Review of Strategies in Breeding for Oil Palm Clonal Propagation

Soh A. C.
AAR-UNMC Biotechnology Research Centre

Abstract

Oil palm clonal propagation has become a technology with commercial output of clonal plantlets constituting about 10% of the annual oil palm planting material requirement in Malaysia. Nevertheless, with the inefficiencies of the tissue culture technique in terms of low amenability and risk of somaclonal variation extant, strategies in clonal propagation have to remain as adjuncts to hybrid breeding programs and strategies. With the lower genetic variability and heritability for oil yield confirmed in advanced DxP hybrids, cloning (and recloning) from such populations is inefficient and runs the risk of concurrent new generations of improved hybrids closing the yield advantage gap of clones, if not surpassing it. Cloning ortets from the early or recombinant phases of hybrid breeding programs would be more efficient with the wider genetic variability and higher heritability for yield and other desirable traits. Perhaps the biggest advantage of cloning would be in the early commercial exploitation of new genetic materials from introgression programs of wide intra or inter-specific crosses which would also broaden the genetic base of the commercial plantings to reduce risk of genetic vulnerability to pest, disease and environmental stress debilitation and ensuring sustainability. These considerations would also apply to the alternative cloning strategies of cloning the best parents for clonal hybrid seed production and cloning the progeny embryos or seedlings of the best parents. These alternative strategies are gaining acceptance if not popularity especially the former.

Clones are unlikely to supersede hybrid seeds as the dominant oil palm planting material until the amenability and fidelity deficiencies in the tissue culture have been resolved or circumvented and their field performance advantage over concurrent improved hybrids clearly demonstrated.

Introduction

The plantation industries in Malaysia and Indonesia have had a long love affair with clonally propagated crops. It started in the early days with e.g. tea, coffee, pepper, sisal hemp etc. and enjoyed the heydays in rubber with the dramatic yield improvements achieved. This approach has spilled over into cacao until it lost its attractiveness as a major plantation crop at least in Malaysia. The underlying reasons for this are that these are usually open-pollinated highly heterozygous perennial tree crops with long generation cycles requiring large, long and tedious breeding efforts to obtain commercial hybrid seeds of acceptable genetic homogeneity (Simmonds and Smartt, 1999). The uniformity of the crop for esthetic, commercial and management considerations and their relative ease of clonal propagation by conventional vegetative means (e.g. grafting, cutting, budding, layering) are the other compelling reasons. There may be also other technical reasons e.g. few or non-viable seeds due to inbreeding depression, sterility due to polypoidy, genetic incompatibility systems, and apomixis. It is thus not surprising that a means of clonal propagation of oil palm was sought which led to the breakthrough in the in vitro or tissue culture clonal propagation of the oil palm in the mid 1970's (Jones 1974, Rabechault and Martin 1976)

Breeding Clonal Propagated Crops

Vegetative propagated crops

While many clonal crop varieties have been developed directly from vegetative propagation of natural occurring mutants or sports, chimaeras and hybrids, these are usually indigenous or relatively unimproved varieties. Breeding methods for more advanced clonally propagated crops e.g. cassava, rubber, usually adopt the following approaches:

Hybridization is made between two or more genetically divergent parents but with complementary desirable traits.

Selection begins in the widely segregating F1 or F2 of the cross of two open-pollinated parents. The final desirable recombinant genotype is expected to be present in this widely segregating population (Simmonds and Smartt 1999).

The mission is to seek out this winning genotype through repeated cycles of selection, cloning and replicated field testings of increasing rigour until at least the fifth cycle (C5) before the selected clones can be considered for release as cultivars.

Oil palm

The above approach is possible because cloning and recloning by conventional vegetative propagation is efficient and reliable producing sufficient propagules of good fidelity. This cannot be said as yet for tissue culture or in vitro propagation of the oil palm as not all palms can be cloned or recloned to give sufficient plant regenerants and of assured fidelity (Soh et al 2006a,b). As such clonal propagation in oil palm has to remain as an adjunct to hybrid seed production. Furthermore, as hybrid seed breeding is an established if not advanced industry, the advantage of commercial clonal cultivars must always be judged against that of contemporaneous hybrid seed cultivars. An oil palm breeding cum adjunct cloning strategy must take this into consideration.

Oil Palm Cloning Strategies and Clone Performance.

Experiences to date

Attempts at commercial clonal palm production (Bakasawit, Tropiclone) soon began at the Unilever and CIRAD laboratories (Jones 1974, Rabechault and Martin 1976) which pioneered the in vitro technique followed by others. The discovery of the ubiquity of the mantling somaclonal variation in the plantlets produced from all the laboratories in the mid 1980s curtailed its further development for a period. With subsequent resurgence in confidence in the efficiency and fidelity of the cloning technique in late 1990s more clones have since being planted in trial, pilot test and commercial fields. Although the trials were mainly designed to evaluate clone performance, analysis of the results would provide insight to the development of appropriate strategies in the breeding and selection for clonal propagation.

In 1986, Soh investigated the feasibility of the projected 30% increase in oil yield of clonal palms over current DxP hybrids (Jones 1974, Hardon et al. 1987), by applying general quantitative analyses (Falconer and Mackay 1996) on data from three Deli Dura (D) x AVROS Pisifera (P) or Tenera (T) hybrid progeny test trials. The following were the results and inferences derived:

Broad-sense heritability (h2B) was 0.2

- 12-15% improvement in oil yield would be achievable by cloning the top 5% of the palms
- 30% improvement might be achieved by recloning the top clones after clonal tests. But by which time, the next generation of improved DxP would be available reducing the advantage of clones back to 12-15%.
- Ortet selection would be more efficient on less advanced DxP hybrids i.e. hybrids from parents which have not been highly inbred and selected.

Alternative cloning strategies suggested in the light of the inefficiencies of cloning and ortet selection were:

- Cloning the parents of the best cross for biclonal F1 hybrid seed production
- Cloning reproduced seedlings of the best cross and recloning the best clones after clonal test.

Selection for oil to bunch (OB) was more efficient than for fresh fruit bunch (FFB) yield.

Subsequent more elaborate quantitative genetic analyses (Falconer and Mackay 1996, Hallauer and Miranda 1981) using between and within family, between and within clone variance components, and difference between pooled within clone and pooled within family variances from the combined results of trials of crossed families where the clones were derived and the clonal trials (Soh et al 2003b) supported Soh's earlier results and inferences. Broad-sense heritability for palms from families of less out-bred parents was 0.07 and 0.26 for more out-bred parents. Likewise in the first clonal test trial of clones derived from Deli x AVROS at HRU/AAR, the average oil yield of clones was about 13% less with the best clone yielding at 21% more than the DxP

(AVROS) Control, mainly via better OB than via better FFB). In a more recent set of results from trials of clones derived from crosses with more out-bred (P) parentage, the average oil yield of the clones exceeded the DxP control by 18%, with the top clones by more than 30% (Soh et al 2006a,b). Recloning the better clones from these have begun but final field test results of are as yet unavailable. Not all the top yielding clones were selected for recloning because of their other less desirable attributes. On average about 20% of the clones were selected. Again the better yielding clones were usually those with better OB. From their latest trial results combining 42 clone-ortet sets and their 17 parent crosses of CIRAD's second reciprocal recurrent cycle (RRS), Potier et al (2006) found that in OY the mean of the clones was 7% higher then than that of the DxP Control (representative of the previous generation's commercial DxP) but was 8.6% below the mean of the crosses from which the clones were derived. The best clones were only on par with the best crosses. Incidentally, h2B (from ortet-clone correlation) CVg obtained was 0.15. AAR (Wong C.K. pers.comm.) observed a similar pattern of results. Thus even if the best clones are recloned they would have to contend with the next generation of improved hybrids from the further selected selfed parents which would be also be readily and easily available by then. If so, the advantage and relevance of oil palm clones as commercial planting materials would be put to question.

Breeding and Cloning Strategies Revisited

As cloning and recloning efficiencies in terms of amenability and fidelity have yet to be substantially improved, the adoption of the conventional breeding strategy/method for vegetative propagated crops remains untenable and the existing strategy of using the cloning option as an adjunct to hybrid seed breeding advisable. However, as many oil palm breeding programs are rather advanced producing near true F1 hybrid seeds, ortet selection within such genetic materials will not be efficient as confirmed by experiences to date.

Ortet selection would be more efficient in the earlier stages of a new breeding program or the recombinant phase of a mature program where genetic variabilities are wider and heritabilities higher. Ortets are usually sought (but not limited) from the DxT/P hybrid progeny test trials in these programs. Ortets can also be sought from the recombinant (TxT/P) parent crosses, which usually manifest wider genetic variability for the desirable traits. However, as transegregants for high yield are less frequent, perhaps due to reduced heterosis or the selected palms are also the important parents for further breeding, few ortets have been selected from such materials.

Cloning from less advanced population would also be advantageous in terms of early commercial exploitation of new genetic materials and broadening the genetic base of commercial field plantings to reduce the risk of genetic vulnerability to pest and disease epiphytotics and environmental stresses because of mono-genotype culture. This would be particularly true with wide crosses and introgression programs e.g. new germplasm x BPRO (breeding parents of restricted origin), O(Oleifera) x G (Guineensis) programs (Escobar and Alvarado 2003), where superior segregants in the intercross or backcross populations may be expeditiously exploited as commercial materials. Presumably the superiority of these segregants arose from linkage disequilibrium or chance recombination or epistasis which may be difficult to recapture by the conventional breeding approach.

The above deliberations would also apply to hybrid seed production from clonal (and dihaploid) parents, which is an alternative cloning strategy, unless it is used to expand the seed parent base on limited seed production due to inbreeding effects in the selfed parents. Production of semiclonal and biclonal seeds is becoming an established technology and is the topic of a subsequent paper in this Conference.

Ortet selection from commercial fields has been shown to be not a worthwhile exercise but would be the only option for laboratories without breeding trials besides outsourcing from those who have.

Owing to the inefficiency of cloning, the availability of sufficient good ortets from breeding trials has always been a limitation in expanding production in most tissue culture laboratories. Use of embryos, seedlings or field plantings of reproduced best crosses or crosses from the best combining parents to serve as 'ortet gardens' have been suggested to circumvent this (Soh et al, 2003c). However, as with recloning, the resultant clones would be one generation behind the concurrent new hybrid in terms of genetic advancement. Hence this approach has not taken off. A modified version of this approach which aims to ensure that cloning improvement runs ahead of breeding improvement has been suggested and being investigated. (Wong Choo Kien, Durand du Gasselin – personal communication). The approach involves cloning a sample of the seed embryos/seedlings of all DxP crosses undergoing progeny-testing. The seedling derived clones and the corresponding DxP families are field-tested at the same time. Only the best clones which supersede the best family in the clone cum progeny test are recloned to produce commercial clones which are better than the best reproduced commercial hybrid seeds. This approach may be used for both the advanced and less advanced hybrid populations.

Lastly, adaptability trial tests are an integral part of a breeding and cultivar development program. The issues of commercial field plantings of clones in terms of their composition, planting configuration and the agro-management practices to fully exploit the advantage of clones and the field trials needed have been highlighted earlier (Soh et al, 2003a, 2006a,b). If these issues are not being addressed, the advantage of clones vis a vis hybrid seeds would be further undermined.

Concluding Remarks

Owing to the inefficiencies in the tissue culture process in terms of clonal amenability and fidelity still extant, clonal propagation strategy in oil palm remains as an adjunct in the hybrid seed breeding program. Cloning (and recloning) ortets from advanced DxP hybrid populations is inefficient due to the low genetic variability and heritability for yield resulting in little yield improvement over new improved hybrids which are concurrently available. This would question the advantage and relevance of commercial clonal plantings with their higher cost and attendant risks of somaclonal variation and pest, disease and environmental stress vulnerability. Cloning in the earlier or recombinant phases would be more efficient with wider genetic variabilities and higher heritabilities for yield and other desirable traits. This would also apply to the alternative clonal seeds and cloning embryos/seedlings approaches, especially the former which has now become a technology.

Perhaps the biggest advantage of clones is the early commercial exploitation of new genetic materials from introgression breeding progenies derived from wide (intra and interspecific) crosses, and thus broaden the genetic base of the commercial crop to reduce its genetic vulnerability risk to biotic and abiotic stresses and ensuring its sustainability.

Adaptability trials are an integral part of cultivar development and such trials on clonal plantings should be carried out to ensure exploitation of the full potential of clones.

Clones can only capture a major share of the oil palm planting material market when the issues low culture amenability and unpredictability of fidelity can be resolved or circumvented (presumably through molecular marker technologies) and their field performance advantage over concurrent improved hybrids clearly demonstrated.

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