INTEGRATED CONTROL OF DISEASES AND PESTS OF CASSAVA (*Manihot esculenta* Crantz)

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SUMMARY

The discussion of different aspects related to integrated control of diseases and pests is presented emphasizing the cultural practices, varietal resistance and biological controls. Cassava, a perennial vegetatively propagated crop cultivated in a wide range of ecosystems, requires integrated control programs for diseases and pests as a prerequisite for yield stabilization and satisfactory production.

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Most agricultural research is directed toward the investigation of a specific factor or set of factors related to the production system of different crop species. The results of this research are rarely integrated in a logistic production package. More recently, research has been oriented on a commodity basis, making the integration of scientific teams to study one crop appear more reasonable; thus scientists can develop broader concepts of the crop and its problems, leading to more applied results.

With regard to cassava, there are several reasons why an integrated control program for diseases and pests is a prerequisite for yield stabilization and satisfactory production. Among these are the following:

1. Cassava is a perennial crop with undetermined physiological maturity (Jennings, 1976); consequently, an established biotic problem could be perpetuated.
2. The vegetative cycle is long, ranging from 8-24 months, depending on the cultivar and/or ecosystem. During this time, the plants can suffer climatic and edaphic pressures (e.g., drought, low or high tempera-

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tures, nutritional deficiencies or toxicities), as well as attack by pathogens, insects, mites and nematodes. The intensity and severity of these stresses vary among ecosystems and from one growing season to another, and are related to the ecological conditions occurring throughout each growing cycle and to the existence of material susceptible to the stresses present.

3. Cassava is propagated vegetatively from cuttings of lignified stems. The quality of the planting material is determined by the climatic, edaphic, pathological and entomological stresses (negative production factors, NPFs) of the genotypes cultivated in a given cycle and their resistance to these stresses. The quality of the stem cuttings determines, to a great extent, the overall success in achieving optimal yields (CIAT, 1979, 1980; Lozano et al., 1977). On the other hand, infected and/or infested propagation material is highly probable in cassava unless preventative measures are taken (Lozano, 1977a).
4. Manihot esculenta is composed of cultivated clones that have been selected for desirable characteristics over many years by farmers in each ecosystem, primarily based on tolerance to the NPFs existing in a given region. The introduction of one or several NPFs from other ecosystems and/or planting clones in ecosystems different from the native one can cause serious damage to the original clones, as well as to those planted outside their native ecosystem (Lozano, Byrne & Bellotti, 1980).
5. Several cassava clones are planted in each region throughout the whole or most of the year. Consequently, in most ecosystems, tissues of diverse genotypes susceptible to different biotic problems are present

throughout the year. The reason for the lack of epiphytotics in traditional plantations or for the presence of biotic problems at levels below the economic threshold is due almost entirely to the biological balance that exists in the ecosystem; and this must be maintained.

6. Cassava has a long genetic cycle (up to 3 years), which delays the development of new, improved varieties, tolerant to specific problems (Kawano et al., 1978); thus a stable-type resistance is preferred.
7. Cassava growers need to exercise great care in the production of their own planting material in order to avoid sanitary, agronomic and economic problems caused by
   a. The low multiplication rate (5-10 cuttings/plant) (Lozano et al., 1977)
   b. damage caused to cuttings since they are easily injured during preparation and transportation, as well as the difficulty of subsequent storage (40% of the buds in some clones failed to germinate after only 2 weeks' storage) (Lozano et al., 1977)
   c. Packing and shipment of cuttings are difficult and expensive because of their weight and volume (10,000 cuttings required to plant 1 ha weigh ca. 1 ton and occupy 2 m^3).
8. Most cassava growers are traditional farmers (Phillips, 1974) with little technical know-how and few economic resources. Problems related to this crop should be solved using a simple, inexpensive but efficient cultivation system.

Based on the foregoing factors, the importance of integrated crop management in the control of pests and diseases can be seen; this system must combine good cultural practices with biological control and varietal resistance.

CULTURAL PRACTICES

Uniform cultural practices cannot be recommended across all cassava-growing areas; they should be adapted to the specific characteristics of each ecosystem. Moreover, the incorporation of different practices should be based on a cost-benefit analysis, bearing in mind the farmer's capacity and that stability of production is the ultimate goal. Some practices may appear unessential, but the roots (the commercial product) may be affected and, unfortunately, can be appreciated only at harvesting time.

The following are some cultural practices that, when applied in combination, can reduce or even eliminate stresses due to NPFs in a given ecosystem, thus producing stable yields.

1. When cassava is planted immediately after the removal of forest, perennial or woody annual crops, severe root-rot problems can appear due to pathogens and/or pests that affect these plant species as well as cassava (Booth, 1977; Bellotti & Schoonhoven, 1978b). A decrease in soil infestation can be obtained by planting nonsusceptible crop species (e.g., cereals) before cultivating cassava and burning the plant debris left on the ground (Booth, 1977; Lozano & Terry, 1977).
2. Soil preparation should be as for any other traditional crop. As cassava is susceptible to flooding and to pathogens favored by this condition (i.e., *Phytophthora* and *Pythium* spp.), soil drainage must be adequate for the quantity and distribution of rainfall in each ecosystem. For example, planting on ridges is recommended when rainfall is higher than

1200 mm/year. The size and depth of these ridges will vary in relation to soil texture and frequency of rainfall (Booth, 1977; Lozano & Terry, 1977; Olivero, Lozano & Booth, 1974).

3. It is well known that the quality of planting material is crucial for the successful cultivation of any vegetatively propagated crop. This is one of the most important factors in any cassava production systems program, responsible not only for good crop stand and establishment (good rooting of cuttings and bud germination), but also for the sanitary conditions of the crop and final yield (commercial roots/plant) per unit area/cycle (CIAT, 1978, 1980; Lozano et al., 1977).

The quality of the cuttings depends on certain agronomic characteristics (lignification, thickness related to each clone, size, number of nodes/cutting, angle of cut, and degree of mechanical damage), sanitary conditions (free of systemic and localized pathogens, insects and mites), and disinfestant and protectant treatments applied before planting or storage (Lozano et al., 1977).

In general cuttings should be taken from the healthiest plantations on the farm or in the region, selecting the most lignified portion of the stem from vigourous 8- to 15-month-old plants, cutting stem pieces 20 cm long at a right angle. Any portion of the stem with signs of necrosis (discolorations), cankers, tumors, galls, galleries and/or insect (scales, borers, etc.) or mite infestations must be eliminated. Infested or infected cuttings can contaminate healthy ones during the storage period (Lozano et al, 1977; Vargas, 1977).

Cuttings must be treated with fungicides and insecticides for disinfestation, disinfection and protection. Planting material should not be stored unless strictly necessary (CIAT, 1979,1980; Lozano et al.,1977).

4. Cuttings should be planted in accordance with the terrain; satisfactory root formation and distribution result from the position of the cutting in the ground (Castro et al., 1976). Good root development leads to vigorous plants which are more resistant to biotic problems and easier to harvest. This in turn can lead to less physiological and microbial deterioration during storage, which are enhanced by mechanical damage during harvesting (Booth, 1976; Lozano, Cock and Castaño, 1977).

   Considerable losses in establishment due to the failure of rooting or bud germination can occur if planting is done during the hottest season of the year in areas with high average temperatures. This may be caused by the effect of soil temperature on horizontally planted cuttings; when planted vertically or obliquely, air circulation cools down the extreme upper portion of the cutting, reducing the effect of hot soils. It is necessary to bear in mind that the bud thermal inactivation point of most cultivars is 52.5°C min (CIAT,1974); high temperatures can also damage the stem epidermis, causing openings suitable for the establishment of pests and pathogens.

5. Good weed control is important because cassava is a poor competitive species (Doll, 1978). Moreover, adequate weed control could reduce both pathogens and pest populations on other host species and also allow good air circulation between plants, increasing the rate of rainfall evaporation.This reduces the relative humidity for sufficient time to decrease the rate of establishment and propagation of some pathogens, insects and mites.However,certain weeds can serve as a host and food

supply for beneficial insects, and their elimination would decrease their populations. Weed control must therefore be carried out with both these aims in mind. In large plantations, it may be wise to keep plots or bands of native weeds to help maintain a natural biological balance.

6. Periodic inspections of plantations are highly recommended in order to (a) determine the scale and timing of agronomic operations such as drainage, weed control, etc.; (b) remove plants or plant parts with initial infection or infestation symptoms of diseases (viroses, mycoplasma, etc.), insects (scales, shoot flies, etc.) and mites, which at the initial stages attack scattered plants in the stand. These plants should be removed from the area in plastic bags and burned to prevent the dissemination of these problems; and (c) forecast the commencement of epiphytotics caused by pathogens and insects, allowing appropriate control strategies to be planned and carried out at the most advantageous time. A full-time trained worker would be justified on farms of 15 ha or larger to carry out control of agro-phytosanitary problems.
7. Since the roots are highly perishable as a result of both physiological and microbial deterioration (Lozano, Cock & Castaño, 1977), it is suggested that planting and harvesting operations be programmed according to marketing conditions. Similarly, since the incidence and severity of this deterioration are enhanced by mechanical damage, this should be minimized or avoided during harvesting, packing and shipping (Booth, 1977).

Recent research on fresh root storage suggests that physiological deterioration is a biochemical process (Lozano, Cock, Castaño,1977; CIAT, 1980) that can be controlled by pruning 2-3 weeks before harvest. Storage of roots in sealed plastic bags in order to prevent dehydration by keeping up the saturated relative humidity also gives good control. Microbial deterioration has been controlled by dipping the fresh roots in a fungicide solution (Lozano, Cock & Castaño, 1977).

8. Plant debris left on the ground after harvest can act as propagation media for pathogens and pests that can cause severe damage to cassava after successive plantings (larvae of Coleoptera; *Rosellinia* spp., *Armillariella* spp., etc.). The elimination, especially of stems and roots, can help maintain these root-rot problems at low levels for several planting periods.(CIAT, 1979; Lozano, 1977b.)

The determination of the percentage of root rot after each harvest, especially on soils rich in organic matter, helps determine whether crop rotation or fallowing is advisable.

In general, plots that have over 3% root rot at harvest require crop rotation or fallowing in order to decrease the inoculum potential of biotics infesting the soil. When crop rotation is planned, care should be taken in the choice of crops in the sequence since several other crops are also attacked by cassava pathogens; cereals are a good choice.(Lozano,1977b;Lozano & Booth, 1974; Lozano & Terry, 1976). On the other hand, cutworm pests of maize and sorghum can also attack young cassava plants. If these are present, it is necessary to apply poison baits or spray the soil with fungal or bacterial pathogens of these insects before planting (Bellotti & Schoonhoven, 1978b).

9. Planting time can affect pest and/or disease incidence. Periods that favor high multiplication rates of pathogens, especially wet periods in the tropics or cool seasons in semi-subtropical areas, should be avoided (Lozano,1977b; Lozano & Terry, 1976). By planting over several periods during several cycles, it is possible to determine the appropriate planting time for each ecosystem.
10. Consecutive planting in the same or in different plots over long periods of time can induce a progressive increase in the inoculum potential of pathogens and pests, causing outbreaks of increasing severity with time. A delay in planting for a few months will lead to a decrease in the biotic problem. This can also be reduced by planting stems of longer than usual length (0.40-0.50 m instead of 0.20 m) in order to obtain large plants with several buds in a short period of time; these will have a higher tolerance to biotic problems such as shoot flies (Silba pendula) than small plants obtained from short cuttings.
11. Cultivation of cassava in association with other crops has been reported to be responsible for the low incidence and severity of biotic problems in tropical cropping systems; traditionally managed farms combine this with planting multicolonal cassava plots. This system should be studied and maintained wherever possible, above all where cassava is used as a staple food. Sudden changes in production systems may bring about unexpected changes in the ecological equilibrium, which in the long term are reflected in the balance existing with the native biological control of the ecosystems.
12. Well-planned spacing of plants can prevent the formation of microclimates favorable for the propagation of diseases and pests, as well

as decrease the spread of biotic problems within the stand (e.g., scale insects). An ideal spacing can be reached by decreasing plant populations per unit area or changing the planting system (i.e., two rows separated by only 0.50 m, followed by another two at 2.00 m distance). The effects of such methods should be evaluated according to each ecosystem and its soil fertility, the clone type, harvesting systems used, etc.

13. Improvement of growth conditions for cassava by increasing the nutritional level of the soil and the water supply during critical growth periods facilitates vigorous plant development, which in turn produces a higher tolerance to the stresses exerted by the biotic problems within a given ecosystem. However, the use of these cultural practices, their levels and frequency of application should be determined by economic analysis. In general plots that are selected for the production of cuttings should receive the best cultural and biological treatments.

14. As several biotic problems are disseminated through vegetative and sexual propagation material, it is of great importance to establish and strictly observe quarantine regulations (Lozano, 1977a). In general it is suggested that only official institutions be authorized to introduce cassava propagation material; vegetative material should be introduced by meristem culture or sexual seeds taken only from healthy plantations.

15. The use of sonic light traps, poison baits, pheromones, gama and x-rays for sterilization, hormones, etc., are control measures that should be considered in order to improve the control of insects during different periods of the crop cycle, taking into account the biotic problem, the ecosystem and the feasibility of its execution (Bellotti

& Schoonhoven, 1979, 1978b; Bellotti, Reyes & Arias, 1980).

BIOLOGICAL CONTROL

The long production cycle of cassava makes chemical control of pests uneconomical. This fact, combined with the great ability of the cassava plant to recover from abiotic and biotic stresses, indicates that biological control may prove very effective (Bellotti & Schoonhoven, 1978b; Bellotti, Reyes & Arias, 1980). Moreover, many beneficial agents exist in cassava plantations: in the case of *Erinnyis ello* alone, some 30 parasites, predators and pathogens have been identified (Bellotti, Reyes & Arias, 1980). Biological control should constitute one of the most important approaches of any integrated control package for the diseases and pests of all ecosystems.

The following suggestions can help maintain the natural biological control already present in a given ecosystem and improve it by increasing populations of native or introduced beneficial agents.

1. Although pesticides are valuable components of integrated control, they must be used only when other control measures are not effective and when it is economically necessary because of yield reductions caused by the biotic problem (Bellotti, Reyes & Arias, 1980; Lozano, 1978). If an outbreak requires pesticide application, this should be selective with, if possible, a low lethal effect on beneficial agents (Bellotti & Schoonhoven, 1978; Bellotti, Reyes & Arias, 1980).
2. A detailed inventory of beneficial insects and microorganisms as well as of pests, diseases, hosts and food sources of these pests is

urgently required. The evaluation of each biotic problem in each ecosystem will aid in the establishment of priorities for each approach to biological control.

3. Ecological studies directed towards explaining the relationship between parasites, pests and the environment will provide valuable information for future strategies on biological control for each ecosystem.
4. Natural biological control can be improved by increasing the populations of the most beneficial species through mass rearing, followed by liberation and colonization (Bellotti, Reyes & Arias, 1980). It can also be improved by the introduction of new, more efficient beneficial species or biotypes that can be adapted to the conditions of a particular ecosystem.
5. Even though modern agriculture uses the monoculture/homogeneous genotype system for several crop species, our experiences with cassava leads us to suggest that it would be better to use the multivarietal system in monoculture or mixed cropping with other crop species, as is the current practice among most cassava growers. The genetic clonal variability in plantations restricts the asemic propagation of pests and pathogens, keeping their populations at low levels, greatly reducing the risk of sudden outbreaks.
6. Alternate hosts of pathogens and pests,grown in or near cassava plantations (e.g., Poinsettia pulcherrima, host of the causal agent of superelongation disease),should be removed, as well as any source of food for pathogens and pests (the hornworm eats leaves of rubber trees; fruitflies feed on rotting fruits; several soil-borne pathogens live on decaying cassava root debris; etc.). Extension programs should explain the advantages of carrying out these practices and if hosts

cannot be eliminated because of their economic importance (rubber trees in Malaysia and Brazil, for example), integrated control programs should also be planned for these crop species.

7. The liberation of irradiated insects or interspecific hybrids of pests in the area has not yet been done in cassava, but would be a promising biological control system for the future. Spraying the soil with bacteria, fungi, viruses, etc., that are pathogenic to soil-borne insects and pathogens of cassava, is another good possibility that merits study.

VARIETAL RESISTANCE

Yield stability with time in a given ecosystem is related to the stresses resulting from the NPFs existing in each ecosystem, as well as to the genetic capacity of clones to tolerate these stresses. Since cassava clones have been selected for a very long time in localized areas and perpetuated vegetatively, the cassava/ecosystem interaction is great. A good, well-adapted clone with tolerance to a given ecosystem could be severely affected by the NPFs of another ecosystem. Consequently, in each particular ecosystem, regional clones or clones from similar ecosystems should be preferred to those introduced from ecosystems with different sets of NPFs. Introductions should be made specifically to improve the gene pool existing in each ecosystem (regional clones). Improvement programs should be decentralized and located in areas selected on the basis of extensive agro-socioeconomic studies (Lozano, Byrne & Bellotti, 1980).

The concept of varietal evaluations should be multiple, integrating the following three general concepts: (a) satisfactory yield of fresh roots, starch, foliage, etc. according to its utilization; (b) good production of high-quality planting material; and (c) highly acceptable root quality according to the socioeconomic requirements in each region. Clones selected according to these criteria would probably be the most stable over time, being the most acceptable to farmers.

Clonal evaluation in each ecosystem should be directed to identifying genotypes with the widest type of resistance to the NPFs existing in it; this evaluation should be performed by observations in areas where the NPFs of each ecosystem are severest and most frequent. These evaluations should be integrated, performed by scientists of different disciplines and during several consecutive cycles (CIAT, 1978, 1979; Lozano, Byrne & Bellotti, 1980). This should not eliminate or underrate evaluations directed to identifying tolerance to specific important biotic problems because this could be needed to improve clones having wide-type resistance but susceptible or deficient in certain required characteristics.

Varietal resistance obviously improves biological control of the area because economic damage occurs only at higher population levels, facilitating the increase of beneficial biotics and reducing or eliminating the need for pesticides. In cassava an attack of *Erinnyis* spp. can produce up to 40% defoliation without causing any yield loss; this permits a delayed insecticide application for their control or the use of any other control measure compatible with the biological equilibrium of the region.

The foregoing general recommendations for the integrated control of diseases and pests in cassava should be complemented by scientific support given by research and extension agencies to growers and processors. The long-term success of cassava production in a given country or region may depend on both the research support and the appropriate application of these control measures.

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