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Sources of pest resistance in cassava

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ABSTRACT

Cassava (*Manihot esculenta* Crantz), a primary food crop in developing countries, can be severely affected by the attack of several Neotropical pests. To contribute to their management, this study sought to identify genetic resources for resistance breeding within the world's largest cassava genebank, held at the International Center for Tropical Agriculture (CIAT), in Colombia. We compiled data from 89 field trials between 1980 and 2004 evaluating natural mite, thrips, and whitefly herbivory in hundreds of cassava genotypes. Highly susceptible genotypes were excluded from subsequent evaluations within one or two trials. Statistical analyses estimating resistance were therefore performed only for genotypes evaluated for a given pest in at least three trials. These analyses revealed potentially-useful genotype variation in resistance to *Mononychellus tanajoa* (Bondar), *Aleurotrachelus socialis* Bondar, and *Frankliniella williamsi* Hood. Based on this variation, we identified 129 potential sources of resistance to *F. williamsi*, 33 to *M. tanajoa*, and 19 to *A. socialis*. Leaf pubescence was positively associated with resistance to the three pests, and root cyanide was negatively associated with resistance to *A. socialis*. Our results support the potential for developing improved cassava cultivars with high pest resistance.

1. Introduction

Cassava (*Manihot esculenta* Crantz) is a staple food for about 800 million people in the tropics (Lebot, 2009). It is a hardy root crop that demands little management and tolerates harsh soil and climate conditions where most other crops would fail (El-Sharkawy, 2004). Partly because of these attributes, the crop plays a central role in food security and carries unique potential for climate change adaptation in developing countries (Burns et al., 2010; Jarvis et al., 2012).

Several arthropod pests can disrupt cassava's contributions to food security (Bellotti and Schoonhoven, 1978; Bellotti et al., 1999; Herrera Campo et al., 2011). The two most notorious — the cassava mealybug (*Phenacoccus manihoti* Matile-Ferrero) and the cassava green mite (*Mononychellus tanajoa* (Bondar)) — threatened many African countries with the risk of famine when they invaded the continent during the 1970s (Herren and Neuenschwander, 1991). Less known, but thought to be similarly destructive, is a complex of monophagous cassava whiteflies largely dominated in the Americas by *Aleurotrachelus socialis* Bondar (Bellotti et al., 1999). In Africa, the polyphagous species *Bemisia tabaci* (Gennadius) is the most important whitefly pest (Omongo et al., 2012). Several thrips species, notably *Corynothrips stenopterus* Williams and *Frankliniella williamsi* Hood, are also considered major cassava pests (Bellotti and Schoonhoven, 1978; Bellotti et al., 1987), but their impact is less serious than that of the other arthropods mentioned above (Schoonhoven and Peña, 1976; Bellotti et al., 1999). Nearly all are native to tropical South America, the center of origin and diversity of cassava.

A valuable, but still underexploited, opportunity exists to breed cassava for resistance to pests. Researchers at the International Center for Tropical Agriculture (CIAT) have evaluated thousands of cassava accessions for field resistance to some of the crop's most serious pests (Bellotti et al., 1987). Considerable variability was observed to exist for resistance to green mites, whiteflies, and thrips, the three most extensively evaluated pest groups. These evaluations, however, have been only partially reported to date (e.g., Schoonhoven, 1974; Bellotti and Byrne, 1979; Bellotti and Arias, 2001).

Our study therefore aims to integrate and statistically-synthesize the outcomes of these previously unreported evaluations. Thus, we hope to shed light on promising sources of green mite, whitefly and thrips resistance for cassava breeding programs.

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Table 1
Sites for screening pest resistance in the cassava collection held at CIAT.

Site	Department	No. of trials[a]			Pest[b]	Lat.	Long.	Precipitation[c]	Temperature[c]		
		SR	PY	AY					Mean	Max	Min
Aremasain	Guajira	1	1	0	M	11.48	−72.68	656	28.4	34.7	22.2
Chicoral	Tolima	9	0	0	M, T, W	4.22	−74.97	1331	27.7	34.8	21.9
Ciénaga de Oro	Córdoba	2	0	0	W	8.87	−75.6	1443	27.6	33.7	22.0
El Carmen	Bolívar	0	2	3	T	7.98	−74.1	2410	24.1	29.9	18.7
La Libertad	Meta	1	0	0	T	4.03	−73.47	2883	26.1	33.0	20.6
Media luna	Magdalena	1	2	3	M, T	10.52	−74.52	1336	28.3	34.7	21.5
Mondomo	Cauca	0	0	1	T	2.88	−76.53	2228	21.0	27.8	14.8
Palmira	V. del Cauca	14	15	17	M, T, W	3.5	−76.36	1019	24.0	30.3	18.1
Puerto Gaitán	Meta	0	3	4	M, T	4.6	−71.32	2218	26.6	33.9	21.5
Quilichao	Cauca	3	0	0	W, T	3.02	−76.47	1903	23.2	29.8	16.9
Santo Tomás	Atlántico	1	0	0	W	10.73	−74.78	1020	28.0	33.5	22.0
Valledupar	Cesar	0	3	3	M, T	10.42	−73.58	2108	20.4	26.7	13.4

[a] SR = single row trial, PY = preliminary yield trial, AY = advanced yield trial.
[b] M = green mite, T = thrips, W = whitefly.
[c] From the WorldClim climate database (http://www.worldclim.org/) based on geographic coordinates. Precipitation values are in mm/year and temperature values in °C.

2. Materials and methods

2.1. Cassava genebank

The cassava genebank held at CIAT is the largest in the world for this crop. It preserves 6739 *Manihot* accessions, most of them collected in Colombia and Brazil (Jaramillo, 2012). About 72% of these accessions are traditional cultivars or landraces of *M. esculenta*. The remaining accessions are improved cultivars, wild species, or hybrids. The collection was established in 1969, and maintained as a field genebank for more than two decades while it was gradually replaced by a tissue culture genebank (Roca et al., 1989).

Many landraces in the genebank have been evaluated under one or more of the sequential selection trials carried out by CIAT's cassava breeding program (Ceballos et al., 2004). The first in the sequence is a single-row trial, where 5–10 plants per genotype are planted in single-row plots, without replication, at a distance of 1 × 1 m within and between rows. The second is a preliminary yield trial, where plants are arranged in a randomized complete block design, with three replicates and 10 plants per replicate, at a planting distance of 80 × 80 cm within and between rows. The third is an advanced yield trial, where the previous design is maintained but with 20 plants per replicate. The three types of trials are typically planted at the beginning of the rainy season, around April. We compiled data from 89 selection trials between 1980 and 2004. They included 31 single-row trials, 27 preliminary yield trials, and 31 advanced yield trials. More than half of them were conducted at CIAT headquarters in Palmira, Colombia (Table 1).

2.2. Resistance evaluations

Accessions were evaluated for resistance only in sites to which they were well adapted and grew vigorously in the absence of pests. Field sites, and their ecological characteristics, are listed in Table 1. The evaluations were facilitated by natural infestations of *M. tanajoa*, *A. socialis*, and *F. williamsi*, which peak during the dry seasons around August and February. Ratings were based on the damage scales described in Table 2. Although the scales are categorical, the evaluators treated them as continuous, often assigning scores with decimal points. Every plant in the trial was evaluated and scored for damage only upon the trial's first natural pest outbreak, typically around August, four months after planting. Subsequent outbreaks (if any) were not evaluated. To reduce the impact of escapes (i.e. when insect pests were not present), which could be falsely interpreted as resistance, the cassava breeding program only retained and recorded the highest damage score per accession per trial.

In addition to pest resistance, the genebank was also separately evaluated for leaf pubescence based on a 1–4 or 1–7 scale, where 1 signifies less pubescent, and for root hydrogen cyanide (HCN) content (Sánchez et al., 2009). Leaf pubescence is a useful cultivar descriptor, and it is often associated with pest resistance. HCN has also been implicated in pest resistance (Riis et al., 2003a), but high root HCN can render cassava toxic for human consumption. We obtained data for these traits from the CIAT cassava program to test for their association with pest resistance.

Table 2
Damage scales used to evaluate pest resistance in the cassava collection held at CIAT.

Green mite[a]	
0:	No mites or symptoms
1:	Mites on bud leaves, some yellow to white speckling on leaves
2:	Many mites on leaves, moderate speckling of bud leaves and adjacent leaves
3:	Heavy speckling of terminal leaves, slight deformation of bud leaves
4:	Severe deformation of bud leaves, reduction of buds, mites on nearly all leaves, leaves have whitish appearance, some defoliation
5:	Buds greatly reduced or dead, defoliation of upper leaves
Thrips[a]	
0:	No symptoms
1:	Yellow irregular leaf spots only
2:	Leaf spots, light leaf deformation, parts of leaf lobes missing, brown wound tissue in spots on stems and petioles
3:	Severe leaf deformation and distortion, poorly expanded leaves, internodes stunted and covered with brown wound tissue
4:	As above, but with growing points dead, sprouting of lateral buds
5:	Lateral buds also killed, plants greatly stunted, showing “witches'-broom” appearance
Whitefly[b]	
1:	No leaf damage
2:	Young leaves still green but slightly flaccid
3:	Some twisting of young leaves, slight leaf curling
4:	Apical leaves curled and twisted, yellow-green mottled appearance
5:	Same as 4, but with sooty mold and yellowing of leaves
6:	Considerable leaf necrosis and defoliation, sooty mold on central and lower leaves and young stems

[a] From Bellotti et al. (1987).
[b] From Bellotti and Arias (2001).

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