Background to oil palm

Palm oil accounts for 38% of the world's vegetable oil market and is harvested from the fruits of the oil palm plant (*Elais guineensis*). Oil palms grow in tropical environments, across the equator and up to 10º north and south (Corley & Tinker, 2003). They grow up to 20 m tall over the average commercial lifespan of 25-30 years. Oil palms have stable commercial fruit production after three years, although they start flowering much earlier. After this time, fruits can be harvested throughout the year. Oil palm fruits grow in bunches that are referred to in the industry as fresh fruit bunches (FFB), and fruitlets are typically comprised of 45-50% oil.

Currently, oil palm plantations produce an average of 21 tonnes of fruit per hectare, which generates 3.74 tonnes of palm oil per hectare, 0.4 tonnes of palm kernel oil and 0.4 tonnes of palm kernel expeller. Palm oil is extracted from the orange flesh of the fruit known as mesocarp. The fruit kernel or nut (white) is crushed to extract palm kernel oil, leaving behind palm kernel expeller (or cake). The products extracted from oil palm fruits are used in a wide range of markets including food, personal care and cosmetics (primarily palm kernel oil), biofuel and energy, animal feed (palm kernel expeller) and pharmaceuticals. Palm oil and palm kernel oil-based ingredients are found in approximately 50% of products on our supermarket shelves.

Customer case study:
Sime Darby Plantation solves the trade-off between trait accuracy and higher throughput costs with KASP genotyping chemistry
Industry challenge

In the early 19th century, European-run oil palm plantations were first set up in Central Africa and South East Asia. Oil palm was introduced to Malaysia in 1910 by William Sime and Henry Darby. Since the 1940s, improvements to the process for refining of palm oil and the development of enhanced transport networks resulted in the adoption of palm oil for use in Western foods. In this growing market, Malaysia then emerged as the world’s largest palm oil producer across the 1970s – 1990s, and maintains this position today.

As the global population continues to grow, the demand for food will also increase. Oil palm is the most efficient oil crop available, and is therefore a crucial commodity in feeding the world’s expanding population. The oil yield of Malaysian palms has been stagnant at 3-4 tonnes/ hectare/year for around 25 years, and increasing palm oil production via increasing the land area of plantations is not sustainable. Sime Darby Plantation is committed to producing certified sustainable palm oil with no deforestation and no peat planting. Palm production also faces new challenges including climate change and agricultural land constraints. It is imperative that the demand for increased palm oil yield is addressed through more sustainable approaches. Other traits of importance to the industry include those that improve ease of harvestability such as long stalks and semi-dwarf palms.

Technical challenge

Marker-assisted selection involves the selection of individuals based on markers within the genome that are linked to traits of interest. This indirect process can be used to select individuals for breeding programmes with a view to enhancing the desired characteristic(s) in subsequent populations.

Markers can also be used to build a predictive model, based on individuals of known phenotype and genotype, which can be used to rank individuals of unknown phenotype for subsequent selection. In the breeding of commercial perennial crops, such as oil palm, the number of progeny in each generation is vastly greater than in cattle. As a consequence, the process of genomic selection can be significantly more expensive as vast numbers of samples need to be analysed for all markers.

The technical challenge in oil palm breeding is to reduce the required marker density without impacting the phenotype prediction accuracy, thus ensuring that genomic selection is an economically viable approach.

High-throughput processes also need to be implemented to ensure individual plants can be sampled, processed and genotyped accurately, quickly and efficiently. It is crucial that desirable individuals are selected in a timely manner, in order to be transferred into the field at the correct growth stage.

The solution

A high-throughput and easy to use genomics technology is required to facilitate detection of the genotypes of all young oil palm plants, to enable relevant phenotypes to be accurately predicted without having to raise palms to maturity.

KASP® genotyping chemistry utilises a unique form of competitive allele-specific PCR that delivers highly accurate bi-allelic scoring of SNPs and InDels at specific loci. It is able to support low-, mid-, and high-throughput studies, reducing costs through elimination of the need for dual-labelled probes.

A typical KASP Assay consists of three primers; two allele-specific primers and one common reverse primer. One allele-specific primer is designed to the wild type sequence, and the second allele-specific primer is designed to the sequence of the mutation. Both allele-specifics work in conjunction with the common reverse primer. The KASP Assay is run across a range of DNA samples and the fluorescent signal generated for each sample plotted on a Cartesian (or cluster) plot. The position of each sample on the plot is representative of its genotype. (Watch how KASP works in this video.)

LGC’s SNPline™ system facilitates high-throughput processing of samples, from DNA extraction to generation of SNP genotyping data. As the SNPline is modular, it can be adapted to meet the needs of the laboratory, preventing any bottlenecks in sample processing. Components of a SNPline include the repliKator™ for DNA transfer, Meridian™ dispensers for dispensing assays of PCR plates and the Hydrocycler™ for waterbath thermal cycling.

Results

The GenomeSelect™ programme was developed involving multi-disciplinary teams from within Sime Darby Plantation including breeders, molecular biologists, bioinformaticians, tissue culture specialists, agronomists, IT, and operations. Over 132 genome sequences were analysed, 200,000 SNPs detected, and oil yield traits assessed during the development stage (Teh et al., 2016). New laboratories and IT systems were also implemented to facilitate and support the approach.

Sime Darby Plantation used a commercial population of oil palms to investigate a range of predictive models for genomic selection (Kwong et al., 2017). All individuals were genotyped and phenotyped for a wide range of markers relating to oil yield traits including shell-to-fruit ratio, fruit-per-bunch, and oil-per-bunch, and this information then used to develop the models. All methods resulted in almost equal prediction accuracy, which correlated with the calculated heritability of each of the traits. Further research, including consideration of linkage disequilibrium, enabled Sime Darby Plantation researchers to effectively reduce the number of markers for each trait without significantly impacting the accuracy of trait prediction.
By reducing the list of markers required to accurately predict phenotypes of young plants, Sime Darby Plantation was then able to work with LGC to develop a set of KASP Assays to genotype their samples. A SNPline system was also installed at Sime Darby Plantation to facilitate high-throughput genotyping of thousands of samples. Once the installing process was successfully up and running (in June 2015), Sime Darby Plantation was able to routinely extract DNA from 30,000 samples per month, generate 5,000,000 datapoints per month and eventually become one of the biggest SNPline genotyping facilities in Asia. Following extensive analysis of the 80 million generated genotyping datapoints, the first GenomeSelect palms were planted in 2016. Sime Darby Plantation aims that by 2023, all replanting will utilise GenomeSelect materials.

As a result of the development and implementation of the process for genomic selection in oil palm, in 2017, Sime Darby Plantation’s GenomeSelect Oil Palm won the prestigious bronze Edison Award for ‘Sustainability’ as well as ‘Best Product Innovation’ at the Malaysia Dutch Business Council Innovation & Sustainability Awards.

Industry-wide benefits

The ability to predict the phenotype of young plants will be advantageous to the oil palm industry as it will facilitate an increase in the percentage of desirable forms that are planted into the plantations including high yield, drought tolerance and easier harvesting. When these reach maturity, the yield of the plantation will be significantly increased.

The development of a straightforward screening process using KASP chemistry and the SNPline system will enable plantations to quickly and cost-effectively assess the markers of interest in plants while they are still in the nursery stage. This will have a huge impact on the industry as productivity can be sustainably increased, without having to expand area of the plantations, resulting in cost-savings and minimal impact on the environment.

Dr. Sukganah Apparow, the Head (In-Charge) of Molecular Breeding Laboratory (MBL) at Sime Darby Plantation described the LGC SNPline platform as flexible, robust and user-friendly. Flexibility of both, the SNPline platform and KASP chemistry, enabled Sime Darby Plantation to quickly scale instrumentation and processes necessary to achieve the throughput required for the GenomeSelect programme. The programme aims to increase the number of samples while simultaneously decreasing the total number of genetic markers that need to be assessed. Dr. Apparow added that the SNPline platform is available at Sime Darby Technology Centre (SDTC) as a service to screen for high yielding and good quality planting materials. MBL currently provides oil palm DNA testing services for legitimacy, pollen purity, fruit form identification, marker-assisted selection, genetic diversity assessment and others.

Dr. David Ross Appleton, Head of Biotechnology and Breeding at Sime Darby Plantation said, “The partnership with LGC was a success story, both the in-sourced and outsourced elements of the partnership. LGC not only contributed to develop the in-house DNA extraction and high-throughput KASP genotyping capabilities at SDTC through extensive training by LGC staff, experienced with operating high-throughput laboratory; but was also able to deliver an outsourced solution to augment capacity using equipment, chemistry and data analysis tools identical to those available at SDTC.”

The work detailed here, performed by Sime Darby Plantation in conjunction with LGC, provides a good reference study for other crop and animal breeding programmes.

The future

Increasing yield is one of the top priorities for agricultural research and sustainable intensification of global agriculture. By utilising KASP chemistry and SNPline instrumentation, there is now a way to easily and confidently identify higher yielding individuals during the early stages of a plant’s development.

Sime Darby Plantation aims to increase the percentage of GenomeSelect materials used in replanting each year, eventually achieving 100 % in 2023. Selecting for yield across all environments is essential for the future. Many sustainability initiatives that were initially pioneered by Sime Darby Plantation are now considered best practices in the industry, including good water management and the zero burning replanting. The hope is that other plantations will follow the example of Sime Darby Plantation in their approach to increasing yields to meet the growing global demand for palm oil.

Reference

About Sime Darby Plantation

Sime Darby Plantation is the world’s largest oil palm plantation company by planted area, accounting for about 4% of total global production of Crude Palm Oil (CPO), with a strong focus on operational excellence, research, innovation and sustainability. As an integrated plantation company, Sime Darby Plantation is involved in the full spectrum of the palm oil value chain. In Upstream, Sime Darby Plantation operates and manages 248 plantation estates and 72 palm oil mills located in Malaysia, Indonesia, PNG and the Solomon Islands and Liberia, which consist predominantly of oil palm cultivation, harvesting and milling. Its downstream business, which spans across 16 countries worldwide-Malaysia, Singapore, Indonesia, South Korea, India, Thailand, Vietnam, Japan, China, Germany, United Kingdom, South Africa, Netherlands, United States of America, Papua New Guinea and Solomon Islands, involves the manufacturing as well as the sales and marketing activities of oils and fats products, oleochemicals, palm oil-based biodiesel, as well as other palm oil derivatives and renewables.

The company also invests heavily in R&D and is the first in the world to successfully sequence, assemble and annotate the oil palm genome. This breakthrough in genome science has resulted in the GenomeSelect Planting Material which was awarded the Edison Award in 2017.

Sime Darby Plantation’s Sustainability Report 2016 bagged the Highly Commended Award for Asia’s Best Carbon Disclosure at the Asia Sustainability Reporting Awards (ASRA) 2017 in Singapore on 6 February 2018. In line with its commitment to be a leader in sustainability, today, Sime Darby Plantation is also the world’s largest producer of Certified Sustainable Palm Oil (CSPO) with an annual production of 2.2 million tonnes. Sime Darby Plantation is also one of the founding members of Roundtable on Sustainable Palm Oil (RSPO), a global multi-stakeholder initiative that ensures companies take ownership in producing sustainable palm oil. Sime Darby Plantation also won the Industry Excellence Award for Plantation category and the Excellence Award for Sustainability Practices at the Minority Shareholder Watchdog Group (MSWG) – Asean Corporate Governance Recognition 2017 for its best practices in sustainability.

As a leader in plantation sustainability, Sime Darby Plantation is committed to its role in the development and promotion of sustainable practices and products in the palm oil sector. Sime Darby Plantation also welcomes partnerships with like-minded organisations to pursue innovative approaches towards developing sustainable products and services in plantation and other related industries.