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Prospects for Biotechnology in Oil Palm (*Elaeis guineensis*) and Coconut (*Cocos nucifera*) Improvement

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There are substantial opportunities for genetic improvement of both oil palm and coconut; both crops are heterozygous, with much unexploited variability from which to select. New sources of resistance to the major diseases in both crops are needed, as well as methods of rapidly transferring resistance into commercial varieties. There is neither understanding of the genetics of host–pathogen interaction nor of the control of resistance in these species, which are a major inhibiting factors. Thus there is at present no chance of isolating and transferring resistance genes other than by traditional breeding methods.

The first application of biotechnology to these crops was in the micropropagation of clonal palms from selected élite individuals. This allows the wide phenotypic variability of the heterozygous hybrids to be stabilized, thus producing recognizable palm cultivars with stable characteristics. This technology will allow major improvements in yield and quality to be achieved, but although the techniques are now widely available for oil palm, commercial development has been delayed by the occurrence of flowering abnormalities in some of the early commercial clones. Commercial clonal coconut propagation is not at present feasible, and no techniques exist.

More sophisticated cell genetic manipulations are completely dependent on the development of a reliable, high efficiency plant regeneration system from culture and, simultaneously, the discovery of quality control methods for detecting abnormalities at an early stage of growth.

Transfer of foreign DNA requires more effective and reproducible DNA delivery systems which, to date, have not been devised. As yet no work has been done on palm transformations, partly through lack of interest and resources, but mainly because the tissue culture systems are still too

Abbreviations: cDNA, complementary DNA; ORSTOM, Office de la Recherche Scientifique et Technique Outre-Mer; PORIM, Palm Oil Research Institute of Malaysia; RFLP, restriction fragment length polymorphism; UPM, Universiti Pertanian, Malaysia

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unpredictable. The advent of reliable transformation systems for other monocotyledonous plants, such as wheat and maize, may assist attempts to apply such systems to palms.

There is an almost total lack of knowledge of the genetics of the characters which may control or modify, for instance, yield, quality, or resistance to drought, wind or disease. Such studies are vital to future applications of recombinant DNA technology.

Molecular biology provides powerful tools for genetic investigation and mapping in the form of DNA probes and, for example, the use of restriction fragment length polymorphisms (RFLPs). Developments in this area could provide great help to palm breeders and reduce the number of plants required in, what are at present, large and expensive field trials. There will be increased utility and application for this kind of technique as our knowledge of the genetics of the crops develops. First applications would be rapid. For example, a probe to distinguish *dura, tenera* and *pisifera* oil palms at the nursery stage, to enable the desired genotypes to be selected from segregating crosses in breeding programmes, would be taken up immediately. This could probably be produced within a couple of years. An RFLP map could provide the basis for genetic mapping of a large number of phenotypic characters within 2–5 years, and contribute to the choice of parents in directed breeding programmes, all of which could lead to improved yields.

Biotechnological developments in competitive crops may provide a threat to the producers of palm and coconut oil in the future, though significant effects are unlikely for about 20 years. In particular, the appearance of a temperate crop producing lauric and other short- and medium-chain fatty acids would pose a threat to coconut oil and palm kernel oil utilization.

Introduction

Modern biotechnology increasingly employs the techniques of molecular biology, particularly recombinant DNA technology. Advances in these areas are extremely rapid, and are finding application to breeding programmes for temperate crops with surprising speed. There is as yet virtually no parallel application to perennial tropical crops, and even the 'old' biotechnology methods involving cell culture and plant propagation have yet to be fully developed for commercial use. This account therefore encompasses the developments in both 'traditional' and 'modern' biotechnology as applied to oil palm and coconut, and indicates some priority areas for research, if rapid progress is to be made.

The agricultural applications of biotechnology to the oil palm were reviewed at the Committee on Science and Technology in Developing Countries (COSTED) symposium in Madras (Rao and Mohan-Ram, 1986). The most recent review of work on oil palm is by Jones and Hughes (1988) and on coconut by Pannetier and Buffard-Morel (1986) and by Blake (1989, in press). A symposium on Biotechnology for the Oils and Fats Industry, in Hamburg (1987) covers the wider aspects of biotechnology in relation to oilcrops and oilseed processing (*see* World Conference on Biotechnology for the Oils and Fats Industry, 1987).

Potential for crop improvement

Both oil palm and coconut are heterozygous outbreeders normally propagated by seed, and showing a high degree of variability within their progenies. Hybridization has been applied effectively to both crops. In the case of coconut, hybrids between the dwarf and the tall varieties show precocity and increased copra yields, while in oil palm mesocarp oil production is improved by hybridization between the *dura* and *pisifera* types. Hybrid production is from specific crosses made in seed gardens from selected parent palms. In coconut, in particular, the small number of seed nuts produced annually by the mother palm is a major limit on seed production. From the observed variation within hybrid seed progenies in both crops, it is apparent that there would be considerable scope for improvement if the best of the hybrid palms could be propagated vegetatively. In oil palm this has been estimated at 30% yield improvement on current progeny means (Meunier *et al.*, 1988), and the potential gain is expected to be considerably greater in coconut. It is also clear that great improvements in coconut yield can be achieved by better agronomic practice, and this must go along with the use of new varieties with improved yield potential.

Yield is the outcome of the crop's integrated response to the environment. In addition to ensuring the correct genetic potential for high yield in ideal conditions, key factors in yield improvement are maintenance of health and vigour under a range of more adverse conditions. A constraint to improvement is the lack of sources of resistance to drought and to diseases such as *Fusarium* wilt (Africa) and Lethal Spear Rot and Sudden Wilt (S. America) in the oil palm, and Cadang-cadang and Lethal Yellows in the coconut.

Crop improvement can also be considered in terms of reduction of cost of production, which includes such factors as ease of harvesting, low crop management costs, (cultivation, pruning, fertilizers, pesticides, herbicides) and reduction of crop losses, such as premature ripe fruit drop in oil palm. Other aspects include quality factors such as oil content and composition, and maintenance of low free fatty acid after harvest.

Applications of biotechnology

DEVELOPMENT OF METHODS FOR VEGETATIVE PROPAGATION USING TISSUE CULTURE

Tissue culture propagation of oil palm and coconut have been the subjects of considerable attention over the past 20 years. Although tissue culture propagation methods are now regarded as 'old' biotechnology, the techniques are still not fully developed for oil palm and remain in the research stage for coconut.

Methods for oil palm propagation

The methods for oil palm propagation are now generally available and have

been the subject of several major reviews (Wooi, Wong and Corley, 1981; Paranjothy, 1984, 1986a, b; Brackpool, Branton and Blake, 1986; Jones and Hughes, 1988). Embryoids form on both primary and secondary calluses, and isolated embryoids can be induced to proliferate to form a continuously propagating morphogenetic tissue capable of producing plants over many subcultures. Clonal propagation, although slow compared with many crops, is now routine in a number of laboratories. Recent problems with abnormal flowering in clones that have been subjected to large-scale production (Corley *et al.*, 1986) have delayed full commercial exploitation of the method, and full understanding of this problem, with appropriate quality control procedures, is required before the method can be used routinely. Evaluation of the numerous clones already in trials and fruiting normally indicate that considerable yield improvements can be achieved, at least matching the 30% predicted at the outset (Jones, 1988). Quality improvements are also possible, with a wide range of different oil compositions within the species and its hybrids from which to select (Jones, 1984; Arasu, 1985; Jones, 1987).

Methods for coconut propagation

Advances in coconut propagation have been much slower. The progress of the work has been reviewed by Blake (1982), Branton and Blake (1986), Brackpool, Branton and Blake (1986), Pannetier and Buffard-Morel (1986) and in a forthcoming review by Blake (1989). Most cultures grow in quite a different way from oil and date palm (*Phoenix dactylifera*). Although they show strong signs of embryogenesis from partially organized calloids early in the culture process, they do not multiply further and they usually develop in an unbalanced way, only occasionally producing shoots, and rarely a complete plantlet (Branton and Blake, 1983). It has proven extremely difficult to maintain active growth of the few plantlets that are produced, and to date there is only one documented example of survival and establishment in soil (Smith, 1986). The plant came from the Unilever programme and was planted in the Solomon Islands in 1984. Experience with *in vitro* germination of zygotic embryos shows that it is possible to raise plants without the benefit of the massive coconut endosperm, but they are slow growing and require a long period of nursing before they can be established. They tend to be about one year behind in their development compared with sister embryos germinated directly on the nuts. The conclusion is that even when the correct sequence of stimuli that will promote normal development of embryoids in culture is known, there will be considerable time and cost involved in raising and establishing coconut plants, so that it is unlikely to become a cheap large-scale process in comparison with oil palm. It will, however, be extremely useful in the propagation of elite parent palms for hybrid seed production, giving very uniform 'clonal' seed.

Efficient tissue culture methods are essential prerequisites for all other cell and molecular biology manipulations involved in 'new' biotechnology.

HAPLOIDS

In heterozygous species, genetic recombination during meiosis results in a very large number of genetically unique pollen grains. The result of embryoid development from pollen grains is the production of haploid plants. More usefully, doubling the chromosome number to produce dihaploids will result in fully homozygous fertile diploids. The majority of these will carry deleterious recessive genes and will be inviable or otherwise of poor quality. Some may have improved qualities, and these can either be perpetuated by self-pollination or used as parents in hybridization programmes.

Little work on haploid cultures of oil palms has been reported (Odewale, 1983), but work is in progress at the Palm Oil Research Institute of Malaysia (PORIM). Work on pollen/anther culture of coconut is in progress in the Philippines (Thanh-Tuyen and de Guzman, 1983). As yet there is no report of plant regeneration from haploid cultures of either species. However, if we assume that the technology will eventually be developed, the major problem will be in the screening and selection of improved genotypes. There are two alternative approaches:

1. Dihaploids (tall or dwarf in *Cocos, dura* or *pisifera* in *Elaeis*) could be used to set up seed gardens to produce uniform F_1 seed. The major problem will be how to select the parents from huge segregating populations, many with deleterious gene combinations which might, however, show complementation on hybridization. This would ideally require diallele cross programmes on large dihaploid populations to identify individuals with high combining ability for use as parents. Parent lines could be propagated by selfing or by clonal propagation. Such a programme would be of long duration, (probably 25 years). Thus, if we assume that the technology is worked out within 5 years from now, the further programme for coconut would require planting a population of dihaploids, say 500 tall and 500 dwarf palms. For oil palms these would be *duras* and *pisiferas*. Since phenotypic performance of dihaploids would be a very poor guide to performance as parents, random crosses could be made as soon as the palms flowered, which takes 3–4 years. This would preferably be in the form of full diallele, but in practice a partial diallele would suffice to find specific combining effects. Many of the dihaploids may show poor phenotypic qualities and some selection of the original population would have to be made to reduce the number of crosses. If only 10% of palms were selected, ignoring the possibilities of complementation, this would give 2500 progenies. Even planting only 10 palms per progeny, at 138 palms ha^{-1} would require 180 ha of trials. In a further 8–10 years it would be possible to evaluate the progenies. From the best selections it would be possible to begin multiplication of parent lines by selfing or cloning, either way taking about 2 years to plants and another 3–4 to the production of hybrid seed.
2. Selected dihaploids could be planted commercially. Jinks (Jinks, 1983; Jinks and Lawrence, 1983) argues that there is no genetic basis for the

widespread belief that the best phenotypes are heterozygous. Heterosis is at least partly a result of non-allelic interactions between genes at different loci, and can therefore occur in a homozygote. This point has been confirmed in experiments with *Nicotiana rustica*, where it has been possible to identify inbred lines which outyielded the best F_1 hybrids. The desired oil palm *tenera* fruit type is heterozygous for the shell thickness gene; all dihaploids would be homozygous *dura* or *pisifera*. However, very thin-shelled *duras* do exist, while it has also been suggested that fertile *pisiferas* be planted commercially (Tang, 1971; Chin and Tang, 1979; Chin, 1988), so dihaploids need not be ruled out on these grounds.

The best coconut genotypes are dwarf × tall hybrids, but the genetic basis of dwarfness in coconut is not known. If dihaploids were produced from pollen grains from hybrids, individuals combining the best characteristics of dwarves and talls might be obtained.

Probably the recovery of viable dihaploids will be very low, with much poor quality that can be rejected in the early stages (*in vitro* and in nursery). Large numbers of dihaploids would have to be planted to give a reasonable chance of finding good individuals. Once identified, these individuals could be propagated by self-pollination. The time needed to produce commercial material of both oil palm and coconut would include 5 years to develop the technology, 2–3 years to recover plants and 8 years to select the best individuals, followed by a further 4 years to multiply those individuals, by selfing, to give a reasonable number of seed parents. The overall time-scale will therefore be about 20 years. Both these programmes require large resources, both technically in the laboratory, where relatively rapid progress is assumed in a species that has proven particularly recalcitrant, and also in extensive and prolonged field trials covering large areas of land. The cost of such a programme would be high with no guarantee of success. The rewards are potentially great, but depend on lipid markets far in the future.

PROTOPLASTS

Protoplasts are widely used for recombinant DNA transformation work, but there are probably better alternatives now available, since no technical success has been reported with plant recovery from protoplasts of either species. Successful production of callus colonies from oil palm protoplasts was achieved by Bass and Hughes (1984) using a nurse culture technique. There may be possibilities in production of protoplasts from embryos or embryoids to develop highly embryogenic cultures from single cells. Difficulties in finding optimum enzyme preparations to digest the cell walls of densely packed embryoid cells have delayed progress in this direction, and it has received relatively little attention. Sambanthamurthi, Oo and Ong (1987) obtained metabolically active protoplasts from embryogenic cultures but did not attempt to subculture them. Combination of these two techniques could lead to highly embryogenic protoplasts with the capacity for plant regeneration and the potential for the development of regenerating suspension cultures. Such a system would allow far greater use of 'fermenter' technology in the scale-up of

the propagation process and reduce much of the dependence on hand labour.

EMBRYO RESCUE

In vitro germination of excised embryos can make a valuable contribution to transfer of aseptic germ-plasm, particularly of coconut, where the bulky and fibrous shell and husk can harbour pathogens. It must be emphasized that embryos cannot be guaranteed to be free from virus/viroid/mycoplasmas and strict quarantine is still required in transfer from infected areas.

In vitro germination of excised embryos of coconut was pioneered by de Guzman (*see* del Rosario and de Guzman, 1982) for *makapuno* nuts, and a commercial production unit is being set up in the Philippines, although beset by delays. An effective protocol was described by Assy-Bah (1986).

Oil palm embryos were extensively worked on by the French workers in the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) in the early 1970s and, more recently, in the Palm Oil Research Institute of Malaysia (PORIM) (Rohani and Paranjothy, 1985). Although *in vitro* germination is regularly possible in both species, the failure rate is still too high for routine use for direct planting of commercial material, and work is still required in the establishment phase.

CRYOPRESERVATION

Some progress has been made in cryopreservation of oil palm cultures and embryos (Grout, Shelton and Pritchard, 1983; Engelmann and Duval, 1986). The success rate with embryogenic tissue cultures is low, but plants have been recovered from liquid nitrogen storage. Embryos can be successfully frozen by plunging the whole kernel into liquid nitrogen. Rapid thawing is critical in the recovery stages, but reasonable success rates are claimed. It is thus possible to maintain oil palm germ-plasm in liquid nitrogen storage. This could be useful for keeping cultured material while clone trials are done, and in maintaining genetic collections. The disadvantages are that storage containers are expensive, and a continuous supply of liquid nitrogen is required. This can become a problem if there are breaks in supply due to industrial action or other causes. The recovery phase is slow and liable to losses. The cheaper alternative is to maintain living collections in the field. Disadvantages are susceptibility to weather, disease and political or commercial expropriation leading to loss of access to the material, which may become significant over the long time-scales involved.

SOMACLONAL VARIATION

Variation induced in tissue culture has been successfully exploited in other crops to provide novel sources of variation. As yet there is little good evidence of somaclonal variation in regenerant oil palms and none in coconut since only one plant has been recovered. It seems likely that such variation will occur. Variants arising in tissue culture programmes should not be rogued out, but planted in observation plots and evaluated for useful characters. Even if the

palm variant itself is not ideal, it could be used as a a parent in further breeding if it carries a useful trait. We know nothing about the heritability of such variant characters in oil palm. In other species some are Mendelian, some maternal and some are unstable. Possible traits for evaluation would be short stature, uniform bunch ripening, loss of the fruit abscission mechanism, low-carotene fruits, long bunch stalk for easy harvest, high bunch index, and so on.

IN VITRO SCREENING

The generation of new genetic variants in tissue or cell cultures opens the way to selection for desirable traits at the culture stage. This can only be effective if the trait is expressed in the cells in culture so that it can be detected. The types of characters successfully selected *in vitro* are limited so far to resistance to herbicides or fungal toxins. This method has not yet been applied to palm cultures, and because of the very low plant regeneration rate it is unlikely to be useful until the techniques are greatly improved. It is proving possible to screen young clonal oil palm plants for resistance to *Fusarium* wilt disease, but as yet this cannot be done *in vitro*. Oil palm calluses capable of growth in the presence of fusaric acid have been selected, and one line has produced embryoids, but no plants have yet been recovered, and there is no certainty that this trait will confer *Fusarium* resistance (Flood, unpublished).

RECOMBINANT DNA

Introduction of new genetic information into oil palm and coconut by recombinant DNA transformations is still technically remote.

First, no effective vector or delivery system is available for monocotyledonous plants. Newer direct DNA transfer methods may prove more effective than attempts to use *Agrobacterium* Ti plasmid transformations, and with the very active work going on to solve this problem, effective methods for some cereals may be available soon. Even so, it is not certain that they will apply to palms.

Secondly, the tissue culture systems are not available for efficient multiplication and selection of transformed cells, and recovery of regenerant plants is very uncertain in oil palm and as yet impossible with coconut.

Thirdly, we know virtually nothing about the genetic systems of either crop. There are no genetic maps, and only very tentative karyotypes. We do not therefore have any idea of which genes to transfer, nor how they might interact with the rest of the genome.

There may be some benefit to be gained in transfer of pest resistance, such as introduction of *Bacillus thuringiensis* toxin, or insect-repellent proteins to reduce predation by leaf-eating caterpillars and leaf miners, but these are pests which are easily controlled by other means and do not usually result in great financial loss. In addition, the introduction of genes conferring pest resistance might not give long-term success with a perennial crop, since the pest would have plenty of time to overcome the resistance. If disease resistance genes can be identified their transfer might be a better bet, at least for soil-borne diseases

such as *Fusarium* wilt, because apparently resistance to soil-borne diseases does not break down too quickly. Unfortunately there is at present no knowledge of the genetic resistance mechanisms, and little chance of finding simple single genes conferring resistance. Thus it is difficult to envisage justification of the effort involved in attempting DNA transformations. If this technology is to be applied to the palms, then a great deal more effort is required in improving the tissue culture methods and understanding the regeneration process, probably by detailed study of the natural endogenous regulation of zygotic embryo development. In an attempt to isolate embryo-specific DNA probes for genes expressed in embryogenesis, Jack and Alang (1987) prepared active mRNA from zygotic embryos and a cDNA library is being prepared. This is the first report of any molecular study on oil palm.

MOLECULAR GENETIC MARKERS

Molecular biology has provided very powerful tools for probing and mapping the genomes of crop plants. Restriction fragment length polymorphisms (RFLPs) enable different genotypes to be distinguished, and genetic maps and linkage groups to be established rapidly. Use of RFLPs correlated with phenotypic characters would enable palm breeders to make genuine genetic advances. Fortunately with these perennial crops, the ancentral palms are, in general, still in existence, so the inheritance of specific markers associated with particular traits can be determined easily on existing material, without the need to make fresh crosses. The existence of a suitable genetic marker closely linked to a particular gene can enable the gene itself to be mapped and eventually isolated, identified, cloned and sequenced. This information is an essential part of modern plant breeding based on genetics. Effective probes for specific genes are only useful when useful genes have been identified and linked with phenotypic expression. As this knowledge develops, the use of molecular probes could reduce the number of plants it is necessary to test in field trials for developing improved varieties. In palms, which have low planting densities and long generation times, this would provide an enormous saving in trials costs and would accelerate plant breeding progress.

cDNA and genomic libraries are being prepared by Cheah in PORIM, Alang at the Universiti Pertanian (UPM), Serdang, and by Shah at the Universiti Kebangsan, Malaysia (personal communication). Probes for mitochondrial DNA have been used to distinguish between *E. oleifera* and *E. guineensis*, and thus, because mitochondria are inherited maternally, to confirm the parentage of interspecific hybrids (Jack, personal communication).

MOLECULAR METHODS IN PATHOGEN RESEARCH

The two most important threats to coconut production are the diseases Lethal Yellows and Cadang-cadang. Lethal Yellows is a mycoplasma disease severely affecting survival of the crop throughout the Caribbean region, southern United States and Mexico (McCoy 1983). Unless this disease is checked, and wider sources of resistance found (resistance currently exists in the Malayan

Dwarf variety) and transferred to other cultures, the future of the crop is in doubt in these areas.

Cadang-cadang is associated with infection by a viroid (Randles, Rodriguez and Imperial, 1988). It is a dangerous disease which has killed an estimated 30 million palms, but is, at present, confined to some islands in the Philippines and is spreading very slowly.

In the case of oil palm, *Elaeis oleifera* is resistant to the major South American diseases, Lethal Spear Rot and Sudden Wilt. Hybrids between this species and *E. guineensis* are also resistant, but yield poorly in comparison with *E. guineensis*. The genetic basis of resistance is not known, but there would be obvious advantages in transferring resistance into high-yielding *E. guineensis* genotypes.

The use of molecular markers, such as RFLPs, will help to determine the genetics of disease resistance and provide tools for identifying resistant genotypes long before there is sufficient knowledge to attempt directed gene transfer by recombinant DNA technology.

Molecular biology and immunology provide the tools for isolation, characterization and recognition of pathogenic organisms such as the Cadang-cadang viroid. Molecular probes which hybridize to the viroid RNA sequence provide a method of screening material for presence of the viroid. There are some current problems in that the viroid can be detected in apparently symptomless material. Palms showing pathological symptoms contain viroids in which a sequence of 41–55 nucleotides becomes reiterated. It may be that the viroid is present in many normal individuals but requires triggering by some other event to become pathogenic. This does not detract from the power of molecular methods to unravel the detail of infection mechanisms and ultimately to provide tools for combatting them.

Molecular probes should also make it possible to distinguish pathogenic and non-pathogenic strains of *Fusarium oxysporum*, an ubiquitous organism with many different races which cannot be recognized easily except by pathogenicity testing. Such probes would greatly ease the task of diagnosis of diseased palms, and in recognition of soils safe for planting.

Impact of biotechnological improvements to other crops

The application of biotechnology to temperate crops is receiving a great deal of attention. If they are successful, advances in these crops will pose a threat to the markets for palm oil and coconut oil. In particular, major efforts are being made to develop a temperate crop producing high lauric oils. Currently the only sources are palm kernel and coconut. There are two approaches: one is to develop *Cuphea* as a crop plant (Arndt, 1985). This is a natural source of lauric and other short–medium chain-length fatty acids, but is an indeterminate flowering annual, with a high degree of pod-shattering. Commercial crops are still regarded as at least 20 years away. The other approach is to use recombinant DNA technology to introduce genes into established oilcrops, such as oilseed rape, which will divert the biosynthetic pathway into early chain termination and substitute medium chain-length fatty acids for 16- and

18-carbon chains in the seed storage oils. Several academic and commercial groups are active in this area. This is a challenging task beset with many difficulties, not least a general ignorance of plant biochemistry, but good progress is being made, and it seems likely that competitors for coconut oil will eventually become available. Again, the time-scale for the production of commercially available seed must be at least 20 years, including the time required for commercial trials, variety registration and approval, even if the recombinant technology is available within the next few years. The incentives to develop such crops are primarily to ensure continuity of supply and to maintain a stable (and low) price. It is widely stated that there is a world shortage of lauric oils for industrial purposes, but this is not reflected at the moment in the coconut or palm kernel oil price. Currently annual oilcrops yield a tonne of oil or less per hectare per year and are only able to compete on price as a result of subsidies to the farmers and processors. It seems unlikely that any new or engineered sources of lauric oils will have higher yields than existing oilcrops, at least in the early stages of development, and thus the commercial viability of growing such crops will rest primarily on political decisions in the countries concerned. Nevertheless, it must be anticipated that alternative sources of laurics will be found by the industrialized nations and will compete with palm kernel and coconut oils on the world market. That being so, it is important for producers of these oils to reduce costs, maintain quality and ensure continuity of supply to customers. In addition, applications of biotechnology will result in higher yields and lower growing costs of temperate oilseeds as a result of introduction of herbicide resistance, pest resistance and improved oil quality. Thus, low linolenic acid soya beans (*Glycine max*) and high oleate sunflowers (*Helianthus annuus*) can be expected to appear in the next few years.

Biotechnology in oils and fats processing

Biotechnology is being applied increasingly to the processing of vegetable oils. The result will be an increasing flexibility of the use of oils of different types for a range of purposes. In some cases this trend can benefit uses of palm and coconut oils, and in others it may pose a threat, enabling other sources to be used. One example is in the enzymic interesterification of cheap palm stearin with olein in the presence of a 1,3-specific lipase (EC 3.1.1.3) at low water activity (Macrae and Hammond, 1985). If properly controlled, this process can result in enhancement of symmetrical triglycerides of the saturated–unsaturated–saturated type which characterize cocoa butter, a much more expensive commodity. Originally designed to use palm oil fractions, the processors are now looking towards other, richer, sources of oleic acid, such as the high oleate sunflower oils. Other biotechnological processes are designed to produce free fatty acids, and to control desaturation (although the biochemistry involved in the latter is complicated by difficulty in isolating the enzymes, and in the need for cofactors). Modern developments in processing were discussed in the World Conference on Biotechnology for the Oils and Fats Industry, Hamburg (1987) (*see also Fat Science Technology*, 1988).

Development of biotechnological processing methods can have far-reaching

implications for future use of palm and coconut oils. As relatively cheap major sources of vegetable oils they can provide feedstocks for bioprocesses, but will have to compete with other cheap and abundant sources, frequently supported by subsidy. The new processes will further enable the processors to upgrade cheap raw-materials, and impose price pressure on specialist oils.

Impact of biotechnology on plant breeding

Biotechnology provides a set of tools of great potential use to the plant breeder. The impact on the oil palm and coconut industries could be in the provision of improved varieties with better yield, lower production costs and improved quality. Clonal propagation provides the opportunity to select from highly variable and heterozygous hybrid populations, and to stabilize selected phenotypes in the form of cloned cultivars. The extension of this technology into cell and genetic manipulation will eventually enable the breeder to introduce valuable traits from other genotypes or other species. These benefits will only be realized if sufficient effort is committed now to long-term programmes. There are numerous reasons why modern biotechnology has been slow to be applied to oil palm and coconut, and, indeed, to tropical perennials generally.

First, the application of new biotechnology relies on an underlying basis of good biochemical genetics of the crop concerned. This is at present absent from these crops. Secondly, appropriate skills and resources are limited in the countries where these crops are important to the national economy. Thirdly, the enabling technologies of transformation with foreign DNA and recovery of plants via tissue culture are not yet available in these species. Fourthly, it is not yet apparent which specific genetic traits should be transferred. None of the attributes desired by palm breeders can be identified as characters carried by single genes. We do not even have a reliable karyotype, there are no linkage maps and no genes have been mapped to chromosomes.

The application of the diagnostic and analytical power of modern biotechnology would be a great advantage in oil palm and coconut breeding programmes. Breeding programmes are slow because of the long generation times, and large areas of land are required for trials. There is a heavy commitment in labour for trials maintenance and recording. All these factors result in high costs of breeding programmes. If biotechnology can reduce the time-scale and numbers of plants required for trials there will be real savings to the breeder. Unfortunately, it is not immediately apparent how biotechnology can be made to return profits in the time-scales required by accountants in biotechnology companies.

A concerted attack is required on the molecular biology to provide RFLP markers leading to genetic markers for heritable traits for use in breeding programmes. Such work would provide genetic mapping, the establishment of linkage maps and ultimately the identification, isolation and cloning of individual genes. Additional work on transformation systems and improved tissue culture is required for the benefits of biotechnology to be realized by the industry as a whole.

Effective programmes require a minimum staffing level of 4–6 scientist teams, say 12–15 people, on an annual budget of $1 million and a 10-year time-scale. Clearly this is only possible in major crop research institutes.

Because of the very different structures of the oil palm and coconut industries, the pattern of research funding is inevitably different in the two crops. Oil palm plantations are, of necessity, organized in large estates close to an oil mill. They are generally in the hands of major plantation companies or integrated, well-managed group schemes, and increasingly use sophisticated methods of plantation management, harvesting and processing. Oil palm growers are receptive of new high technology inputs and can quickly exploit improved varieties in their replanting programmes, while absorbing premium prices of better planting material, provided these guarantee a financial return.

Coconut growing, on the other hand, is largely in the hands of small growers (plantation sizes usually less than 2 ha) with few resources, who are unable to afford to replant frequently or to buy expensive planting material, and usually replant with their own seednuts.

It is likely, therefore, that development in the two crops will be different, and may lag for coconut, simply because of the lack of an organized research base. It is quite possible that traditional plant breeding techniques will yield the most rapid benefits in the latter case.

Centres of research

The following laboratories and other organizations are known to be active in this field.

OIL PALM

Research Institutes

IRHO, Bondy, Paris.
Marihat Research Station, Indonesia.
NIFOR, Benin, Nigeria.
PORIM, Bangi, Selangor, Malaysia.
Universiti Kebangsan, Bangi, Selangor, Malaysia
Universiti Pertanian, Serdang, Selangor, Malaysia.
Wye College, University of London.

Commercial

FELDA, Malaysia.
Guthries, Malaysia.
Highlands Research, Malaysia.
IPRI, San Carlos, California.
Plantek, Singapore.
Sime Darby, Malaysia.
Socfindo, Malaysia.
Tropiclone, Montpellier, France.

Unifield T.C., Bedford, UK (Unilever plc and Harrisons & Crosfield Ltd).
United Plantations, Malaysia.

COCONUT

Research Institutes

Central Plantation Crops Research Institute, Kerala, India.
CICY, Yucatan, Mexico.
Coconut Research Institute, Lunuwila, Sri Lanka.
EMBRAPA/National Center for Coconut Research, Aracaju, Brazil.
IRHO, Bondy, Paris.
MARDI, Kuala Lumpur, Malaysia.
National Chemical Laboratory, Poona, India.
PCA-Albay Research Center, Albay, Philippines.
St Aloysius College, Mangalore, India.
University of the Philippines, Los Banos, Laguna, Philippines.
Visayas State College of Agriculture, Leyte, Philippines.
Wye College, University of London.

Commercial

Kao Corporation, Tochigi, Japan.
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