Coast, a combination of 3–3.5 kg diuron with either 0.3 kg paraquat when grasses dominate, or 0.75–1 kg fenoprop when broadleaved weeds dominate, applied 20 days after planting has given good results. However, the duration of weed control has not been long enough and an additional weeding is required 4–5 months after planting. Weeds such as *Digitaria horizontalis*, *Brachiaria lata*, *Commelina* sp., *Ageratum conyzoides* and *Tridax procumbens* have been poorly controlled by the diuron paraquat mixture (Renaut and Merlier, 1973). For such a treatment to be economical, the crop would have to be weeded at least four times (Anon, 1973b).

Simazine (5.6 kg), monuron (4.5 kg) and monuron plus dalapon (2.6 kg + 2.4 kg) are recommended for controlling weeds in yam in Kenya even though they caused temporary injury (Attenburrow, 1965). In Puerto Rico, simazine applied at 9 kg/ha either in a single application soon after planting or as a split application – equal amounts being applied pre-emergence and three months after planting – has given excellent weed control without having a detrimental effect on yield (Costas *et al*, 1968).

At IITA, ametryne has given good results (Anon, 1973a) while in the Ivory Coast in 1972 up to seven months weed control was obtained with metribuzin at 1.4–2.1 kg either alone or in combination with paraquat. Other promising treatments were mixtures of alachlor and diuron, ametryne and paraquat, and cyanazine and paraquat (Renaut and Merlier, 1973). Onochie (pers. comm.) reported good weed control with diphenamid at 6.7 kg/ha but a similar rate failed to give sustained weed control at IITA (Moody, unpubl.).

Because of the rapid 'disappearance' of herbicides from some tropical soils, three months weed control may be difficult to achieve with pre-emergence treatments. Either a follow-up post-emergence treatment or an initial post-emergence treatment about a month after planting may be needed to prolong the period of weed control. In some instances, three months weed control can be obtained and such a follow-up treatment would be used to help keep the plot weed free and make harvesting easier rather than to increase yields. Dalapon at 5 kg/ha applied as directed application is recommended for grass control in the Caribbean (Kasasian and Seeyave, 1968) and paraquat has also been used successfully (Kasasian, 1971).

Cassava (*Manihot esculenta* Crantz)

Africa produces about 40% of the world's cassava on slightly more than 50% of the area devoted to growing the crop. The majority of the African crop is grown in West Africa with Nigeria producing about 20% (Anon, 1972b). Cassava is probably increasing in importance in West Africa. It seems to be replacing yams and cocoyams as it is easier to grow and requires less labour (Irvine, 1969).

In West Africa, cassava is usually the last crop to be planted in a rotation before the land is left to fallow (Doku, 1967). It is planted into a fairly clear seedbed just prior to or soon after harvest of the preceding crop. When it is grown as a cash crop it may be grown continuously on the same piece of land or alternated with maize (Jennings, 1970). It is often grown in mixed culture (Doku, 1967).

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*All rates in this review refer to the active ingredient in kg/ha.

In Western State of Nigeria, hoe weeding a sole crop of cassava requires about 110 man-days per ha (Anon, 1972d). Slightly less time is required if the cassava is intercropped with maize (Table 1). When the cassava is the last crop in a rotation, labour requirements are much less as it is not clean cultivated (Phillips, 1964). As with all tropical root and tuber crops large yield decreases will occur if cassava is not weeded (Table 2).

TABLE 2. AVERAGE CROP YIELD LOSSES IN TROPICAL ROOT CROPS DUE TO UNCONTROLLED WEED GROWTH

Crop	Yield Loss (%)
Yams	
West Indies	69
Nigeria, Ife	72
Nigeria, IITA	73
Ivory Coast	91
Cassava	
Fiji	75
Venezuela	92
Nigeria, IITA	92
Colombia	94
Sweet potatoes	
Hawaii	22
West Indies	78
Nigeria, IITA	91

Weed control is one of the major constraints in cassava growing and Terry (pers. comm.) reported a scarcity of labour for this task in Tanzania. In Colombia, weeding was found to be the major labour absorbing activity (Pinstrup-Andersen and Diaz, 1973). It is only necessary to control weeds during the early growth of cassava. Cassava when grown as a sole crop, with the proper variety, planting distance and fertiliser has, after three months, usually formed a canopy so that further weeding is minimal or not necessary (Anon, 1972a). Even in widely spaced cassava, the weeds remaining after the first few months of growth are probably more of a help in protecting the soil than a hinderance to growth (Nye and Greenland, 1960).

Onochie (1973) found that weeding cassava for four months gave yields as good as those obtained when the crop was weeded throughout its life cycle. Similar results have been found in Colombia (Doll and Piedrahita 1973). However, at IITA in 1972, in a preliminary trial, it was observed that weeding cassava after the first two months of crop growth may be unnecessary (Anon, 1974).

When cassava was weeded twice, 30 and 60 days after planting, yields were the same as when weeding was started 30 days after planting and continued until harvest. These yields were only 10 to 15% less than the yield obtained when the crop was maintained weed free throughout the season; the decrease being caused by the initial delay in start of weeding (Doll and Piedrahita, 1973). Yield losses due to weeds in the first month of cassava growth have been less at IITA, in the order of 5% (Anon, 1974).

Doll and Piedrahita (1973) observed that cassava kept weed free mechanically yielded about 10% less than a crop kept weed free chemically. In the mechanically weeded plots, the first hoe weeding was carried out 15 days after planting. This indicates that the delay in weeding or, more likely, soil disturbance causing root injury, was detrimental to the crop.

Pre-emergence applications of atrazine or diuron at 1.8–3.5 kg/ha plus TCA at 5.6 kg/ha are recommended for weed control in cassava in the Caribbean (Kasasian and Seeyave, 1968). However, crop damage has been observed at rates at or above 2 kg in Fiji (Patel, 1971) and Colombia (Anon, 1972c). No damage occurred at rates less than 2 kg/ha in Venezuela (Barrios, 1973).

Fluometuron applied pre-emergence has been recommended for weed control in cassava in Venezuela and the cost of this application is about one-third that of manual weed control (Anon, 1969a). This herbicide also gave good results in trials conducted in Colombia (Anon, 1972c), Venezuela (Barrios, 1973) and Nigeria (Onochie, 1973). Cassava grown from seeds was damaged by this herbicide in trials at IITA (Anon, 1974).

In West Malaysia, alachlor at 0.5–1.0 kg proved highly effective against seedling grasses and fairly effective against broadleaved weeds and sedges. No crop damage was observed (Wong, 1970). The same compound gave acceptable weed control and only slight damage to the cassava in Thailand (Somabhi and Pothisoonthorn, 1969) but in another trial in Thailand weed control was unacceptable (Harper, 1973). In Colombia, cassava was found to be tolerant to alachlor at rates up to 8 kg (Anon, 1972c).

Directed post-emergence applications of paraquat applied at rates of 0.2–0.4 kg have been used successfully in Thailand (Harper, 1974) and Doll (pers. comm.) reports good weed control with directed applications of paraquat and diuron.

Only chloramben plus diphenamid applied pre-emergence gave acceptable weed control without damage to cassava grown from seeds at IITA (Anon, 1974). If weeds are present at the time of application, a contact, non-selective, nonresidual herbicide should be added to the mixture otherwise weed control may not be satisfactory.

Sweet potatoes (*Ipomoea batatas* (L.) Lam.)

One of the major disadvantages of sweet potatoes as an African crop is storage difficulty. Unlike the other root and tuber crops, and in particular cassava, sweet potatoes cannot be stored in the ground beyond maturity as they sprout easily and are subject to insect attack (Johnston, 1958).

Sometimes sweet potatoes are used as the closing crop in a rotation but examples can be found where they are used as the first crop after clearing (Macdonald, 1967). Quite often they are grown in mixtures with other crops such as beans or cassava in East Africa, pigeon peas, okra and maize in Jamaica (Kasasian, 1971) and taro and a number of other crops in New Guinea (Clarke, 1973).

In the West Indies, three weedings at three week intervals commencing three weeks after planting were as good as keeping the crop weed free until harvest with regard to yield. Delaying the first weeding until four weeks after planting caused a significant yield reduction (Kasasian and Seeyave, 1967). In another trial, excellent results were obtained when the sweet potatoes were weeded for the first five weeks and then every three or five weeks (Kasasian and Seeyave, 1969).

In Uganda, Macdonald (1967) found that a highly significant yield decrease occurred when sweet potato plants were not allowed to root freely at the nodes. Greatest decreases occurred when the vines were disturbed weekly. Yield decreases have also occurred in the West Indies when sweet potatoes have been weeded frequently after the first five weeks (Kasasian and Seeyave, 1969) while at IITA weeding after the second month caused crop damage and yield reductions (Anon, 1973a).

Mixtures of diphenamid (1.4 kg) with either chloramben (1.1–2.4 kg) for use on light soil or chlorthal-dimethyl (1.4 kg) for use on heavy soils are recommended in the West Indies (Kasasian and Seeyave, 1968) but in later trials noruron proved to be more promising (Kasasian, 1971) but this is no longer available. Disappointing results were obtained at IITA with a mixture of chloramben (1.5 kg) and diphenamid (2 kg) (Anon, 1973a).

In Hawaii, the most promising treatments were chlorthal-dimethyl (8–11 kg) and diphenamid (4.5–6 kg) applied pre-emergence. If application is delayed, unsatisfactory weed control results. Better results can be obtained through a combination spray which contains a lower rate of each herbicide (Crozier and Romanowski, 1969).

In Jamaica, metobromuron failed to control *Cyperus rotundus* but other weeds were controlled satisfactorily for eight weeks (Hammerton, 1972). This compound performed well in Nigeria in 1972 (Anon, 1973a).

Four to eight weeks weed control with herbicides is usually sufficient for the vines to cover the soil and provide adequate weed control through shading (Crozier and Romanowski, 1969).

Aroids

The family Araceae comprises more than 100 genera and 1500 species. Of these *Colocasia* and *Xanthosoma* are important tropical food crops while *Alocasia* and *Cyrtosperma* are important in certain countries or regions. Of less importance is *Amorphophallus* which is used more as an emergency food or for subsistence (Plucknett,

1970). In Ghana, whenever a piece of secondary forest is cleared cocoyam plants (*Colocasia*) grow in the cleared area from tubers which have been lying dormant in the soil since the old farm land was abandoned. These plants are thinned out when growing too thickly and gaps are filled in. Usually mixed cropping is practised and then the gaps are not filled in with cocoyam after thinning but with other crops such as maize, plantains and cowpeas (Doku, 1967).

Taro (*Alocasia*) grown in this manner often does well if the soil fertility is high and only occasional weedings may be necessary to complete a successful crop cycle (Plucknett, 1970). In some areas when planting takes place immediately after clearing, weeding is not necessary (Handy and Handy, 1972). In Niue, three or four hand weedings are required in upland taro and these constitute the most laborious aspect during the growing of the crop (Lucas *et al*, 1973). When grass weeds begin to become dominant, weeding may become too difficult and a change to another crop or abandonment of the land may then occur (Plucknett, 1970). In Western Samoa after about two years of cultivation, decreasing yields forced the farmer to abandon his taro land to the increasing weeds and regenerating secondary regrowth (Watters, 1959).

Aroids are also grown as intercrops in tropical plantations such as rubber, cocoa, and coconut while these perennial crops are growing to maturity (Plucknett, 1970). In parts of West Africa, notably Ghana and Western Nigeria, *Xanthosoma* and to a lesser extent *Colocasia* have been planted as shade plants to protect young cocoa trees (Coursey, 1967).

Newly planted lowland taro is most susceptible to weed competition during the first three or four months when growth of the foliage is just beginning and little canopy exists. By the fourth month, a heavy leaf canopy develops which may shade out the weeds. As the crop matures, however, the leaf canopy recedes as successive leaves become smaller resulting in a more favourable environment for weed growth. The mature stage of the crop is also especially susceptible to severe yield reductions due to weeds since this is the most active starch storage period (Plucknett *et al*, 1967).

In upland taro, weed control is a problem throughout the cropping period, shading becomes less important in suppressing weeds because plant spacings are wider and total growth and resultant canopy are sometimes reduced because of insufficient moisture (Plucknett *et al*, 1967).

Mulching of upland taro and cocoyams has been practised (Enyi, 1967; Handy and Handy, 1972) probably to control weeds and conserve moisture (Plucknett *et al*, 1970). Black plastic mulches have been used successfully to control weeds in the row in Hawaii but entrapment of the suckers may occur (Plucknett *et al*, 1967). Row planting in specially dug holes on flat surfaces (Migvar, 1968) or on ridges (Enyi, 1967) are important cultural improvements. These allow easy movement and the use of hoes or cutlasses to control weeds without causing excess damage to plants.

Many weeds are killed by flooding but high spots in lowland fields become fertile areas for weed infestation and growth. Fields should be well levelled and water depth should be made as uniform as possible throughout the field. Under flooded conditions weeding requires less than 10% of the labour needed to grow a crop (Ikehara and Hiroshige, 1966).

Since mechanical weeding is impractical and labour costs make hand weeding uneconomic it is apparent that herbicides must be employed for upland taro weed control (Plucknett *et al*, 1967). A major factor delaying the mechanisation of taro culture in Hawaii is a lack of effective means of controlling weeds under upland conditions (Ezumah, unpubl.).

Several herbicides have been found to be promising in both upland and lowland taro. In upland taro, prometryne at 1.2 kg/ha applied pre-emergence is recommended in the Caribbean and gives four to eight weeks weed control (Kasasian and Seeyave, 1968) In Hawaii, trifluralin, prometryne and ametryne have given good weed control with little injury to the crop (Plucknett *et al*, 1967). In Niue, the best herbicide combination tested so far is a combination of paraquat and prometryne (Lucas *et al*, 1973).

In Fiji, atrazine, simazine, linuron and monolinuron have given promising results. However, because of the slow development of the canopy a post-emergence directed application of paraquat or a hand weeding is required in addition to the pre-emergence treatment (Patel, 1971). Atrazine and simazine have caused taro injury in Trinidad (Kasasian, 1968). In Western Samoa, grasses were successfully controlled with dalapon at approximately 3 kg/ha post-planting and post weed emergence (Anon, 1962).

In Niue, taro has been successfully planted into Siratro (*Macroptilium atropurpureum*) which had been killed with either 2,4-D or a mixture of 2,4-D and picloram. The Siratro is envisioned as replacing the forest regrowth in the shifting agricultural pattern (Lucas *et al*, 1973).

For *Xanthosoma* grown under upland conditions, linuron or simazine are recommended for use on light soils and TCA plus either linuron or atrazine is recommended for use on heavy soils (Kasasian and Seeyave, 1968).

In lowland taro, weeds are controlled mainly by flooding. Those which escape are either pulled by hand or sprayed with a contact oil spray (Plucknett *et al*, 1970). In Hawaii propanil post-emergence, ametryne and prometon pre-emergence and nitrofen are promising herbicides for weed control in lowland taro (Plucknett *et al*, 1967). Propanil, ametryne and prometon are applied after the paddy has been drained. Nitrofen provides excellent weed control without injury to the taro and has been especially successful when the herbicide is applied in the irrigation water as it circulates through the growing crop (Plucknett and de la Pena, 1971). Recently nitrofen was approved in the United States for use in taro (Plucknett, pers. comm.).

Conclusions

There are a number of herbicides which have shown promise for weed control in these crops but the absorption of sophisticated research is limited by the economic sphere of the areas in which tropical crops are grown (Holm, 1969). In most tropical areas, therefore, the cheapest means of weed control is still hand weeding or other physical means.

Enormous disadvantages are encountered with these methods of weed control. Hand labour often causes soil compaction, plant damage and promotes erosion. At periods of peak labour needs, labour is in short supply and delays in weeding can mean substantial reduction in crop yields. With diminishing farm labour supply as more and more young people leave the land for the cities as industries increase in the developing countries and with increasing labour costs, methods of weed control which reduce labour input must be used. Until now chemical weed control offers the greatest potential to overcome these problems.

Herbicides are used sparingly in tropical root and tuber crops at present. However, when one takes into consideration that chemical weed control only gained impetus in temperate countries after World War II and considers the unfortunate but usual time lag in development between temperate and tropical regions of the world, one can surmise that the future of chemical weed control in the tropics looks bright.

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