# Genética y Germoplasma de Cacao

## EL CULTIVO DEL CACAO

## ESTACIÓN DE INVESTIGACIONES EN AGRICULTURA TROPICAL del USDA-ARS

# Diversidad genética

- El cacao es oriundo de Sur América
- Originalmente se empezó a seleccionar material silvestre en los bajos del amazona
  - Estas selecciones se hicieron en base a productividad
  - las selecciones empezaron a base de semilla
- Al desarrollarse técnicas mejoradas de producción como la injertía y siembras mas organizadas se empezaron a hacer selecciones clonales

United States Department Of Agriculture
Agricultural Research Service

# Diversidad genética

- Expediciones modernas tratan de colectar material genético (clonal o de semilla) con diferentes propósitos:
  - Enfermedades de consecuencia económica en siembras comerciales dictan que mucho de lo que buscamos en material nuevo genético es resistencia a dichas enfermedades y plagas
  - Productividad todavía importante
  - Organoléptico (jugando mas un rol)
    - Criollo, Nacional, Chuncho

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# Diversidad genética

- Centro de diversidad genética = centro de origen
- Debido a la globalización recursos fitogenéticos se están perdiendo
  - Por ende, colecciones de material genético se establecen *ex situ* para poder salvopreservarlas y aprovecharlas en el futuro
  - Colecciones tratan de incorporar la mayor cantidad de diversidad genética de la manera mas eficiente
- Colecciones internacionales
  - CRU, Trinidad, y CATIE, Costa Rica - **Colecciones NACIONALES

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# Diversidad genética

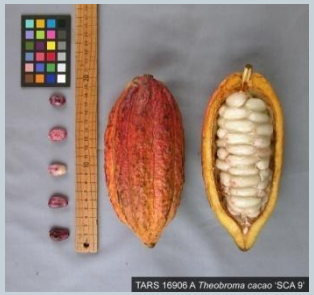
- Como se determina que es diverso genéticamente o que se debe de incorporar en una coleccion
  - Cualquier planta con rasgo útil
    - resistencia a enfermedad, raro en apariencia
  - Área geográfica
  - Estudios morfológicos y agronómicos
  - Estudios con marcadores moleculares

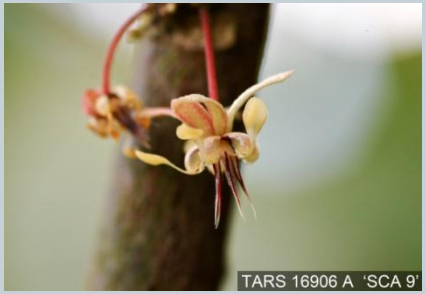
TARS 12044 *Theobroma cacao* 'RIM 30 [MEX]'

TARS 16734 *Theobroma cacao* 'MOCORONGO 1'

TARS 16584 *Theobroma cacao* 'CAS 1'

TARS 16788 *Theobroma cacao* '015 R'


TARS 16906 A *Theobroma cacao* 'SCA 9'

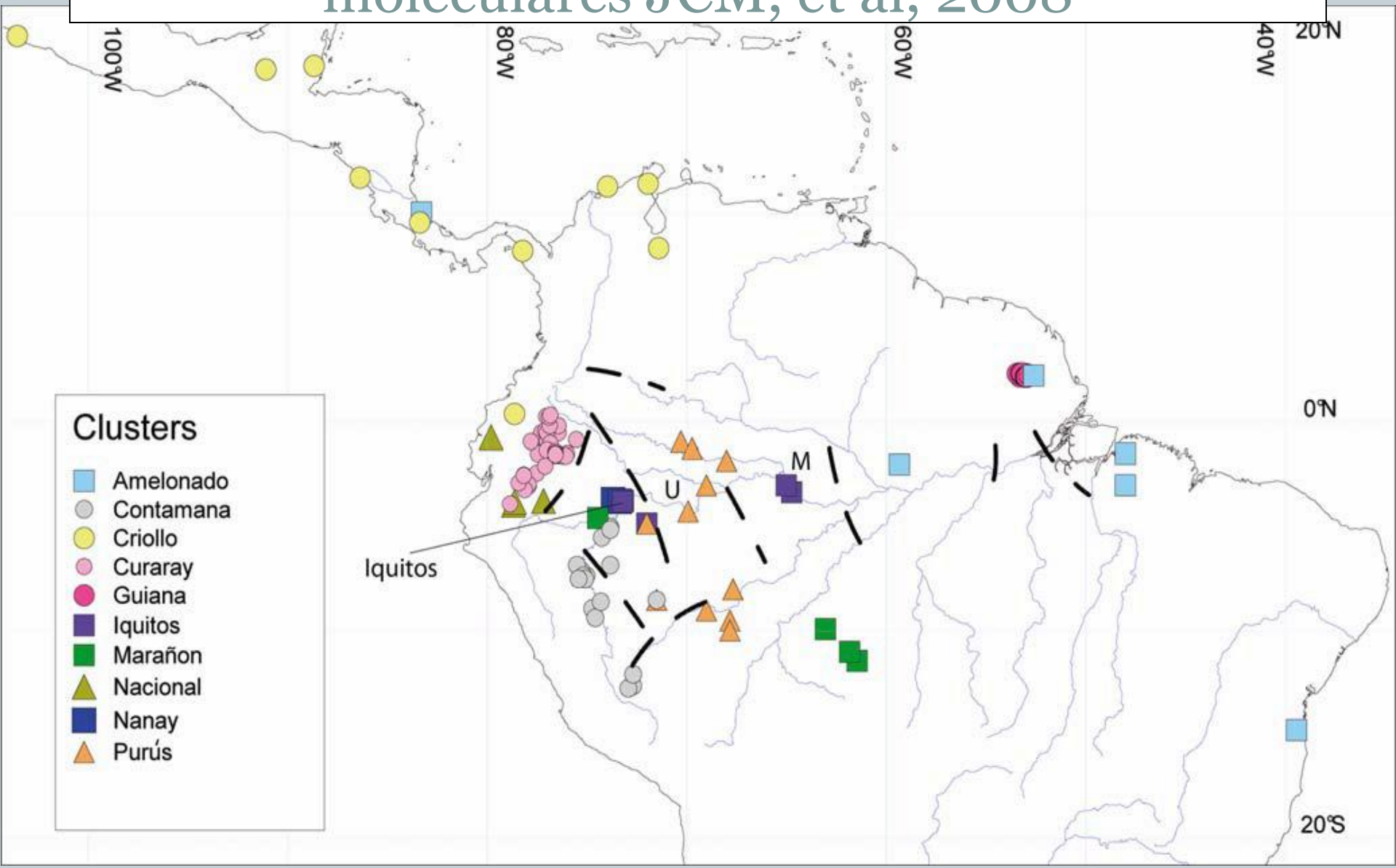

TARS 16906 A 'SCA 9'

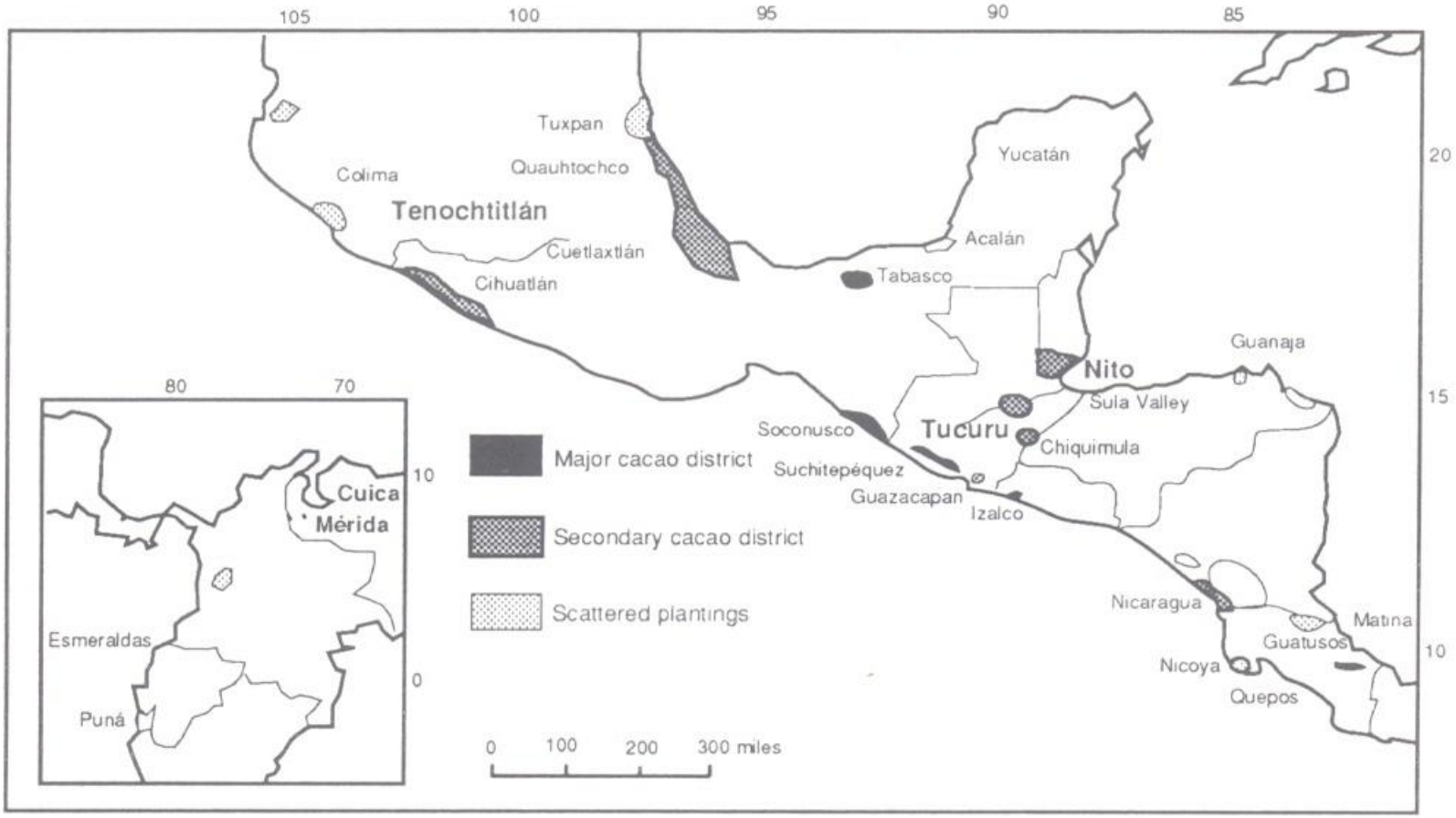
TARS 16847 'SPA 9 [COL]'

TARS 12044 'RIM 30 [MEX]'

TARS 16593 B 'CC 38'

# Clasificacion nueva en base a marcadores moleculares JCM, et al, 2008






The distribution of cacao cultivation in Pre-Columbian America. From Bergmann (1969). Reproduced with permission from the *Annals of the Association of American Geographers* 59:85–96.

# Colección de germoplasma (TARS/CACAO)

- Se empezó a introducir a TARS desde 1939
- Colección actual replantada: 2001-2003
- Lugar: Mayaguez, PR
- **154** clones/accesiones
- Diseño Experimental: RCBD
  - 3 bloques con 2 árboles por bloque
- Pleno sol, riego, abonado
- Colectando información fenotípica, agronómica y organoléptica
- Personal de apoyo

United States Department Of Agriculture
Agricultural Research Service

PA 13 (PER)

Pudrición negra (black pod) = *Phytophthora* spp. (*palmivora*).
***En nuestro caso cosechamos una vez al mes.

| Field No. | Accession name | GROUP | Infected | Total | % infection |
|---|---|---|---|---|---|
| **42** | **EET 353 [ECU]** | **B** | 6.67 | 18.67 | **35.71** |
| 32 | RIM 30 [MEX] | | 10.58 | 32.17 | 32.90 |
| 92 | PA 16 [PER] | B | 1.83 | 6.08 | 30.14 |
| 114 | POUND 7 [POU] | B | 1.67 | 5.92 | 28.17 |
| 69 | CC 37 | B | 7.00 | 26.50 | 26.42 |
| 58 | CC 39 | | 0.75 | 21.18 | 3.54 |
| 56 | CC 41 | | 1.00 | 32.73 | 3.06 |
| 88 | PA 13 [PER] | | 1.05 | 34.91 | 3.00 |
| 94 | TARS 15 | A | 1.00 | 37.50 | 2.67 |
| **21** | **PA 303 [PER]** | | 0.33 | 13.75 | **2.42** |

Índice de Mazorca = cantidad de mazorcas requeridas para un kilogramo de peso seco (entre mas bajo el numero mejor)

| Field No. | Accession name | GROUP | Dry Wgt | CountofPOD | Pod Index |
|---|---|---|---|---|---|
| **135** | **HY 27 1420** | | **3568** | **50** | **14.01** |
| 47 | CC 10 | A | 2894 | 44 | 15.20 |
| 134 | HY 27 1419 | | 2458 | 38 | 15.46 |
| 29 | ICS 40 | | 3182 | 50 | 15.71 |
| 87 | UF 10 | | 3152 | 50 | 15.86 |
| 59 | CC 54 | | 1182 | 50 | 42.30 |
| 152 | IMC 67 | B | 490 | 21 | 42.86 |
| 69 | CC 37 | B | 246 | 11 | 44.72 |
| 132 | MX 75/3 | B | 854 | 40 | 46.84 |
| **32** | **RIM 30 [MEX]** | | **950** | **49** | **51.58** |

# Productividad = producción promedia de mazorcas sanas por árbol y dividiendo por el índice de mazorca

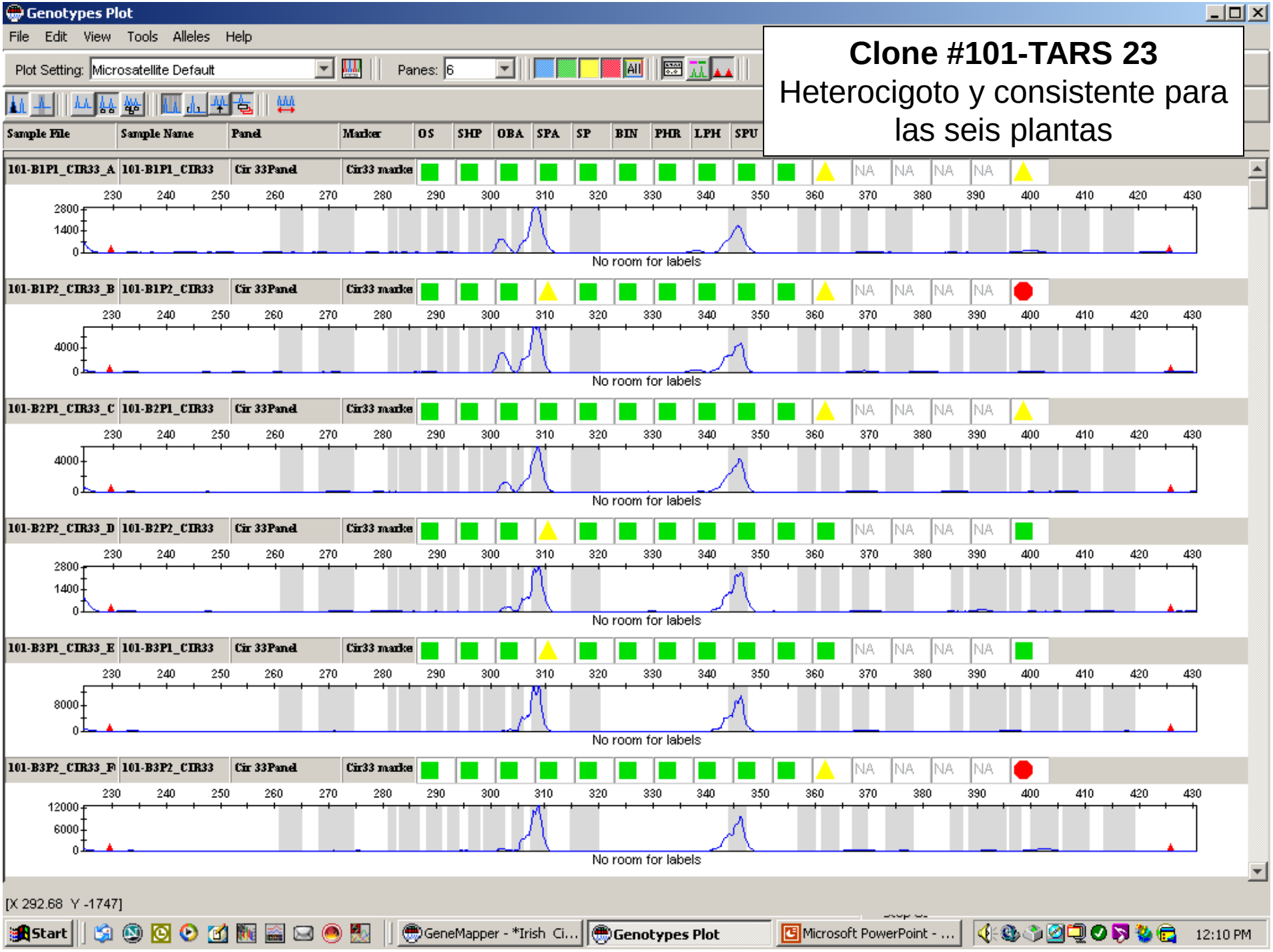
| Field No. | Accession name | GROUP | Total | Dry Wgt | CountOfPOD | PodIndex | KgPerTree |
|---|---|---|---|---|---|---|---|
| **100** | **TARS 27** | | **56.96** | **1704** | **50** | **29.34** | **1.94** |
| 111 | SPA 10 [COL] | | 45.79 | 2032 | 50 | 24.61 | 1.86 |
| 45 | CC 38 | A | 39.75 | 2202 | 50 | 22.71 | 1.75 |
| 98 | TARS 30 | | 45.41 | 1916 | 50 | 26.10 | 1.74 |
| 88 | PA 13 [PER] | | 33.86 | 2000 | 40 | 20.00 | 1.69 |
| 114 | POUND 7 [POU] | B | 4.25 | 454 | 8 | 17.62 | 0.24 |
| 19 | STAHEL | | 5.51 | 1860 | 45 | 24.19 | 0.23 |
| 92 | PA 16 [PER] | B | 4.25 | 694 | 13 | 18.73 | 0.23 |
| 77 | UF 710 | | 4.31 | 2126 | 42 | 19.76 | 0.22 |
| **128** | **AC T 2/11 [TTO]** | | **3.96** | **1148** | **34** | **29.62** | **0.13** |

| Mars Code | 3791 | | | |
|---|---|---|---|---|
| **Clone** | **SIC 1** | | | |
| | Avg | | Std Dev | |
| Cocoa | 4.4 | | 0.5 | |
| Total Acidity | 0 | | 0 | |
| Acid-Fruit | 0 | | 0 | |
| Acid-Acetic | 0 | | 0 | |
| Acid-Lactic (vomit like) | 0 | | 0 | |
| Acid-Mineral | 0 | | 0 | |
| Bitterness | 2.2 | | 0.4 | |
| Astringency | 5.8 | | 0.8 | |
| Fruit-Berries | 0 | | 0 | |
| Fruit-Citrus | 0 | | 0 | |
| Fruit-Dark tree (cherries, plum) | 0.4 | | 0.9 | |
| Fruit-Tropical (yellow) | 0 | | 0 | |
| Fruit-Dried | 0 | | 0 | |
| Fruit-Brown, mature (raisins, prunes) | 0 | | 0 | |
| Fruit-Over ripe | 0.4 | | 0.9 | |
| Floral-Woodsy | 0 | | 0 | |
| Floral-Grassy (green) | 0 | | 0 | |
| Floral-Green vegetative | 0 | | 0 | |
| Floral-Earthy | 0.4 | | 0.9 | |
| Floral-Herbal | 0.8 | | 1.1 | |
| Floral-Mushroom | 2.6 | | 1.7 | |
| Floral-Orange blossom | 0 | | 0 | |
| Floral-Flowers | 0.8 | | 1.1 | |
| Floral-Perfumy | 0 | | 0 | |
| Woody-Light wood | 0.8 | | 1.1 | |
| Woody-Dark wood | 1.4 | | 1.3 | |
| Woody-Resin | 2 | | 1.2 | |
| Spice-Tobacco | 0 | | 0 | |
| Spice-Peppery, savory | 0 | | 0 | |
| Spice-Other | 0 | | 0 | |
| Bark-Wood | 0 | | 0 | |
| Nutty | 3.6 | | 0.5 | |
| Nut Skins | 0 | | 0 | |
| Caramel / Browned sugar | 3.8 | | 0.4 | |
| Roast Degree (browned) | 4 | | 0 | |

| | | | | |
|---|---|---|---|---|
| Mouldy | 0 | | 0 | |
| Smokey | 0 | | 0 | |
| Hammy | 0 | | 0 | |
| Raw | 0 | | 0 | |
| Leather | 0 | | 0 | |
| Over Fermented-0rotten fruit | 0 | | 0 | |
| Over Fermented-putrid | 0 | | 0 | |
| Over Fermented-manure | 0 | | 0 | |
| Dirty | 0 | | 0 | |
| Other off flavor | 0 | | 0 | |
| Off Flavor Description | ### | | ### | |
| Other Comments | #### | | #### | |
| Nut Type (for nutty Flavor) | #### | | #### | |
| Cocoa | 4.4 | | 0.5 | |
| Total Acidity | 0 | | 0 | |
| Bitterness | 2.2 | | 0.4 | |
| Astringency | 5.8 | | 0.8 | |
| Total Fruity | 0.6 | | 1.3 | |
| Total Fresh Fruit | 0.4 | | 0.9 | |
| Total Brown / Mature Fruit | 0.4 | | 0.9 | |
| Total Floral | 5.3 | | 1 | |
| Floral: Herbal / earthy | 3 | | 1.8 | |
| Floral: flowers | 0.8 | | 1.1 | |
| Floral: woody | 3.1 | | 0.8 | |
| Floral: Spice | 0 | | 0 | |
| Bark--Wood | 0 | | 0 | |
| Nutty / Roasted Nuts | 3.6 | | 0.5 | |
| Nut Skins | 0 | | 0 | |
| Caralem / Browned sugar | 3.8 | | 0.4 | |
| Roast Degree (browned) | 4 | | 0 | |
| Off-Mouldy | 0 | | 0 | |
| Off-Smokey / hammy | 0 | | 0 | |
| Total Other Off | 0 | | 0 | |

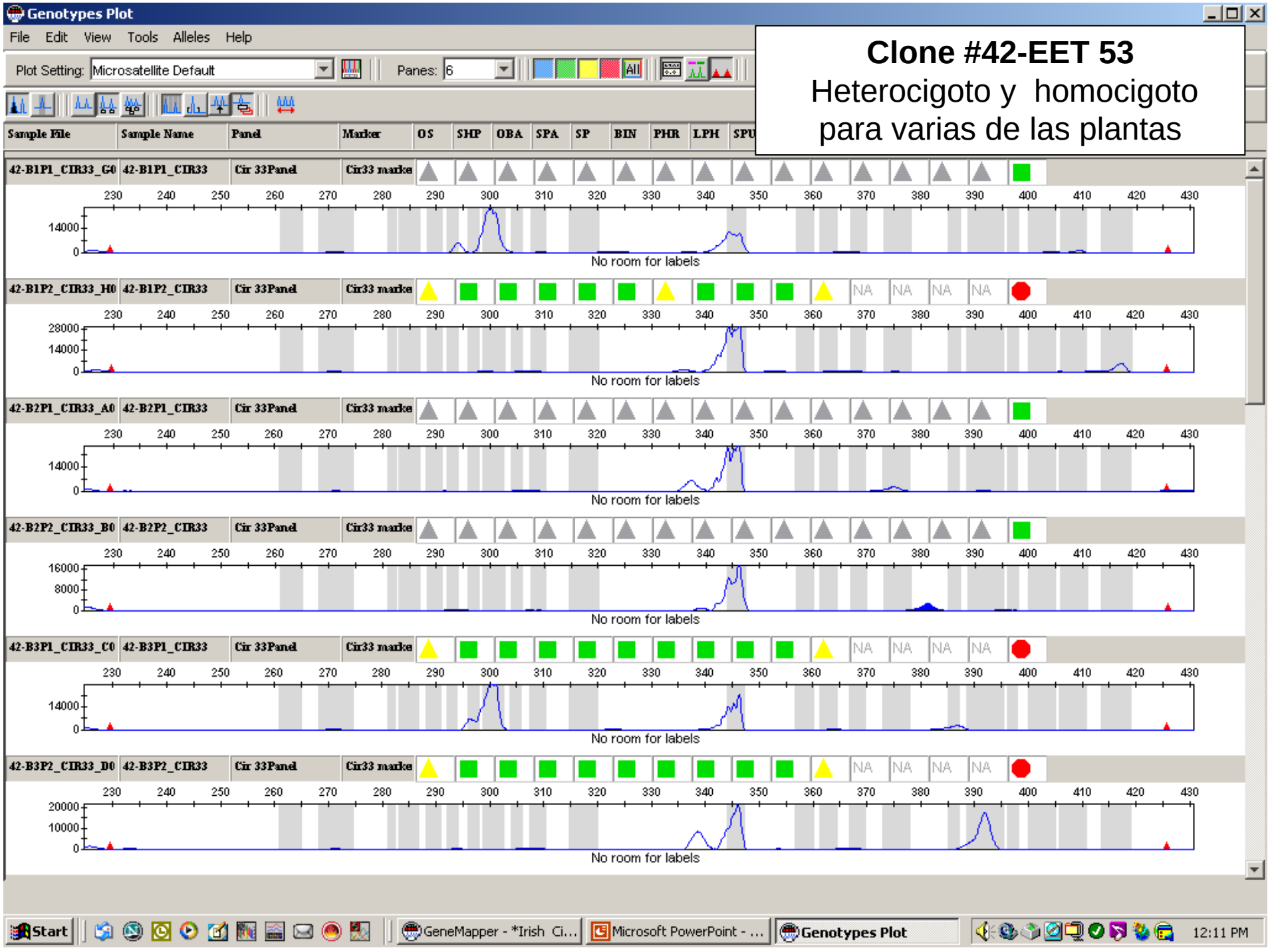
Table 3. Characteristics and summary statistics for the 15 International set of microsatellite primers utilized for fingerprinting the USDA-ARS Tropical Agriculture Research Station cacao (*Theobroma cacao*) collection.

| **Primer name** | **Forward and Reverse Sequences (5' - 3')** | **Chrom** | **Tm** | **Repeat Motif** | | **Alleles/ Locus†** | **$H_{Obs}$‡** | **$H_{Exp}$‡** | **PIC** |
|---|---|---|---|---|---|---|---|---|---|
| **mTcCIR1§** | F: gcagggcaggtccagtgaagca<br>R: tgggcaaccagaaaacgat | 8 | 51 | $(ct)_{14}$ | 127-144 | 5 | 0.47 | 0.45 | 0.44 |
| **mTcCIR6** | F: ttccctctaaactaccctaaat<br>R: taaagcaaagcaatctaacata | 6 | 46 | $(tg)_7(ga)_{13}$ | 222-247 | 9 | 0.64 | 0.64 | 0.96 |
| **mTcCIR7** | F: atgcgaatgacaactggt<br>R: gctttcagtcctttgctt | 7 | 51 | $(ga)_{11}$ | 148-163 | 6 | 0.61 | 0.65 | 0.65 |
| **mTcCIR8** | F: ctactttcccatttacca<br>R: tcctcagcattttctttc | 9 | 46 | $(tc)_5$ tt$(tc)_{17}$ ttt$(ct)_4$ | 288-304 | 6 | 0.56 | 0.62 | 0.92 |
| **mTcCIR11** | F: tttcctcattattagcag<br>R: gattcgatttgatgtgag | 2 | 46 | $(tc)_{13}$ | 288-317 | 11 | 0.61 | 0.66 | 0.74 |
| **mTcCIR12** | F: tctgaccccaaacctgta<br>R: attccagttaaagcacat | 4 | 46 | $(cata)_4$ $n_{18}$ $(tg)_6$ | 188-251 | 10 | 0.73 | 0.74 | 0.80 |
| **mTcCIR15** | F: cagccgcctcttgttag<br>R: tatttgggattcttgatg | 1 | 46 | $(tc)_{19}$ | 232-256 | 11 | 0.82 | 0.81 | 0.87 |
| **mTcCIR18** | F: gatagctaaggggattgagga<br>R: ggtaattcaatcatttgaggata | 4 | 51 | $(ga)_{12}$ | 331-355 | 9 | 0.66 | 0.67 | 0.72 |
| **mTcCIR22** | F: attctcgcaaaaacttag<br>R: catccaaggagtgtaaatag | 1 | 46 | $(tc)_{12}$ $n_{146}$ $(ct)_{10}$ | 279-290 | 6 | 0.60 | 0.58 | 0.59 |
| **mTcCIR24** | F: tttggggtgatttcttctga<br>R: tctgtctcgtcttttggtga | 9 | 46 | $(ag)_{13}$ | 185-203 | 7 | 0.57 | 0.50 | 0.95 |
| **mTcCIR26** | F: gcattcatcaatacattc<br>R: gcactcaaagttcatactac | 8 | 46 | $(tc)_9$c$(ct)_4$tt$(ct)_{11}$ | 282-307 | 9 | 0.71 | 0.67 | 0.69 |
| **mTcCIR33** | F: tgggttgaagatttggt<br>R: caacaatgaaaataggca | 4 | 51 | $(tg)_{11}$ | 264-346 | 10 | 0.71 | 0.72 | 0.73 |
| **mTcCIR37** | F: ctgggtgctgatagataa<br>R: aataccctccacacaaat | 10 | 46 | $(gt)_{15}$ | 133-185 | 12 | 0.67 | 0.70 | 0.72 |
| **mTcCIR40** | F: aatccgacagtctttaatc<br>R: cctaggccagagaattga | 3 | 51 | $(ac)_{15}$ | 259-284 | 9 | 0.70 | 0.79 | 0.84 |
| **mTcCIR60** | F: cgctactaacaaacatcaaa<br>R: agagcaaccatcactaatca | 2 | 51 | $(ct)_7(ca)_{20}$ | 187-223 | 12 | 0.64 | 0.73 | 0.86 |
| **Mean** | | | | | | **8.8** | **0.65** | **0.66** | **0.78** |




**Clone #101-TARS 23**

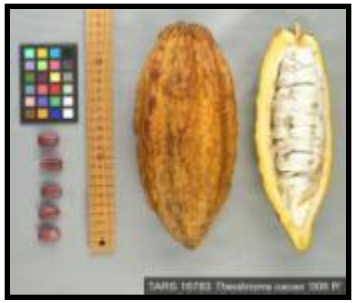
Heterocigoto y consistente para las seis plantas




**Clone #42-EET 53**

Heterocigoto y homocigoto para varias de las plantas

RIM 2 [MEX]


RIM 6 [MEX]

RIM 10 [MEX]

RIM 13 [MEX] A

RIM 2 [MEX]

RIM 15 [MEX]

RIM 34 [MEX]

RIM 41 [MEX]

RIM 48 [MEX]

RIM 52 [MEX]

RIM 75 [MEX]

RIM 105 [MEX]

P 10 [MEX]

P 22 [MEX]

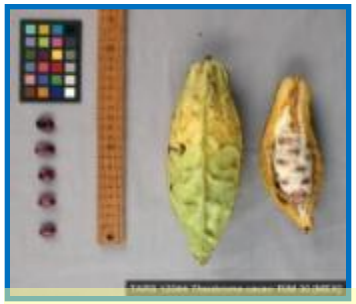
P 43 [MEX]

EET 381

EET 353

SGU 69

RIM 13 [MEX] B


RIM 30 [MEX]

TARS 16615 - Theobroma cacao - EET 94 [ECU] - - Windows Internet Explorer
http://www.ars-grin.gov/cgi-bin/npgs/acc/display.pl?1076497
Google Search Sidewiki Check Translate AutoFill bmirish
TARS 16615 - Theobroma cacao - EET 94 [ECU] - Page Tools

# TARS 16615

Theobroma cacao L. MALVACEAE

Maintained by the Natl. Germplasm Repository - Mayaguez. NPGS received: 06-Jul-1939. Life form: Tree. Improvement status: Clone.

## Accession names and identifiers

EET 94 [ECU]
Idtype: INSTITUTE. Comment: Estacion Experimental Tropical, Pichilinque, Ecuador
PI 315286
Idtype: OTHER. Group: CACAO-TARS.

## Availability

Material is available for distribution.
Request this germplasm

## Observations (Genotypic Only)

## Vouchers for accession

- Computer image. On: 2009.
  Flower.
- Computer image. On: 2009.
  Flower Bud.
- Computer image. Taken by: Goenaga, R., USDA, ARS. On: 10/2004.
  Cacao Pods and Seed.



Cite as: USDA, ARS, National Genetic Resources Program. *Germplasm Resources Information Network - (GRIN)*. [Online Database] National Germplasm Resources Laboratory, Beltsville, Maryland. Available: http://www.ars-grin.gov/cgi-bin/npgs/acc/display.pl?1076497 (28 January 2010)

# Programas de fitomejoramiento

- Todos los programas nacionales tienen un componente de selección
  - Ejemplo: Republica Dominicana donde tienen programas destinados a identificar selecciones locales a nivel de campos de agricultor que sean productivas y resistentes
- Programas de fitomejoramiento si existen
  - CATIE, INIAP, CRIG "USDA-ARS TARS"
  - Proceso largo y costoso
    - Cruza, fruta, semilla, arboles – evaluación (10 anos fácil)

United States Department Of Agriculture
Agricultural Research Service

# USDA-ARS TARS

- Selecciones echas en Puerto Rico
  - Cruces fueron hechos en CATIE Costa Rica
    - ‘UF-668’ x ‘POUND-7’; ‘IMC-67’ x ‘UF-613’; ‘EET-400’ x ‘SCA-12’; ‘SCA-6’ x ‘EET-62’; y ‘IMC-67’ x ‘SCA-12’
    - Clones padres: productivos y resistentes a enfermedades
  - Se evaluaron arboles de semilla en varios lugares
  - Se obtuvieron 9 clones seleccionados por su alta productividad
    - Serie TARS 1, 9, 14 ,15, 23, 27, 30 ,31, 34
      - Un poco bajos en índice de mazorca -compesan con productividad

Comparación de producción de nueve selecciones de cacao superior y la de los parentales correspondientes a pleno sol y bajo manejo intensivo en Puerto Rico durante cuarto años de cosecho, 1994 a 1997.

| TARS Clone Number | Family pedigree or parental clone | Mean dry bean weight per year (Kg/tree) | Dry bean weight per year (Kg/ha) | Pod Index [z] |
|---|---|---|---|---|
| 14 | SCA-6 x EET-62 | 1.60 [a y] | 2,400.0 [a] | 36.6 [c] |
| 31 | SCA-6 x EET-62 | 1.54 [a] | 2,310.0 [a] | 43.3 [b] |
| 34 | UF-668 x Pound-7 | 1.48 [a] | 2,220.0 [a] | 25.0 [ef] |
| 23 | UF-668 x Pound-7 | 1.45 [a] | 2,175.0 [a] | 24.5 [ef] |
| 27 | EET-400 x SCA-12 | 1.43 [a] | 2,145.0 [a] | 39.7 [bc] |
| 30 | SCA-6 x EET-62 | 1.43 [a] | 2,145.0 [a] | 40.4 [bc] |
| 9 | EET-400 x SCA-12 | 1.38 [a] | 2,070.0 [a] | 28.7 [de] |
| 15 | SCA-6 x EET-62 | 1.36 [a] | 2,040.0 [a] | 41.2 [bc] |
| 1 | UF-668 x Pound-7 | 1.35 [a] | 2,025.0 [a] | 25.4 [ef] |
| | *UF-668* | *0.94 [b]* | *1,410.0 [b]* | *22.0 [f]* |
| | *SCA-12* | *0.85 [bc]* | *1,275.0 [bc]* | *31.0 [d]* |
| | *Pound-7* | *0.79 [bc]* | *1,185.0 [bc]* | *31.3 [d]* |
| | *EET-400* | *0.57 [c]* | *855.0 [c]* | *50.3 [a]* |
| | *IMC-67* | *0.52 [c]* | *780.0 [c]* | *23.6 [f]* |
| | **Mean of parental clones** | **0.73** | **1,095.0** | **31.6** |

Ricardo Goenaga, Heber Irizarry, and Brian Irish. 2009. **TARS Series of Cacao Germplasm Selections.** HORTSCIENCE 44(3):826-827.

Table 3. Chocolate flavor profiles of nine cacao clones selected for high yield in Puerto Rico during a four-year harvesting period, 1994-1997.

| Clone | Flavor profile of 65% chocolate |
|---|---|
| TARS -1 ----- | A very complex nut character comes through, more like chestnuts roasting with a blend of some hazelnuts skins. |
| TARS-9 ----- | Gorgeous color. Very smooth in flavor profile. Very mild chocolate notes up front with low overall bitterness and a distinct nut character that persists. Aftertaste has a residual nut / nut skins note. Really good chocolate. |
| TARS-14 ----- | Good base chocolate notes with a deep woody source. Slight earthy, woodsy and mushroom notes. Overall flavor comes off as quite good, very complex and very dark. |
| TARS-15 ----- | Very dark color. Early mild astringency with an interesting wood resin/floral note that comes through nicely. The late taste has an aldehyde, fruit character that is quite interesting. The continuing aftertaste of the chocolate is very notable. Complex floral/mild fruit note. |
| TARS-23 ----- | Rich, smooth chocolate profile up front with lots of deeper, mild dark wood notes. Really good overall flavor profile. The aftertaste is really a good chocolate. |
| TARS-27 ----- | Smoother flavor profile from the beginning with some very mild floral notes and some mild chocolate cocoa. Some mild spice notes along with slight flowers. The color is also a very attractive brown, lighter brown hue. |
| TARS-30 ----- | More of a woody late floral taste. Astringency comes back at the aftertaste. |
| TARS-31 ----- | Interesting fruit tartness along with some astringency and a complex mildly floral with tropical fruit notes. |
| TARS-34 ----- | Mild chocolate note with some mild fruit character. More of a fleshy yellow fruit flavor and some mild brightness. Acceptable flavor. |

# IDIAF – Mata Larga

- Selecciones echas en Republica Dominicana
  - Selecciones a nivel de campo de agricultor
  - Evalúan a nivel de campo de arboles originales
  - Después evalúan a nivel de ensayos clónales

| | | Rasgos importantes de algunas de las selecciones locales | | | | | |
|---|---|---|---|---|---|---|---|
| Nombre de seleccion local/clone | Origen | Color fruto inmaduro | Color fruto maduro | Promedio de # semilla | Indice mazorca(g) | Incice de semilla | % grasa |
| **MEDIO PESO (ML4)** | San Francisco de Macoris | verde | amarillo | 38 | 17.0 | 1.60 | 52.5 |
| **PEPINO (ML3)** | San Francisco de Macoris | verde | amarillo | 40 | 16.0 | 1.60 | **48.8** |
| **GENOVEVA 2** | Barranca, La Vega | rojo | Rojo-anaranjado | - | - | - | 52.2 |
| **GENOVEVA 5** | Barranca, La Vega | rojo | Rojo-anaranjado | 38 | 24.0 | 1.20 | 51.9 |
| **IML-44** | **SF de Macoris 'El Cercado'** | **verde** | **amarillo** | **-** | **8.1** | **3.20** | 51.7 |

**Cuadro 1.** Principales características de seis clones seleccionados para distribución a los productores en Centro América. ** adaptado de Astorga et al.,

| Clon | CATIE R1 | CATIE R4 | CATIE R6 | CC-137 | PMCT-58 | ICS-95 |
|---|---|---|---|---|---|---|
| **Producción** | | | | | | |
| Prom (Año 3-9) [a] | 738 | 972 | 1010 | 825 | 704 | -- |
| Año 8 | 826 | 1211 | 1298 | 1386 | 941 | -- |
| Año 9 | 1856 | 2488 | 2600 | 1688 | 1416 | -- |
| **Índice de Mazorca** | 29 | 18 | 24 | 24 | 27 | 22 |
| **Índice de semilla** | 1.3 | 1.5 | 1.4 | 1.7 | 1.2 | -- |
| **Enfermedades** | | | | | | |
| % Monilia | 11 | 8 | 6 | 26 | 20 | R |
| % Mazorca negra (Nat.) | 6 | 1 | 1 | 1 | 4 | |
| % Mazorca negra (Art.) | S | S | MR | MR | MS | |
| **Compatibilidad** | Si | No | No | Si | No | si |
| **Calidad** | | | | | | |
| Calidad 1 - Guittard | 3 | 1,4 | 3,3 | 3-2 | 2-1 | -- |
| Calidad 2 - Felchlim | -- | 3 | 1 | 3 | 2 | -- |
| **% Grasa** | 56 | 60 | 57 | 54 | 58 | -- |

•Datos obtenidos por el Programa de Mejoramiento Genético del CATIE
•[a] Promedio basado en el peso de la semilla
•R= Resistente, MR= moderadamente resistente, MS= moderadamente susceptible, S= susceptible