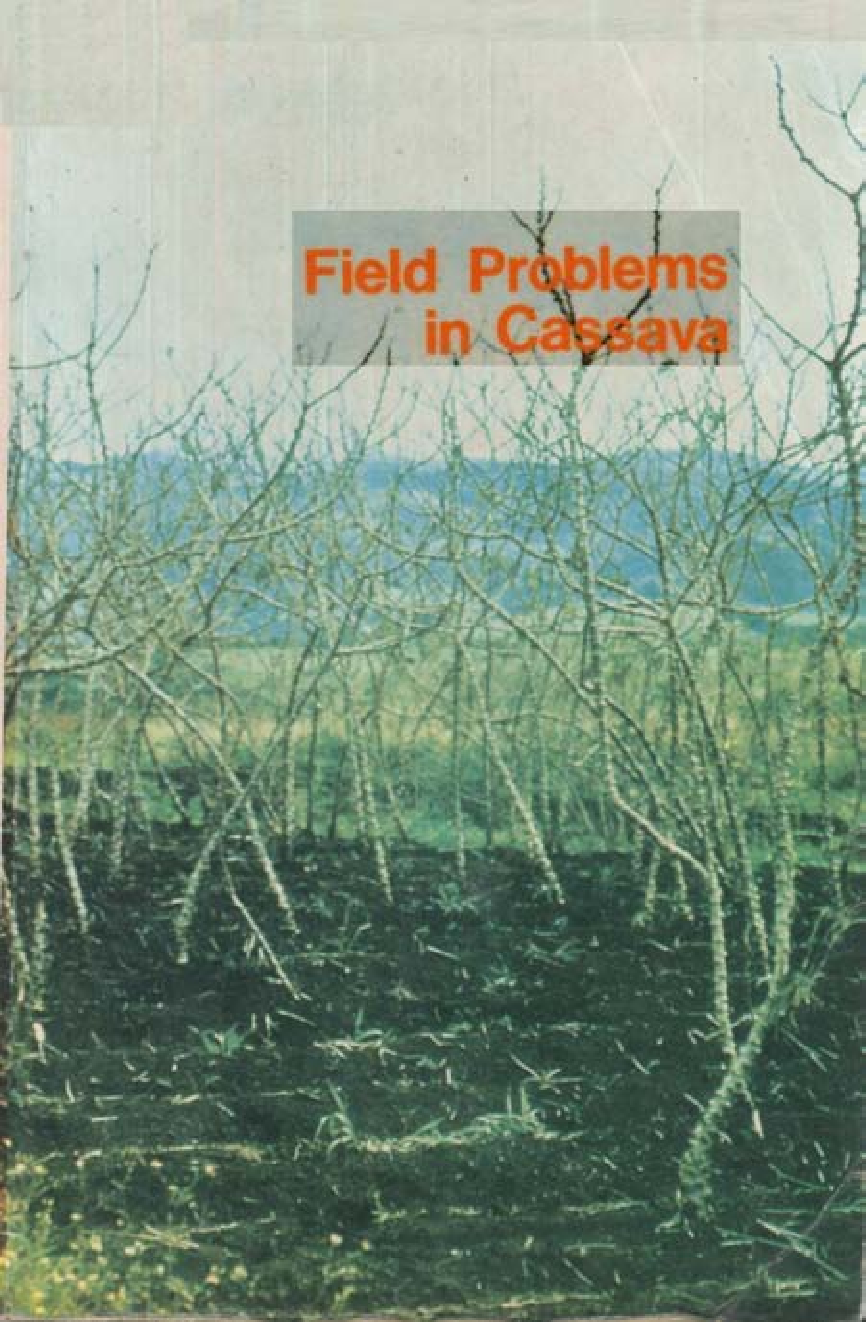
Field Problems in Cassava



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Cassava/Diseases and pathogens/ Bacterioses/ **Xanthomonas manihotis/ Xanthomonas cassavae/ Erwinia carotovora/Agrobacterium tumefaciens/** *Viroses/Cassava African mosaic virus/Cassava common mosaic virus/Cassava vein mosaic virus/Mycoplasmoses / Mycoses/* **Cercospora henningsii/Cercospora vicosae/ Phaeoramularia manihotis/Phyllosticta/ Sphaceloma manihoticola/Oidium manihotis/ Glomerella/Uromyces/ Phytophthora dreschsleri/ Rosellinia necatrix/Diplodia/** *Deterioration/Disease control/Pests/Injurious mites/* **Mononychellus tanajoa/Tetranychus urticae/Oligonychus peruvianus/** *Thrips/ Injurious insects/* **Erinnyis ello/Silba pendula/ Anastrepha pickeli/Aleurotrachelus socialis/Agrotis ipsilon/Aonidomytilus albus/ Phenacoccus/Vatiga manihotae/ Coptotermes/Jatrophobia brasiliensis/** *Pest control/Predators/ Nutritional requirements/ Mineral deficiencies/N/P/K/Ca/Mg/S/Zn/Cu/Fe/Mn/B/Toxicity/ B/Al/Mn/pH/Plant toxicity caused by herbicides/*

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Contents

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Introduction

The pathological, entomological and nutritional problems, as well as the physiological disturbances occurring in cassava-growing areas, can become of great economic importance, although, in many occasions, they pass unnoticed. They are particularly important because cassava is a long-cycle crop (8-24 months), it is vegetatively propagated, and its roots, whose quality and production can only be evaluated at harvest, are the most valuable commercial product.

Because of its long growth cycle, cassava plants are exposed to the attack of many pests and diseases and to the variable climatic and edaphic conditions of each region. To control such problems during the growing season can be too expensive or even impossible (as it is the case with certain climatic and edaphic problems); therefore, the farmer should give priority to their prevention rather than to their control.

Although the vegetative propagation of cassava is relatively easy when mature stem pieces are used, the sanitary, nutritional and agronomic conditions of such cuttings determine, to a high percentage, the profits and the stability of a given variety within the region or of the crop within the same plot. This is, therefore, one of the essential factors upon which success depends as far as yields and the occurrence and severity of pathological and entomological problems are concerned (see CIAT's publication series GS-17, Appendix 3).

Occasionally, the farmer is extremely disappointed at harvest, either because of low root production or serious root rots, due to unprevented problems inherent to the crop or to not having paid the necessary attention to it. The application of all the agronomic and sanitary practices intended for the prevention of pests and the improvement of the crop will undoubtedly result in a successful harvest.

This manual describes some diseases and pests that attack cassava, as well as the symptoms induced by nutritional deficiencies and damage resulting from the misuse of herbicides. Although some specific and general recommendations regarding the control of the described problems are included, it is suggested to consult CIAT's publications on cassava for further information (see Appendix 3).

Important Diseases

Cassava is attacked by more than 30 bacterial, fungal, viral, viruslike and mycoplasmal agents. Diseases affecting cassava cause losses in crop establisment, lessen normal plant vigor, reduce photosynthetic capacity, or cause pre- or post-harvest root rot. Some pathogens attack only the stalk, which is the normal propagating material, inducing tissue necrosis. They may also invade the vascular system, causing no visible damage but constituting primary sources of infection in the plantations. Other pathogens attack foliar tissues and the tender parts of the stalk, causing spots, blight, defoliation, wilting, dieback and hypertrophies (exaggerated elongation or profileration of buds and internodes). Others attack only root tissue and the basal, woody part of the stem, causing preharvest root rot. Damage is characterized by a sudden yellowing accompanied by wilting and sudden defoliation. These symptoms may occur at any stage of plant growth, generally during periods of heavy, prolonged rains.

Recently harvested cassava roots may be affected by soft or dry rot shortly after they have been harvested. Although this appears to be a physiological-pathogenic effect, it is frequently correlated with and accelerated by mechanical damage to the roots, which occurs during harvesting.

General recommendations for disease control on a commercial scale

Cassava is a perennial crop grown from stem cuttings, approximately 20 cm in size, and harvested from 8 to 24 months after planting. These factors favor the dissemination of pathological and entomological problems through propagating material, and their perpetuation in areas where cassava is cultivated; in addition, because of its long growth cycle, cassava may be exposed to many climatic and edaphic conditions and be attacked by different pathogens and pests. Therefore, an integrated pest and disease control program, including cultural practices, biological control and varietal resistance, is required during the whole production process. The following practical recommendations are suggested in order to reduce the damages caused by disease in cassava plantations:

1. Select the soil carefully; it should be light, well drained and not very high in organic matter. Do not plant cassava on soils previously covered by woods or planted to forest and other perennial crops, because this could result in a high percentage of root rot. In these cases, grow a cereal crop (maize, sorghum, etc.) before planting cassava.

2. Prepare the soil well, install a good drainage system and plant on ridges when rainfall is high (more than 1200 mm/yr, approximately) or the soil is heavy.

3. Use the best regional varieties or varieties known to give high yields in such ecosystem. Do not introduce varieties from other regions because, since they are not adapted, they can be severely attacked by problems existing in such ecosystem and produce even less than regional varieties after several consecutive growing cycles.

4. Use clean "seed" only. Produce and select planting material only from vigorous, disease-free plantations and plants. Do not store cuttings; if needed, treat them with captan and BCM before storage (see CIAT publication series GS-17).

5. Handle planting material carefully, avoiding mechanical damage during its preparation and planting. Treat this material with a seed disinfestant fungicide mixture, such as captan and BCM, immersing the cuttings for 3 minutes in a .6% suspension of each commercial product in water (approximately 3000 ppm a.i.). This treatment should prevent damage caused by soil-borne pathogens (see CIAT publication series GS-17).

6. Plant cuttings following recommended procedures, leaving an adequate distance between plants according to the variety used.

Plant at the beginning of the rainy season to assure good germination and crop establishment. Eliminate weeds, which may act as hosts for pathogens.

7. Do not use machinery or tools that have been used on other plantations —especially where there is bacterial blight—or permit workers from other farms to visit the plantation. Desinfest tools (machetes) with 10% formaldehyde, in case of bacteria, or with soapy water (detergent) in case of virus. Machetes may also be heated by fire in order to desinfest them.

8 Improve drainage and rotate cassava with a cereal (maize or sorghum) for a period of no less than six months if indices of root rot in the plantation are higher than 3%. These practices can reduce the occurrence of most cassava root rots.

9. Burn debris from previous cassava crops; do not leave old plant debris after the land has been prepared.

10. Avoid damage to roots during harvesting; pack roots carefully in adequate packing material.

11. Sell or process the harvested product inmediately; otherwise harvest only what is to be sold, processed or used. If it is necessary to maintain roots fresh for a short period, use the appropriate system to preserve them: either prune the aboveground part of the plants 2-3

weeks before harvest and treat roots with disinfestant, or treat roots with disinfestants and pack them in plastic bags (see CIAT publications).

12. Follow established quarantine measures and avoid introducing vegetative material from nearby regions. Pests and diseases may be readily disseminated by stem cuttings.

Bacterial blight *(Xanthomonas manihotis)*

This is one of the most serious diseases affecting cassava. It is recognized by the presence of water-soaked, angular spots, blight, partial or total wilting of the branches, gum exudate on stems or green branches, dieback and necrosis of some vascular strands of the stems and roots. These symptoms, which are evident during the rainy season, vary in accordance with the susceptibility of the variety affected and the time that the plant has been infected. The pathogen is generally introduced

1. *Leaf spots.*

2. *Partial wilting.*

through the use of cuttings taken from plants from affected plantations or through true seed taken from infected crops.

The best way to prevent this disease is to use always planting material from disease-free plantations.

3. *Gum exudation.*

4. *Dieback.*

Bacterial angular leaf spot *(Xanthomonas cassavae)*

This disease is characterized mainly by the presence of water-soaked, angular spots on leaf lobes where small gummy drops of exudate may be observed. While these characteristics are similar to those of the bacterial blight, the bacterial angular spot is generally restricted to the foliar system, although the pathogen sometimes also invades stem buds and young branches via the phloem. Infected leaves show initially lesions surrounded by yellowish halos which coalesce, inducing yellowing of the whole leaf. Leaves fall prematurely causing plant defoliation. The causal agent is a typical *Xanthomonas* species, which produces a yellow pigmentation in any medium containing sugars.

To control this disease avoid taking stem cuttings from affected plantations.

5. *Water-soaked angular spot.*

6. *Coalesced angular spots.*

Bacterial stem rot *(Erwinia carotovora* p.v. *carotovora)*

The disease is characterized by a pungent, soft stem rot, discoloration of the woody portion of the plant; shoots of infected plants wilt. On the stem surface, there are holes made by insects *(Anastrepha* spp.), which appear to be the vectors that spread the bacteria. These holes are easy to distinguish by the traces of dry latex exudated after the stem has been perforated. Diseased cuttings used for planting do not always germinate; and if they do, plants are stunted with a small number of thick roots.

Always use clean "seed" and select varieties resistant to the vector; burn all stems and branches affected.

7. *Partial wilting.*

8. *Stem cankers.*

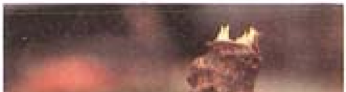
9. *Stem rot.*

Bacterial stem gall *(Agrobacterium tumefaciens)*

The symptoms of this disease generally appear on the lower part of the stem and in plants older than seven months; they are characterized by galls on the stem nodes. These galls grow considerably and show proliferation of buds on their epidermis. Affected plants may be stunted, and when the attack occurs in an early stage, it may cause dieback up to one of the main galls. The same plant may have several galls along the stem and even on the lower branches, but the disease is usually initiated through wounds left after old leaves fall, that become infected by infested soil splashed by the rain.

It is controlled by rotating cassava when more than 3% of the plantation is affected; disinfesting machetes (5% commercial formaldehyde); using always planting material taken from healthy plants; and burning all diseased material within the plantation.

10. *Stem galls.*



11. *Systemic formation of stem galls.*

African mosaic (causal agent unknown)

This disease, spread by insects of the genus *Bemisia* (whiteflies), is found in Africa, where it causes considerable losses. A similar disease has also been recorded in India. Its symptoms are characteristic of other mosaics. Young plants have yellowish areas and frequent leaf deformation. The reduction in size of young leaves is also very common (with the presence of yellowish areas) in adult plants. All cuttings from infected plants generate diseased ones; therefore, the introduction of planting material from Africa should be strictly prohibited since the majority of plantations in that continent are affected by this disease.

Use resistant cultivars and cuttings from disease-free plants in areas affected by this disease.

12. *Infected plant.*

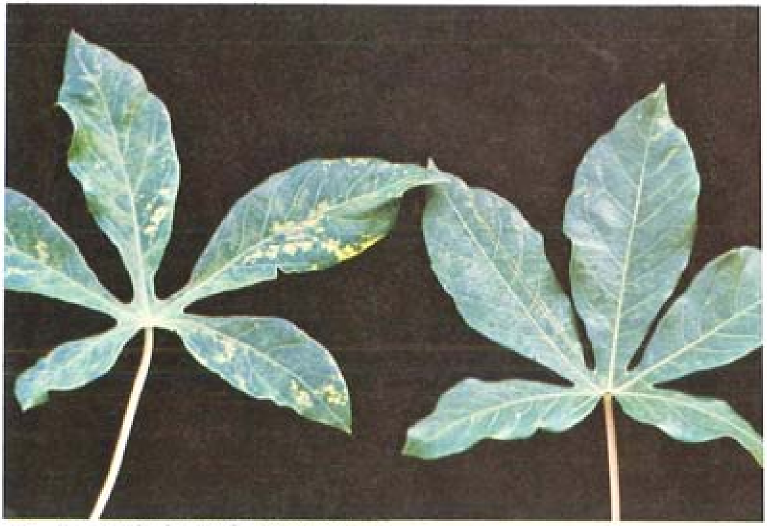
13. *Leaf distortion and mosaic.*

14. *Heavily infected leaf.*

Common mosaic (caused by a virus)

This as an American disease that has also been recorded in Africa (Ivory Coast). The disease is caused by a virus that appears to be transmitted only by mechanical means and is spread by the use of cuttings from diseased plants and infested machetes. The symptoms are characteristic of all mosaics, consisting primarily in the presence of yellowish areas in the leaf blade and the stunting of diseased plants. In general the yellowish areas are not well defined as in African mosaic; otherwise, the symptoms are quite similar. These symptoms may also be confused with severe attacks of thrips and whiteflies in susceptible cultivars (see corresponding section in chapter on insects).

Use healthy cuttings only, remove and burn all diseased plants; do not use infested machetes.



15. *Two typical mosaic symptoms.*

16. *Characteristic distortion and mosaic.*

Colombian cassava mosaic (unknown virus)

This disease has been observed in the variety Secundina, one of the most widely cultivated in the North coast of Colombia. Its symptoms are similar to those of the common mosaic, but it causes greater leaf distortion and irregular, green-yellowish areas near the main veins giving the appearance of vein yellowing, in some cases, and vein banding, in others. However, when carefully examined against the light, it can be noticed that such lesions resulted from the coalescence of numerous chlorotic spots occasionally accompanied by ring spots. Symptoms are more serious at the end of the rainy season (September-November), when a marked stunting may be observed; at the beginning of the rains, they become imperceptible because of the high temperatures occurring normally during the dry season (December-March), which apparently have a negative effect on the pathogen making diseased plants look healthy.

17. *Characteristic symptoms of this disease.*

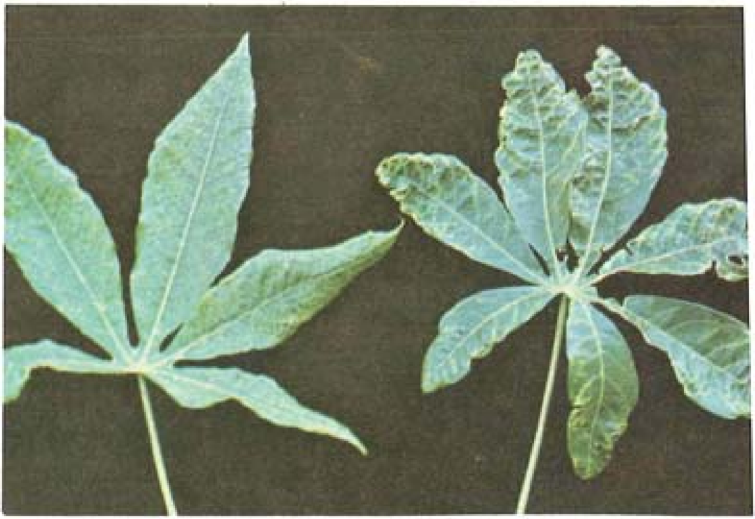
18. *Green blisters surrounded by yellow spots.*

Leaf vein mosaic (caused by a virus)

Because of its reduced incidence in Latin America, its economic importance is limited. The symptoms of the disease are characterized by yellowing of the veins and leaf curling. The disease can be transmitted mechanically or by grafting; moreover, all cuttings taken from infected material produce diseased plants.

To eradicate this disease, all plants with suspicious symptoms should be eliminated. Always use disease-free planting material; do not use infested machetes.

19. *Vein yellowing and leaf tip curling.*



20. *Two symptoms typical of leaf vein mosaic.*

Frog skin disease (apparently a virus disease)

This disease, recently described in Latin America, may cause losses from 50 to 100% being, therefore, one of the potentially most dangerous diseases of cassava. It is characterized by a reduced number of swollen roots and suberization and thickening of root epidermis, resulting in a low production of little commercial value. Roots are thin, the periderm (cortical zone) swells irregularly and breaks easily; the epidermis is thick, cracked, wrinkled, similar to a toad's skin. The storing parenchyma is fibrous and of reduced capacity. Occasionally, the same plant presents normal and diseased roots. Infected plants have no noticeable symptoms in the arterial part; in general, the plant looks more vigorous and the stem base is thicker, but these symptoms pass unnoticed because they are difficult to differentiate. Affected plants can only be completely identified at harvest by root symptoms. The disease agent is readily transmitted by cuttings taken from infected plants and by grafting. There is some evidence that the causal agent may be disseminated in the field when infested tools are used or by the intercrossing of healthy roots with those of nearby affected plants.

Frog skin disease is controlled using healthy plants for propagation, disinfesting machetes with detergents and burning all diseased plants.

21. *Corky formation on epidermal tissues.*

22. *Yield of healthy and diseased plants.*

23. *Characteristic fibrous and corky formation of roots.*

Witches' broom (caused by a mycoplasma)

This disease has been recorded in Brazil, Venezuela, Mexico and in the Amazonian region of Peru. Although its incidence is low, the percentage of diseased plants in affected plantations is much higher than with the other diseases caused by the American viruses. There are several types of symptoms, probably due to different races or biotypes of the causal agent. Among them, the most important are (1) plants that show stunting and excessive proliferation of branches; shoots have small leaves and shortened internodes, without showing distortion or chlorosis; (2) proliferation of shoots from the cutting; these are generally weak but grow without showing any other visible symptom of being affected; (3) only a few weak and stunted shoots germinate from the cutting; they never reach normal size. Plants affected by the mycoplasma generally produce up to 80% less than healthy plants.

As the disease is transmitted mechanically and through the use of cuttings taken from diseased plants, their elimination and the disinfestation of machetes (by heating or washing them with 5% formaldehyde) are indispensable for its control. Always use disease-free material for planting.

!4. *Stunting and witches' broom.*

25. *Proliferation of shoots from the cuttings as compared to normal plant.*

5. *Stunted and weak shoots.*

Brown leaf spot *(Cercosporidium henningsii)*

This is one of the most common diseases in cassava. It almost always occurs in plantations located in areas with high temperatures. When the crop is more than five months old, the disease is more widespread and severe, depending upon the susceptibility of the cultivar. The disease is characterized by angular, uniformly brown spots on both sides of the leaf; the margins of the spots are well defined and dark. On the undersurface of the leaf, the spots have a grayish olive cast due to the presence of the fruiting bodies of the causal agent. At times, according to the susceptibility of the cultivar, there is an indefinite yellowish halo around the lesions. As the disease advances, the affected leaves become yellow, dry and fall. Susceptible cultivars can be severely defoliated at the end of the rainy season.

Use resistant or tolerant cultivars if possible.

27. *Brown angular leaf spots.*

28. *Yellowing induced by brown leaf spot.*

Blight leaf spot *(Cercospora vicosae)*

This disease appears where brown leaf spot is prevalent; in contrast, this leaf spot is large and without well-defined borders. Each spot may cover one fifth or more of the leaf lobe. As with brown leaf spot, it is a uniform brown in color but with a grayish center on the underside of the leaf due to the presence of fungal fruiting bodies. The general appearance of this leaf spot disease is similar to that caused by *Phoma* sp. *(Phyllosticta* sp.); nevertheless, lesions caused by *Phoma* sp. have concentric rings on the upper leaf surface. The pathogen can cause heavy defoliation in susceptible cultivars; the severity of the disease is greater when the plants are more than six months old.

Plant resistant or tolerant cultivars if possible.

29. *Typical leaf blight.*

White leaf spot *(Phaeoramularia manihotis)*

This disease is commonly found in humid, cooler cassava-growing areas and causes defoliation in susceptible cultivars. Lesions are small, circular to angular, white or yellowish brown; they are sunken from both sides, reducing the thickness of the normal leaf blade to about one half. The lesions on the underside of the leaf often have a diffuse-colored border that looks like an irregular violet-brown line surrounded by a yellowish halo. The center of the spots may have a grayish, velvety appearance during the fructification of the pathogen, which occurs mainly on the underside of the leaf.

Plant resistant varieties if available.

30. *White spots on upper leaf surface.*

31. *White spots on under leaf surface.*

Concentric-ring leaf spot [*Phoma (Phyllosticta)* spp.].

This disease appears during the rainy season when the temperature is less than 20°C; it causes severe defoliation in susceptible cultivars and occasionally dieback or total death of the plant. The spots are large and brown in color; they do not have well-defined margins and are located near the tips or the edges of the lobes or along the midrib or main veins. Initially, the upper surface of the lesions presents concentric rings, formed by the fruiting bodies (pycnidia) of the fungus. Old lesions resemble lesions produced by *C. vicosae* since their concentric rings are washed off by the rain. On the underside, there are no pycnidia so the lesions are dark brown in color. Veins and veinlets become necrosed, forming black threads that radiate from the lesions. The fungus invades the leaf, then the petiole and the green parts of the stem, causing defoliation, dieback or total death of the plant. It spreads to the stem, starting from cankers that form towards the base of the petiole of the affected leaf.

In cooler areas, always plant resistant or highly tolerant cultivars.

32. *Leaf spots and dieback*

33. *Concentric rings on upper leaf surface.*

Superelongation *(Sphaceloma manihoticola)*

This is a disease that has been described only recently; it causes considerable losses in plantations where susceptible cultivars are used. The disease can be recognized by the exaggerated elongation of the stem internodes. The affected stem is thin and weak; diseased plants are much taller and/or weaker than healthy ones. On the green part of the stem, the petioles and the leaves, deformations associated with the formation of cankers can be found. These eye-shaped cankers are found along the midribs or main veins, in the petioles or in the stem. There is occasional dieback and partial or total necrosis of the blade, which results in considerable defoliation. The disease is most severe during the rainy season.

As it may be spread by the use of cuttings taken from infected plantations, clean "seed" should always be used. Resistant cultivars should be planted if possible. In regions where the disease is endemic, cuttings should be treated by immersing them in a captafol solution (3000 ppm a.i.).

34. *Characteristic elongation and leaf distortion.*

35. *Cankers on petiole and midrib.*

36. *Cankers on young stem shoots.*

37. *Cankers on midribs and leaf spots.*

Cassava ash *(Oidium manihotis)*

This disease occurs during the dry season, being more prevalent on lower leaves. It is characterized by the presence of yellowish leaf spots. Initially, a white mycelium grows on the leaf surface; affected cells turn yellow, forming indefinite pale yellow lesions. Within these lesions, there are areas of necrosed tissue, which form different-sized, pale brown angular spots. Symptoms can be confused with certain types of damage caused by insects and spider mites. The disease is considered to be of minor importance in yield reduction.

38. *Yellow leaf spots on upper leaf surface.*

Anthracnose *(Colletotrichum* spp. or *Glomerella* spp.)

This disease appears after long periods of rain. It is characterized by the presence of leaf spots found near the edges of young leaf lobes, which are distorted; there is partial or total necrosis of the affected tissue. The pathogen also attacks the green part of the stem producing cankers and dieback. In the central part of these lesions, pinkish areas, formed by the fructifications of the fungus, can generally be found. Most severe damage is done to cultivations under one month old; attacks after this time can lessen the quality of cuttings obtained from these affected plants.

Use clean "seed" and do not plant at the height of the rains. Resistant cultivars should be planted if possible.

39. *Leaf tip blight.*

40. *Stem cankers.*

41. *Shoot dieback.*

42. *Fruiting bodies of* **Diplodia** *sp. (left) and* **Colletotrichum** *spp. (right).*

Rust *(Uromyces* spp.)

Six species of rust pathogens have been recorded in cassava, localized in different parts of the world. Nevertheless, their incidence and severity are low. It seems that some species of rust occur only in temperate zones where the disease is most severe towards the end of the rainy season; other species are prevalent during the hot, dry season. The disease is characterized by the formation of pustules on the veins, petioles or green stems. These pustules are orange or light to dark brown in color, depending upon the age of the pustule or the type of fungal fructification. Mature pustules show a high degree of parasitism of fungi *(Darluca* spp.). Occasionally the pustules are bordered by a yellowish halo and, in general, they induce distortion of the affected parts.

Although the disease is of low economic importance, biological control is suggested by means of aspersions with *Darluca* spp. suspensions.

43. *Pustules on stem.*

44. *Pustules on stem, petioles and leaves.*

Stem rot (various pathogens)

The stem, which is normally used as propagation material in cassava, is attacked by pathogens of woody perennials. The affected tissue is generally of a different color from healthy tissue, especially around the vascular strands or pith area. At first, the epidermis may show superficial rot; later, fruiting bodies of the pathogen may appear. These bodies vary in form, color, size, etc., according to the species of the pathogen. The occurrence of this rot is more noticeable at the end of the rainy season and in cuttings that have been stored under conditions of high relative humidity for periods of more than 15 days. All wounds caused by insects or by field workers leave the plant predisposed to the occurrence of these diseases.

Avoid planting "seed" with symptoms of any disease.

45 *and* 46. *Fungal fruiting bodies on stem.*

Infected propagating material (various pathogens)

Certain pathogens (causal agents of bacterial blight, bacterial stem rot, superelongation, viruses, viruslike organisms and mycoplasma) translocate systemically in the vascular or cortical system and superficially from the stem of diseased plants, without producing any visible symptom in the tissue they invade. When this material is used for cuttings, the resultant plants develop symptoms characteristic of the diseases caused by these pathogens and constitute a focus for secondary infection. Since the mature (lignified) part of the

47. *Diseased shoots resulting from CBB-infected cutting.*

48. *Absence of swollen roots in plant from cutting infected with "frog skin" root disease.*

stem does not generally present any symptoms of infection, the symptoms of these diseases must be looked for towards the upper part of the plant and generally during the rainy season when they are more noticeable.

Never use planting material taken from plantations where these diseases have been observed.

49. *Elongated shoot from superelongation-infected cutting.*

50. *Skin of healthy and diseased shoot affected by* **Diplodia** *sp.*

Soft root rot (various pathogens) *Phytophthora drechsleri, Pythium* sp., and others

Certain fungi of the soil that cause root rot during the rainy season are widespread in heavy, poorly drained soils with a high organic matter content. *Phytophthora drechsleri* is the most common and important. These pathogens attack young or mature plants, especially when they are near drainage ditches or in poorly drained soils. They cause sudden wilting, severe defoliation and soft root rot. Roots exudate a pungent, watery liquid and decompose completely.

Select a suitable soil for cultivating cassava, install a good drainage system and plant on ridges. Keep the soil clean and drained, rotate cassava with a cereal, or stop planting cassava for a period of no less than six months if indices of root rot in the plantation are higher than 3%.

51. **Phytophthora drechsleri** *root rot.*

52. **Pythium** *sp. root rot.*

Dry root rot (various pathogens) *Rosellinia necatrix, Armillariella mellea, Rigidoporus lignosus,* and others

Certain species of fungi cause considerable root rot during the rainy season, but only when cassava has been planted immediately after forest clearance or after woody perennial species. Among these, *Rosellinia necatrix* is the most important pathogen of the mountainous regions in Latin America. The disease induced by this pathogen is called "black rot" because of the characteristic black color of the infected tissues and the canker-like root lesions that are formed. To avoid this group of diseases caused by pathogens of woody perennial species, it is necessary to rotate with nonsusceptible crops (cereals) before planting cassava. These diseases are generally found just before harvest or at harvesting. Infected crops initially present —in zones or patches— yellowing, then wilting, and finally defoliation and dieback.

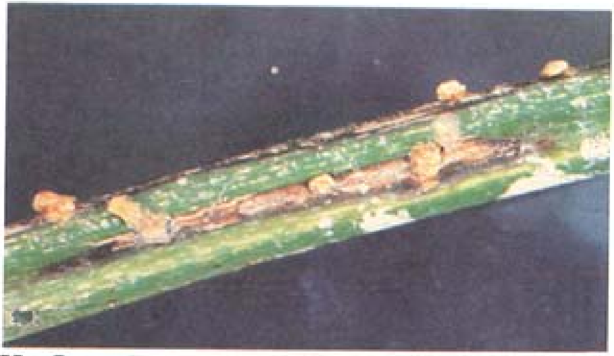
Rotate with cereals whenever plant necrosis or root rot reaches 3%. Remove infected cassava debris and/or debris from perennial trees (decomposing trunks and branches).

53. **Rosellinia** *root rot.*

Dry root and stem rot *(Diplodia manihotis)*

This disease has caused considerable losses in cassava plantations in Africa and Latin America. It has two stages: (1) root rot which is initiated when soils are infested or when cuttings taken from diseased plants are used. Its symptom, similar to that induced by root pathogens, consists in sudden death of the whole plant caused by root deterioration; and (2) stem rot caused by the systemic invasion of the fungus from the roots or through wounds. The fungus produces fruiting bodies (pycnidia), whose fructifications (pycniospores) germinate and penetrate into the aerial part of the plant through any wound. Pycnidia are black, pear-shaped, and are found mainly on the epidermis, where they are readily visible with a magnifying glass. Symptoms at this stage are characterized by necrosis of the vascular system (the phloem, initially), rupture of the epidermis with gum exudation, partial or total wilting and dieback.

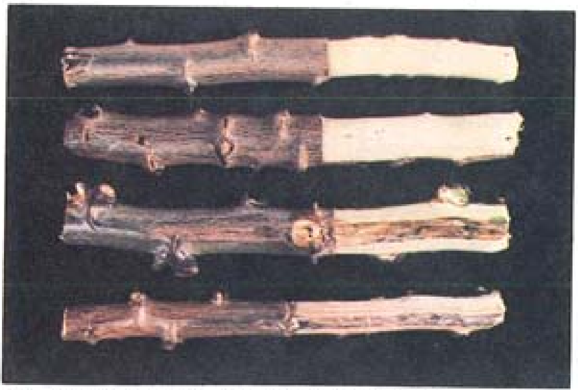
54. *Sudden death caused by* **Diplodia manihotis.**



55. **D. manihotis** *gum exudation.*

These symptoms are very similar to those caused by *X. manihotis* (see bacterial blight), but they differ in that *D. manihotis* produces a large amount of pycnidia in the affected part. The pathogen is disseminated over long distances by the use of cuttings taken from infected plantations and, within the same plot, by the wind and rain carrying the fructifications of the fungus, infested tools, irrigation water and by cultural practices.

To control this disease, rotate with nonsusceptible crops (maize, sorghum, etc.) whenever the infection reaches more than 3%. Do not use planting material from affected plots and disinfest cultivation tools. Varietal resistance has not been found yet.



56. *Healthy and infected cuttings attacked by* **D. manihotis**.

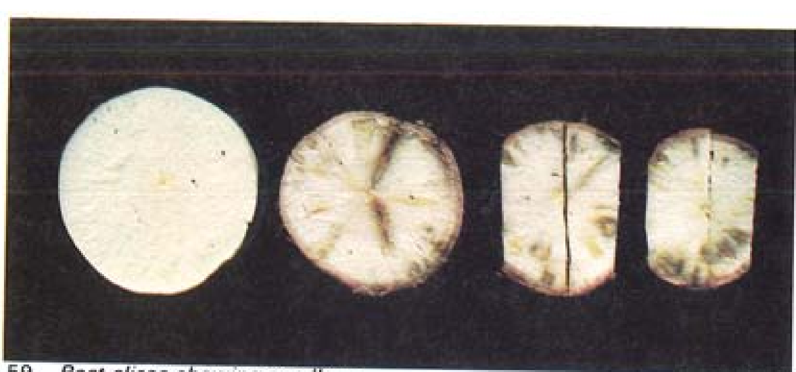
57. *Systemic* **D. manihotis** *invasion from infected roots.*

Root smallpox disease (indirect damage due to localized lesions that can be caused by the subterranean sucking insect and other agents)

This disease has been found in Colombia in association with the subterranean sucking insect *(Cydnidae)*, causal agent of the initial lesion; however, other agents causing similar lesions (e.g., nematodes) can also induce this disease. While sucking, the insect wounds with the stylet the epidermis and cortical zone of the root. The microorganisms penetrating through these wounds cause localized cortical and epidermal rots, due to the degradation of cortical tissues. Lesions are light to dark brown in color, limited by healthy areas, and show fermentation of tissues invaded by microorganisms. Symptoms, visible at harvesting, lessen root quality considerably.

To solve this problem, it is necessary to control the subterranean sucking insect (see pest section) or any other wound-causing agent.

58. *Root necrosis after damage by vector insect.*



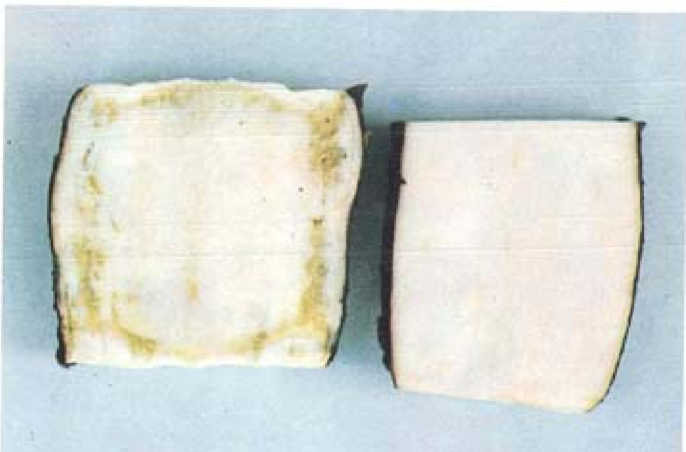
59. *Root slices showing smallpox.*

Postharvest root rot (physiological and/or pathogenic causes)

Cassava roots generally deteriorate a few days after harvesting. This deterioration seems to be related to the cultivar's susceptibility to deterioration and to damage that the roots suffer during harvesting. Roots of some cultivars deteriorate rapidly, whereas those of others remain in good condition for several days. Roots with no mechanical damage remain sound longer, even when the cultivar is susceptible to deterioration. The causes of deterioration have not been determined yet; but it seems that deterioration is a result of physiological and/or pathological effects, taking place during harvesting or immediately afterwards.

Avoid storing cassava roots. Pruning of plants two-three weeks before harvest prolongs storage time, but sprouting should be avoided.

60. *Two degrees of post harvest deterioration as compared with control: physiological (left) and microbial (right).*



61. *Internal post harvest root rot.*

Important Pests

Cassava is attacked by a large number of mites and insects, some of which cause considerable economic losses. Since cassava is a long-cycle crop, the continued application of insecticides for pest control would be very costly. It should be kept in mind that cassava has the capacity to recover from pest attack when climatic conditions are favorable, especially during the rainy season.

Preventive measures

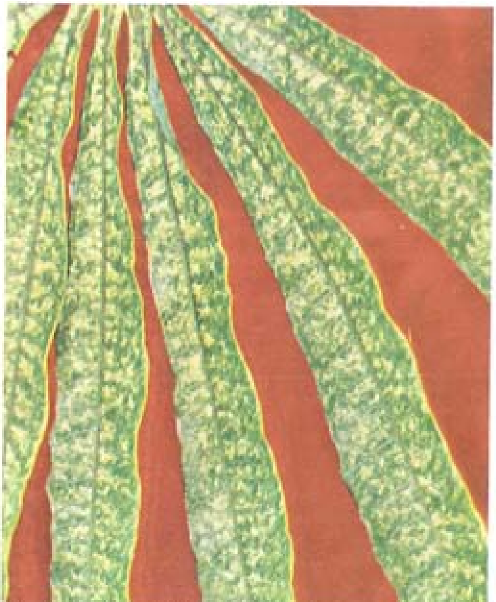
The best control is to maintain a low incidence of pests. The following measures are recommended to achieve this:

1. Use insect and disease-free planting material taken from vigorous plants.
2. Use cultivars that are resistant or tolerant to pests.
3. Do not plant in soils that are highly infested with insects or postpone planting until the population is as low as possible. This can be achieved by applying insecticides to the soil.
4. Do not destroy natural enemies of pests. When pesticides are applied, pests as well as their parasites and predators are killed, increasing the number of harmful insects. Therefore, selective products should be used, i.e., *Bacillus thuringiensis,* against the cassava hornworm.
5. Apply insecticides only when necessary (i.e., when the plant is in no condition to recover without this aid). The insecticide should be selective and, preferably, not very toxic to mammals.
6. Observe quarantine measures to avoid introducing pests to zones where they are not found.
7. Maintain debris-free fields of cassava; stem and root pieces should be collected and destroyed.

Mites *(Mononychellus tanajoa)*

Populations of *M. tanajoa* develop on the upper part of the plant, growing points, young leaves and green portions of the stem. Damage begins as a yellow spotting that later becomes uniform, and takes a blotched, bronzed, mosaic-like appearance. Rudimentary leaves grow with deformations. When the attack is severe, the foliar area is reduced, the stem turns rough and brown, and defoliation and stem necrosis take place progressively from top to bottom. Severe damage stunts plant growth and induces branching.

62. **Mononychellus** *sp. damage to growing point.*



63. **Mononychellus** *sp. leaf damage.*

Tetranychus urticae

T. urticae first attacks mature leaves at the basal part of the plant, then moves to the upper leaves. Damage is more evident on basal leaves. First symptoms generally occur at the base of the leaf and along the midrib. Mite colonies attack mainly the lower surface, but in cases of heavy infestations, they attack both surfaces causing a considerable amount of webbing. Initial spotting becomes reddish or rust-colored as the infestation increases; defoliation takes place from bottom to top and, if dry conditions persist, plants may die.

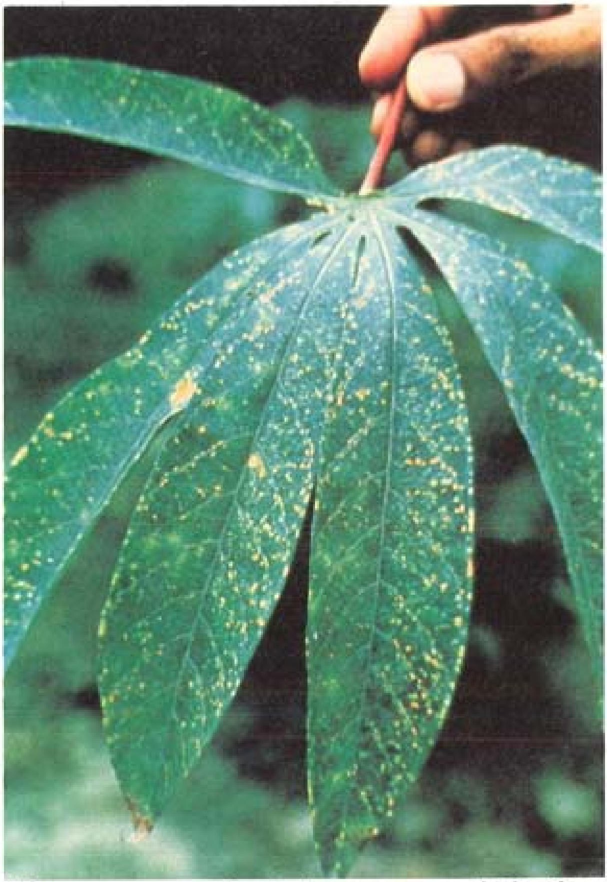
64. **Tetranychus urticae** *damage to leaves.*

65. *Cassava plant attacked by* **T. urticae.**

Oligonychus peruvianus

The presence of this mite can be detected by the small webs spun by the female on leaf margins and along the center and lateral veins on the underside of lower and intermediate leaves. The female lays her eggs under the webs, where larvae and nymphs develop. On the upper leaf surface, small yellowish spots, which later turn brown, are observed. These yellow spots are delimited by the underside webs.

66. *Leaves attacked by* **Oligonychus peruvianus.** *White spots are webs spun by female mite below which immature stages develop.*



67. **Oligonychus peruvianus** *damage on upper leaf surface. Yellow spots correspond to mite colonies on lower leaf surface.*

Mite management

Management of the mite complex should be based on the use of resistant varieties,t he action of its natural enemies, and the application of selective products. Some considerations that should be taken into account are:

1. Mite populations increase during prolonged, dry periods and decrease considerably at the beginning of the rains, inducing rapid plant recovery.

2. Attacks begin on isolated plants, then in patches, and later on, mites invade the entire crop. When necessary, acaricides should be applied to the patches.

3. Products, such as chlorobenzilate (= Acarben) and acricid (= Morocide), which do not affect beneficial insects, should be used.

4. Host plants should be eradicated.

5. The application of water under pressure can reduce mite populations.

Thrips *(Frankliniella williamsi, Corynothrips stenopterus, Caliothrips masculinus)*

Several species of thrips attack cassava, principally in the Americas. The most important is *F. williamsi,* which damages the growing points of the plant. Leaves develop abnormally; young leaves are distorted and deformed, with irregular yellow spots. Brown epidermal wounds are found on the green portion of the stem; internodes are usually shortened. The growing points sometimes die, thereby inducing growth of lateral shoots, which can be attacked with equal severity, giving an appearance of witches' broom. Outbreaks of thrips are more frequent during dry periods, causing losses of up to 25%. Plants may recover at the beginning of the rains when thrips populations decrease.

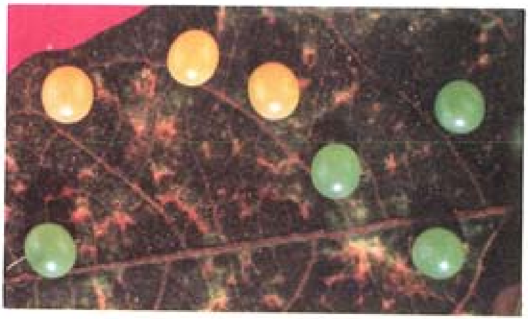
Best control is obtained through the use of resistant cultivars. Systemic insecticides such as dimethoate (1 - 1.5 cc a.i./liter of water) or thiometon (1 cc/liter of water) give good control.

68. *Thrips damage.*

69. *A thrips-susceptible and a thrips-resistant variety.*

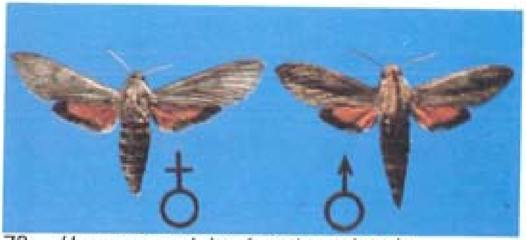
Cassava hornworm *(Erinnyis ello)*

This insect is generally considered as the most important pest of cassava in the Americas. High populations can defoliate large plantations in a short time. When defoliation occurs in the initial phase of crop development, yields are reduced and young plants may die. The ash-colored female is nocturnal; she oviposits up to 1800 light green eggs freely on the leaf surface. Larvae vary in color (yellow, green, black, etc.), reaching a size of 10 to 12 cm before migrating to the soil, where they form chestnut brown or black pupae. Greatest incidence generally occurs at the beginning of the rainy season, but outbreaks are sporadic and may be absent for several years. Sound agronomic practices (weed control, good land preparation) reduce adult and pupa populations.



70. *Hornworm eggs.*

71. *Polymorphism of hornworm larvae.*



72. *Hornworm adults, female and male.*

73. *Hornworm pupae.*

There are several parasites and predators of the cassava hornworm. *Trichogramma* spp. and *Telenomus* sp. parasitize hornworm eggs, and *Chrysopa* sp. is an egg predator. Larvae are parasitized by *Apanteles congregatus* and *A. americanus,* and by Tachinidae flies. The main larval predators are the paper wasps *Polistes canadiensis* and *P. erythrocephalus.* Cassava plantations can be colonized by placing *Polistes'* nets in tentlike protective shelters. One shelter/4 ha and 20 nests/shelter are recommended; nests should have more than 50 cells in order to favor the establishment of colonies. Other larval predators include the Pentatomidae *Alceorhynchus grandis* and *Podisus* sp. Effective control can also be obtained by spraying bacterial suspensions of *Bacillus thuringiensis* (2-3 g a.i./liter of water); *B. thuringiensis* is more effective against the first three larval instars. A larval virus (Baculovirus) and a pupal fungus from the genus *Cordyceps* have also been identified.

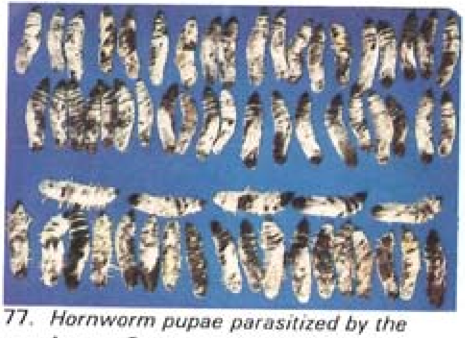
Chemical control with Dipterex sp. 80 (2 g a.i./liter of water) is effective against the larvae, but should be avoided since the beneficial insects are affected, thereby increasing the frequency of attacks. On the other hand, black light traps (BL type) may also be used to capture adults. These traps do not constitute a control method, but facilitate the study of population fluctuations of the hornworm within the plantations, allowing for better planning of the application of the different pest management alternatives.

Natural enemies of *E. ello*.

74. *Hornworm eggs parasitized by* **Trichogramma.**

75. *Paper wasp* **(Polistes sp.)** *predating on hornworm larvae.*

76. *Hornworm larvae parasitized by* **Apanteles** *sp.*



77. *Hornworm pupae parasitized by the fungus* **Cordyceps.**

Shoot flies *(Silba pendula, Carpolonchaea chalybea)*

This pest, found only in the Americas, can damage terminal shoots, resulting in a reduction of plant growth. The adult fly is dark, metallic blue in color; eggs are oviposited among unexpanded leaves in the growing points or in small cavities made by the ovipositor in the plant tissue. After hatching, the larvae tunnel in the young plant tissue and eventually kill the growing point. Several whitish larvae may be found in the affected growing point, where there is generally a yellowish or brown exudate. The death of the growing point retards normal growth and induces the formation of new side shoots that may also be attacked. Young plants are more susceptible; mature plants (3 - 4 months) do not suffer as much as young ones. Since heaviest infestations occur at the beginning of the rainy season, planting should be programmed so that initial crop growth takes place when shoot fly populations are low.

Larvae are difficult to control, but systemic organophosphorous insecticides, such as dimethoate, can be used at commercial rates of application. Plants older than two months do not require insecticide applications. Yield losses due to shoot fly damage have not been reported.

78. *Shoot fly damage to growing point.*

79. *Shoot fly larvae.*

Fruit flies *(Anastrepha pickeli, A. manihoti)*

This fly has been frequently reported as attacking the cassava fruit, causing no economic losses; nevertheless, it can also cause severe damage to the stems. The attack on the stem occurs 10 to 20 cm below the growing point, leaving a small entrance or exit hole. The female, which is yellow in color, oviposits in the stem tissue. Upon hatching, the yellowish white larvae bore their way into the pith region. A bacterial pathogen (see "bacterial stem rot") has been found in association with the larvae; from this association a severe stem rot results. A white latex exudate is often seen flowing from the larval tunnel. Heavy attacks may cause the death of the growing point, thus retarding growth and inducing the formation of lateral shoots. This bacteria-insect association has not caused yield losses but reduces the quality of the propagation material coming from affected plants. Yield losses from 4 up to 33% were recorded when infected material was planted; thus the importance of selecting healthy planting material.

The application of insecticides such as fenthion (1 to 1.5 cc a.i./liter of water) controls the larvae of this insect, making it possible to obtain healthy propagating material.

80. *Fruit fly* **(Anastrepha)** *adult and damage to stem.*

81. *Bacterial stem rot associated with fruit fly attack.*

Whiteflies *(Aleurotrachelus socialis, Aleurothrixus aepin, Bemisia tabaci, B. tuberculata* and *Trialeurodes variabilis)*

Whiteflies have been recorded in the Americas, Africa and Asia. *Bemisia tabaci* is a vector of the African mosaic disease (see chapter on diseases), which causes heavy yield losses in Africa and Asia. Since this disease does not exist in the Americas, and *B. tabaci* does not feed on cassava in America, this species is of minor importance on this continent. The most widespread species in the Americas is *A, socialis;* severe attacks and yield losses caused by this insect have been reported when present in large populations. High populations can be detected by shaking the growing points of the plant, which disturbs the adults into flight. Pupae and nymphs are found on the undersides of the lower and intermediate leaves. Pupae of *A. socialis* are black surrounded by a white waxy excretion and are readily detected on the undersides of leaves. The presence of a sooty

82. *Whitefly* **(Aleurotrachelus socialis)** *adult and eggs.*

83. *Severe damage caused by whiteflies* **(A. socialis)**.

mold is commonly found in association with whitefly attack. Whiteflies are found throughout the year in high rainfall areas. Yield losses up to 76%, due to serious attacks to very susceptible cultivars during 10 months, have been recorded. Pupae are parasitized by the wasps *Amitus* sp. and *Eretmocerus* sp.

To control whiteflies the following insecticides are suggested: dimethoate or fenthion at a rate of 1 and 1.5 cc a.i./liter of water, respectively. Insecticides should only be applied when high populations are present because low populations do not affect yields.

84. *Cassava plants with high whitefly populations.*

85. *Pupa of* **A. socialis.**

White grubs (larvae of Coleoptera belonging to the families *Scarabaeidae* or *Cerambycidae)*

The grubs, whose adult stage is a beetle, attack the cuttings and roots of the cassava plant. Various species have been recorded in many cassava-growing regions of the world. The presence of these larvae can be detected when the soil is being prepared for planting. Damage is characterized by the destruction of the bark of the cuttings and the presence of tunnels in the woody part. These cuttings may rot and die. When young plants (1 to 3 months) are attacked, they suddenly wilt and die. The larvae also feed on the bark of the basal part of the stem, generally in the area immediately below the soil. The larvae are white with black heads and reach up to 5 cm in length. They can generally be found around the cutting or roots of the affected plant. Normally, these insects have one cycle each year.

The most effective control is obtained with aldrin as a dust (1.5 kg a.i./ha) and granular carbofuran (0.09 g a.i./plant), applied to the soil, right under the cutting.

86. *White grub larvae and adults.*

87. *Young cassava plants attacked by white grubs.*

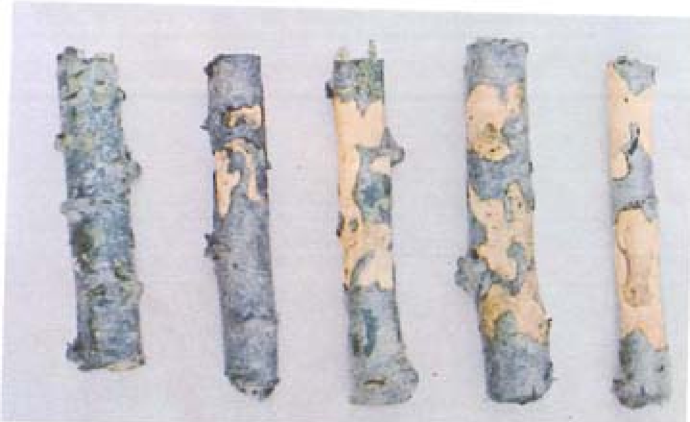
Cutworms (larvae of *Agrotis ipsilon* and *Prodenia eridania)*

There are several species of cutworms that attack cassava. These can be grouped into the following categories:

Surface cutworms. The black cutworm *(Agrotis ipsilon)*, which feeds on the basal part of the stem near the surface of the soil, leaves the plants lying on the ground. The larvae are greasy gray to brown in color, with faint, lighter stripes.

Climbing cutworms. These cutworms climb the stem feeding on the buds and foliage; they may also girdle the stem, causing the upper part of the plant to wilt and die. The larvae of the southern armyworm *Prodenia eridania* have been recorded causing this type of damage in many cassava-growing areas. They are dark gray to black in color, with lateral yellow stripes.

88. *Cutworms attacking the stem cutting.*



89. *Cutworn damage to stem cuttings.*

Subterranean cutworms. These remain in the soil, feeding on the roots and underground parts of the stem. They cause damage to young plants (killing up to 50%), making it necessary to replant. Although the attacks may occur sporadically, they are more frequent when cassava has been planted after maize.

Crickets. The most important species are: *Gryllus assimilis* or the black cricket and *Gryllotalpa* sp. or the mole cricket. The adults cause the major damage by cutting the young shoots right after germination. Occasionally they may also attack the basal part of the young plants, rendering them susceptible to lodging due to strong wind.

All these larvae can be controlled by using poison baits (10 kg sawdust, 8-10 water, 500 g sugar or molasses, and 100 g trichlorfon for ½ to 1 ha). For underground cutworms, applications of aldrin or carbofuran around the cuttings can be effective.

90. *The black cutworm* **(Agrotis).**

91. *Crickets.*

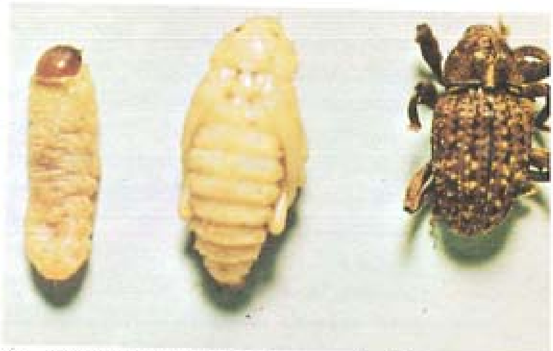
Stemborers (various species of Coleoptera, Lepidoptera and Hymenoptera)

Many insect species feed on the stems and branches of cassava plants, causing considerable damage. These stemborers are distributed worldwide; but they are particularly important in the Americas, where they cause sporadic or localized damage. Most stemborers are the larval stage of Coleoptera *(Coelosternus* sp. and *Lagochirus* sp.), Lepidoptera *(Chilomima* sp.) and Hymenoptera. The larvae vary in size and shape, depending on the species; some reach a size of 30 mm in length. They are usually white, yellow or tan in color and can be found tunneling through the aerial part of the plant. The stems and branches may break because of strong winds or be reduced to sawdust. During dry periods, affected branches may lose their leaves and dry up; when the infestation is severe, the plants may die. A stemborer attack is very easily detected by the presence of excreta, sawdust and exudate ejected from burrows made by the insect in the infested branches; the insects can be found at the site of infestation or on the ground, beneath the plant.

Control with pesticides is impractical since it is difficult to kill the larvae inside the stems. Populations can be reduced by removing the infested parts of plants and burning them. Always use disease-free cuttings for planting. Maintain fields free of cassava stem debris.

92. *Larvae of* **Chilomina** *sp.*

93. *Adult of* **Chilomina** *sp.*



94. *Coleopteran larvae, pupae and adult.*

95. *Adult of* **Lagochirus** *sp.*

96. *Larvae, pupae and damage of* **Lagochirus** *sp.*

Scale insects *(Aonidomytilus albus, Saissetia miranda,* others)

Several species of scales attack cassava stems and leaves. The incidence of this insect is greater when scale-infested planting material is used; in these cases, the scale population may increase rapidly and cause greater damage to plants. Yield losses up to 20% have been recorded. *A. albus* can cause leaves to yellow and fall. When damage is severe, the stem is completely covered with scales, plant growth is stunted, the stems may dessicate, causing plant mortality. Although some species attack the leaves, the greatest damage seems to be related to the loss of propagation material: the germination of heavily infected cuttings is greatly reduced; and when they do germinate, the roots are poorly developed, and their quality reduced. Heaviest outbreaks occur during dry periods, becoming worse during prolonged periods of drought.

Most effective control is obtained by using disease-free cuttings and by removing and burning infested plants to prevent later dissemination. Since scales attacking buds may pass unnoticed when in low populations, cuttings may be treated with Formula No. 1 or Formula No. 2 of Appendix 1, but using Malathion C.E. 57%.

97. *The black scale*
Saissetia miranda

98. *The white scale* **A. albus.**

Mealybugs *(Phenacoccus* spp.)

In recent years mealybug problems in cassava have increased, especially in Africa and Brazil, due to increased populations of the pest. Several species have been identified; these include *P. gossypii* (Colombia), *P. grenadensis* (Brazil), *P. manihotis* (Africa, Paraguay) and *Phenacoccus* sp. (Colombia, Brazil).

In Africa *P. manihotis* Matile-Ferrero has been identified as a seriòus problem in cassava since 1970; this pest is especially damaging within the African environment where there are few natural enemies.

In the Americas, mealybug populations have usually remained low due to the extensive complex of natural enemies; nevertheless, occasional outbreaks of the pest do occur. These outbreaks usually are due to the indiscriminate use of pesticides to control other pests.

Mealybugs cause two types of damage; a mechanical or direct damage caused by their sucking feeding habits, and an indirect damage produced by the build-up of sooty mold on the leaf surface due to mealybug excrement. This fungus build-up causes reduced leaf photosynthesis. Feeding by *P. gossypii* causes leaf yellowing and eventually defoliation beginning with the basal leaves. Attacks by *P. manihoti* and *Phenacoccus* sp. start at the apical part of the plant, often causing a cabbage-like effect to the growing point.

99. *Plants attacked by* **Phenacoccus.** *spp.*

100. *Plants attacked by* **P. gossypii.**

Parasites. Seven parasites, all belonging to the order Hymenoptera and divided into four families, were found at CIAT. The most frequent is *Anagyrus* sp., which has been reported in all countries where research on mealybugs is being conducted. *Anagyrus* sp. is a very specific, nymph and female parasite.

Predators. Two dipters, *Ocyptamus stenogaster* Complex (Sirphidae) and *Kalodiplosis coccidarum* (Felt) (Cecidomyiidae), whose larvae are egg predators, were found at CIAT. The most specific coccinellids for mealybugs were *Coccidophilus* sp., *Cleothera* sp. and *Scymnus* spp., the latter being the most frequent. Other predators, found in high populations in the field, are *Chrysopa* sp. and *Sympherobius* sp. In areas subject to mealybug attack, cuttings should be treated with Formula No. 2, Appendix 1.

101. **Ocyptamus stenogaster.**

102. *Ovisac of* **P. gossypii** *containi.* **K. coccidarum** *larva*

Natural enemies of the mealybug

103. **Coccinellidae,** *predator of* **P. manihotis.**

104. *Adult of* **Chrysopa** *sp.*

Lace bugs *(Vatiga manihotae* and *Vatiga illundens)*

Lace bugs have been reported attacking cassava in several South and Central American countries. The species *V. manihotae* and *V. illudens* have been recorded in Colombia and Brazil, respectively. Economic damage caused by these species has not been determined yet. Lace bug attacks occur mainly during the dry season, damage being greater with prolonged droughts. Adults are gray in color and about 3 mm long. Nymphs are white and slightly smaller; both adults and nymphs are found in large quantities on the undersides of leaves. Insect populations are usually limited to lower and intermediate leaves, but, when the attack is severe, they may reach the apical leaves. Damaged leaves have small yellow spots that later turn reddish brown, resembling mite damage. Considerable damage can be done to all the foliage of one plant. In addition, the rate of photosynthesis decreases and lower leaves fall.

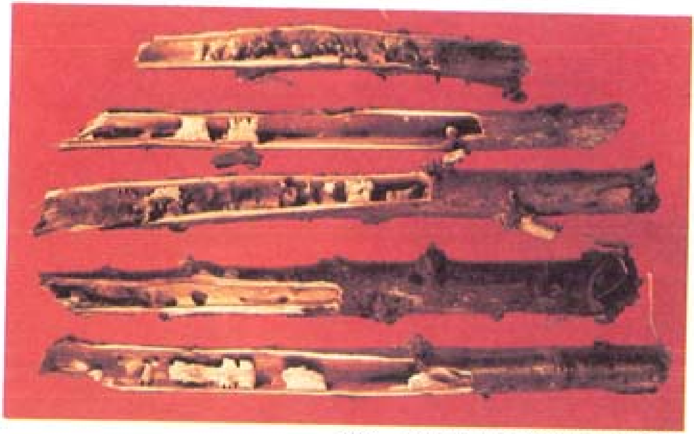
This pest can be controlled using organophosphorous insecticides; however, lace bugs may repeat their attack, and continuous pesticide applications are not only costly but can destroy the natural enemies of other pests.

105. *Lace bug leaf damage.*

106. *Lace bug adults and nymphs; black spots are the insects excrement.*

Termites *(Coptotermes* spp.)

Termites have been found attacking cassava in the tropical lowlands. They feed on propagation material (cuttings), on roots, or on those parts of growing plants that are wilting or dying due to unfavorable climatic conditions, pathogens or low quality planting material. Since termites are vectors of different pathogens attacking cassava, it is necessary to protect the cuttings before crop establishment in order to obtain good bud germination and plant development. This can be achieved using fungicide mixtures, such as captan + BCM (3 g a.i./liter of water), and then dusting the cuttings or the soil with aldrin at a rate of 0.025 g a.i./cutting or site.



107. *Termite damage to cuttings.*

108. *Termite damage to roots.*

Leaf-cutting ants *(Atta* sp., *Acromyrmex* sp.)

Several species of ants can defoliate a plantation rapidly when a large number of worker ants invade it. They cut semicircular pieces of leaves, which they then carry to their nests; in heavy attacks, even the buds are removed. Outbreaks usually occur during the first month of crop growth, but their effect on yield is not yet known. Their nests can usually be seen easily because of the piles of dirt deposited around the entrance holes.

Insecticides are the most effective means of control. Ants can be destroyed in the nest by fumigating with carbon disulfide, sulfur smoke or arsenates. Aldrin (in powder and solution), heptachlor, dieldrin, BCH, applied in or around the nest, also give good results. Granular mirex, spread along the ant trails leading to the nests, is carried into the nest by the ants, giving effective control also.

109. *Damage caused by leaf-cutting ants.*

110. *Leaf-cutting ant nests.*

Gall midges [*(Jatrophobia brasiliensis)* (species of the Cecidomyiidae family)]

Several species of flies that induce galls on cassava have been recorded in the Americas. These small flies are generally found on the leaf upper surface where they lay their eggs. The larvae cause abnormal cell growth, forming galls. The galls, found on the upper leaf surface, are yellowish green to red in color, narrow at the base and often curved. When the galls are opened, a cylindrical tunnel with the larva inside can be seen.

Gall midges are generally of little economic importance and therefore do not require control. Nevertheless, there have been cases of retarded growth when there are severe outbreaks in young plants (2 to 3 months). To reduce their incidence, infected leaves should be collected and destroyed at weekly intervals.

111. *Leaf galls.*

112. *Galls on the upper and lower leaf surface.*

Subterranean sucking insect (Hemiptera: cydnidae, *Cyrtomenus bergi* Froeschner)

Nymphs and adults of this insect feed on cassava root by means of a thin and strong stylet, which permits them to reach the parenchyma. After removing the cuticle of attacked roots, small, brown to black spots, corresponding to the sites where the insect inserted its stylet, are clearly visible. These sites serve as entrances for microorganisms which cause the complex known as root smallpox disease. Adults are black in color, with short legs, provided with strong spines, which help them to move in the soil; the nymphs have a yellowish white abdomen. This subterranean insect is difficult to find not only because of its color but because it can remain immobile. Occasionally, these insects are found attached to the roots at harvest. Their presence can be detected by the offensive odor they produce and because the soil looks disturbed due to their tunneling. Serious attacks have been observed in cassava plantations previously planted to sugar cane or pastures.

Crop rotation with nonsusceptible plants is recommended to control this insect. Insecticides used to control white grubs are equally effective.

113. *Nymphs and adults of* **Cyrtomenus bergi.**

114. *Root damage caused by* **Cyrtomenus bergi.**

Nutritional Deficiencies and Toxicities

Although cassava is well adapted to grow on poor soils, the crop requires rather high rates of fertilization to attain maximum yields and maintain the soil's fertility. Because large amounts of potassium are removed in the root harvest, soil potassium reserves may become depleted with continuous cassava production without adequate fertilization.

Deficiencies of macronutrients do not always result in easily noticeable symptoms; rather, they are reflected in reduced growth and yields. As a result, many farmers never notice the existence of these deficiencies, and never realize the crop's yield potential.

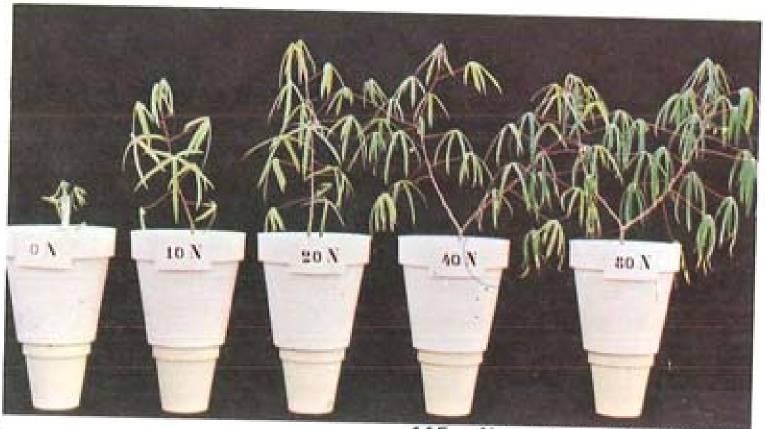
Among the macronutrients, phosphorous deficiency is the most common in the vast areas of oxisols, ultisols and inceptisols of tropical America. In Africa and Asia, nitrogen and potassium deficiencies may be more common. Cassava also seems to be sensitive to magnesium and sulphur deficiencies. Among the micronutrients, zinc deficiency is the most common, and the crop appears to be particularly sensitive to an inadequate supply of this element at the early growth stage. Other micronutrient deficiencies are rather uncommon, but copper deficiency has been shown to be a main limiting factor on the peat soils of Southern Malaysia.

Cassava is generally well adapted to acid soils. High applications of lime are seldom necessary and may induce deficiencies of minor elements, especially zinc. However, cassava is sensitive to salinity and alkalinity. Nevertheless, there are cultivars with a high degree of tolerance to salinity; in this case, the selection of tolerant cultivars is the best solution to this problem.

Nitrogen (N) deficiency

Nitrogen deficiency significantly reduces plant growth and root yields, but many cultivars do not show clearly distinguisheable symptoms. Photograph 115 shows cassava plants growing in sand culture with different levels of N applied as a nutrient solution. Stunting of plants occurred at low levels of N, but there was no typical yellowing of leaves. Other cultivars (photo 116) show a general and uniform chlorosis of the leaves at suboptimum nitrogen concentrations. Photo 117 shows nitrogen deficiency in the field. The nitrogen-deficient plants in the foreground are small and pale green, compared with healthy plants in the back.

Nitrogen deficiency is not as common in cassava as in many other crops, but it can be found in infertile sandy soils or in acid soils (e.g., oxisols and ultisols). In these soils, the application of N should be moderate (50-100 kg/ha) since root yields decline if N is applied in excess. Applications



115. *N response in sand culture.*

should be made at planting and then at two or three months, or whenever the plant starts growing vigorously after a prolonged period of drought or cold temperature. In very sandy soils, N may have to be applied more than twice and in smaller doses so as to prevent leaching. Soil applications of fertilizers after canopy closure (3-4 months normally), however, are impractical. No significant differences have been observed between various N sources such as urea, ammonium sulphate, calcium nitrate or sodium nitrate. Slow-release nitrogen sources, such as sulphur coated urea, were not superior to fractionated normal urea.

Normal N levels in upper fully expanded leaves at 3-5 months after planting range from 4.5 to 6.0% for the blades and 1-2% for the petioles, while stems and roots are extremely low in this element containing between 0.25 and 1% N.

116. *General chlorosis due to N deficiency.*

117. *N deficiency on sandy soils.*

Phosphorus (P) deficiency

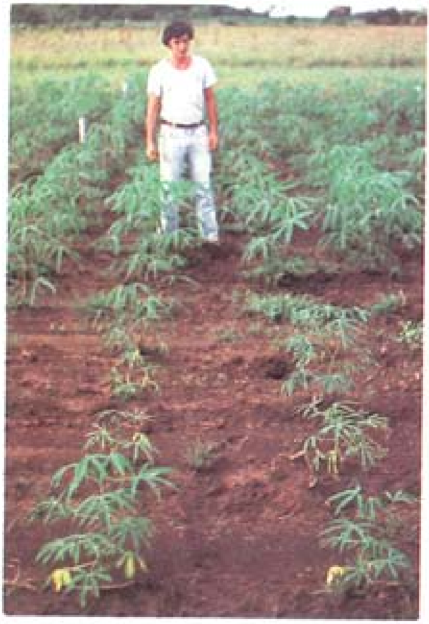
Phosphorus deficiency can markedly reduce plant growth and yields without showing clear leaf symptoms (photo 118). In that case plants have thin stems, narrow leaves and fewer lobes. Photo 119 shows P deficient plants on the left and normal plants on the right and in the back. Note the marked difference in plant height and canopy density, but the lack of clear symptoms in the deficient plants. Hence, mild deficiencies can only be diagnosed by plant analysis, soil analysis or field experimentation. However, under conditions of severe deficiency many cultivars show clearly recognizable symptoms: a few droopy yellow lower leaves, which later become necrotic and fall off (photo 120). Unlike in the case of N deficiency, the top leaves retain their healthy dark green color but may be small and pendent (photo 121).

118. *P response in solution culture.*

119. *P response in an oxisol.*

Phosphorus deficiency is common in oxisols, ultisols and certain inceptisols (volcanic ash soils). It can be corrected by band application of highly soluble P fertilizers such as triple and simple superphosphates, or by incorporation of less soluble sources such as basic slag, thermophosphates and rock phosphates. The latter are good sources of P in acid soils. All P sources should be applied to the soil before or at time of planting.

Normal P levels in the youngest fully expanded leaf blades range from 0.3 to 0.5% and in the corresponding petioles from 0.12 to 0.20%. The critical available P content of the soil is about 8-10 ppm extracted with Bray II, 6-7 ppm with Bray I, and 4-5 ppm with Olsen-EDTA.



120. *P deficiency in foreground.*

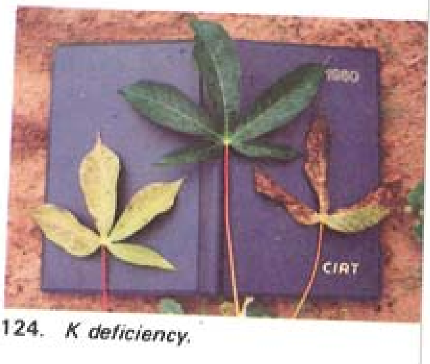
121. *P deficiency.*

Potassium (K) deficiency

Potassium deficiency is characterized by a reduction in plant height and vigor, thin stems, short petioles and small leaves, as indicated by photograph 122. Only in case of very severe deficiency are specific symptoms observed: initially small purple spots on the lower leaves followed by curling and chlorosis of the leaf margins and tips, which finally develop into a border necrosis of the older leaves (photographs 123, 124). These leaves senesce prematurely and fall off. The necrotic spotting is often due to antracnoses associated with K deficiency. In field grown cassava, severe K deficiency in some varieties is characterized by grooves and cracks in the upper stem, which is followed by a premature lignification (photo 125). The upper stem tends to be crooked and has short internodes. Plants have a highly branched growth habit (photograph 126).

122. *K deficiency on right.*

123. *Severe K deficiency.*



124. *K deficiency.*

Potassium deficiency is most common on sandy soils as well as on low-base-status oxisols and ultisols, while many volcanic ash soils are well supplied with K. Cassava roots are relatively high in K, and with each 25 t/ha root harvest, about 100 kg K is removed from the field. Thus, continuous cassava production without adequate K fertilization may lead to soil exhaustion. Potassium is generally band applied as KCl, at the rate of 100-150 kg K/ha, half at planting and half 2-3 months thereafter. High rates of K application may result in low yields due to the induction of Mg deficiency, or due to Cl-induced S deficiency. Thus, in low S soils, the use of K_2SO_4 or of KCl mixed with S is recommended.

Normal levels of K in the youngest fully expanded leaf blades range from 1.2 to 2.0%, and in the corresponding petioles from 1.5-3.0%, while roots contain about 0.5-1.0%. Because the upper petioles are more sensitive to fluctuations in the K supply than the leafblades, the sampling of this tissue is often recommended for diagnosing K deficiency. Critical K-levels in the soil have not yet been well established, but a tentative range of 0.09-0.15 meq/100 g in neutral ammonium-acetate extract has been reported.

125. *Crooked stem due to K deficiency.*

126. *Prostrate growth due to K deficiency.*

Calcium (Ca) deficiency

Calcium is an element of low-phloem mobility, thus not readily retranslocated within the plant. For normal growth, plants require a continuous supply of Ca, and if this supply is inadequate, deficiency symptoms develop mainly on the youngest, actively growing tissue, both of the top and of the roots. Thus, Ca deficiency is characterized by poor root formation as indicated by photograph 127, and by yellowing (photo 128) with burning and deformation of the tips of youngest leaves, as shown by photographs 129 and 130. These symptoms are not commonly seen in field grown cassava, as most soils are either adequately supplied with Ca, or receive enough Ca through applications of lime or simple superphosphate. Moreover, cassava was shown to be more tolerant to low levels of Ca than many other species.

127. *Root growth response to Ca.*

128. *Ca deficiency.*

Calcium deficiency is most likely to occur on sandy soils or on low-base-status oxisols and ultisols with high levels of exchangeable aluminium. The latter can strongly inhibit Ca uptake by the plant. Calcium is generally supplied as calcitic or dolomitic lime or as calcium oxide or hydroxide; calcium sulphate (gypsum) can also be used in soils without toxic levels of aluminium or manganese.

Normal levels of Ca in the youngest fully expanded leaf blades range from 0.6 to 1.5% and in the corresponding petioles from 1.5 to 3%. Unlike the phloem mobile nutrients, Ca concentrations tend to be higher in lower than upper leaves. Stems have a relatively high Ca concentration of 0.6 to 1.0% while roots generally contain less than 0.1%.

129. *Ca deficiency.*

130. *Ca deficiency.*

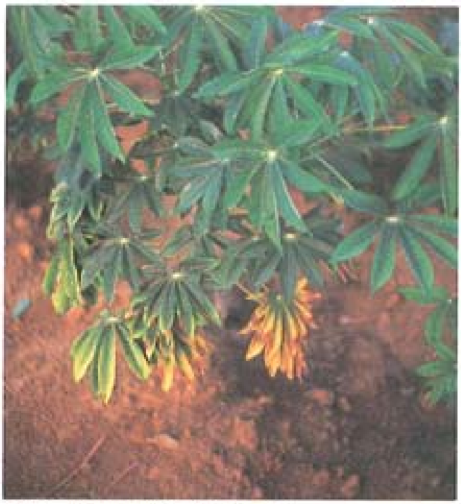
Magnesium (Mg) deficiency

Plants suffering from magnesium deficiency have typical symptoms of interveinal chlorosis or yellowing of the lower leaves, as indicated by photograph 131. The yellowing begins towards the tip or edges of the leaves, advancing towards the center. Under severe Mg deficiency conditions, the leaf margins may become necrotic, as shown in photograph 132. High applications of K can induce severe symptoms of Mg deficiency. In solution culture experiments, cassava was found to be more susceptible to Mg deficiency than several other species.

Magnesium deficiency is most likely in sandy soils, in oxisols and ultisols of low base status, as well as in high K volcanic ash soils. The element is generally supplied by incorporation of 20-50 kg Mg/ha as dolomitic lime, magnesium oxide or sulphate. The latter may also be band-applied at planting, and is the preferred source for soils low in sulphur.

Normal Mg levels in the youngest fully expanded leafblades range from 0.25 to 0.30% and in the petiole from 0.3 to 0.4%. At high levels of applied Mg the concentration tends to be higher in the petioles than in the corresponding leafblades.

131. *Mg deficiency.*



132. *Severe Mg deficiency.*

Sulphur (S) deficiency

Sulphur deficiency is characterized by a uniform chlorosis or yellowing of leaves, similar to that due to N deficiency (photo 133). Although S is usually considered a phloem mobile element, in cassava it seems to have low mobility. Hence, deficiency symptoms are not necessarily confined to the lower leaves; in fact, in nutrient solution experiments symptoms were found exclusively on the younger leaves (photo 134), while in field grown cassava they were found in the bottom and middle part of the plant (photo 135). Cassava may be particularly sensitive to S deficiency since symptoms were observed at a site where other field crops failed to show these symptoms. High application of K in the from of KCl induced S deficiency symptoms in cassava.


133. *S deficiency.*


134. *S deficiency in nutrient solution.*

Sulphur deficiency has been reported in many oxisols and ultisols in Latin America as well as in Australia. Near industrial centers much of the plant's S requirement is met from the high S content in the air. Hence, S deficiency is more common in areas far removed from industrial centers. Sulphur can be applied at a level of 10-20 kg S/ha as elemental sulphur or in the form of sulphates such as potassium, magnesium or ammonium sulphate, or as simple superphosphate and gypsum.

Normal S levels in youngest fully expanded leaf blades range from 0.3-0.4%, and in the corresponding petioles about 0.13-0.15%. Lower leaves, stems and roots were found to be very low in S.

135. *S deficiency in an oxisol.*

Zinc (Zn) deficiency

Zinc deficiency is very common in cassava and produces a characteristic interveinal chlorosis of the upper leaves. Initially, little white or yellow spots or patches appear between the veins (photo 136), but as the plant grows, each successively formed leaf is smaller and more chlorotic with very small and narrow lobes, all pointing away from the petiole (photo 137). At this stage the youngest leaves are very light green to nearly white and may grow in a typical rosette form. Although zinc deficiency symptoms appear mainly in the upper leaves, in some cultivars the lower leaves produce necrotic spots, rather similar to those due to boron toxicity or *Phaeoramularia manihotis,* as shown by the right hand plant in photograph 138. In the field, Zn-deficient plants are generally small and chlorotic (photo 139). High applications of lime to acid soils can easily induce Zn deficiency and reduce yields. Large cultivar differences have been observed in susceptibility to Zn deficiency.

136. *Zn deficiency.*

137. *Severe Zn deficiency.*

Zinc deficiency is common in alkaline soils due to decreased Zn availability at high pH. It has also been observed in acid soils of low total Zn content, especially after application of high rates of lime or P. Zinc can be incorporated at rates of 10-20 kg Zn/ha as zinc oxide or band applied at rates of 5-10 kg Zn/ha as zinc sulphate. The latter source may also be applied to leaves at a concentration of 1-2%; the immersion of planting stakes in a solution of 2-4% zinc sulphate for 15 minutes before planting is a cheap and effective method to prevent Zn deficiency at the early stage of growth.

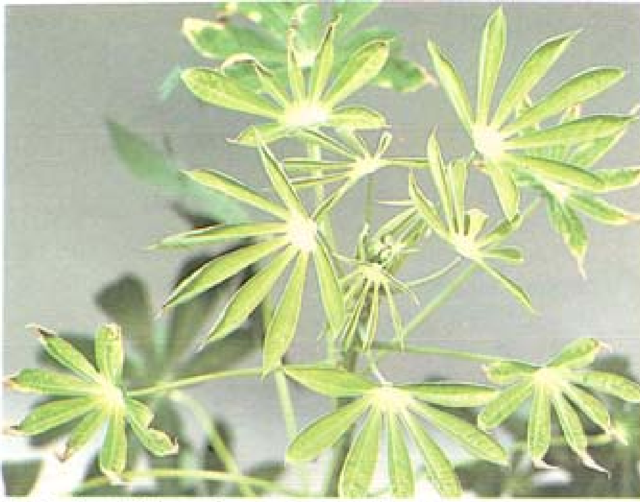
Normal Zn levels in the youngest fully expanded leaf blades range from 50 to 100 ppm, and symptoms of Zn deficiency are generally observed when the concentration of this element is below 20 ppm in upper leaves.

138. *Zn deficiency.*

139. *Zn deficiency in oxisol.*

Copper (Cu) deficiency

Copper deficiency in cassava is not common but severely reduces yields on the peat soils of Southern Malaysia. The deficiency is characterized by uniform chlorosis and deformity of the young leaves. Often the leaf tips become necrotic, and the leaf edges are either cupped upward or downward (photo 140). Stem internodes are not seriously reduced, so plant height may be nearly normal even with rather severe Cu deficiency. Fully expanded leaves tend to be large and suspended on long droopy petioles (photo 141). Similar symptoms were observed in Cu-deficient peat soils of Malaysia (photo 142). Under very severe conditions stem tips may dieback, followed by new growth at the base of the plant. The deficiency can also seriously affect root growth as shown in photograph 143.



140. *Cu deficiency in nutrient solution.*

141. *Cu deficiency.*

Copper deficiency is commonly found in soils of high pH or high organic matter content (peat soils) in which Cu availability is low; it may also occur on acid sandy soils of low total Cu content. It can be corrected by soil application of 2.5-3.5 kg Cu/ha as copper sulphate. Excess Cu is highly toxic, and lower rates are recommended for sandy soils. A stake dip in 1% copper sulphate seriously impaired germination.

Normal Cu levels in upper fully expanded leaf blades range from 7 to 15 ppm and from 2 to 10 ppm in the roots. Plants with severe Cu deficiency had Cu concentrations of less than 7 ppm in upper leaves.

142. *Cu deficiency in Malaysian peat soils.*

143. *Poor root growth due to Cu deficiency.*

Iron (Fe) deficiency

Iron deficiency results in a uniform chlorosis of the youngest leaves, rather similar to that due to N deficiency. Initially the veins remain green (photo 144), but under more severe conditions the veins loose their green color and the whole leaf including petioles turn light yellow to almost white (photo 145). Leaves are not deformed but only reduced in size; likewise, plant height is reduced (photo 146, plants on left). Iron deficiency can be induced by toxic levels of manganese in the soil, as well as by high concentrations of zinc or copper. Cassava was more tolerant to Fe deficiency than maize or rice.

144. *Fe deficiency.*

145. *Severe Fe deficiency.*

Iron deficiency is not common in cassava, but has been observed on calcareous soils of the Yucatan peninsula in Mexico, in association with zinc and manganese deficiency (photo 147). It can also be expected on high-Mn volcanic ash soils. The deficiency may be induced by liming acid sandy soils of low Fe content or by high application of P. Iron deficiency is best controlled by a foliar spray of iron chelate or 1-2% ferrous sulphate. A stake dip in 5% ferrous sulphate for 15 minutes before planting had no adverse effect on germination.

Normal Fe levels in upper fully expanded leaf blades range from 60 to 200 ppm, while the corresponding petioles contain only 30 to 50 ppm Fe. Thus, for diagnostic purposes, blades and petioles should never be mixed in the same sample.

146. *Fe response in nutrient solutions.*

147. *Fe deficiency on calcareous soil.*

Manganese (Mn) deficiency

Manganese deficiency results in an interveinal chlorosis of young fully expanded leaves. Unlike Fe deficiency, the newly emerging leaves tend to be green (photo 148), while in the chlorotic leaves the boundary between green veins and the yellow interveinal tissue is generally diffuse. Thus, the green veins stand out clearly on a yellow background like a "fishbone" pattern. Under very severe Mn deficiency conditions, even the uppermost leaves are yellow and the veins loose their green color, as indicated by the lower left leaf of photograph 149. As in the case of Fe deficiency, the affected leaves are not deformed, but may be smaller in size, while plant height is also reduced (photo 150). Although Mn deficiency symptoms generally appear in younger leaves, they may be found on almost any part of the plant (photo 151), as new healthy leaves are formed as soon as Mn availability in the soil improves. This generally happens during periods of heavy rain, when temporary waterlogging may reduce higher oxides of manganese to Mn^{2+} form which is available to the plant.

148. *Mn deficiency in nutrient solution.*

149. *Mn deficiency symptoms.*

Manganese deficiency is not very common, but has been observed in calcareous soils of the Yucatan Peninsula of Mexico, in high pH soils at CIAT in Colombia, and on acid sandy soils in Bahia, Brazil. It may also be expected in organic soils. The deficiency can be corrected by soil application of manganese oxide or sulphate, or by foliar sprays with Mn-chelate or sulphate. A stake dip in 5% manganese sulphate had no adverse effect on germination.

Normal Mn levels in upper fully expanded leafblades range from 50 to 250 ppm. Lower leaves have higher Mn concentrations than upper leaves, especially under conditions of high Mn supply.

150. *Mn response in nutrient solution.*

151. *Mn deficiency in the field.*

Boron (B) deficiency

Symptoms of B deficiency are seldom seen in the field, but can be produced readily in solution culture. Being a phloem-immobile element, B deficiency affects mainly the growing points of tops and roots. Plants show suppressed development of lateral roots and sometimes death of the root tip (photo 152). Boron-deficient plants are typically short, because of a marked reduction in internode length towards the growing point (left plant, photo 153). Upper leaves are dark green, small and deformed, and carried on short petioles. Lower fully expanded leaves develop a chlorosis of minute grey, brown or purple specks concentrated mainly near the tip and margins of the leaf lobes (photo 154). A distinctive characteristic of B deficiency is the development of lesions on the stem and petiole, from which a brown gummy substance exudes (photo 155). Later these lesions develop into stem cankers.

152. *Death of root tips due to B deficiency.*

153. *B response in nutrient solution.*

Cassava appears rather tolerant to B deficiency as no symptoms and no B response has been observed in very low B-soils in Colombia. However, in Southern India, significant responses to B application have been obtained in oxisols. In nutrient solutions of various temperatures, it was found that B deficiency was most easily induced at low temperatures (19°C). Thus, B deficiency might be expected more in cold-climate regions. The deficiency can be controlled by band application of 1-2 kg B/ha as borax or other sodium borates. Higher rates may be toxic, and a stake dip in a borax solution of more than 1% caused B toxicity (photo 158).

Normal B levels in youngest fully expanded leaves range from 20 to 100 ppm.

154. *Leaf symptoms of B deficiency.*

155. *Exudate due to B deficiency.*

Boron (B) toxicity

Boron toxicity is characterized by white or brown spots on lower leaves (photo 156). The spots are usually surrounded by a dark brown halo (photo 157). Later these spots may become necrotic, join up, and form a border necrosis, after which the affected leaves fall off.

Natural B toxicity has not been reported for cassava, but might be expected in some high-B alkaline soils. However, B toxicity symptoms due to excessive or non-uniform B application have been

156. *B toxicity symptoms on lower leaves.*

observed in field-grown cassava (photo 158). Generally, lower leaves become chlorotic around the margins, which curl up; this is followed by border necrosis and leaf fall. Plants generally recover as B is not easily redistributed within the plant.

Boron concentrations above 140 ppm in plant tops were found to be associated with B toxicity.

157. *B toxicity.*

158. *B toxicity in the field.*

Aluminium (Al) toxicity

Aluminium toxicity is often confounded with other associated problems of soil acidity such as low pH or deficiency of Ca, Mg, Mo, or P. High concentrations of Al in the soil solution mainly affect plant height, vigor and root development. At high Al concentrations, and in the presence of an adequate supply of P and Ca, the plants show an interveinal chlorosis of the older leaves. Sometimes necrotic spots develop within the chlorotic area (photo 159), and these leaves may fall off.

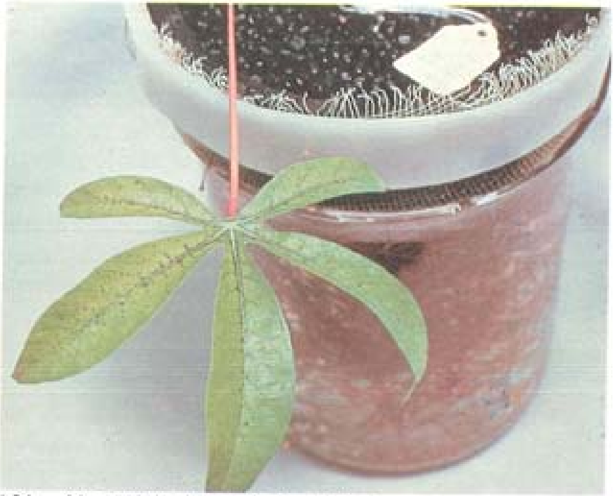
In general, cassava is very tolerant to high levels of Al in the soil, but large differences in this respect exist between cultivars (photo 160). Thus, cultivars can be selected that will grow on very acid high Al soils. High levels of exchangeable Al are found in oxisols, ultisols and inceptisols at soil pH values of less than 5. In general, cassava will tolerate soil pH values as low as 4.6 and up to 80% Al saturation of the effective exchange capacity. If necessary, aluminium toxicity can be reduced by liming; however, large applications of lime may induce micronutrient deficiencies, especially that of Zn.

159. *Al toxicity in nutrient solution.*

160. *Cultivar differences in Al tolerance.*

Manganese (Mn) toxicity

Manganese toxicity symptoms usually develop first as small dark brown spots concentrated along the veins of bottom leaves (photo 161). At a more advanced state these leaves become yelow and hang flaccid from the petiole (photo 162). Eventually they fall off. Manganese toxicity also affects the root system as shown by the right hand plant in photograph 163. Since an excessive supply of Mn inhibits the uptake of Fe, the upper part of the plant may show symptoms of Fe deficiency, while bottom leaves show symptoms of Mn toxicity (photo 164). Cassava was found to be more tolerant of Mn toxicity than cowpea and Phaseolus beans, and less tolerant than some other species like pigeon pea and Centrosema.

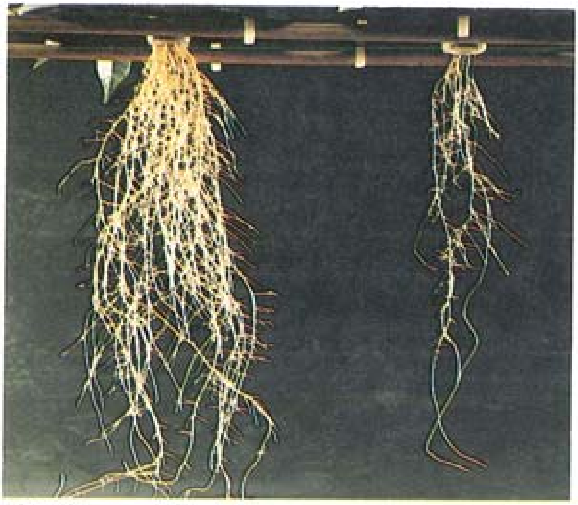


161. *Mn toxicity in nutrient solutions.*

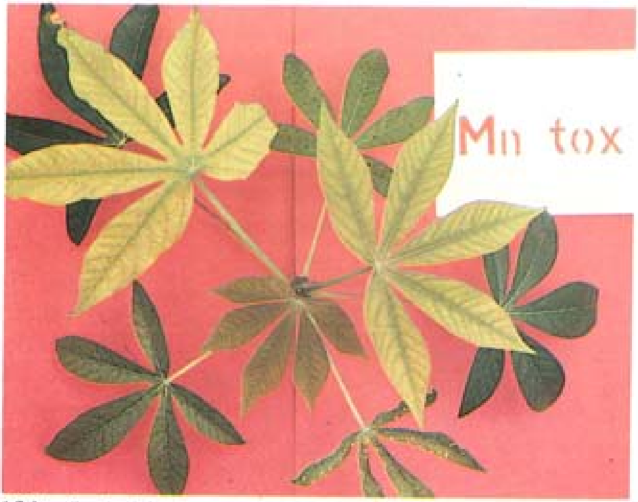
162. *Mn toxicity in volcanic ash soil.*

Manganese toxicity is common on acid high-Mn volcanic ash soils as well as on acid hydromorphic soils. Since higher oxides of Mn are reduced to plant available Mn^{2+} during waterlogging, Mn toxicity is most severe in poorly drained soils during the wet season. However, severe symptoms of Mn toxicity and partial defoliation may result in the dry season due to excessive accumulation of Mn in the lower leaves during periods of stagnated growth. Manganese toxicity can be reduced by liming and by improvement of drainage.

Critical levels for Mn toxicity were found to range from 250 to 1450 ppm in whole tops of various cultivars. A level of 1000 ppm in upper fully expanded leaves was also associated with Mn toxicity.



163. *Poor root development due to Mn toxicity.*



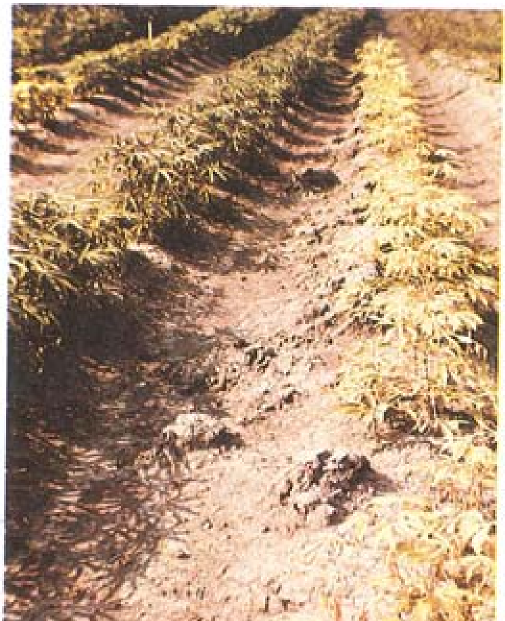
164. *Fe deficiency symptoms induced by Mn toxicity.*

Salinity and Alkalinity

Although cassava is quite tolerant of acid soils, it is rather sensitive to high pH, and the associated problems of salinity, alkalinity and poor drainage. Also, micronutrient deficiencies may be induced in high pH soils. The symptoms due to salinity are characterized by a uniform yellowing of the upper leaves, which proceed downwards affecting the whole plant (photo 165). The leaves become necrotic at the edges and fall off resulting in dieback. Some cultivars are much more tolerant than others, and special cultivars may be selected for saline-alkaline soils (photo 166).

Salinity problems often occur in isolated "salt-spots" of high pH, high conductivity and often high Na content. Here plants may die while others nearby, growing at a slightly lower pH, may be completely healthy. In general, cassava will not tolerate a pH above 7.8-8.0, a conductivity of more than 0.5 mmhos/cm or a Na saturation of more than 2.5%.

165. *Salinity and/or alkalinity.*



166. *Varietal differences in salinity tolerance.*

Symptoms of Damage Caused by Herbicides

The use of herbicides in cassava can replace weedings that the crop requires during its growth cycle. In particular, preemergence herbicides can be helpful in eliminating weed competition during the first weeks of development and thus maximum productivity can be reached. There are many factors that affect the effectiveness and selectivity of weed-killers in any crop.

In the case of cassava, many preemergence and postemergence products have been found to be selective when they are employed properly; nevertheless, there are cases in which herbicides cause crop damage. The most frequent are as follows:

1. An overdose because of failure to read the label carefully, poor calibration of equipment, or an error in weighing or in calculating the quantity of the product to be added to the sprayer.

2. The utilization of a product or a rate of application not recommended for light soils. The same rate should not be used for all types of soil. When the organic matter content is low and/or the soil tends to be sandy loam or sandy, the rate has to be reduced.

3. The utilization of a sprayer contaminated with other herbicides. The herbicide group that most commonly causes this type of problem is the "hormone" herbicides such as 2;4-D; 2, 4, 5-T; picloram and dicamba. These products are utilized a great deal in gramineous crops and in pastures. They can cause damage when the same sprayers are used for broad-leafed crops unless the sprayers have been washed well.

4. Volatilization of herbicides. Some "hormone" herbicides are formulated as esters, which range from intermediately to highly volatile. When applied to gramineous crops or in pastures near cassava plantations, the vapor may affect the latter.

5. Drift. If an herbicide that is nonselective to cassava is applied to another crop nearby, the wind may carry the spray, causing damage to the cassava.

6. The leaching of herbicides. Some preemergence herbicides maintain their selectivity due to the fact that they remain in the first few centimeters of the soil and are not in direct contact with the roots; however, should heavy rains occur, they can be leached to the zone of the roots, causing damage. This occurs only in light soils and with soluble products.

7. A poorly directed postemergence application. Cassava does not tolerate much leaf contact with any postemergence herbicide. Therefore,

recommendations indicate that the postemergence application should be directed at the weeds, avoiding as much contact with the crop as possible. If this is not done, damage can be caused.

8. The use of contaminated products. Although infrequent, there have been cases where insecticides, fungicides and fertilizers are contaminated with herbicides because they are all stored together in the same warehouse. Besides, when pesticides are not kept in their original packing, they can be confused with other agricultural products.

9. The accumulation of incorporated preemergence herbicides. The construction of beds or ridges for planting will increase the concentration of some incorporated herbicides; as a result, when the cuttings are planted, there will be areas where there is a relative overdose of the product.

10. The residual effect of herbicides applied to previous crops. Some herbicides have a longer life than the cycle of the previous crop and the residue is sometimes toxic to cassava; i.e., a strong rate of atrazine in maize or sorghum could persist and cause symptoms of damage when cassava is planted.

There is very little to do that will stimulate crop recovery; the best thing to do is to wait and see if this happens. Cassava will generally recover as long as damage is light. Fertilization is suggested for this purpose. If the damage is due to hormone herbicides or poorly directed post-emergence applications, irrigation can be used if the soil is dry; but if the damage is caused by a soil-applied herbicide, it is best not to irrigate since this will only cause more damage.

Diuron (preemergence application)

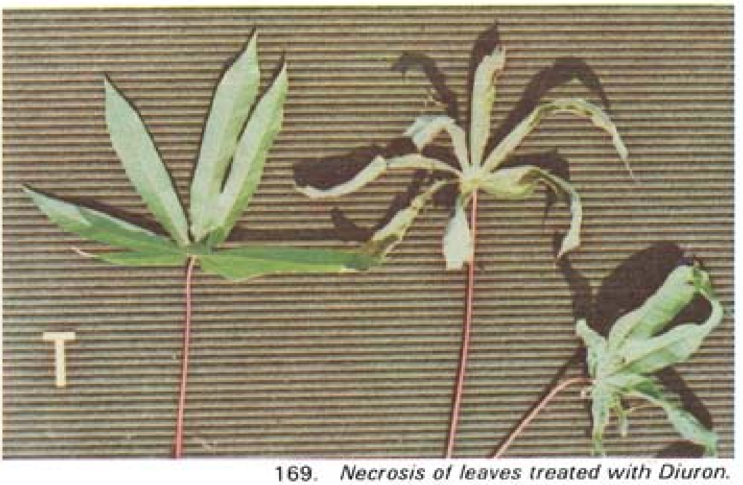
This herbicide is recommended for weed control in cassava because it is normally selective. It can, however, cause yellowing and/or necrosis of the lower leaves when an overdose is used (two or three times more than the recommended rate, photo 167), when it is applied in light soils or when applied to partially sprouted stakes. The yellowing and necrosis begins at the leaf edges and the veins. When the initial toxicity effect is over, newly formed leaves do no longer show the symptoms. In some varieties, the symptom is an interveinal yellowing (photo 168) which may be easily confounded with magnesium deficiency (compare page 139). The symptoms of Linuron and Fluometuron would be the same because they belong to the same chemical group.

167. *Necrosis of lower leaves.*

168. *Interveinal chlorosis.*

Diuron (postemergence application)

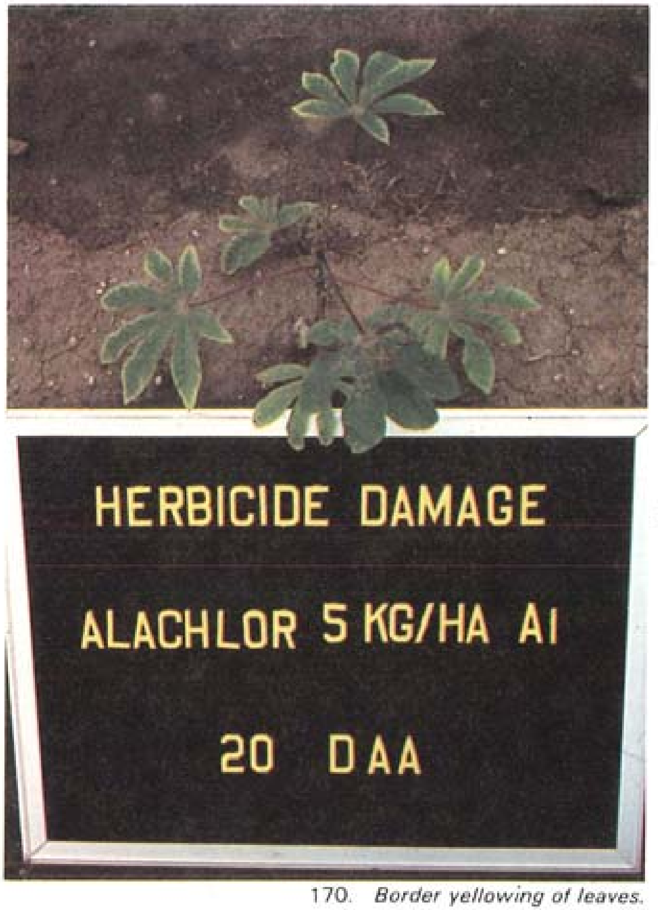
When diuron is applied after cassava has germinated and the application is poorly directed, it will cause the leaves that have come in contact with the product to necrose and fall prematurely. The product is not systemic; therefore, the damage will be restricted to the sprayed leaves. The plants recover normally.



169. *Necrosis of leaves treated with Diuron.*

Alachlor

This preemergent herbicide is highly selective to cassava and kills mostly narrowleaved weeds (grasses). Chemical injury caused by Alachlor is rare and can only occur when extreme overdoses are applied by error. In this case, cassava shows a marked border-yellowing of lower leaves without necrosis. Alachlor is often used in a tank-mix together with Diuron. The mixture is effectively controlling both narrow-and broadleaved weeds.



170. *Border yellowing of leaves.*

Oxifluorfen (Goal)

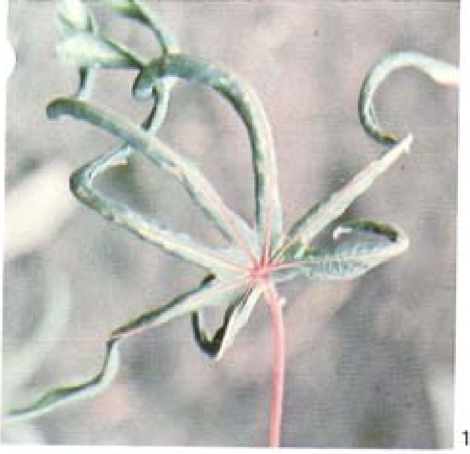
This herbicide is recommended for cassava, being classified as moderately selective. It is effective against broadleaved and narrowleaved weeds and gives a protection of up to 80 days after application in preemergence. It is safe on both heavy and light soils, being normally not translocated from the soil surface downwards. After application under dry conditions on loose soil, chemical injury can be caused by subsequent rain splashing soil particles with herbicide onto lower leaves (photo 171). When an overdose is applied, a light, more or less uniform yellowing of lower leaves may occur together with growth retardation (photo 172). However, the crop usually recovers without permanent injury; Oxifluorfen is also suitable for applications in postemergence, showing a synergistic effect in combination with Paraquat (Gramoxone). This mixture kills growing weeds effectively and has a residual effect preventing regrowth.

171. *Splash injury.*

172. *Injury due to overdose.*

Dicamba, Picloram, 2, 4-D or 2, 4, 5-T

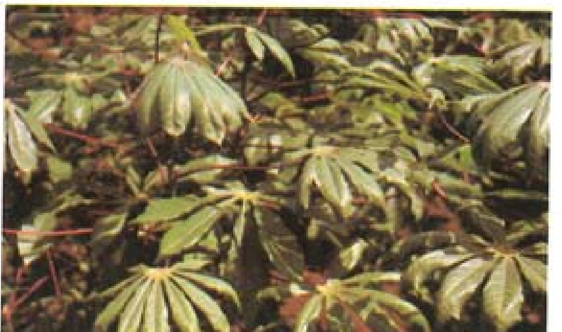
These products are not recommended for use in cassava. Nevertheless, damage may occur when contaminated sprayers are used or when these products are applied in nearby lots, due to the high volatilization of the ester formulations or when the wind carries the droplets to the crop. Damage is characterized by irregular growth and distortion of the leaves and stems, almost always with leaf deformation (photos 173 and 174). The damage due to drift or volatilization is normally less drastic being recognized as a rolling-in of leaf tips and slight curling downwards (photo 175). The buds and young leaves are the most sensitive to these products.



173. *Leaf deformation.*

174. *Leaf deformation.*

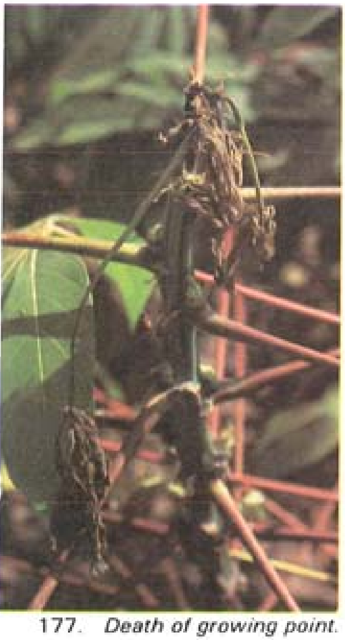
175. *Effect of volatilization.*

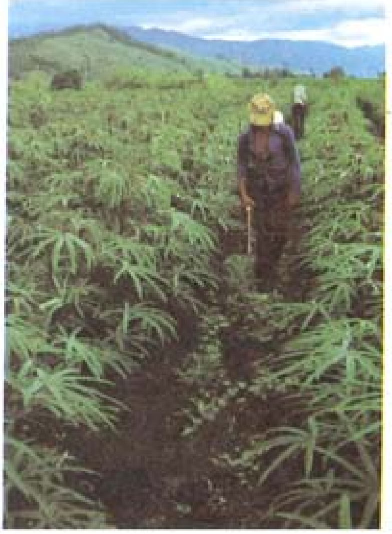


Paraquat and Glyphosate

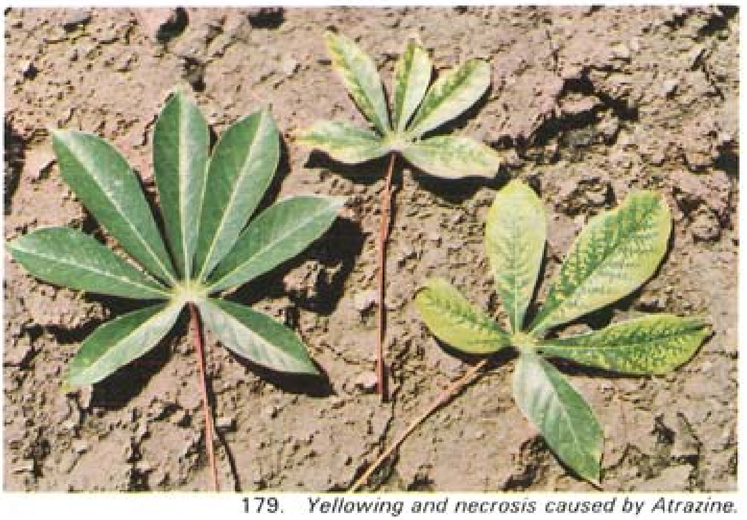
These herbicides can be used in directed postemergence applications. However, they can cause death of the sprayed leaf tissue or of the whole plant if applied improperly. Paraquat, which is a contact herbicide, causes necrosis of green leaf tissue and blight of the stems in the sprayed area due to the destruction of the cell chloroplasts (photo 176). Glyphosate is systemic and therefore translocated in the plant causing distortion, leaf wilting and death of the whole plant by inhibiting the synthesis of an aromatic aminoacid in the plants metabolism (photo 177). Damage from these two herbicides occurs when the products have been poorly sprayed, allowing too much contact with the crop. A properly directed spray of postemergence herbicides is facilitated by use of a shielded nozzle and a somewhat wider spacing between cassava rows which has to be compensated for by narrower between-plant distances to maintain the same plant population (photo 178).

176. *Destruction of green tissue.*


177. *Death of growing point.*

178. *Correct application.*


Atrazine



179. *Yellowing and necrosis caused by Atrazine.*

This herbicide is frequently used in maize and sorghum. In cases of an overdose, the residue remains in the soil and may cause symptoms of damage in cassava. The lower leaves and interveinal areas become yellow and necrose. When there is a lot of residue, the normal development of the crop is delayed.

Appendix 1

Formulae Suggested for Stake Treatment before Planting and Storage

Formula No. 1

Trade name	Common name	Rate (g of commercial product/ lt of water)
Dithane M-22	Maneb	2,22
Antracol	Propineb	1,25
Vitigran 35%	Copper oxychloride	2,00
Malathion W.P. 4%	Malation*	5,00

* With E.C. 57% use 1.5 cc

Formula No. 2

Trade name	Common name	ppm*	Rate (amount of commercial product/lt of water)
Malathion E.C. 57%	Malathion E.C.	1000	1,5 cc
Bavistin W.P. 50%	Carbendazim	3000	6 g
Orthocide W.P. 50%	Captan	3000	6 g

Formula No. 3

Trade name	Common name	ppm*	Rate (amount of commercial product/lt of water)
Orthocide W.P. 50%	Captan	3000	6 g
Bavistin W.P. 50%	Carbendazim	3000	6 g
Aldrin 2.5%	Aldrin	---	1 g/stake

*ppm = parts per million

1000 ppm = 1 g/lt of a.i. of the product.

Appendix 2

Key for Identifying Some Cassava Diseases

I. **Bacterial diseases**

A.	Angular water-soaked spots; leaf blight; partial or total wilting of branches; gummy exudate on young stems, petioles and angular spots	**Bacterial blight**
B.	Angular water-soaked spots on leaf lobes with small gummy exudate; occasional death of stem buds	**Bacterial angular leaf spot**
C.	Wilting of growing points; total soft rotting of green stems; mature stem pith necrosis; perforations in stems made by insects	**Bacterial stem rot**
D.	Galls generally located towards the basal portion of the stem	**Bacterial stem galls.**

II. Diseases caused by viral, viruslike, or mycoplasmal causal agents

A. Leaves with yellow patches and distortions

   1. Occurring in high percentages and in all the affected area — **African mosaic**

   2. Localized incidence and in low percentages

      a. Yellow areas between veins in the leaf blades — **Common mosaic**

      b. Yellowish irregular areas, sometimes chlorotic spots, along the midribs or main veins — **Northern Coast mosaic**

B. Leaves with yellowing in the veins, crinkling and distortion of the tip of each lobe — **Leaf vein mosaic**

C. Inhibition of root swelling; suberization of root epidermis; reticular-alveolar cracks on root epidermis — **Frog skin disease**

C. Pronounced stunting and proliferation of growing points; normal, but very small leaves; proliferation of shoots from the planted cutting — **Witches' broom (mycoplasma).**

III. Fungal diseases

A. Foliar diseases

1. Spots on the leaf blade

a. Indefinite yellow spots — **Cassava ash**

b. Brown or white spots
- Angular brown spots — **Brown leaf spot**
- Indefinite brown spots — **Blight leaf spot**
- Indefinite brown spots with concentric rings — **Concentric-ring leaf spot**
- Indefinite brown spots on edges only; leaf distortion — **Anthracnose**
- Round or angular white spots — **White leaf spot**

2. Lesions on the leaf veins and petioles

a. Erupted cankers with brown margins and white centers; leaf distortion — **Superelongation**

b. Brown or black pustules on either side of the leaf; distortion of leaves and petioles — **Rust**

B. Diseases of the stem

1. Lesions on the young parts of the stem

a. Erupted cankers of different sizes; elongation of internodes; dieback	**Superelongation**
b. Cankers with blackish margins and pink centers; dieback	**Anthracnose**
c. Brown cankers with circular rings; dieback	**Concentric-ring leaf spot**
d. Brown black cankers; distortion	**Rust**

2. Lesions on mature (lignified) parts of the stem, induced by various pathogens of woody crops, generally species of Ascomycetes or Basidiomycetes — **Various**

C. Diseases of the roots

1. Preharvest root rots

a. Generalized pungent soft rot	*Phytophthora* **sp.**
b. Generalized nonpungent rot	*Pythium* **sp.**
c. Localized rot, limited by healthy tissue	**Smallpox root disease**

2. Postharvest root rots

   a. Circular, dry deterioration, brownish-black streaking of the vascular strands — **Physiological deterioration**

   b. Soft deterioration, fermentation; brown streaking of the vascular strands — **Microbial deterioration.**

Key For Identifying Some Cassava Pests

1. **Mites**

Small, almost microscopic, with 4 pairs of legs, found in large quantities on the undersides of leaves

A. Young leaves attacked; yellow spots and deformation of leaves; death of growing point — *Mononychellus* **sp.**

B. Initial attack on basal leaves; yellow to reddish leaf spots; drying and falling of leaves — *Tetranychus urticae*

C. Initial attack on basal leaves; presence of irregular, yellowish brown spots on the upper surface and white spots (webs) on the underside, near the veins and leaf margins — *Oligonychus peruvianus*

II. Insects

Different sizes; found in or on all parts of the plant and beneath the soil

A. Insects causing deformation and/or lesions in the leaf area or green part of the plant

1. Growing points attacked, causing deformation and yellowish, long spots on leaves, and proliferation of buds — **Thrips**

2. Presence of yellow, streaked spots on the upper surface of leaves; small insect (adult gray, nymph white) found on underside of leaf — **Lace bug**

3. Chlorosis and curling of shoot leaves; presence of sooty mold; yellowing and drying of basal leaves; adult small, white in color, found on shoots; nymphs and pupae on the undersides of lower leaves — **Whiteflies**

4. Yellow to reddish galls, induced by a toxin produced by the insect, formed by abnormal growth of the leaf — **Gall midge**

B. Leaf-cutting and/or leaf-eating insects

1. Defoliation by cutting leaves, sometimes petioles and buds; large larvae of different colors, with a horn on the posterior extremity — **Cassava hornworm**

2. Defoliation by cutting semicircular pieces of leaves; presence of ants on the plant and/or debris from leaf pieces, and trails in the plantation — **Leaf-cutting ants**

C. Stem-boring insects

1. Lesions localized on the terminal part of the plant; presence of yellowish brown exudate, death of growing point and presence of white larvae in affected part — **Shoot flies**

2. Galleries in fruit and orifices in stem that exudate white latex; sometimes necrosis of the upper third part of the plant; soft rot and presence of yellowish white larvae — **Fruit flies**

3. Orifices and tunnels in stem and branches; presence of sawdust and excreta in the orifices and/or on the soil — **Stemborers**

D. Stem and branch suckers

Yellowing and weakening of the plant in general, and sometimes defoliation; presence of scales on stem and branches — **Scale insects**

E. Stem and leaf suckers

Shoot deformation; yellowing of basal leaves; presence of sooty mold on stem and leaves; presence of mealybugs on the stem and on the undersides of leaves — **Mealybugs**

F. Insects attacking roots

Subterranean sucking insect with short legs covered with strong spines, allowing it to move easily within the soil, adults black in color, nymphs with brown thorax and yellowish white abdomen; cuticles removed from attacked roots show brown to black spots, corresponding to the sites where the stylet was inserted — **Subterranean sucking insect**

G. Insects attacking cuttings and/or seedlings

1. Wounding and consumption of bark and roots of cuttings and seedlings; dieback of seedlings, reduced germination; white larvae with black heads found around cuttings or roots **White grubs**

2. Dieback or seedlings cut at the base; reduced germination; bark and roots consumed; larvae gray to black in color, almost always found in the ground near the attacked plant **Cutworms**

3. Problems in germination; cuttings with tunnels and presence of insects in them; small adult, cream colored **Termites.**

Appendix 3

CIAT's Cassava Publications

Problemas en cultivos de la yuca, serie GS-16

Problemas no cultivo da mandioca, serie GP-16

Field problems in cassava, series GE-16

Diseases of cassava, series DE-5

Ensayo enzimático para determinar el contenido de cianuro en las raices y en los productos derivados de la yuca, serie 05SC-6

Enzymatic assay for determining the cyanide content of cassava and cassava products, series 05EC-6

Secamiento de la yuca, serie 05SC-4

Cassava drying, series 05EC-4

Un implemento para cosechar la yuca, serie 05SEn-3

A cassava harvesting aid, series 05EEn-3

Métodos de control de malezas en yuca, serie 05SW-3

Methods of weed control in cassava, series 05EW-3

Producao de material de plantio da mandioca, serie GP-17

Production of cassava planting material, series GE-17

Desórdenes nutricionales de la yuca, serie 09SC-3

Nutrición mineral y fertilización de la yuca, serie 09SC-4

Plagas de la yuca y su control, serie 09SC-2

Cassava pests and their control, series 09EC-2

Proceedings of cassava protection workshop, series CE-14

Manual de producción de yuca

Cassava production course, Vols. I, II

Resúmenes analíticos sobre yuca, volumen II, serie HS-28

Abstracts on cassava, volume II, series HE-28

Resúmenes analíticos sobre yuca, volumen III, serie HS-31

Abstracts on cassava, volume III, series HE-31

Resúmenes analíticos sobre yuca, volumen IV, serie 08SC-4

Abstracts on cassava, volume IV, Series 08EC-4

Resúmenes analíticos sobre yuca, volumen V, serie 08SC-5

Abstracts on cassava, volume V, series 08EC-5

Resúmenes analíticos sobre yuca, volumen VI, serie 08SC-6

Abstracts on cassava, volume VI, series 08EC-6

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