MORPHOLOGICAL AND PHYSIOLOGICAL BASES FOR THE BREEDING OF SUNFLOWER IDEOTYPES

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VARIETIES

Sunflowers are, today, the second most important oil crop in the world. This situation is the result, certainly, of economic requirements, but also, and perhaps more especially, of progress made during the last twenty years in the genetics, breeding and agronomy of this species. I shall not discuss here the important role which the Russian high oil varieties first played in the world-wide development of the crop. I shall not consider either the fundamental importance and the consequences of the more recent discovery of male sterilities which have enabled the production of hybrid cultivars. Sunflower breeders know of these results. However, they know also that maintenance and extension of sunflower production in the world depend on the progress which can be made in the field of genetics and varieties.

The variety is of great strategic importance. It can, by itself, resolve simply and economically many complex problems such as adaptation to environments, techniques and utilizers requirements. It must also respond, as far as possible, to the socio-economic canstraints of the moment, for the breeder is not independent of the pressures of Society. Thus, the energy crisis, pollution and nature conservation, man's nutrition and health, are leading at present to breeding and genetical research which will provide more and more biological answers, in varieties, to numerous technical and economic questions. For example a resistance gene could replace a pesticide, and drought tolerance could make unnecessary irrigation techniques, using increasingly rare and costly water. The variety can thus provoke general technical progress and contribute to better economic efficiency of a species.

PERFECTION — THE IDEOTYPE

This is why the breeder often thinks of a type of sunflower with greater productivity than any known cultivar, with very regular yields in time and space, with a vegetative cycle which is adjusted to the environment and to the rotation system, with a satisfactory capacity to utilize the factors of this environment, with high resistance to the main local diseases and sufficient tolerance to predator attack, with highly fertile florets and with seeds of constant quality, well adapted to market requirements. This sunflower would give the farmer a satisfactory revenue with great security and easy production for a moderate cost. Is this the ideal plant, perfection ? Is this the ideotype ? Is it a dream ? Perhaps. It is, in any case, a goal to be attained, o model and a guide, which can be discussed and continually perfected and which must be adapted to the constraints of each of the physical and human environments in which it would be exploited.

PRESENT CULTIVARS

It is well known that no present sunflower cultivar unites, in all environments, all these qualities. Yields in particular are, as a result, still low and very irregular, especially in regions with hot, dry summers. One can question whether the present types of plant, already very different from primitive forms and which result from an ancient choice, no doubt intuitive and empirical, are adapted to modern agricultural conditions.

These plants can be grown quite easily. However, they are often difficult to establish : the have a weak root system and a shoot system which may be too vigorous and susceptible to lodging and to various diseases. These plants can withstand drought periods, but the size of their organs and their productivity are reduced as a result. They take up very large quantities of water when it is abundent and satisfies maximal real evapotranspiration. However, they utilize this water poorly, for dry matter and seed production do not increase in proportion to the quantity of water taken up. Flowering generally occurs in unfavourable hot, dry conditions. The capitulum is susceptible to diseases, is the quarry of birds and often looses its seeds. Finally the fertility of the florets is frequently insufficient.

Physiology teaches us that the sunflower is a C_3 plant, with strong photorespiration and weak apparent photosynthesis. In addition, this photosynthesis appears to decrease at temperatures above 20°C, whereas, at the same time, respiration continues to increase. Also in present types a reduction in transpiration is accompanied by a reduction in photosynthesis. The leaves have weak stomatic resistance and are extremely permeable to gases ; they have thus a strong aptitude for transpiration. Inspite of a moderate leaf area index, water losses can be very large and very rapid. When coupled with reduced photosynthesis, this leads to a poor efficiency of the water taken up. In dry conditions, leaf area, stomatal opening, transpiration and photosynthesis are reduced. The ratio net photosynthesis/transpiration (which corresponds approximately to total dry matter/water taken up) and the ratio seed/water taken up are thus rather low. It appears, in addition, that the translocation of assimilates is popor and that they are immobilised in the stem. Finally the radio seed/total dry matter (harvest index) is low.

One may therefore consider that present sunflower types, modeled by recent breeding but resulting from an ancient choice, are not yet highly evolved. What choice should one make today ? Along what lines should research and breeding be orientated to obtain new types, closer to the ideal and with morphologies and physiologies which will permit improved performances and better security of cultivated varieties ?

A number of possible lines of research will be quickly and simply outlined. They take into account particularly the work of my colleagues of the Institut National de la Recherche Agronomique : Leclercq, Piquemal and Vear for breeding, Rapilly and colleagues for pathology, Blanchet and his team for agronomy.

LINES OF RESEARCH

Research for a new type of plant, adjusted to the environment and to agro-technical requirements could have, especially in Europe, the following main themes, which are not considered by order of their importance.

1. **The vegetative cycle** with as objectives :

— a relatively short cycle, insensitive to photoperiod, permitting a wide range of uses in any rotation system ;

— a cycle which can begin early in the spring, after an early sowing, so that flowering occurs before the summer drought. The genotype must thus be resistant to cold, in order to emerge and grow rapidly at low temperatures ;

— a short emergence-flowering phase ;

— a long flowering period, obtained by a long flowering-maturity phase or, perhaps, by a new architecture involving for example, several capitula on one stem.

2. **The morphology** with as objectives :

— a strong, deep, agressive root system, capable of exploiting the water and mineral reserves of the soil offering weak resistance to water transit ;

— a not excessive shoot system with short stems, of the semi-dwarf, or perhaps dwarf type, not lodging, with a reasonable leaf area but covering the ground well, and with a disposition of folliage permitting good use of light energy ;

— a flat, thin, vertical capitulum, without persistance of the senescent florets in order to limit disease development.

3. **The physiology** with as main goals :

— improved net photosynthesis, especially at high temperatures, but with reduced or at least stable transpiration ;

— improved resistance of the leaves to gas diffusion, with selection for morphology, orientation and tissue anatomy which limit water loss through the stomate and outside but which do not reduce photosynthesis ;

— iproved sink/source ratio favorising photosynthesis, obtained, perhaps, by a leaf area and orientation to be determined, and the presence of braching and several capitula ;

— photosynthesis accompanied by active translocation of assimilates to the seeds ;

— regular fructification of all the flowers, obtained by high autocompatibility of the pollen.

Research for a harmonious relation of vegetative and reproductive organs and improvement of the functioning of these organs should increase the ratios : net photosynthesis/transpiration and seed/water taken up, which indicate the water efficiency, and, lastly the seed/total dry matter ratio.

4. **Diseases**

This is a very important problem in sunflowers. In many cases, it has not been resolved by the ideal solution of genetic resistance as with the example for downy mildew.

We could consider that a vegetative cycle such as the susceptible stages of the plant occur outside the periods favourable for disease development ; that a morphology and anatomy of the stem and the capitulum as were suggested earlier ; that knowledge and utilization of certain biochemical reactions at the cellular level, particularly in the capitulum, would all, no doubt, favorise better tolerance to the main pathogens *Botrytis cinerea, Sclerotinia sclerotiorum* and *Macrophomina phaseoli.*

5. **Oil and seedcake quality**

This important aspect of suflower production is not independent of the biology of the whole plant in its crop environment. The role and the importance of environmental, agrotechnical, morphological and physiological factors in the elaboration of the necessary qualities need to be determined.

CONCLUSIONS

It would be difficult, if not impossible, to attain the perfection that one can imagine. The chances are extremely small that breeding could give the ideal genotype, corresponding exactly to an ideotype constructed «a priori», and definitively perfect in time and space.

Productivity first of all, depends on a large number of genetic factors which are difficult to control. In addition, the characters of a plant are not independent ; frequently there is incompatibility between some of the desired qualities. Further, these qualities are not always simply controlled : several genes may be involved and certain may be on the same chromosome. Finally, the physiological functions are generally under complex genetic control. These functions are strongly influenced by the environment and their level of heritability is thus reduced and the efficiency of selection weakened. Thus one must keep a sense of realities. Nevertheless, one must also have the courage to undertake research for the ideal, for the impossible synthesis of all perfections.

This research will have stages, successive compromises. An improved variety will, no doubt, show increased aptitudes, but it will still have faults. At first one must accept these faults, but then try to eliminate them by another compromise, another still more improved variety, perhaps using original methods : mutagenesis, interspecific crosses... It is a long and difficult research programme which must closely associate genetics and whole plant biology. The variability of the species must by explored and the role of numerous morphological and physiological factors determining yield must be determined.

This research is of great scientific, technical and economic interest, the results of which should help to satisfy man's needs and promote general progress. However, this research requires the utilization of all the scientific resources available and permanent cooperation between scientists of all diciplines and all countries.