Breeding for sustainability

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Through seed breeding and genome technology, scientists are forming a better understanding of the oil palm and are using their knowledge to make palm oil more productive and sustainable. Rose Hales writes

Major breakthroughs have recently been made in oil palm breeding and genome technology, which are set to boost productivity and improve sustainability.

With the world's population set to grow by 2.3bn to reach 9.1bn people by 2050, the agricultural industry must produce 70% more food in 2050 than it produced in 2015. The palm oil industry, therefore, needs to revolutionise to produce a greater quantity of food and limit further deforestation of important ecological areas.

In her plenary lecture at PIPOC 2015, Datuk Dr Choo Yuen May – director general of the Malaysian Palm Oil Board (MPOB) – said that the palm oil industry needs to overcome the challenges of population growth, food demand, green technology demand, stagnant yields and steep competition from other crops such as soyabean.

The MPOB has two major strategies for increasing productivity and revolutionising the industry. These are to enhance productivity upstream and enhance value downstream – this means making the growing and collecting process more productive while reducing costs at the source.

Improving productivity

Genome technology seeks to change the traits of plants to produce desired characteristics. In contrast to genetic modification, genomics alters the DNA of plants without introducing any foreign DNA.

Seed breeders create hybrids that amplify positive characteristics while reducing negative ones. Different types of the same plant are bred and a superior hybrid with features from both is formed.

In addition, genome technology is used to sequence the genome of an organism. By decoding the DNA, scientists can pinpoint the specific genes that cause certain characteristics – some positive and some negative. Screening methods are developed to show whether a seed or plantlet carries a particular gene; this process allows breeders and growers to select only the most superior plants, which is called marker assisted selection.

Finally researchers use tissue culture, a range of techniques used for maintaining or growing plant cells or tissues under sterile conditions. Through the method of micropropagation, high-quality plants can be cloned to quickly grow genetically identical replicas.

Traditional forms of seed breeding are time consuming and it takes many years to produce improved planting materials. Genomics based technologies have sped up the process. A report in *The Planter* in December 2014 said such technologies are well-suited for oil palm and new, better planting materials are being produced quickly and more efficiently.

The MPOB formed a strategic collaboration with Orion Genomics, a small USA-based genomics company, and together they have made three significant breakthroughs, all of which promise to transform and develop the palm oil industry for the better.

Palm oil genome sequenced

A major breakthrough came in July 2013 when scientists from the MPOB announced through a report published in *Nature* journal that they had successfully sequenced the genome of the oil palm. According to a *BBC* report on the achievement, scientists used very advanced technology to decipher 1.8bn "letters" of DNA. Such a breakthrough creates the opportunity to better understand the role of each gene in the sequence and use such knowledge for marker assisted selection.

The shell gene

Simultaneous to the genome sequencing, the MPOB and Orion Genomics made a second announcement in the *Nature* journal, publicising the discovery of the oil palm shell gene.

The shell gene decides which of the three known shell forms the tree will produce: *dura* (thick), *pisifera* (shell-less) and *tenera* (thin). *Tenera* is a hybrid between *dura* and *pisifera* palms and contains two forms, or alleles, of shell genes, one shell gene is normal and the other is mutant. The consequence of this combination is 30% more oil/land area than *dura* plants produce. Because it refers to the ideal shell-to-fruit ratio, scientists also refer to it as the 'Goldilocks gene'.

Before the discovery, growers had to rely on selective breeding techniques in an attempt to ▶

PHOTO: MPOB

THE DURA (LEFT) AND TENERA (RIGHT) GENE VARIETIES maximise plantings of *tenera* plants. According to the MPOB and Orion, due to uncontrollable external pollination up to 10% of plants could be the low-yielding *dura* shell form, and it could take up to six years for growers to identify the low-yield trees by which time it was too late to uproot them.

In addition to the discovery a simple molecular screen has been developed that can be used for both seeds and plantlets to scan for and reveal the undesired *dura* plants. These plants can be discovered early enough to remove them before they grow to maturity.

With less *dura* plants being grown, the efficiency of oil palm plantations has increased and the sustainability of the industry boosted as more high-yield *tenera* plants will reduce competition between plantations and rainforests. MPOB and Orion say that this will have a "significant impact on the Malaysian economy, because for every 1% increase in palm oil yields, Malaysia gains RM1bn (US$230M) in income".

The VIR gene

Orion and the MPOB's second important discovery was reported in June 2014 and concerned the identification of the gene that triggers colour change in oil palm fruit – the VIR gene.

The two most common types of oil palm are the *virescens* and the *nigrescens* varieties. The VIR gene is only found in the *virescens* palm and changes the colour of the fruit to bright orange when ripe. This is useful for palm fruit harvesters who can easily see the bright colour of the fruit from the ground and it gives a clear indication that the fruit is ripe. Ripe fruit contains the highest quantity and quality of oil. The fruits of the *nigrescens* type do not contain the VIR gene and turn only from black to dark purple when they are ripe, according to *The Malaysian Star*, which reported on the discovery in 2014. This subtle change makes it extremely hard for growers to tell if the fruit is at the peak of ripeness.

Currently the *virescens* type is rarer than the

PHOTO: MPOB

EXAMPLES OF A NORMAL (*TOP*) AND MANTLED PALM FRUIT

nigrescens variety, which is much more prevalent across Malaysia and Indonesia. The MPOB and Orion say that this new knowledge of the VIR gene will allow palm growers to choose *virescens* over the *nigrescens*, as the benefits of the former are now much greater. Growers will find it easier to judge the ripeness of the fruit if they choose the *virescens* variety.

In addition, the companies say that the shell gene and the VIR gene used in combination would enable seed breeders to develop new lines to further boost plant efficiency.

The mantle gene

The final and, in many ways, the most significant discovery was made in September last year when Orion, MPOB and Cold Spring Harbor Laboratory announced they had found the epigenetic cause of mantling. This is a huge breakthrough that explains a previously unknown phenomenon that has caused millions of dollars of spoilage.

In the 1980s, most palms in plantations were produced by cloning the highest-yielding plants in culture dishes, *Phys.org* reported. However, often these fine hybrid clones grew into barren adults with misshaped and worthless fruits. The mutant form displayed by the plants was called 'mantled'.

According to Dr Choo at the MPOB, the mantling has "severely curtailed the ability of oil palm growers to take advantage of the significantly increased yield that cloned palms can have over palms produced from seed." Previously there has been no way for growers to identify the mantled phenotype until too late, as young plants do not show signs of mantling until mature. Many oil palm cultivators, especially smaller growers, were unwilling to take the risk that their entire plantations could conceivably transpire to be only mantled plants.

The MPOB and Orion's study shows that mantled palms are genetically identical to their parents, however "the loss of DNA methylation in a specific region of an oil palm genome containing a transposable element called 'Karma' is responsible for the low-yielding mantled fruit". DNA methylation is necessary for cells to develop normally and is essential for a number of key processes. Low methylation of Karma (dubbed 'bad Karma' by the scientists) disrupts the gene's normal splicing, causing the mantled phenotype. In the reverse situation, dense methylation of Karma ('good Karma') causes palm clones to thrive in production fields.

In revealing the discovery of the 'bad Karma' causing the mantled phenotype, Orion and the MPOB also say a simple, leaf-based test has been developed that can predict if the palm will be mantled. Crucially the test can provide a result before the palms are planted out and many years before physical signs of the phenotype would appear. In future only the high-performing clones will reach maturity, optimising land resources. This allows growers to propagate high-yield clones, which the companies say have the potential to produce 20-30% more oil/planted area than palms grown from seedlings. The team was not able to say what causes the 'bad Karma', but identifying its presence and producing a test to reveal it will still transform the industry.

The breakthrough was made possible owing to the MPOB's vast collection of highly characterised clonal palms with a solid knowledge of palm oil and tissue culture, alongside Orion's MethylScope technology, which can precisely map DNA methylation across entire genomes, the companies said.

Priority traits in oil palm

Although improving oil yield is one of the main drivers of genome technology there are other desirable characteristics that seed breeders are working on making available.

Table 1 (*left*) shows the priority traits in oil palm that were identified and prioritised by the MPOB through brainstorming sessions in 2001 and 2003, a report, in *The Planter* revealed in December 2014. According to the report, the 10 traits were then incorporated into a fast track breeding programme involving breeding activities and cloning via tissue culture. Seed breeders collaborated with the MPOB in pursuing the different traits. The companies responsible for pursuing each trait are also shown in Table 1.

The Planter says that besides high fresh fruit bunches (FFB) and oil yield, the traits that are most popular are those that simplify harvesting – these include short height, *virescens* (an indicator

TABLE 1: THE PRIORITY TRAITS IN OIL PALM

No	Trait	Current	Benchmark	Company
1	High oil yield	3.70 tonnes/ha/year	9.00 tonnes/ha/year	Kulim Group
2	Ganoderma tolerance	70%	90%	Kulim, AAR, UP, FELDA, Sime Darby, IOI, Borneo Samudera and Genting Green
3	High bunch index	0.40	0.60	FELDA
4	Low height/ compactness	45-75cm/year	30cm/year	FELDA
5	Long stalk	10-15cm	25cm	FELDA and AAR
6	Low lipase	22-73% of FFA level	Half of the current level of FFA	(no takers yet from the industry)
7	High oleic acid	22-40%	65%	(no takers yet from the industry)
8	Large kernel	5%	20%	FELDA
9	Vitamin E	660ppm	1,000-1,500ppm	FELDA
10	High carotene content	E.guineensis 500ppm E.oleifera 1500ppm	E.guineensis 2000ppm E.oleifera 3000ppm	IJM, Sime Darby

Source: The Planter, December 2014 (Mond Din et al. (2005))

of ripeness), low lipase (for the slow build-up of free fatty acid after harvesting) and non-abscissing (no loose fruits).

In order to improve breeding, the Malaysian industry needs to broaden the genetic base. According to *The Planter* article, the Asian palm oil industry is built on just four palms, and the genetic base needs to be widened. The MPOB began collecting oil palm germplasm and, in December 2014, it had the largest oil palm germplasm collection in the world.

In the 2011 paper *'Breeding for Sustainable Palm Oil'*, Tristan Durand-Gasselin concludes that there are three traits, which, if changed, would improve sustainability. One of which is improving yield through bunch production and oil content. The second is vertical growth, which has been largely reduced. A shorter statured palm facilitates harvesting and also prolongs the palm's lifespan by five to seven years as its replanting age is usually determined by its height. Durand-Gasselin says that this would allow growers to replant when the time is right economically rather than by necessity. The final important trait is disease resistance. Scientists are seeking to find disease resistant palms for each of the major oil palm viruses.

Disease resistance

Oil palm diseases can have major economic repercussions for palm oil-producing countries. Durand-Gasselin records three diseases affecting the industry. These are:

- *Fusarium* – can cause losses of up to 70% and mostly specific to Africa
- *Ganoderma* – may cause up to 80% mortality, present in Southeast Asia and also in parts of Africa (sometimes in combination with *Fusarium*). Beginning to be seen in Latin America too
- Bud rot, probably related to *Phytophthora palmivora* – can cause 100% mortality very quickly. Mostly seen in Latin America

In terms of creating disease resistance, Durand-Gasselin explains the difference between total resistance (specific) and partial resistance (non-specific). Total resistance is specific and can be bypassed easily by the pathogen, the report says. Partial resistance encourages and provides sustainable and non-specific resistance to a larger diversity of pathogens. Although such a method will not result in diseased plants disappearing completely from the field, it will be more efficient in limiting their number than total resistance does.

Results from *Fusarium* resistance have been reasonably successful and go back to the 1980s and 1990s. Research on *Ganoderma* resistant varieties is much more recent and no *Ganoderma* varieties have been released yet, although results are promising, Durand-Gasselin says.

Drought resistance

In October 2015, the *Borneo Post* reported that Malaysia is developing a drought-resistant oil palm breed that could withstand several seasons of dry spell – including the effects of El Niño. Such a breed could be available within 10 years the report said.

According to the president of the International Society for Oil Palm Breeders (ISOPB), Dr Ahmad Kushairi, no efforts were made to breed a drought-resistant oil palm previously because the climate did not necessitate such a development. Although initiatives for drought-resistant breeds are being developed in other parts of the world, Malaysia is only just beginning this process, Kushairi told the *Borneo Post* at the International Seminar on Gearing Oil Palm Breeding and Agronomy for Climate Change on 5 October last year. As the current extreme and unpredictable weather affects food crops, the need to address climate change in relation to palm oil productivity has emerged. Malaysia needs to be prepared for the consequences of extreme weather.

PHOTO: THUNGSARNPHOTO/DOLLARPHOTOCLUB.COM

THE DISCOVERY OF THE SHELL AND MANTLE GENE AND THE INVENTION OF SCREENING TESTS WILL ALLOW FOR LOW YIELDING PLANTS TO BE DISCARDED WHILE THEY ARE STILL IN THE NURSERY

A presentation published in September 2011 by Univanich Palm Oil PLC, entitled *'Some Best Practices in Thailand's Oil Palm Industry'*, explained how palm oil breeding is making it possible to grow oil palms in parts of Thailand up to 15° from the equator. Usually palm oil is only grown 10° either side of the equator. Thailand's supply and demand is growing because oil palm breeding is improving drought tolerance. The Univanich Breeding Programme in Thailand had the objective to produce world-class *tenera* hybrids especially suited to dry growing conditions. In particular the company made selections based on high oil yields, drought tolerance and low height increments.

ISOPB

The International Society for Oil Palm Breeders (ISOPB) is part of the MPOB but it represents oil palm breeds from countries across the world. According to the ISOPB website it has a current membership of around 200, most of which are based in Indonesia or Malaysia.

The society's aim is to advance the knowledge of oil palm breeding through international cooperation. In order to achieve this, its rules decree that it should hold symposiums, workshops and meetings locally and internationally; establish committees, commissions or working groups to deal with specific problems; arrange meetings of experts to exchange views, collaborate and distribute information; promote and assist in the international exchange of genetic material for breeding; publish a newsletter or journal to report on research activities; and where possible carry out these activities in consultation with the Food and Agriculture Organization of the United Nations and with other international, governmental or non-governmental organisations.

The future

When it succeeded in sequencing the oil palm genome, MPOB began a process that is already leading to increased understanding and improved productivity of the oil palm. The discovery of the mantled gene in particular has reopened the door to growing superior hybrid clones again, allowing for fast-growing, high-class oil palms to become the norm across the industry.

According to MPOB director general Dr Choo, oil palm is now 10 times more productive than soyabean and genomics will only continue to improve its productivity in the future. ●

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TABLE 2: DEMAND FOR GERMINATED SEEDS FROM 2005-2013 IN MALAYSIA (SEEDS/REGION)

Year	Penisula	Sabah & Sarawak	Total
2005	77,606,255	4,509,184	82,115,439
2006	58,744,419	8,251,130	66,995,549
2007	56,645,073	8,540,413	65,185,486
2008	74,620,293	13,622,642	88,242,935
2009	71,907,565	14,578,910	86,486,475
2010	64,008,546	12,565,259	76,573,805
2011	57,812,058	14,842,943	72,655,001
2012	56,634,583	18,639,958	75,274,541
2013	47,396,304	15,232,476	62,628,780

Source: MPOB