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ALGUNAS RELACIONES BIOTICAS Y ABIOTICAS ENTRE *Manihot esculenta* Y CINCO ECOSISTEMAS*

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Cassava/Ecosystem Relationships and their Influence on Breeding Strategy

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Summary. The influence of ecosystems on cassava (*Manihot esculenta* Crantz) cultivars and the possible reasons for this are discussed, as well as the effect of distinct negative production factors, i.e., edaphic and climatic constraints, and disease and pest stresses, on regional and introduced varieties. Decentralised improvement programmes in different ecosystems based on 10 years research are suggested, and are selected according to socioagro-economic studies related to actual and/or potential production of cassava.

Introduction

Cassava (*Manihot esculenta* Crantz) originated in America with a major centre of diversity in South America and a secondary centre in Guatemala and Mexico (Leon, 1977; Lozano, 1977), where it has been cultivated for more than 5000 years. Some 400 years ago the crop was introduced in Africa and more recently in Asia (Jennings, 1976; Leon, 1977; Mauny, 1953). It is composed of clones under cultivation; no wild types have been found (Leon, 1977).

The species has 36 chromosomes and is generally regarded as tetraploid (Toro and García, 1977). Clones are highly heterozygous (CIAT, 1976; Kawano *et al.*, 1978) but not heterogeneous, mainly because of vegetative propagation and inbreeding depression.

In a multiclonal population cassava has a very high rate of selfing (Kawano *et al.*, 1978); however, selfed plants are not competitive with crosses due to strong inbreeding depression (Kawano, 1978; Kawano *et al.*, 1978). Plants grown from botanical seed do not compete well with those grown from vegetative cuttings or with weeds; thus plants from true seed are not common in traditional farming systems.

Cassava has been traditionally cultivated under mixed cropping systems where stem cuttings of different clones are planted on recently cleared land. This system is still being used to a great extent in the Americas (J. K. Lynam, personal communication). Monocropping has only recently been introduced, but still with the traditional multiclonal cassava population.

These early plantations were isolated, locally by forests and regionally by mountains. The American cassava-growing areas are characterised by a great diversity of edaphic and climatic conditions. Soils vary in pH (3.0–9.5), texture, macro- and/or micronutrient deficiencies, salinity or mineral toxicity, e.g., aluminum, and organic matter content. Climatic conditions are often dependent on elevation, except for Paraguay and south-eastern Brazil and Peru: temperatures can be stable or fluctuating, averaging from 8 to 33°C; there are equatorial to subequatorial photoperiods; semi-desert to very wet regions (500–6000 mm/year) with 1 or 2 rainy or dry periods of 1 to 8 months/year; and relative humidities ranging from 15% to near saturation during a given period of the year. All these factors combine to form a great number of different ecosystems.

Due to their relative isolation, farmers usually plant vegetative material obtained from a previous crop or from neighbouring farms. Clone introductions have occurred only occasionally, each being selected by the farmer on comparison with the performance of local clones as regards adaptation to the ecosystem, yield stability and resistance to diseases and pests found in the new ecosystem.

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Although research has shown that *M. esculenta* has a high yield potential (Cock, 1974; Kawano, 1978), commercial yield/unit area is very low (FAO, 1971). This has been generally attributed to inadequate agronomic practices, as well as to the lack of improved, high-yielding cultivars resistant to diseases and attack by pests. Great advances in cultural practices have been reported (CIAT, 1976, 1977, 1978, 1979; Toro and García, 1977), but promising selections or improved lines have given variable results when grown in regions other than those from where they were selected. This suggests that regional testing of varieties and programmes for incorporating specific resistance to the different pressures or negative production factors (NPFs) in a given ecosystem are required.

The relationships between the cassava plant and the NPFs existing in the different cassava-growing areas are studied on the basis of experimental results obtained over the past 10 years at CIAT, with emphasis on pathological problems; their impact on breeding strategies is discussed.

Breeding programmes: impact of past strategies

Cassava breeding programmes are relatively recent; one of the first was initiated 50 years ago at the Instituto Agronômico de Campinas, Brazil (Normanha and Pereira, 1950). Later a breeding programme in Africa began work on the development of varieties resistant to African mosaic disease (Storey and Nichols, 1938). During the past decade, the International Institute of Tropical Agriculture (IITA), Nigeria and the Centro Internacional de Agricultura Tropical (CIAT), as well as several national programmes, initiated breeding projects (Mauny, 1953; Nestel, 1974).

IITA's breeding programme involves massive crossing and selection against two major diseases, cassava bacterial blight (CBB) and African mosaic disease, and their dissemination. Improved true seed from different interpollinated superior females with sources of resistance and other agronomic traits is sent to different locations in Africa. CIAT's programme has used conventional crossing of superior lines following a pedigree method; selected material at one centre is vegetatively disseminated and tested in three different locations.

The impact of these programmes on the species to date, however, has been limited. Regional cultivars probably have most of the genetic traits characteristic of the first domesticated and selected clones, having been selected over the centuries for ecological adaptability, resistance to diseases and pests, and good agronomic characteristics. These clones constitute an excellent source of basic material for breeding programmes, the success of which depends on their correct identification and use.

Experimental results related to breeding strategies

Results of research over the past ten years have led us to believe that (a) disease and pest incidence and severity of attack are related to the ecological characteristics of a given region; (b) pathogenic race specialisation among cassava diseases appears to be rare; (c) stable resistance to most major NPFs exists in *M. esculenta*; (d) clones in existence today are regionally adapted cultivars that have persisted in a given ecosystem because of certain desirable characters; and (e) clones with resistance to the main NPFs in an ecosystem can be found.

Recent studies have shown that diseases and pests are often restricted to certain regions, and if present, become severe only during a certain season. Cercospora leaf spots, *Cercosporidium* (*Cercospora*) *henningsii* Allescher and *Cercospora viscosae* Muller and Chupp, anthracnose, *Colletotrichum* and *Gloeosporium* spp., and rusts, *Uromyces* spp., are not found or are only mild during dry periods or in semi-desert regions (CIAT, 1976; Lozano, 1978; Lozano and Booth, 1974; Teri, Thurston and Lozano, 1978); whereas CBB, *Xanthomonas manihotis* (Arthaud-Berthet & Bondar) Starr, and superelongation, *Sphaceloma manihoticola* Bitanc. & Jenk. are severe only during periods of prolonged rainfall (Krauz, Lozano and Thurston, 1978; Lozano, 1975; Lozano, 1978). Moreover, CBB infection is moderate in areas where temperatures are stable, independent of the rainy season or the amount of rainfall in a given period (CIAT, 1979; Takatsu, 1977). Concentric-ring leaf spot, *Phyllosticta* spp., and white leaf spot, *Phaeoramularia manihotis* = *Cercospora caribaea* Chupp and Ciferri, occur in regions where temperatures fall below 18°C during the rainy season and during the winter in the subtropical zones of southern Brazil and Peru, northern Argentina, Uruguay and Paraguay (Lozano and Booth, 1974). Phytophthora and Pythium root rots are most prevalent in heavy, undrained soils (Booth, 1978; Lozano and Booth, 1974; Oliveros, Lozano and Booth, 1974), whereas Armillaria, Rosellinia and Rigidoporus root rots cause heavy losses when cassava is planted following forest or perennial crops (Booth, 1978; Lozano and Booth, 1974). Stem rots are severe in areas where relative humidities are near saturation for prolonged periods. Incidence of African mosaic is particularly high when there are high populations of its vector, *Bemisia* spp., in the rainy season (Bock and Guthrie, 1977; Leuschner,

TABLE 2. SOME NEGATIVE PRODUCTION FACTORS (NPFs) THAT REDUCE YIELDS IN FOUR DIFFERENT ECOSYSTEMS IN COLOMBIA

NPFs	Location			
	Popayán	Darién	Carimagua	CIAT
Climatic conditions				
Mean temperature (°C)	18.0 (+)*	19.5 (+)	26.1 (−)	24.0 (−)
Rainfall (mm/year)	2500 (−)	1500 (−)	2031 (−)	1000 (+)
Rainfall duration (month)	6 (2 periods) (−)	6 (2 periods) (−)	8 (1 period) (+)	5 (2 periods) (−)
Edaphic conditions				
pH	4.1 (+)	4.3 (+)	4.7 (+)	6.8 (−)
Al concentration	High (+)	High (+)	High (+)	Low (−)
Fertility	Good (−)	Medium-low (+)	Low (+)	Good (−)
Texture	Clay loam (−)	Silt loam (−)	Sandy loam (−)	Clay (±)
Diseases				
Concentric-ring leaf spot	+	+	−	−
Anthracnose	+	+	+	−
White leaf spot	+	+	−	−
Bacterial blight	−	−	+	−
Superelongation	−	−	+	−
Brown leaf spot	−	−	+	±
Cercospora leaf blight	−	−	+	+
Pests				
Mites: *Oligonychus* sp.	±	±	±	±
Mononychellus sp.	−	−	+	±
Thrips	+	+	+	+
Scale insects	−	−	+	−
Stemborers	−	−	+	+
Lacebugs	−	−	−	+

*+ = severe damage; ± = moderate damage; − = no damage.

is highest. Thus far, clones with resistance to the following adverse factors have been reported: low levels of phosphorus, high levels of aluminum, saline soils (Howeler, 1978); stable low temperatures (Irikura, Cock and Kawano, 1979); *Cercospora* spp., *Phoma* sp., *Colletotrichum* and *Gloeosporium* spp., *Sphaceloma manihoticola* (Krauz, Lozano and Thurston, 1978; Lozano, 1978; Lozano and Booth, 1974), African mosaic (Bock and Guthrie, 1977; Hahn, 1979), mites, thrips and lacebugs (Bellotti and van Schoonhoven, 1978; CIAT, 1979).

Resistance to specific sets of NPFs

Although sources of resistance to all major diseases, as well as to several insects, and tolerance to adverse edaphic and climatic conditions have been identified, combining these characters into one variety poses a serious problem for breeding programmes since it requires a large number of crosses and several generations of testing. Consequently, emphasis has been placed on identifying lines tolerant to many NPFs. Work at CIAT has concentrated on two regions in Colombia, each with different adverse factors that can greatly reduce yield (Table 1).

Popayán ecosystem

The major NPFs at this site are leaf spot diseases, low temperatures and low soil pH. Reactions of a resistant line, CMC 92, an intermediate line, CMC 39 (resistant to low temperatures and pH but not to leaf spot diseases), and a susceptible line, M Col 22, were studied over a 5-year period (Fig. 1).

TABLE 3. FIELD EVALUATION IN THE POPAYÁN ECOSYSTEM OF RESISTANCE TO NEGATIVE PRODUCTION FACTORS (NPFs) IN RELATION TO RAINFALL*

Growing cycle	Reaction to NPFs†			Rainfall (mm)
	M Col 22	CMC 39	CMC 92	
Year 1	4.9‡	4.1	2.1	3119
Year 2	3.5	2.0	1.5	2475
Year 3	4.8	4.0	1.9	3103
Year 4	5.0	3.9	1.9	3319
Year 5	4.8	3.5	2.0	3365

*Elevation 1760 m, mean temperature 18°C (4°C min, 20°C max).
†Average data taken from 36 plants/variety over a 15-month period.
‡1 = normal plant growth, no disease or pest attack.
2 = less than 30% leaf fall due to disease or pest attack and/or climatic or edaphic factors, normal plant growth.
3 = up to 80% leaf fall and stem cankers or injuries due to disease or pest attack and/or other climatic or edaphic factors, slight stunting and yellowing.
4 = total defoliation, stem cankers, stunting and slight dieback due to disease, pest and/or climatic or edaphic factors.
5 = severe stunting or plant death due to disease, pest and/or climatic or edaphic factors.

Carimagua ecosystem

Although this area is representative of much larger areas with a tremendous potential for increased production, there are many NPFs, such as bacterial blight, superelongation, low soil fertility, low pH, aluminium toxicity and mites (Table 2). In selection trials of 800 clones over a two-year period, eight were selected as resistant.

Recommended breeding strategy

The foregoing considerations suggest that in order to breed for varieties with a wide-type resistance, that is, to several NPFs, the breeding programme should be decentralised. Several representative ecosystems should be chosen as selection sites where parental material and progeny should be evaluated for both resistance and agronomic characters over several years. Hybridisation for different ecosystems could be done on a centralised basis. Large quantities of vegetative material, selected at various sites, can be returned to a central location for hybridisation by using the technique of Lozano and Wholey (1974) for production of CBB- and other disease-free planting material.

The progress of these improvement programmes would depend greatly on the genetics of the desired traits, the number of traits that have to be incorporated, the effectiveness of the evaluation techniques, and the number of progeny evaluated yearly. In some areas, for example, the local varieties may lack resistance to one factor but otherwise are well adapted with yield and quality. In this case the local variety should be improved by incorporating the resistance, crossing the local variety or varieties with a resistant one(s), and then selecting for resistance and the characteristics of the local variety. Several cycles would be required to accomplish this. An extreme case would be an area where there are no good local varieties, for example, Carimagua. In this case a large number of possible parents would have to be evaluated before beginning a recurrent population improvement programme (random crosses between parents, selection of progeny, random crosses between selections, etc.).

These decentralised programmes would produce varieties with the necessary resistance for the ecosystem in question, in addition to stable, high yields. They would then be distributed to similar ecosystems and evaluated for several years. The validity of this distribution strategy is supported by the yield results of several varieties adapted to CIAT or Popayán and Darién, for example, and their respective yields at the other site (Table 4). With several regionally located breeding programmes, the unstable yields frequently exhibited by introduced high-yielding varieties bred in ecologically different areas could be avoided.

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