HOW SHOULD BREEDING SYSTEMS BE REVISED SO AS TO DEVELOP VARIETIES WITH MAXIMUM GRAIN YIELDS?

Norman E. Borlaug

It is my contention that progress in the development of higher yielding wheat varieties is being slowed primarily by the extreme conservatism of most wheat breeders.

Most wheat breeders have become slaves to their own narrowly based gene pools. They have, with but few exceptions, shortsightedly organized their programs in such a way that they have given undue emphasis to the following two aspects of varietal improvement, at the expense of yield:

1. Improvement in disease and insect resistance.
2. Maintaining status quo (good or acceptable) or slight improvement in milling and baking quality, while improvements are being made in disease and insect resistance.

Perhaps somewhere between 70 to 80 percent of the entire wheat breeding effort in the U. S. A. and Canada in the past 30 years has been devoted primarily to developing new varieties with better resistance to diseases (especially to the rusts and smuts) and to insects (Hessian fly and sawfly). As new races of rust, for example, have appeared rendering a formerly acceptable commercial variety, such as Thatcher, susceptible, new sources of resistance have been found and crossed into it. Subsequently,

Thatcher is used as the recurrent parent in a long backcross program so as to assure that both the phenotype of Thatcher and its milling and baking quality is recovered in the progeny. Unfortunately this system, which is advantageous and almost foolproof from both a plant pathology and cereal chemistry point of view, is disastrous from the standpoint of improvement in both grain yield and agronomic type.

Increasing Grain Yield

One of the first lessons which we learn in genetics is that maximum levels of heterosis are obtained when we cross genetically distinct parents. This principle we promptly ignore in our breeding programs in self-pollinated plants. It has been our experience that wheat crosses that give high yielding F_1 progeny are also likely to produce high yielding lines in advanced generations that will exceed the grain yield of either parent.

It is our contention that a crossing program designed to increase grain yield in wheat should involve:

1. Crossing of unlike outstanding parental types within the spring wheat groups (that is, between the best commercial variety in one zone of operation and the best varieties from aggressive spring wheat breeding programs in other parts of the world).
2. Crossing unlike outstanding parental types - within the winter wheat group from the world's best winter wheat breeding programs.
3. Crossing outstanding parental spring wheat varieties with outstanding parental winter wheat varieties.

In order to enhance the possibilities of finding the correct segregates in such crosses, large F_2 and F_3 populations should be grown. Moreover, it is suggested that one backcross be made, preferably on the F_1 plants, to the commercial variety indigenous to the area where one is working. We are opposed to ever making more than two backcrosses.

In order to maximize variability even further, we frequently make crosses between superior F_1 single crosses. In some cases outstanding well indexed (described) F_2 or F_3 plants are crossed into superior F_1 single crosses. Both of these types of crosses introduce tremendous genetic variability into the breeding program and thus enhance the possibility of isolating lines which surpass the yield of all of the parents, if properly screened.

Breeding for the Simultaneous Improvements in Grain Yield, Improved Agronomic Type, Disease Resistance and Quality

We have found that if proper screening tests are used it is sometimes possible to simultaneously make improvements in

1. grain yield,
2. agronomic type (straw shortness and strength),
3. breadth of adaptation,
4. disease resistance,
5. milling and baking quality,
6. insensitivity to length of day.

The Use of the International Spring Wheat Yield Nursery to Select Parents for Increasing Grain Yield

In recent years it has become increasingly clear that certain spring wheat varieties have outstanding yielding ability under a wide range of climatic, soil, moisture, and disease conditions. The data from the Third International Spring Wheat Yield Nursery is summarized in a preliminary manner in the attached tables. From these data it is clear that some varieties such as: 1) Pitic 62, 2) Lerma Rojo 64, 3) Penjamo 62, 4) Nainari 60, Crespo 63, Huelquen, and Triple Dirk, are high yielding at many locations, both when grown on fertilized and non-fertilized soil, and under irrigated and non-irrigated conditions.

Several of the newer high yielding Mexican varieties, i.e. 8156 (from Penjamo "S" x Gabo 55); INIA 66 and Noroeste (both derived from Sonora 64A x Lerma Rojo 64A); CIANO (from Pitic - Chris x Sonora 64); Tobari 66 (from Sonora 64A x Tezanos Pintos Precoz); and Jaral 66 [from Sonora 64 x (Tezanos Pintos Precoz x Nainari)], were derived from crosses involving the aforementioned high yielding parents. All of the latter are distinct improvements in industrial quality and disease resistance and agronomic type over the former group.

I maintain we all remain too conservative in our breeding methods. Our advancements in increasing grain yields via genetics on a per annum basis is less than the annual world population growth. Most of the current increases in yield that the U. S. farmer is exploiting - to stay in business