Generation of promissory cacao clones with high yield potential, disease resistance, and quality to improve the farmer's conditions in Latin America

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Introduction

The development of improved cocoa varieties in combination with good agronomic and agroforestry practices is a constant need. Therefore, the research developed in the genetic breeding program at CATIE, Costa Rica, is focused on the selection of promising genotypes with high yield potential, self-compatibility, good industrial quality and tolerance to the main diseases, with emphasis on moniliasis (FPR, *Moniliophthora roreri*) and black pod (BPR, *Phytophthora palmivora*).

Thus, in 2007, CATIE selected and released a group of 6 improved cacao clones that are already established in 9 Latin American countries (Phillips-Mora *et al*. 2012). Since then, CATIE continues the evaluations of other promising materials such as: CATIE-R5, CATIE-R52, CATIE-R58, CATIE-R73, CATIE-R78, CATIE-R91 and CATIE-R92. In order to release the best genotypes.

Objective of the study

Characterize 7 promising clones with yield parameters, natural incidence of FPR and BPR, determination of pod and seed indices, sexual compatibility and quality.

Methodology

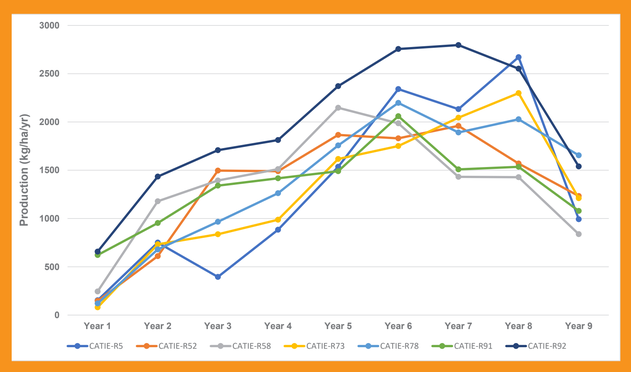
Based on monthly evaluations during 9 years of exercising a trial of 160 clones established in La Lola farm, located in the Atlantic Coast of Costa Rica (40 m.a.s.l, 3369 mm of annual rainfall and 24.5 °C average temperature), with high inoculum pressure to cacao moniliasis (FPR), CATIE selected a group of 7 clones being the most productive and with low natural incidence of FPR and BPR. After this selection, morphological evaluations continued using 6 flowers, 10 fruit and 5 seed characters. Pod and seed indices were also evaluated. Using artificial inoculation methods, the reaction to diseases was determined. (Phillips-Mora *et al*. (2005); Phillips and Galindo (1989)). Self and inter compatibility evaluation was determined following the standard protocol described by Royaert et al. (2011) and Eskes et al. (2000), where a matrix of 49 crosses with a total of 1960 pollinations was constructed. Quality evaluations included chemical analyses (theobromine, caffeine and epicatechin), complemented by sensory profile analyses performed at 2 main harvest times (March-April and November-December). Finally, the cacao trees were given structural prunings at the beginning on the trial and periodic maintenance prunings. On regular basis 600 g of granular fertilizer formula 18-5-15-6-0.3-7 divided into four applications of 150 g were applied every 3 months. No diseases control is carried out in the trial other than the cutting of diseased fruit at the time of the monthly evaluations.

Preliminary results

The results suggest that 57% of the evaluated genotypes were green in color, with an indented apex, intermediate roughness and hardness of the mesocarp, with the exception of CATIE-R92, which has an intense roughness and hardness; the shape of the fruit varied between cundeamor, angoleta and amelonada, with an intermediate basal constriction between slight and intermediate (Figure 1).

Figure 1. Fruits of the seven clones selected by CATIE

Except CATIE-R78, the new clones have an average yield higher than 1300 kg/ha/year, with the CATIE-R92 clone standing out with an average higher than 1900 kg/ha/year. (Figure 2)



1/ Year 1: first year of the production after two years of the establishment in the field

Figure 2. Annual average of 9 years of data of production (kg/ha/year) for 7 elite clones

Table 1 shows the results for the pod and seed indices, as well as the number of seeds per pod. At least 30 fruits were used for their determinations.

Table 1. Pod and seed indices and number of seeds per fruit of seven cacao clones selected by CATIE

Characteristic	GENOTYPE						
	CATIE-R5	CATIE-R52	CATIE-R58	CATIE-R73	CATIE-R78	CATIE-R91	CATIE-R92
Pod index	19	25	23	39	26	36	40
Seed index	1.6	1.2	1.3	1.1	1.3	1.3	1.1
Number of seed per pod	34	31	31	22	33	35	29

Clones CATIE-R58, CATIE-R5, CATIE-R91 and CATIE-92 were the most resistant to FPR, with a cumulative incidence lower than 8%, while for BPR, CATIE-R73, CATIE-R5 and CATIE-R78 stood out with cumulative incidences lower than 5% (Figure 3). Artificial inoculation evaluations are still under evaluation.

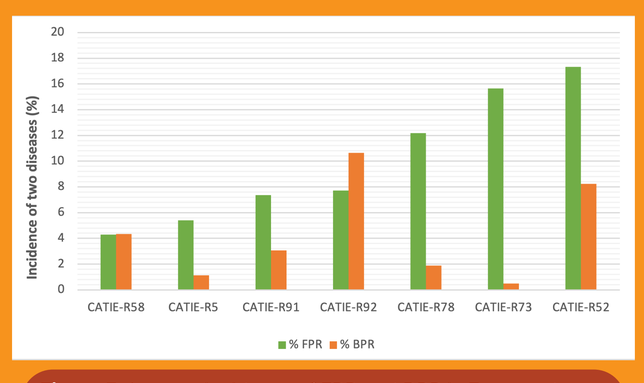


Figure 3. Average incidence of FPR and BPR in 7 cacao clones over 9 years

Regarding compatibility, a high inter-compatibility (≥40%) was observed among the clones; and CATIE-R5, CATIE-R52, CATIE-R58, CATIE-R78 and CATIE-R91 were determined to be self-compatible with a retention ≥30%.

Table 2. Matrix of self and cross sexual compatibility of seven selected clones

Female Parent	Male parent						
	CATIE-R5	CATIE-R52	CATIE-R58	CATIE-R73	CATIE-R78	CATIE-R91	CATIE-R92
CATIE-R5	+/1	++	++	++	++	++	++
CATIE-R52	++	+	++	--	--	++	--
CATIE-R58	++	++	+	++	++	++	++
CATIE-R73	++	++	--	-	--	++	++
CATIE-R78	--	--	--	--	+	++	++
CATIE-R91	++	++	++	++	++	+	++
CATIE-R92	++	++	++	++	++	++	-

1/ (+) = Self-compatible; (-) = Self-incompatible; (++) = Inter-compatible (≥ 30%); (--) = Inter-incompatible (≤ 30%).

Average theobromine contents of 14.16 (mg/g); caffeine of 2.15 (m/g); Theobromine Caffeine relationship of 6.64 and Epicatechin of 6.86 (mg/g) are recorded. The sensory profiles show an interesting combination of cocoa intensity and smoothness, with fruity, floral, herbal and nutty notes. As an example, the sensory profile of CATIE-R5 at two harvest times is shown. A slight difference is observed in the herbal floral attributes, which are not present in time 1, while the other attributes are similar in greater or lesser intensity. The sample lacks complexity and is characterized by cocoa flavor with a subtle acidity of fresh citrus and nutty fruit. Ephemeral aftertaste.

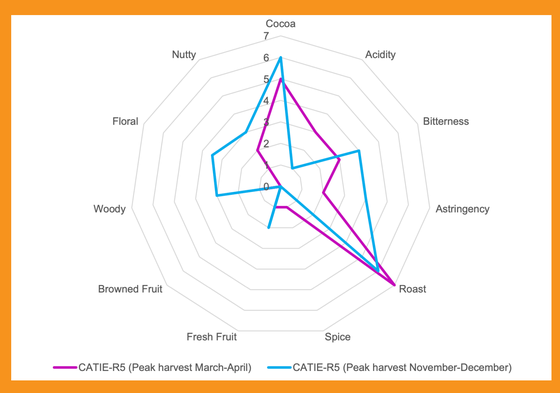


Figure 4. Sensory profile of clone CATIE-R5 at two times of the year. **A.** Peak harvest March-April. B. Peak harvest November-December.

Conclusions

The selection of improved varieties with outstanding characteristics from targeted crosses requires 15 to 20 years to reach growers. In this case, only 4% of the clones evaluated in the trial were selected, suggesting that despite having a large population of crosses with promising parents, there is high selection pressure on individuals and very few become a valuable source of germplasm available to benefit the cocoa sector.

The new genotypes created by CATIE have high production potential, combined with good disease resistance and sexual compatibility. These clones are options for producers to improve their production and income. Producers can combine them with the best clones currently available, CATIE-R6 or CATIE-R4. The new clones will be tested in multi-location trials in several Central American countries and a catalog with a complete characterization of the clones will be distributed to producers.

Recommendations

The results obtained from this research cannot be generalized to other environments. Therefore, it is recommended to corroborate their agronomic performance, phytosanitary behavior, expression of compatibility and quality in contrasting environmental conditions, before becoming commercial varieties at the producer's service.

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