PLANT BREEDING

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INTRODUCTION

Plant breeding is one of the oldest arts and is basic to our civilization. Hunter/gatherers in different parts of the world became so familiar with the wild plants which they gathered each year that they began planting them and selecting seed to be saved each year for the following season. This occurred around 10,000 years ago in the Middle East (based on wheat, barley, peas, lucerne and other crops), and somewhat more recently in Central America (maize, beans, tomatoes, sunflower) and Asia (rice, soybeans). The main domestication process in these crops was completed at an early stage, whereas many other food and fibre crops and ornamental plants have been taken into cultivation since, with the process still underway for crops such as fennel and boronia.

As a science, plant breeding dates to the 19th century, in either established crops like cereals, where the Australian, William Farrer, was a pioneer, or in new crops such as sugar beet and rubber. An understanding of genetics, following Gregor Mendel, and evolution, after Charles Darwin, gave the subject a sound theoretical basis, built on by advances in cytology, biochemistry, statistics, and plant physiology.

I will review the main features of plant breeding from a practical point of view, to suggest how decisions could be made as to whether a programme is needed or not and how objectives and methods can be defined. I work with agricultural crops, having been involved in breeding programmes on perennial tree crops in the tropics and annual seed crops in temperate areas. I hope you will, therefore, pardon the lack of emphasis on ornamental plants, but instead be able to arrive at some basic principles of use in any crop, taking the word in its widest sense.

BREEDING OBJECTIVES

These will sometimes be obvious and relate to either demands of processors and consumers, or weaknesses which develop in the crops such as disease susceptibility. Many plant breeders spend most of their time on such "fire brigade" duties, broadly classified as "elimination of defects." They will range from adaptation of the crops, to make them flower and fruit in a particular environment, through greater resistance to drought, lodging, disease or pest attack, to suitability for mechanical harvesting. This involves uniformity of ripening, presentation of the parts to be removed and separation of desired parts such as seeds from leaves, stems, chaff, etc. Product quality is also increasingly important in nutritional value, flavour, and keeping quality.

Other objectives may be to breed for higher yields, allowing the crop to integrate all the various internal and environmental factors to produce the desired result, or to breed a ''model'' plant or ideotype. Most of our annual seed crops are being constrained towards a similar type with short strong stems, a minimum of leaf to intercept sunlight, and efficient distribution of photosynthate to seeds.

UNDERSTANDING THE CROP AND ITS BIOLOGY

Good plant breeders are very careful ''students'' of their crop, developing an almost instinctive understanding of how it reacts to different conditions and a flair for picking out useful variants, often from segregating populations. Incidentally, they often become allergic to the crop or its pollen! An understanding is needed of where the crop came from originally (soil and climate as well as location) and what range of variation is currently available. This would be either from the wild or in breeders' or international collections which are becoming increasingly the main source of new material for the major crops. Often ''new'' types can be induced by mutation, interspecific hybridization, or other means, but the same may already be in existence—nature, or the evolutionary process, has tried most possibilities before.

The reproductive biology of the crop needs to be known before it can be ''interfered with'' by the breeder. Where propagation in nature is by vegetative means, such as runners, tubers, corms, or bulbs, the plants may have largely lost their ability to reproduce sexually, as with crops like yams and sweet potato where tricks, such as grafting, may be needed to get them to flower. Even where seeds are produced, they may be of parthenocarpic origin, i.e. produced without fertilization, as in some citrus, blackberries, and mangoes, so crossing with a male parent may not give a successful hybrid—a real trap for young players! Some plants are complex interspecific hybrids, such as sugar cane or blackberries, and the proportion of viable seed produced may be very low. Many cultivated crops are polyploids, with multiples of the basic chromosome number for the species. Some of these are triploids which again do not produce fertile seed. Examples are bananas, where only the wild ''monkey bananas'' produce seeds, and azaleas, where the absence of seed set is an asset as it prolongs flowering.

The crops which do successfully produce seed can be divided into two main groups for plant breeding purposes—those which pollinate themselves, such as wheat, subterranean clover, or peas (flowers never open up in the latter two), or cross-pollinators such as maize, pumpkins, and most of the perennials. Within some groups there are differences, such as in the brassicas. Cabbage, broccoli, and turnips are all diploid, cross-pollinated and hence closer to the wild type, whereas swede and rape are polyploid and mainly self-pollinated. Cross-pollinated species such as lucerne (alfalfa) or cabbage often have self-incompatibility mechanisms so that self-pollination is largely prevented, but the cunning breeder who wants to produce inbred lines can pollinate in the bud stage or even shave off the top of the stigma, where the incompatibility mechanism often operates.

To determine whether a crop is self-or cross-pollinated, a variety of means can be employed. Examination of the flowers will show whether they open up or not and which parts (male or female) are receptive and when. If a plant is isolated either in a glasshouse or by bagging and does not produce seeds, it is probably cross-pollinated. If it does produce seeds, however, it may either be self-pollinated or usually cross-pollinated but self compatible. A breeding test, with alternate rows of two different cultivars is needed, preferably with a marker gene on one cultivar, such as coloured seeds. Seed from the other cultivar, which normally produces colourless seeds, can then be harvested and the proportion of crossing determined.

BREEDING METHODS

Most breeding involves crossing of two different lines and then selection of new combinations of genes from the resulting generations. Crossing usually requires that the intended female parent be emasculated, the anthers being removed before pollen is shed. This is not necessary in self-incompatible species. The foreign pollen is then transferred from the male parent and the flower then bagged to prevent any accidental further pollination.

The self-pollinated crops mainly exist as "pure lines," which were originally selected out of the old "land races," or mixtures of lines with occasional outcrossing that were grown from ancient times. New lines now are generated by crossing two parents which complement each other (one makes up for the deficiencies in the other) or which appear to have potential for a new and better combination of genes between them. The resulting hybrid seed is then grown out, self-pollinated and selected for between five and seven generations to reach pure line status again. Various devices such as two or more generations per year, or double haploids from pollen culture are available to speed this process.

The cross-pollinated crops exist as heterogenous, interbreeding populations and hence are more difficult to handle than the inbreeders. The population as a whole can be improved by mass selection, which means just collecting seed from desirable individuals from each generation to be mixed and used as seed for the next generation. This depends on being able to distinguish ''desirable'' types. Often this is not possible as environmental effects are too large and a progeny test is needed to determine breeding value.

Many crops are now marketed as hybrid cultivars, which is a way of combining hybrid vigour and uniformity into normally cross-pollinated crops. Usually inbred lines that breed true are first produced by self-pollination for 5 to 7 generations. These lines are tested by crossing with other inbred lines, preferably from more distantly related original sources, and the best hybrids can then be produced for commercial release. On a large scale,some form of male sterility (genetic and/or cytoplasmic) is used in the female so that the crossing is reliable. On a small scale, however, hand crossing is satisfactory if the resulting seed is of sufficient value to justify it, for example, in tomatoes where several hundred seeds may be produced from a single cross. It is not essential to use inbred lines to produce hybrids but it is the only way to ensure uniformity in the produce. Crosses between non-inbred parents are used in, for example, cocoa, rubber, and oil palm, taking advantage of hybrid vigour among different source populations without the hazards of inbreeding.

Crops normally propagated vegetatively, including many of the ornamentals and fruit crops are, as indicated previously, highly complex genetically. In principle, breeding is simple as all that is needed is to make a cross between two different lines or cultivars and grow out the resulting seeds. Every plant should be different, with plenty of scope for selection. Desirable lines can then be multiplied up by cuttings or increasingly, these days, by tissue culture, then tested and released. A real problem is in getting both parents to flower at the same time and then produce viable seed.

Many new techniques are now being used to aid plant breeders, although the basic methods are not being replaced. Tissue culture is widely used to multiply desirable clones, either where existing methods are too slow, as in pyrethrum and boronia, or where vegetative propagation was not previously possible, as in oil palms. Tissue culture itself is also generating useful variation under some conditions, where ''somaclones'' have been produced which resist, for example, high salt levels or toxins produced by diseases.

Mutation breeding, using X-rays or chemicals to produce a range of mutations, occasionally produces something useful in with all the "genetic junk"—it is like hitting a watch with a hammer and hoping to get a useful change in function. More refined techniques are now being used in "genetic engineering," to cut and paste the DNA which determines heredity, but little has yet been produced in the way of new crop cultivars. The potential is no doubt there, however.

REFERENCES

1 Simmonds, N W 1979 Principles of Crop Improvement Longmans (David McKay Co), New York