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BREEDING SUNFLOWERS FOR MEDITERRANEAN—TYPE CLIMATIC CONDITIONS

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Russian varieties of sunflower have been grown successfully as a summer crop in regions experiencing conditions similar to those where the crop was developed. The same varieties have been grown in summer in areas with a Mediterranean-type climate but have had to rely almost exclusively on stored soil moisture while experiencing conditions of high evaporative demand. Here high temperatures and moisture stresses reduced the yield of seed and its oil content. To improve the performance of sunflowers in winter rain zones, different strategies are necessary.

Environmental and physiological factors affecting sunflowers under Mediterranean-type conditions have been considered elsewhere (Downes, 1974; de León, 1974; Muriel and Downes, 1974; and Gimeno, 1974). It has been concluded that greater production can be anticipated if varieties are sown early (when the average daily temperature is 8—10°C); and at high populations, perhaps 0.25 million/hectare, so that crops of the early flowering, frost-tolerant varieties necessary can mature before the onset of adverse moisture and temperature conditions (Downes, 1974). Since, so far as is known, no varieties have yet been selected for such conditions, a comprehensive breeding programme is necessary. To provide more suitable varieties in the short term, various steps are being taken, but for the longer term, a more extensive programme has been developed. This will be descibed here.

Although the specific combination of characters required may not exist in an available variety, many genotypes are sufficiently variable that useful types can be selected, and other varieties can be used directly in recombination blocks. Certainly extensive recombination appears highly desirable.

Fortunately a good deal of the effort expended in the development of theoretical and practical aspects of selection in other species can be assessed with respect to sunflowers so that suitable breeding programmes can be devised. However sunflowers are unique. Although inbreeding reduces vigour and hybrids can be produced as in maize, in other respects these two crops differ substantially. The fact that self-incompatibility normally ensures cross pollination in sunflowers, is reminiscent of the situation in many pasture species. The cytoplasmic male sterility system is similar to that in sorghum and in this paper I will use the sorghum terminology (viz. A, cytoplasmic male sterile ; B, non-restorer ; R, restorer). Various possible approaches will be evaluated by referring to theoretical treatments of the problems faced, and the result, the programme which has evolved, will be described.

SELECTION IN SUNFLOWERS

Theoretical considerations. Since the sunflower is normally open pollinated, a consideration of the theory developed for random-mating populations is appropriate. If the use of hybrids is not envisaged, both partial and overdominance are accommodated by crossing and testing within the one population. This suggests that most gain can be made by recurrent selection (Griffing, 1963).

However since the availability of cytoplasmic male sterility makes hybrid production possible, it is necessary to consider the most appropriate selection system in this case.

Griffing (1963) evaluated the concept that hybrids should be made by crossing unrelated lines and he concluded that in the cases of both partial and overdominance, the use of two separate populations does not allow maximum potential to be realized. He proposed that available germplasm should be pooled for recombination before being split into two parts arbitrarily so that the new populations contain all alleles in the system at each segregating locus. Further, he stressed the importance of moving from mass selection to selection based on performance of reciprocal crosses between the two populations before a plateau is reached, so that selection may remain efficient.

Although diallel, top-, variety-, and poly-, crosses have been used to provide material for progeny testing genotypes, Latter (1964) concluded that sib crossing and family selection have many advantages in the improvement of self-incompatible pasture species. Selected plants in superior families are crossed with four or five other selections to provide progenies which are evaluated before the next cycle of selection.

Family selection may be regarded as an alternative to progeny testing and certainly, when heritabiliy is high (greater than 20%) progeny testing reduces the rate of annual gain (Morley and Heinrichs, 1960). Yet family selection does not lead itself to the production of large quantities of seed so that genotypes can be evaluated under diverse conditions. More seed is available with minimal effort if a polycross is employed. With adequate testing, selection of widely adapted genotypes is possible (Finlay and Wilkinson, 1963).

In maize breeding, self pollination is widely used to fix desirable combinations. Inbreds are crossed to produce single cross hybrids, and commonly these are subsequently crossed to produce commercial double cross hybrids. It is worth noting that yields of single — and double — crosses are comparable though one results from crossing homozygotes and the other from heterozygotes. This suggests that there is no particular genetic advantage in inbreeding to produce hybrids. Indeed even in maize there is emphasis on population breeding rather than inbreeding at CIMMYT in Mexico (Sparague, personal communication).

Practical considerations. Since hybrid production is possible and may be desirable, two populations have been developed after up to 5 generations of re-combination in an extensive collection of germplasm. The R population has cytoplasmic male sterile cytoplasm and carries fertility restorer genes while the B population has normal cytoplasm and does not contain restorers. Thus selections from each can be used directly.

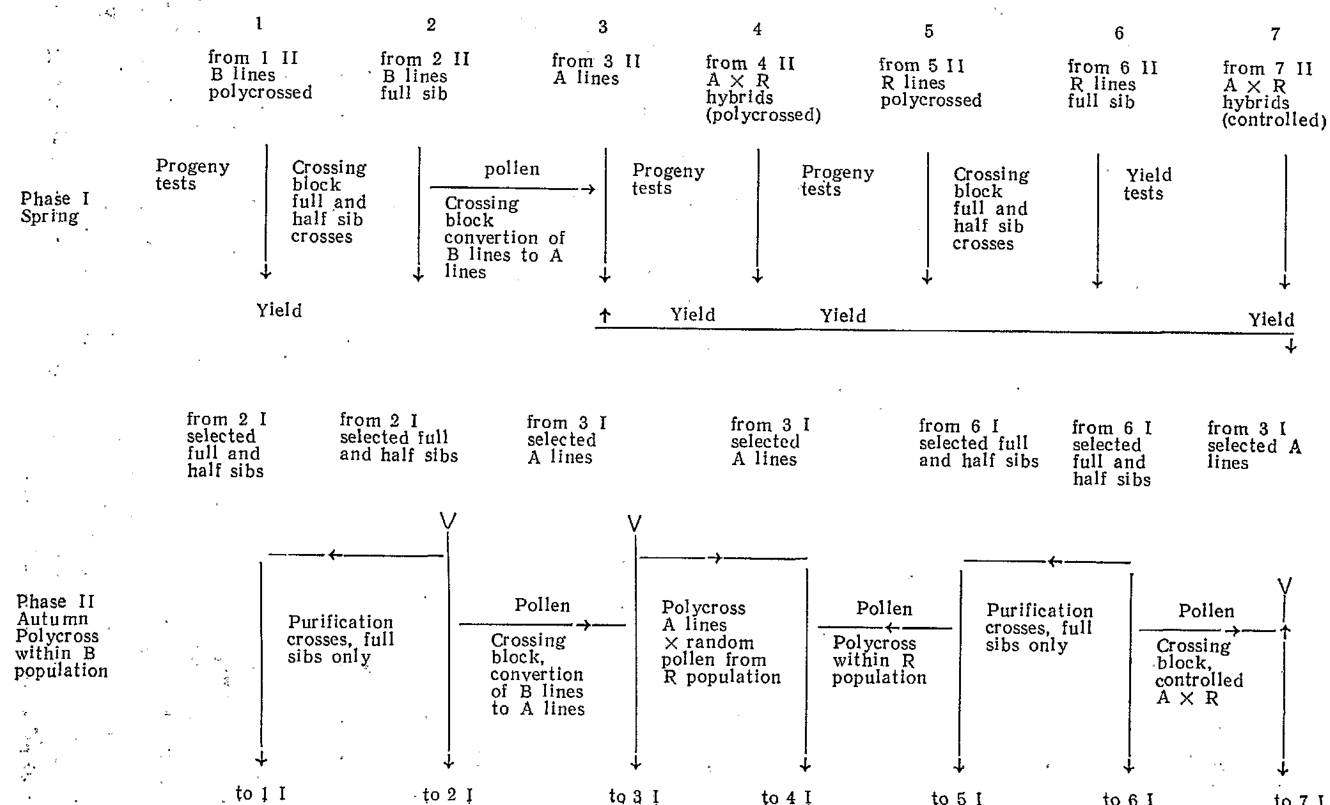
So that adapted varieties may be developed rapidly, the programme consists of two phases which constitute one cycle per year. Evaluation and recombination are conducted concurrently in spring, so that normal development patterns are expressed. In the autumm, lines are purified and seed is increased for the yield trials in the following spring.

The breeding programme is outlined in figure 1. In phase I, in spring, progeny tests evaluate the polycross progenies of populations B, R and the hybrid, while specific A x R crosses can be evaluated on a smaller scale. The emphasis in testing is on evaluation under diverse conditions ; climates, soils, times of planting and populations. Analysis of the data in the manner described by Finlay and Wilkinson (1963) permits the identification of the genotypes exhibiting high and stable production over sites, and hence adaptability.

During phase I selected families are grown in a crossing block under conditions as normal as possible (Downes, 1972) so that phenological expression is typical. Within both populations full and half sib crosses are made in families. Pollen from individual identified plants in B families is used to produce counterpart A lines. All plants used in crosses are identified so that value of crosses can be determined by oil analysis of seeds. A proportion of the crosses is discarded in view of results of concurrent progeny tests. The remainder proceed to the autumn programme.

In the autumm, phase II of the programme also consists of two parts. On the one hand, B lines are polycrossed in isolation and R and A lines are grown together to produce respectively, polycrosses in the R population and inter-population hybrids on the A lines, to produce seed for progeny testing the following spring. At the same time the full and half sib families of both the B and R populations are further selected by within-family crosses and the conversion of B lines to the cytoplasmic male sterile form continues. It is also possible at this time to make controlled crosses between elite A and R lines for preliminary evaluation of hybrids on a limited scale.

Fig. 1—**Outline of a breeding programme to produce population hybrids in sunflowers**



The populations contain all available sources of mildew resistance, verticillium and rust resistance and variation in maturity, yield, and oil content. If moderate rather than high selection differentials are applied with high and stable oil production being the selection goal, further recombination can be obtained and the selection base will not be narrowed. Populations can be exposed to cold soil conditions, frosts, diseases and drought conditions to select the most desirable plants. There is sufficient variability included that resistance to new diseases and pests may well be available. If not, there is a support programme to convert wild races and species into a useful agronomic background and this population possibly provides a reserve source of resistance to new problems, different levels of oil quality, and hopefully, new sources of cytoplasmic male sterility and restoration.

It is not desirable to force the breeding populations rapidly into standard morphological and phenological patterns. The breeding programme is conducted concurrently with various complementary agronomic and physiological studies and findings can be accommodated in breeding programmes more readily if adequate variation remains. But so that new varieties can be produced quickly, sub-programmes can be generated to extract the most desirable combinations from time to time. The evaluation of full sibs in both the B and R families and specific A x R hybrids will indicate the possibilities continually.

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