

22 al 25 de septiembre de 2015



Oil Palm Breeding for the Past 50 Years

Rajanaidu N.
**SENIOR RESEARCH
FELLOW
MALAYSIAN PALM OIL
BOARD**



Scope of the Paper

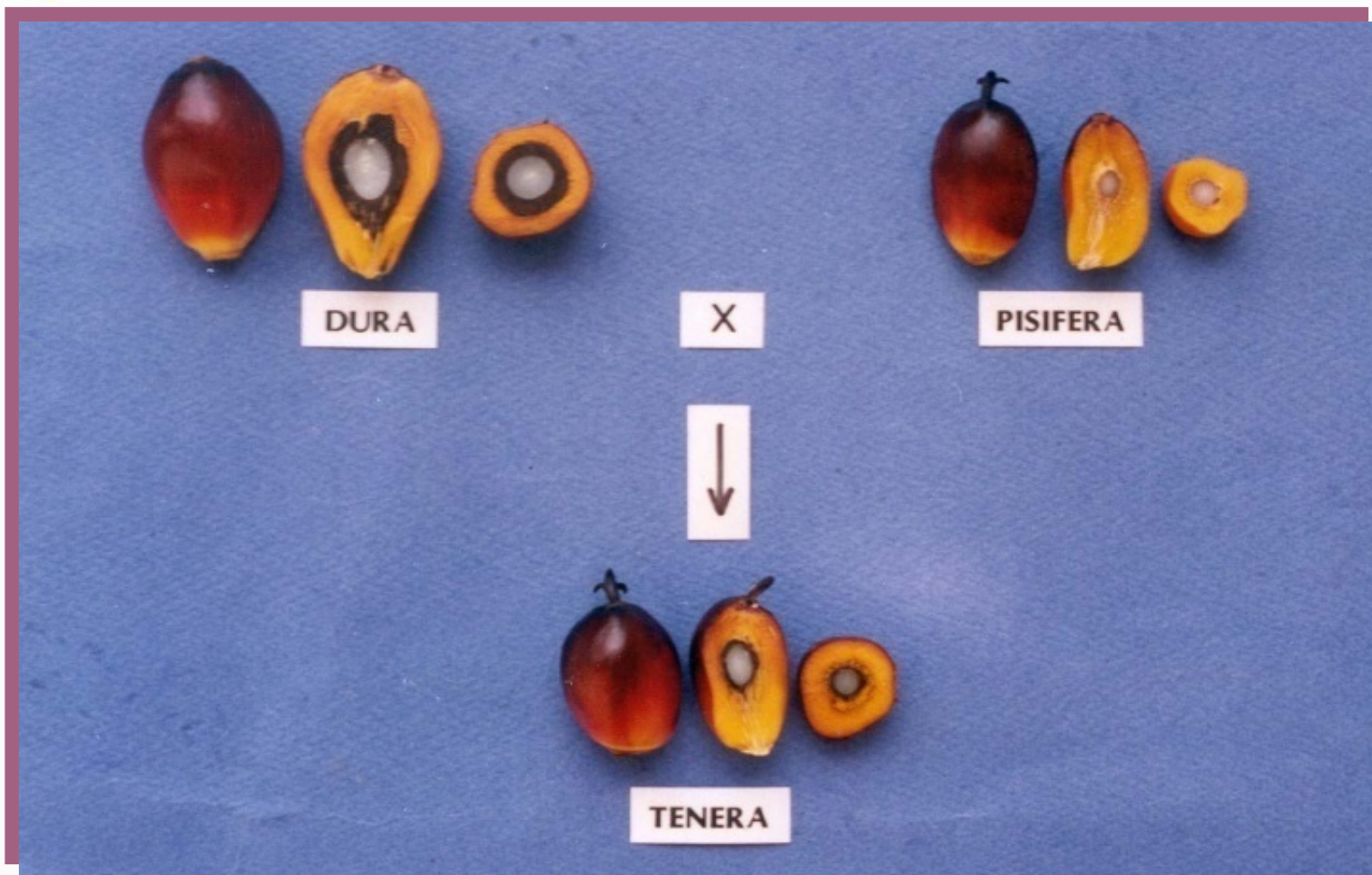
- Discovery of Shell Gene (Beirnaert, 1941)
- Developments before 1960 (DXP)
- Yangambi, NIFOR, Unilever, CIRAD (IRHO), AVROS (Indonesia), DOA of Malaysia, ASD, Cinepalma
- Science of Oil Palm Breeding
- Tissue Culture
- MAS / Genomic Selection
- Oil Palm Genome Sequence
- Shell, Virescens, “Karma”
- Future Developments / Conclusion

Major Palm Oil Producing Countries (2014)

Country	Production (1000 T)	Yield (t/ha)	Mature Area (1000 ha)
Costa Rica	210	2.92	72
Honduras	460	3.68	125
Brazil	370	2.85	130
Colombia	1109	3.41	325
Ecuador	490	2.07	237
Indonesia	31000	3.80	8150
Malaysia	19217	4.25	4620

Oil World, 2015

Discovery of shell by Beirneart, 1941 INEAC



Exchange Programmes

- Experience Internationale **1946**
 - ❖ Socfin, IRHO & INEAC
- Cooperative Breeding Scheme (CBS) **1956**
- Oil Palm Genetics Laboratory (OPGL) **1963**
- Sabah Breeding Programme (SBP) **1964**
- Combined Breeding Programme (CBP) **1980**



Basic Oil Palm Breeding Populations

Duras

- 4 Bogor palms – *Deli duras*
- Some African *duras*


Pisiferas

- SP540, AVROS
- Yangambi (718...)
- Calabar (Nigeria)
- Ekona (Cameroon)
- La Me (Ivory Coast)
- URT (Deli X Congo)



Cooperative Breeding Scheme (CBS) 1956

- DOA
- Ulu Remis (Guthrie)
- Klanang Baru (Golden Hope)
- Johore Labis (Socfin)
- Jenderata Estate (United Plantations)



Oil Palm Genetics Laboratory (OPGL) 1963

- Guthrie (KGSB)
- Harrisons (HMPB)
- Dunlops
- Pamol

Introduction of Genetic Material by OPL (Chan et al., 1986)

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	Year Planted	Experiment No.	
		HMPB	Guthrie
<i>E. guineensis</i>			
Dura Programme			
Historical collection of old <i>dura</i> material in Bogor, Sumatra and Malaysia	1970	PT49	
Tenera and Pisifera Programme			
Elite commercial DXP from Nifor	1967	PT29	GB31
Introduction TXT from Nifor	1967	PT30	
Crosses obtained from Nifor, Camerouns and IRHO	1968	PT33	
Open pollinated <i>teneras</i> from Bamenda (Camerouns)	1969	PT40	GB57
Crosses Ex-Yangambi material with BM119 and Socfin <i>teneras</i>	1969	PT42	
Ghana Ex-Nifor for DXT	1972	PT53	
Binga (Zaire) TXT	1973	PT54	GB67
Disease Resistance			
Wilt resistance material from the Camerouns	1968		GB46
<i>E. oleifera</i>			
Collection from Panama, Costa Rica and Colombia			
<i>E. oleifera</i> , F1 (GXO), F2 (GXO) and backcross (GXF1)	1969	PT50	GB62
<i>E. oleifera</i> (open-pollinated)	1971		GB64a GB64b



Sabah Breeding Programme (SBP) 1964

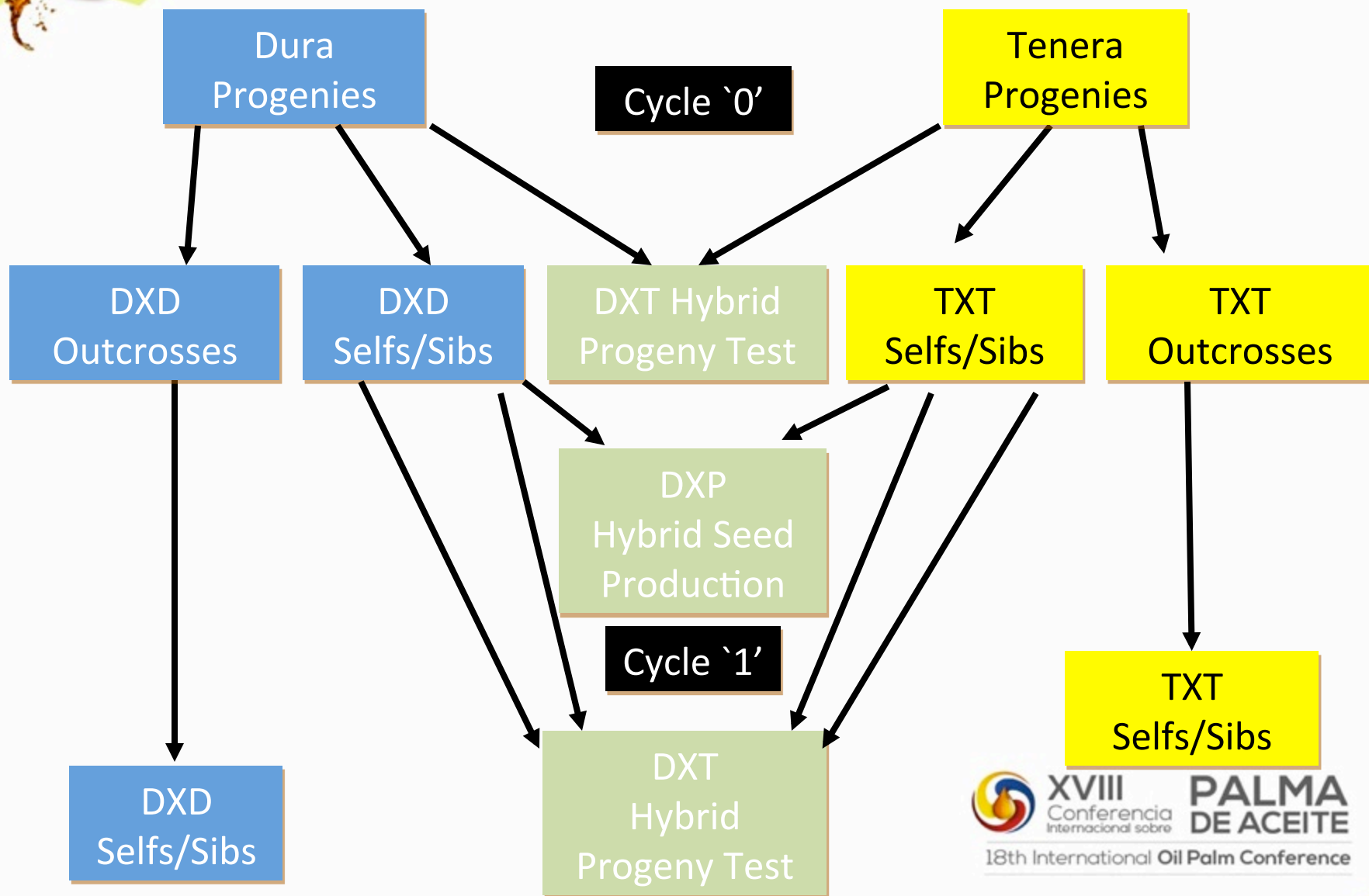
- Initiated by C.W.S. Hartley for Sabah
- Chemara (Deli *duras* & URT)
- HMBP (Deli *duras*)
- Socfin (Deli *duras*)
- DOA (Deli *duras*)
- Unilever Nigeria (Calabar – WT)
- Unilever Cameroons (Ekona)
- NIFOR



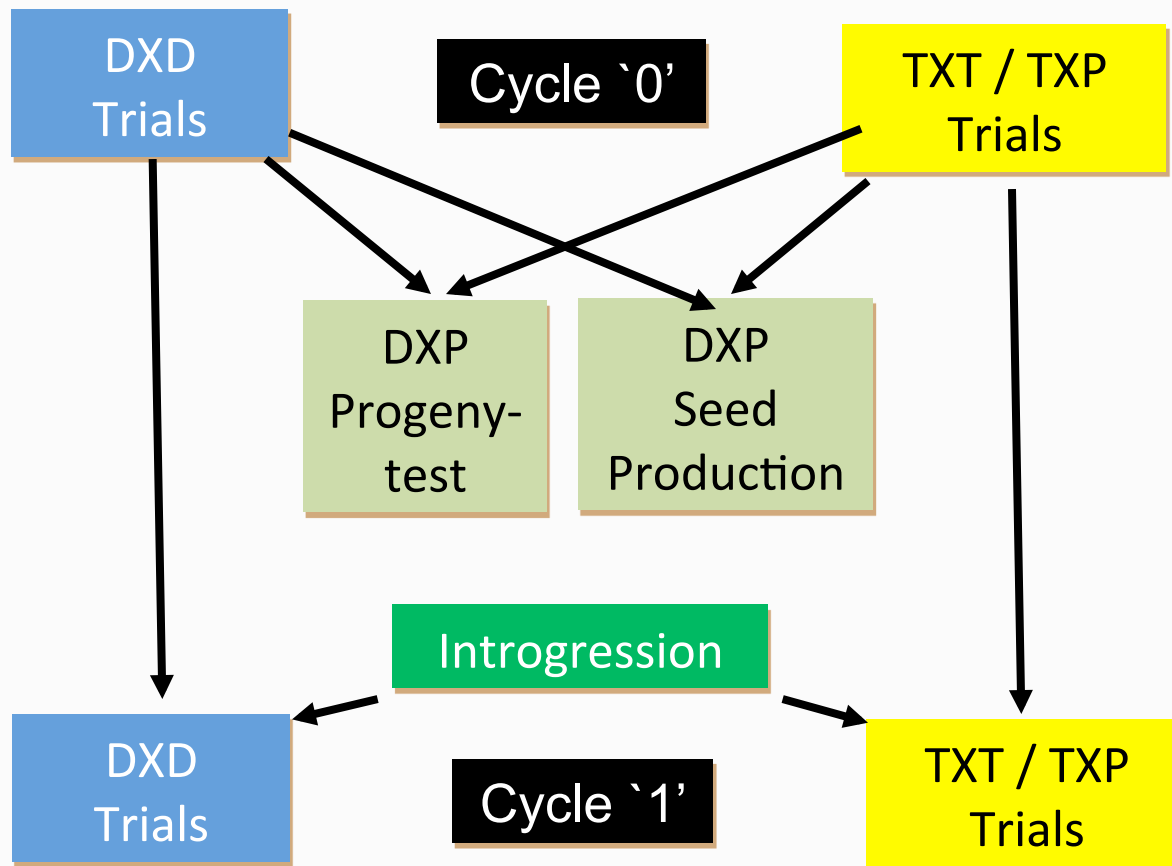
Combined Breeding Programme (>1980)

- Exchange between Congo and Cameroon, Indonesia, Thailand, PNG and Colombia(Unilever)
- *Pisifera* (Ekona, Djongo, AVROS X Djongo, Mongana, Mongana X NIFOR)
- *Duras* (Ekona, Djongo, Ekona x Djongo, Yangambi X NIFOR, Brabanta X Djongo, Mangana X Djongo, PNG)

Breeding Methods - RRS



Breeding Methods - MRS





Experimental Designs – RCBD

- Experimental design such as RCBD was used to study the performance of the breeding materials
- Popular experimental design

CRD



G X E

- GXE interaction is important in breeding for disease tolerance
- For example, *Ganoderma* is prominent in South-east Asia, *Fusarium* in Africa and Bud-rot/Spear-rot in South America
- Dr Rafii, Dr Lee Chong Hee, Rajanaidu

MPOB's Collection

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Country **Year** **No of Accessions**

Elaeis guineensis

Nigeria	1973	919
Cameroon	1984	95
Zaire	1984	369
Tanzania	1986	60
Madagascar	1986	17
Angola	1991, 2010	54
Senegal	1993	104
Gambia	1994	45
Sierra Leone	1996	56
Guinea	1994	61
Ghana	1996	58

Elaeis oleifera

Honduras	1982	14
Nicaragua	1982	18
Costa Rica	1982	61
Panama	1982	27
Colombia	1982	41
Suriname	1982	6
Ecuador	2004, 2006	5



Elaeis guineensis



Senegal

Gambia

Guinea

Sierra Leone

Ghana

Cameroon

Africa

Nigeria

Zaire

Tanzania

Angola

Madagascar



Elaeis oleifera



Central-South America

PS Series

- PS1 – slow height increment
- PS2 – high iodine value
- PS3 – high kernel palms
- PS4 – high carotene (*E. oleifera*)
- PS5 – thin-shell *teneras*
- PS6 – large fruit *duras*
- PS7 – high bunch index
- PS8 – high vitamin E (*E. guineensis*)
- PS9 – peach palm (*Bactris gasipaes*)
- PS10 – long-stalk palm
- PS11 – high carotene (*E. guineensis*)
- PS12 – high oleic
- PS13 – low lipase



ASD Germplasm collections

1970: a large *oleifera* collection from Central America and Colombia with more than **300** accessions was established in Costa Rica

1978: first progeny trial, **236 O_xG** combinations using different *guineensis* pollen-sources: AVROS, Ekona, Ulu Remis, Yangambi, WAIFOR , composite Deli-Yangambi

1979: new *E. oleifera* from Surinam and Brazil

2003: *E. oleifera* from Ecuador

Oleifera genes in several compact populations

POPULATION	<i>E. oleifera</i> genes
OxG hybrid (open pollination)	50%
Original Compact Palm (OCP)	25%
First backcrossing cycle (BC ₁)	12.5%
Sub population: BC ₁ F ₁	12.5%
Sub population: BC ₁ F ₂	12.5%
Sub population: BC ₁ F ₁ x <i>E. guineensis</i>	6.25%
Second backcrossing cycle (BC ₂)	6.25%
Sub population: BC ₂ F ₁	6.25%
Third backcrossing cycle (BC ₃)	3.125%



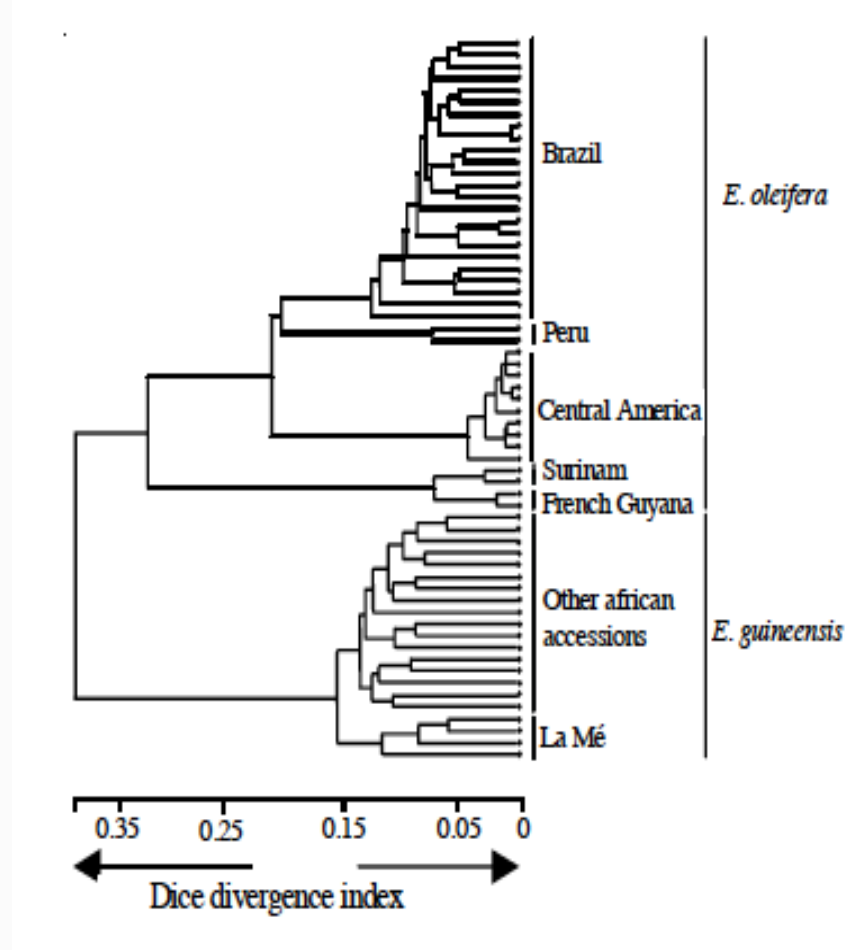
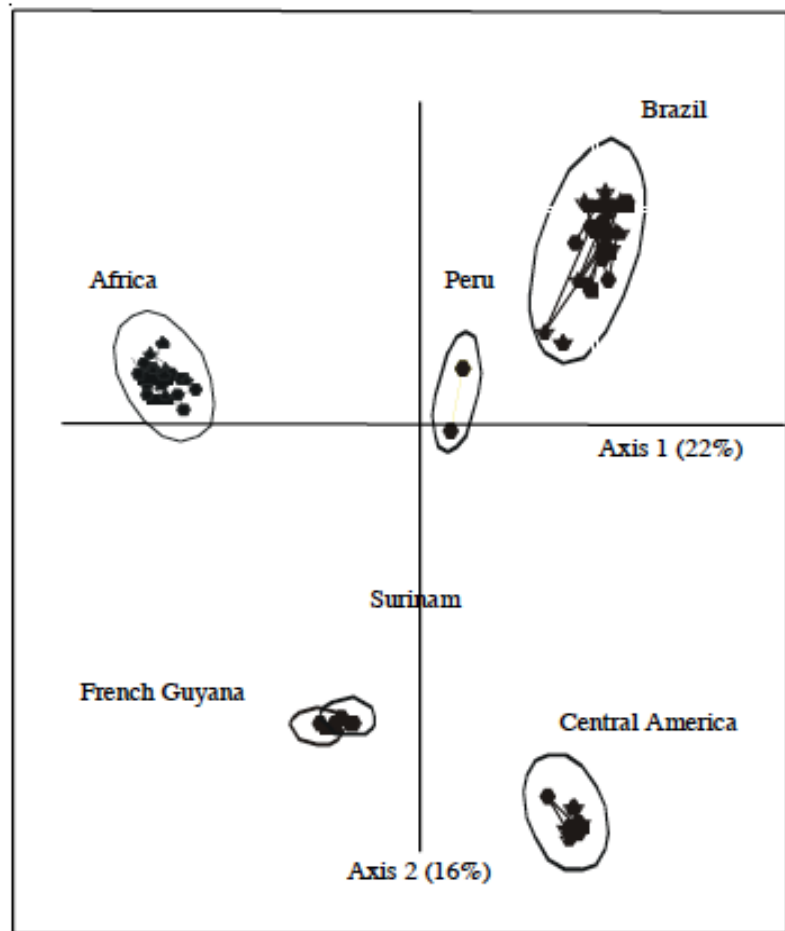
Genetic diversity of *Elaeis oleifera* (HBK) Cortés and interspecific hybrids OxG from different origins

Diana Marcela Arias Moreno, Fausto Prada Chaparro and
Hernán Mauricio Romero

**Oil Palm Biology and Breeding Program
Colombian Oil Palm Research Center
Cenipalma**

Department of Biology, Universidad Nacional de Colombia

Genetic Diversity of *E. oleifera*



Source Barcelos, 2002

Genetic diversity of *Elaeis oleifera* and interspecific hybrids OxG from different origins

Origin	<i>N</i>	<i>A</i>	<i>A_e</i>	<i>H_o</i>	<i>H_e</i>
Colombia	43	4.692	2.416	0.343	0.526
Brazil	103	4.600	2.219	0.343	0.453
Peru	267	3.769	2.042	0.372	0.425
Ecuador	24	1.231	1.209	0.121	0.113
Coari x La Mé	9	3.796	2.956	0.667	0.600
Cereté x La Mé	10	4.538	3.188	0.692	0.636

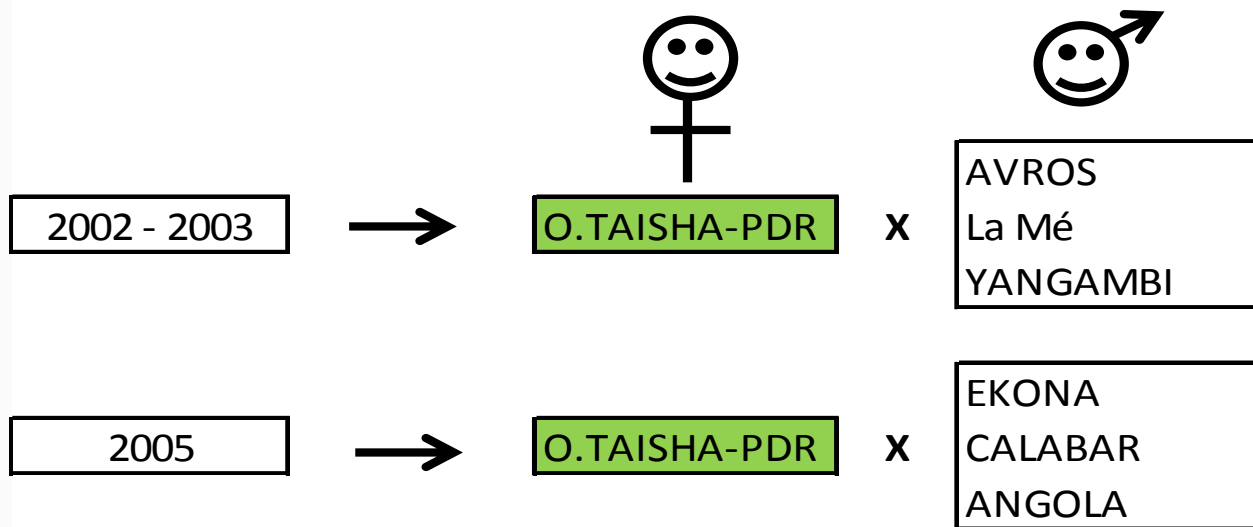
N: number of palms evaluated per geographical region, *A*: average number of alleles per geographic region, *A_e*: effective number of alleles, *H_o*: observed heterozygosity, *H_e*: Nei's (1978) expected heterozygosity.

Represent a useful genetic resource

PDR



Taisha oleífera x Pisíferas



Collection of *E. oleífera* at PDR

Origen	Colección	Año Colección	Región	Poblaciones	Accesiones	Palmas sembradas
Ecuador	Morona	1996	1	1	3	26
		1997		3	5	560
Ecuador	Nuevo Rocafuerte	2006	2	1	5	38
				2	7	67
Ecuador	Pastaza	2007	2	12	43	610
				1	5	185
Colombia	America* (* Intercambio)	2006	Cereté		1	3
Brasil		2008	Coari		7	97
Total			7	20	76	1586

Performance of Hybrids at PDR

Característica físico - químicas de los frutos al año tres de producción, valores promedio de familias por progenitor	Hibridos O x G	Hibridos O x G	Hibridos O x G
	E. oleífera - Taisha E.guineensis - AVROS	E. oleífera - Taisha E.guineensis - La Mé	E. oleífera - Taisha E.guineensis - Yangambi
Forma del racimo	Redonda	Triangular	Redonda
Frutos por racimo - unidades	1985	1758	1466
Peso medio del fruto - gramos	21,42	16,85	18,05
Frutos en racimo (%)	73,50	69,97	84,34
Frutos Normales (%)	43,86	39,10	46,17
Frutos Partenocarpicos (%)	29,16	33,11	27,17
Frutos vanos y blancos (%)	9,50	2,89	9,52
Pulpa en fruto (%)	88,99	85,69	87,39
Aceite en mesocarpio (%)	31,56	31,07	33,22
Aceite en racimo (%)	21,7	19,29	21,41
Producción de aceite (Ton/ha/año)	5,58	3,22	4,00



Morpho-agronomic and molecular characterisation of oil palm *Elaeis guineensis* Jacq. materials from Angola

Diana Marcela Arias Moreno, María Yuli González González,
Fausto Prada Chaparro, Edwin Restrepo Salazar and Hernán
Mauricio Romero Angulo.

Oil Palm Biology and Breeding Program
Colombian Oil Palm Research Center
Cenipalma

Number of palms evaluated at the morpho-agronomic and molecular traits

Geographical regions	No. Families	Bunch analysis	Components yield	Molecular Markers
Caixito	9	571	287	88
Sumbe	8	473	242	100
Cabinda	11	723	354	119
Benguela	6	323	175	58
Uige	9	575	295	90
Total	43	2.665	1.353	455



- ✚ 3 years bunch analysis
- ✚ 5 years yield
- ✚ 30 SSR



Hybrids (*E. guineensis* X *E. oleifera*)

- Hybrids (*Elaeis guineensis* X *Elaeis oleifera*) resistant to fatal yellowing in Colombia
- Tolerant to the bud-rot disease in Latin America
- Source of new genetic variation in oil palm
- Need assisted pollination
- OER is lower

Mortality level of PC (%) in guineensis

Female	Male	GP 8	GP 9	GP 9
LM 404 D self	LM 2T self	75.0	68.0	41.2
DA 128 D self	LM 9 T self	17.8	21.4	10.1

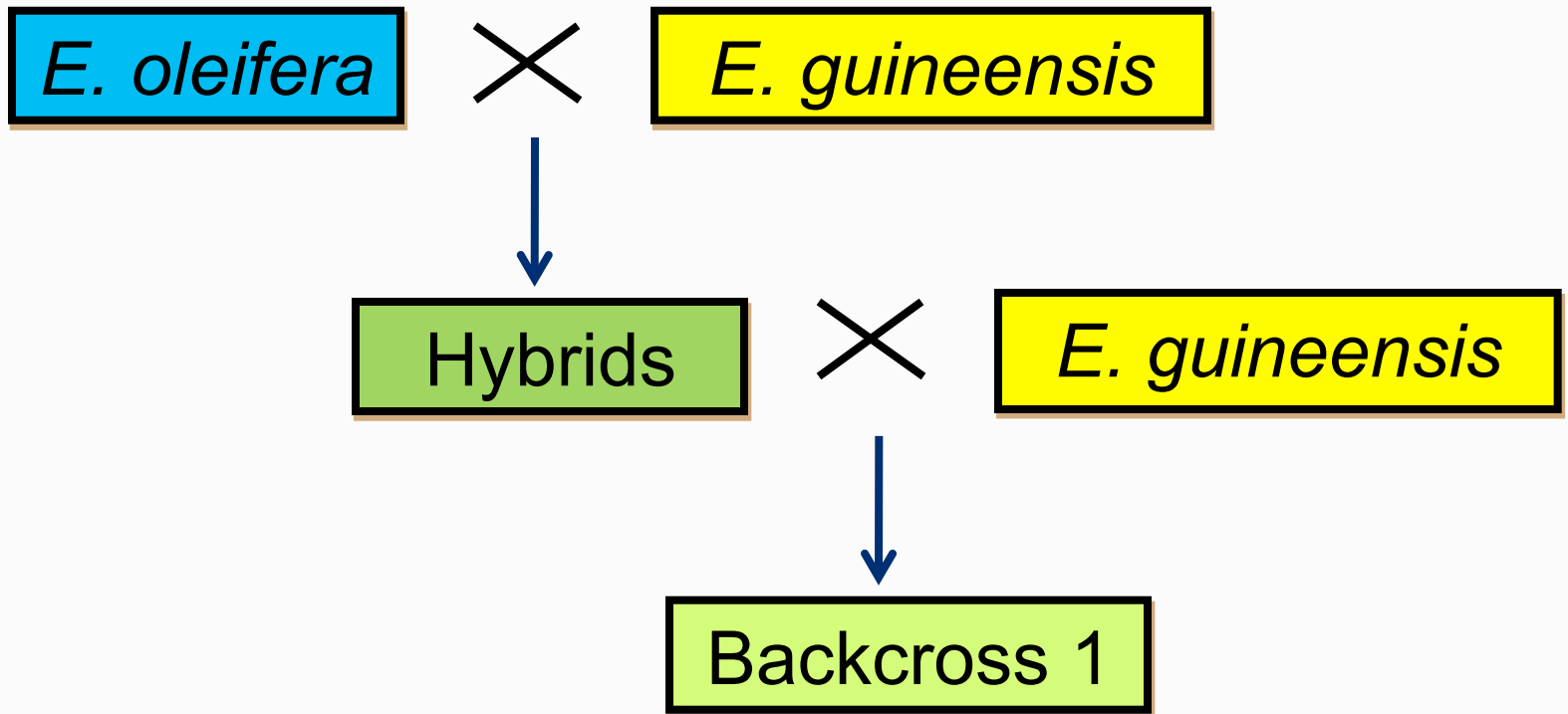
Source: Amblard (2010)

Mortality level of PC (%)

Cultivar	% Final Cumulative Severity
Coari x La Me	52.2
Coari x Pobe	44.0
Patuca (E.g)	98.0
Pepilla (E.g)	96.0

Source: Edwin A et al (2014)

Backcrosses

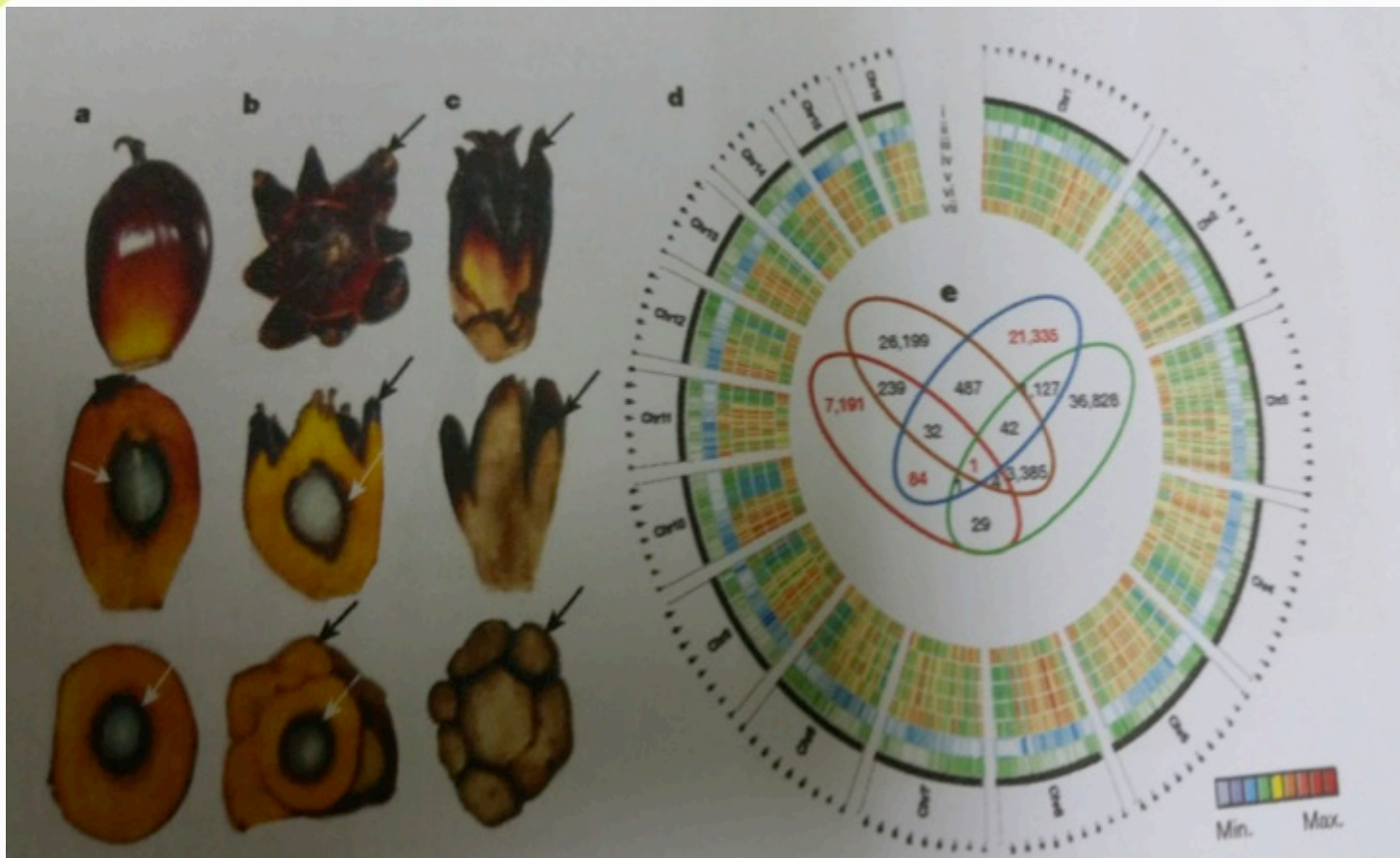


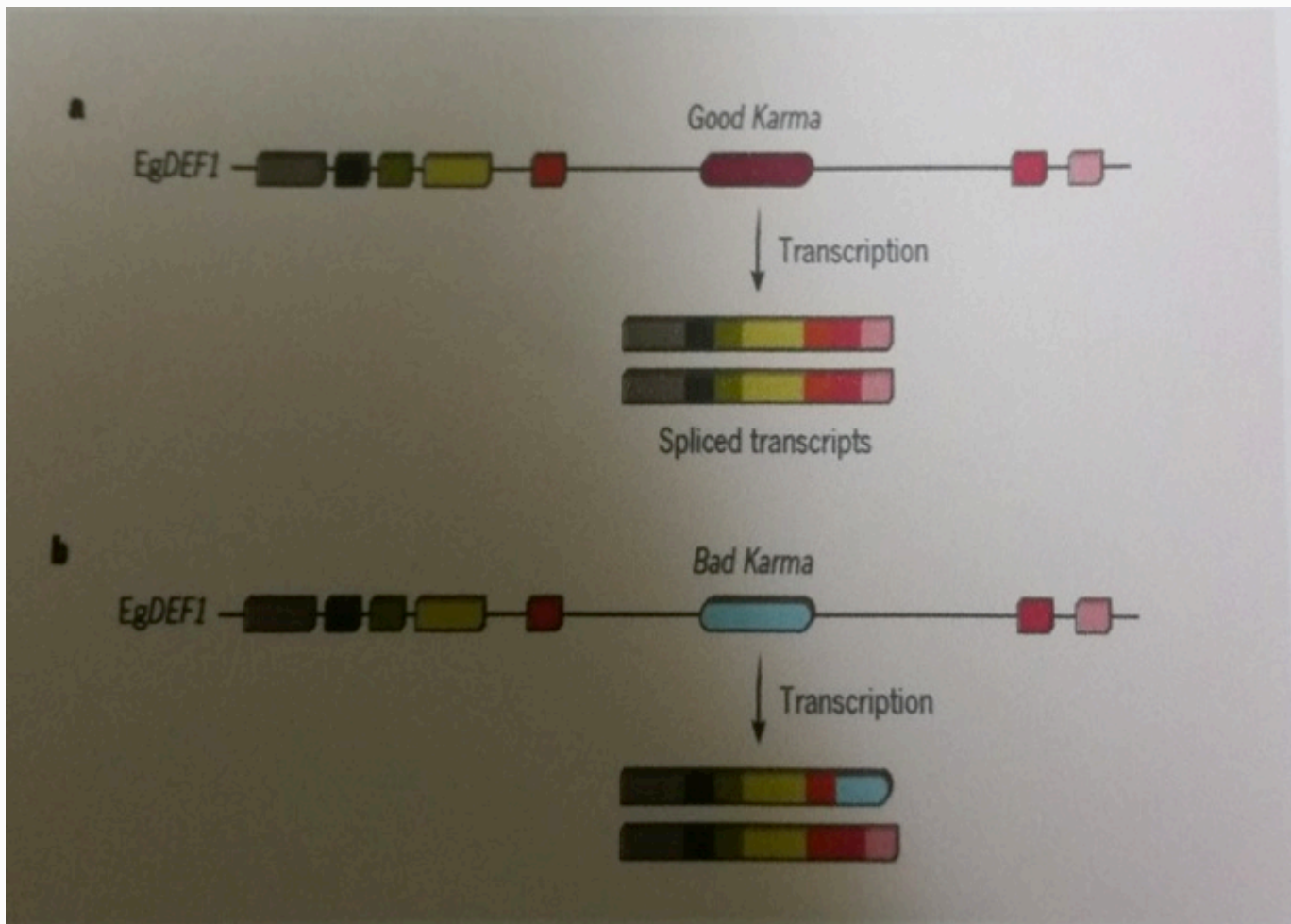
* Note: MPOB, UP and FELDA carry out extensive research on inter-specific hybrids and backcrosses



Tissue Culture

- In Malaysia, the current ramet production has reached five million(AAR,TSH,IOI,FELDA)
- Low conversion rate of explants to callus (approximately 19%) and from callus to embryoid stage (approximately 4%)
- Critical issues includes somaclonal variation, cloning efficiency, ortet selection, recloning and the suspension culture system need to be resolved





Clonal Seeds

- An alternative to clones
- Parents with good SCA

Dura clone X Pisifera
↓
Semi-Clonal Seeds

Dura X Pisifera clone
↓
Semi-Clonal Seeds

Dura clone X Pisifera clone
↓
Bi-Clonal Seeds



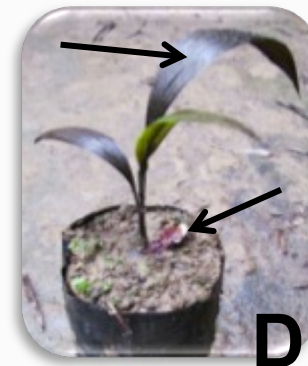
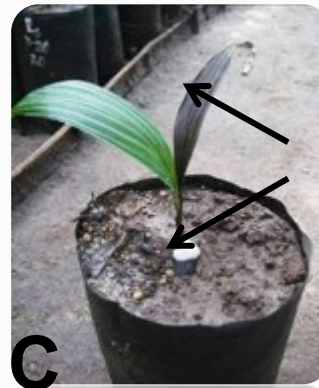
Disease Resistance

- Bud-rot
- Ganoderma
- Fusarium

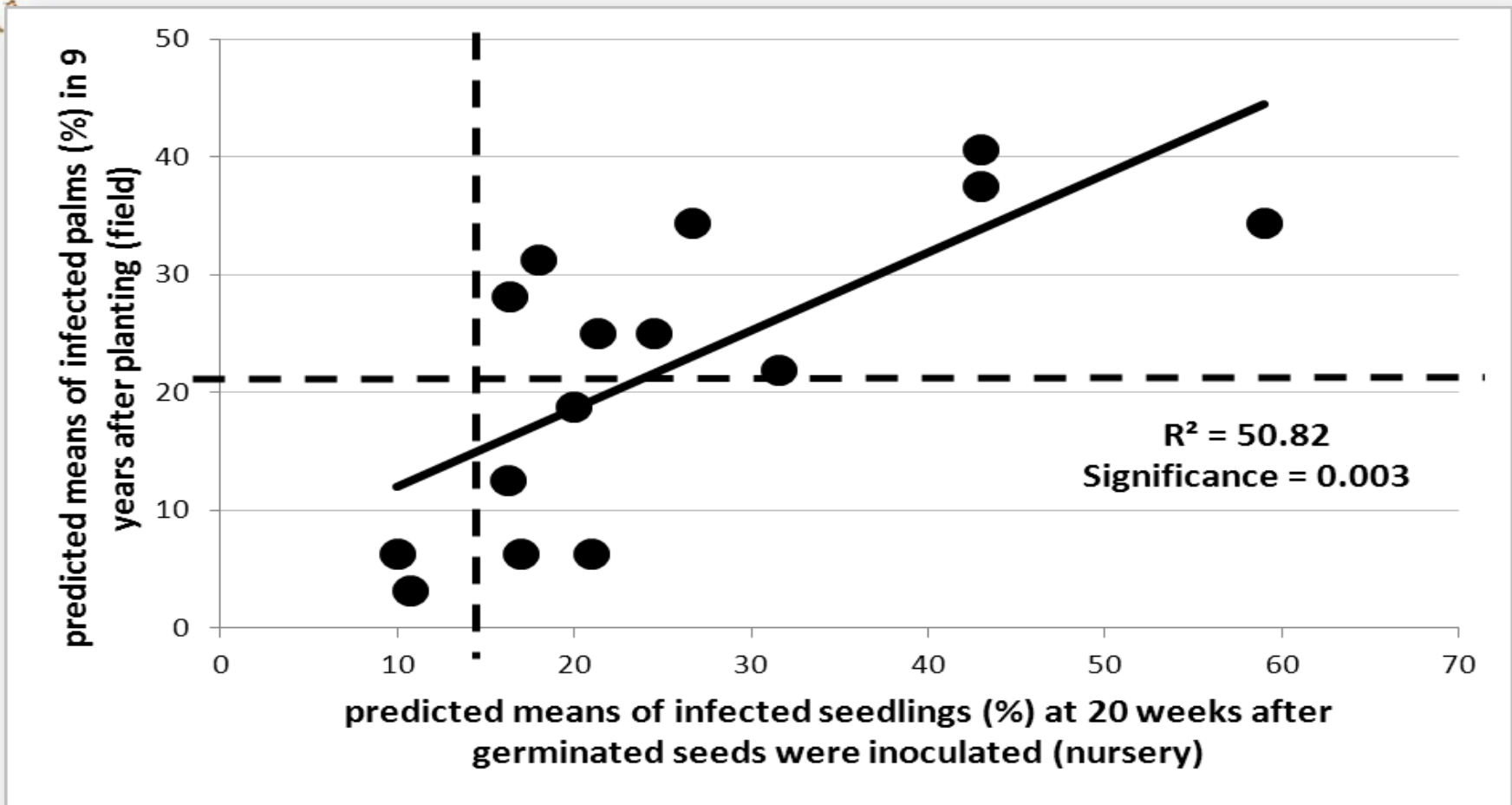
NURSERY SCREENING

External observation :

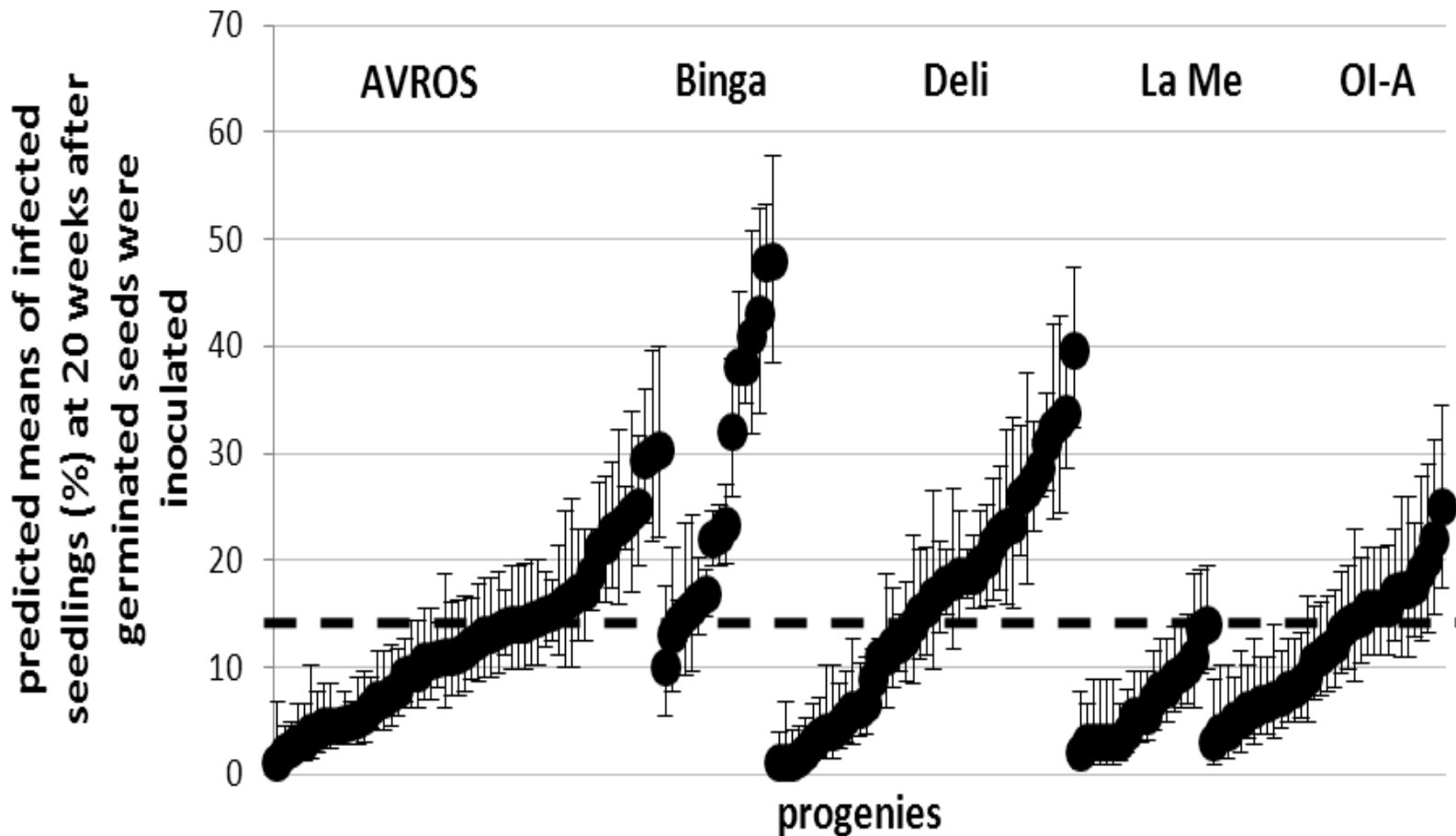
- healthy seedling (A)
- infected seedling with dry leaves (B), *Ganoderma* mycelium and dry leaves (C) and *Ganoderma* basidiocarp (fruiting body) and dry leaves (D)



NURSERY AND FIELD RELATIONSHIP



ORIGIN/POPULATION IN *GANODERMA* TOLERANCE



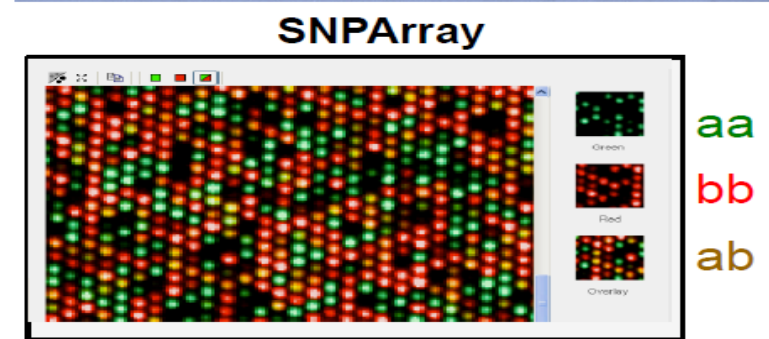
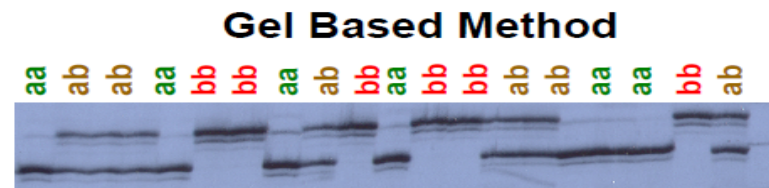
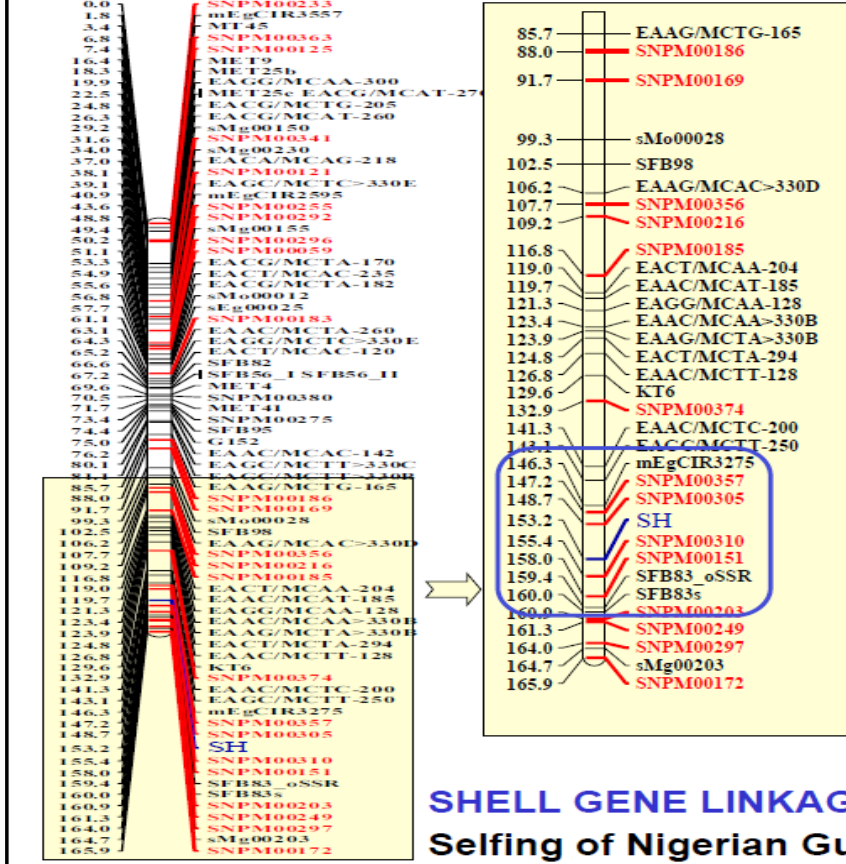


Molecular Technologies

- Isozyme was first used in oil palm to study the genetic diversity in *Elaeis* spp.(Hayati)
- RFLP (Maizura)
- AFLP (Kularatne)
- SSR (Bakoume)
- Genome studies – 2 papers published in Nature by MPOB (Singh et al)



TRAIT: SHELL GENE (SH)



4 SNP markers mapped adjacent to the shell gene loci (3-5cm)



SHELL GENE LINKAGE GROUP
Selfing of Nigerian Guineensis (T128)



COMPARISON OF VIRESCENS & NIGRESCENS PALMS

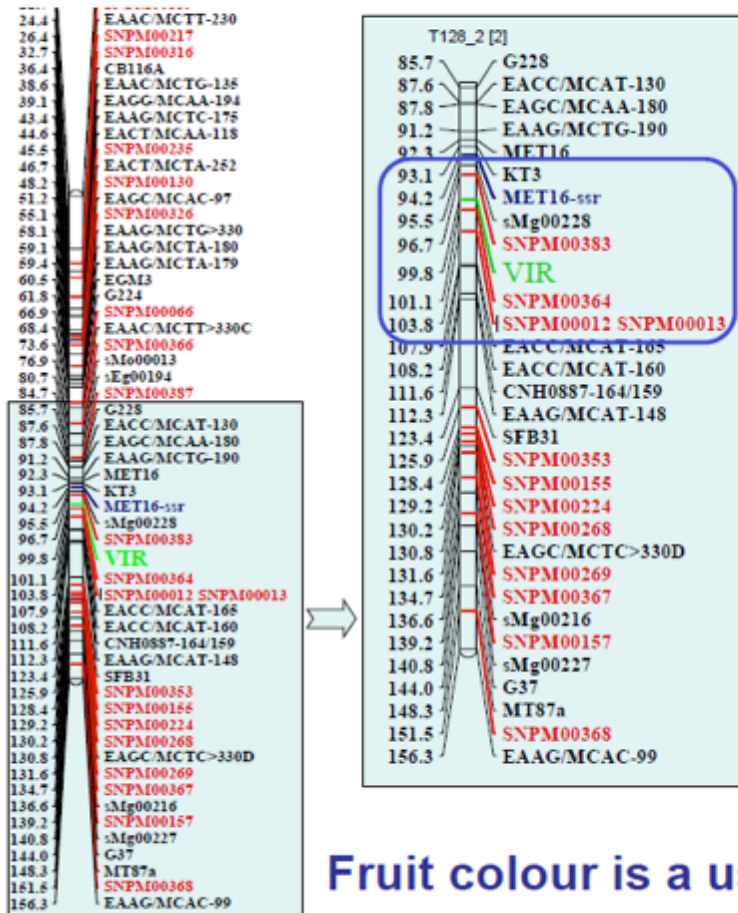
VIRESCENS



NIGRESCENS



MAPPING THE VIRESCENS GENE



Fruit colour



Fruit colour is a useful indicator for harvesting

GENOME LAUNCH @



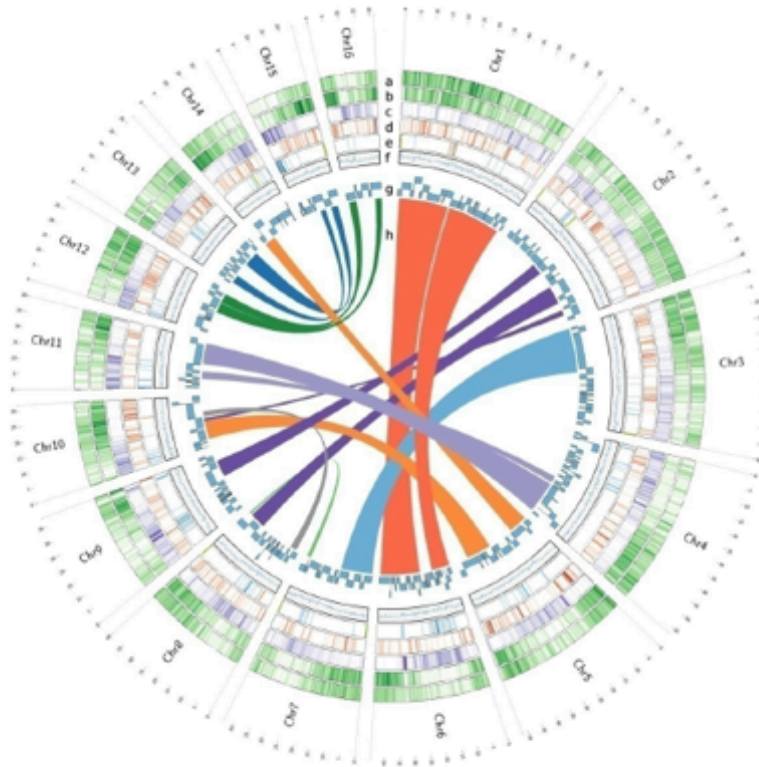
Sequenced **three** Oil
Palm Genomes

This enables...

- a new era of genomics guided breeding, and
- a new era of epigenetics guided tissue culture



E. guineensis GENOME



- *E. guineensis* genome sequenced (1.8 Gb)
- 1.5 Gb Assembled Sequence



XVIII
Conferencia
Internacional sobre

PALMA
DE ACEITE

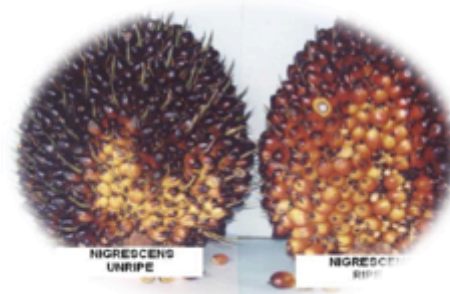
18th International Oil Palm Conference



APPLICATION OF GENOME DATA



Identification of *Shell &* *Fruit Colour (Vir) Genes*

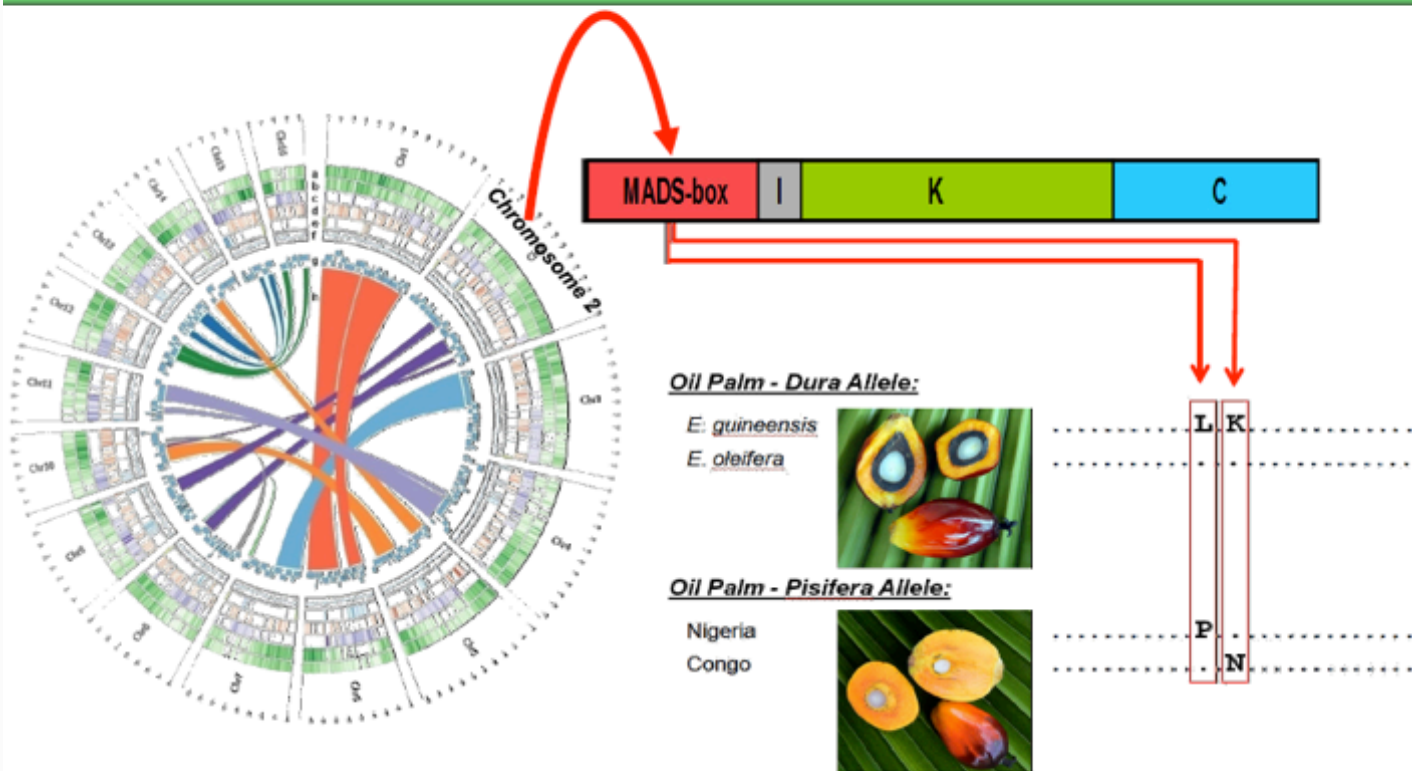


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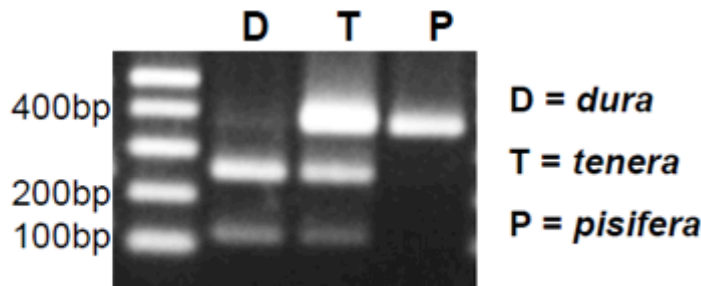
SHELL IS A MADS-BOX TRANSCRIPTION FACTOR



Singh et al. (2013) *Nature* 500(7462):340-344



SureSawit™ SHELL IDENTIFICATION KIT



- Our collaboration developed the **SureSawit™ Shell Kit** – the first commercial gene-assay for oil palm
- Predicts fruit-form in nursery palms or seeds
- Blind testing of > 600 palms: 100% technical success with 100% accuracy
- Kits and services available Q3/Q4 2014.....

**Differentiate
dura, *tenera* and
*pisifera***



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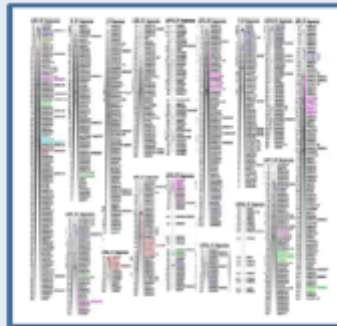
**PALMA
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QUANTITATIVE TRAITS

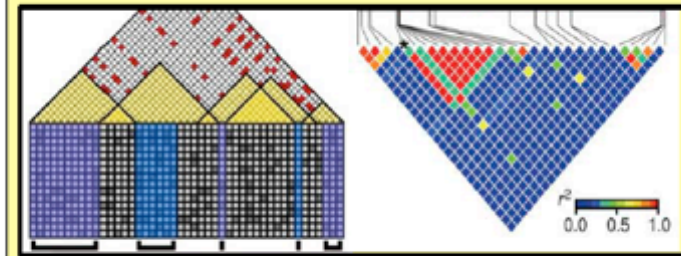
GENETIC MAPPING

- limited population size
- limits detection power



ASSOCIATION MAPPING

- exploits genetic variation across populations
- complements QTL mapping



MARKERS LINKED TO COMPLEX TRAITS



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What is genomic selection ?

Meuwissen, Hayes and Goddard, 2001:

“Estimate the effects of ~50,000 marker haplotypes simultaneously from a limited number of phenotypic records”

Accuracy of Bayesian methods = 0.85

“Selection on genetic values predicted from markers could substantially increase the rate of genetic gain in animals and plants”

Genetics 157: 1819–1829 (April 2001)

Prediction of Total Genetic Value Using Genome-Wide Dense Marker Maps

T. H. E. Meuwissen,* B. J. Hayes[†] and M. E. Goddard^{†,‡}

**Research Institute of Animal Science and Health, 8200 AB Lelystad, The Netherlands, [†]Victorian Institute of Animal Science, Attwood 3049, Victoria, Australia and [‡]Institute of Land and Food Resources, University of Melbourne, Parkville 3052, Victoria, Australia*

Manuscript received August 17, 2000
Accepted for publication January 17, 2001

ABSTRACT

SIRIM Standards (DXP) 2005

SIRIM Standard (MS157:2005) states the minimum requirement for the seed production is as below:

1. Minimum Dura Yield of 160kg
 2. Oil to Bunch of 16%
 3. Oil Yield /Palm of 25.6kg
 4. Minimum Progeny Yield of 160kg
 5. Oil to Bunch of 24%
 6. Progeny Oil Yield/Palm of 38.4kg
 7. Minimum Kernel Yield of 3%
 8. Oil Yield /Ha (136 palms) of 5.22 tons
- Deli dura*
Mother palm
- DXP
Progenies



SIRIM Standards (Clones) 2008

The MS (2099:2008) also includes requirements for ortet selection:

- materials of known pedigree and known performance of family and individual palms;
- materials of unknown pedigree and known performance from known seed producers; or
- materials from field-tested clones for recloning.

The minimum standard requires for selection of an ortet are 50kg/palm/yr oil yield and 27% O/B ratio, recorded over four consecutive years and five analyses respectively.



Licence for Seed Production

- SIRIM Certificate
- MPOB Licence

* Note: Every 5 years MPOB evaluates the performance DXP seeds produced in Malaysia



OUTLOOK
Cancer

nature

THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE



The epigenetic trait that can ruin an oil palm crop

PAGES 486 & 533

Weed out *Bad Karma*

PRIVACY

OLD TAX FILES WANTED
Making administrative data accessible and anonymous
PAGE 440

ENERGY

DUAL-USE FUEL CELLS
A smart way to boost electrical power grids
PAGE 447



CAREERS

USE YOUR IMAGINATION
Sci-fact as an entrée into sci-fi
PAGE 503

NATURE.COM/NATURE

24 September 2015



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Conclusion

- 1960 - 2015, great transformation and development oil palm industry
- MAS and genomic selection will integrate with conventional breeding
- Haploid technology, C4 oil palm, low lipase, transformation, gene editing, dwarf and resource efficient planting material make impact on oil palm breeding

ACKNOWLEDGEMENTS



MPOB



OTHER COLLABORATORS



Cold Spring Harbor Laboratory



MOgene, LC



Ministry of
Plantation
Commodities
and
Industries



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THANK YOU



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