Breeding Better Alfalfa

by H. M. TYSDAL

THE BACTERIAL wilt disease of alfalfa forcefully brought to the attention of alfalfa growers the need for improved, disease-resistant varieties of alfalfa. This serious disease, first identified in 1925, is caused by the bacterium Corynebacterium insidiosum. It can be classed with winterkilling and drought as among the most serious enemies of alfalfa. Although it was first noticed in the river valleys of Nebraska and Kansas and in some of the Corn Belt States, it is now found in every major alfalfa-producing State. It kills out stands in 2 to 3 years, and even before killing greatly reduces yields.

The Department of Agriculture and several State agricultural experiment stations undertook the problem of combating bacterial wilt by whatever method seemed feasible. Various control methods were tried, including rotation of crops, soil amendments, and breeding for disease resistance. The trials indicated that the selection of resistant varieties was the only practical method of solving the problem. Because domestic varieties were not resistant, the Department sent explorers over much of the world searching for wilt-resistant alfalfas. Through the efforts of H. L. Westover, resistant strains were found in Turkistan.

By intercrossing, plant breeders combined the resistance in the Turkistan varieties with desired characters of domestic strains. Within the past few years two new varieties have been produced and increased that are resistant to bacterial wilt. They have been named Ranger and Buffalo. In areas where bacterial wilt is present, they maintain a good stand after 3 or 4 or more years, while the old varieties, such as Grimm or Common, have been completely killed.

Ranger, produced by Department plant breeders in cooperation with the Nebraska Agricultural Experiment Station, originates from selec-
tion within Turkistan, Cossack, and Ladak. In regions where bacterial wilt is not a factor, Ranger is about equal to Grimm in productivity of forage and seed and cold resistance. One disadvantage, particularly in the Eastern States, is that Ranger is slightly more susceptible to leaf-spot diseases and leafhopper yellowing than Grimm or Hardigan. Ranger, however, is recommended for the northern regions of the United States wherever bacterial wilt is serious. It was released for commercial production in 1940, and now several thousand acres are producing seed.

Buffalo, produced by plant breeders of the Department and the Kansas Agricultural Experiment Station, originates from selections made from an old Kansas Common field. Buffalo compares favorably with Kansas Common in yield and adaptation. It surpasses Kansas Common in resistance to the bacterial wilt disease. Buffalo, like Kansas Common, is best adapted in the general latitude of Kansas, and south and east from that State, but its range of adaptation probably will be farther north than that of Kansas Common because of its greater cold resistance. It is recommended for use anywhere within this range where bacterial wilt is a problem.

Ranger and Buffalo have been tested by many experiment stations. At the Iowa station, for example, Buffalo produced 3.60 and Ranger 3.55 tons to the acre in their third year of production. In the same replicated test, the better standard varieties, such as Grimm and Baltic, produced only 2.5 and 1.5 tons an acre, respectively. Similar results were had in Idaho, Ohio, Minnesota, and elsewhere—in fact, wherever the bacterial wilt disease is present. In areas where the disease is unimportant, Ranger and Buffalo yield about the same as an ordinary variety.

Strains resistant to bacterial wilt are not the only new alfalfas introduced to alfalfa growers during the war years. Two other newcomers were released for commercial production: Atlantic, produced by plant breeders of the New Jersey Agricultural Experiment Station; and Nemastan, an introduction from Turkistan.

Atlantic is a vigorous-growing, high-yielding variety and is adapted to the Eastern States. It originates from selections within many varieties, including Hardigan, Grimm, and Baltic. Although it does not withstand the bacterial wilt disease, it is somewhat more tolerant of that disease than standard varieties such as Hardigan or Grimm.

Nemastan, one of the many introductions brought in by Mr. Westover, has been found by research men in the Utah and Nevada Agricultural Experiment Stations and the Department to resist stem nematode. Efforts were started to increase its seed stocks for use in localities in Nevada and Utah and neighboring States where the stem nematode is a serious limiting factor. It is also resistant to the bacterial wilt disease. Nemastan is not recommended for use anywhere in the Eastern States, however, because of its susceptibility to leaf spots. Progress is being made in improving its
seed and forage yield and its resistance to other diseases. It is now serving an extremely useful purpose in areas where alfalfa cannot be grown because of the stem nematode.

Plant breeders can use ordinary selection methods to produce good strains of improved alfalfa, but the best strains with maximum improvement can be produced only by making use of hybrid vigor.

**Using Hybrid Vigor**

In corn, hybrid vigor is obtained in first-generation crosses by detasseling one of the parents to prevent any self-pollination from occurring. In alfalfa it is not practical to prevent self-pollination artificially. About 15 percent of the alfalfa plants, however, are self-sterile. In these self-sterile plants, pollen from a given plant will not fertilize flowers on the same plant but may be fully fertile on another plant. Hence it is possible to obtain practically 100-percent crossing by planting two such plants in an isolated block. The pollen of each plant readily fertilizes the flowers of the other plant, but not its own.

One might raise the question that two such plants would not produce enough seed for a very large hay acreage. Here is where another characteristic of alfalfa comes into use. Alfalfa can be very readily propagated by vegetative cuttings, much in the manner of making geranium slips; a single desirable plant can be increased to any number of plants. Because alfalfa is a perennial, moreover, these plants will live many years and frequent replantings will not be necessary.

Plants selected for hybrid-seed production must be relatively self-sterile. They must also be resistant to diseases, cold, and insect pests. They must combine well with each other. This combining ability is a rather abstract thing. The plant breeder cannot say by looking at a plant whether it will combine well (or "nick" well, as livestock breeders say) with another plant or not. Combining ability depends upon how the genes, or inheritance carriers, of one plant complement those in the other plant. The only way to determine this point definitely is to make the cross. However, a procedure called the polycross method has been developed that helps to pick out the best combiners just as the top-cross in corn helps corn breeders choose the best inbred lines in corn.

In the polycross method, stocks used in the polycross nursery are highly selected, desirable plants. They are selected either from the better varieties of nursery-bred alfalfa or from old fields that have had natural elimination. Highly self-fertile, or autogamous, plants are not selected, because self-fertilization reduces progeny yields. It is not necessary to use selfed lines, as corn breeders do. The plant breeder chooses self-sterile plants and they are propagated vegetatively. These plants are subjected to various diseases to test their resistance. Those that resist
diseases and, as far as possible, insect pests, and have the other desirable characteristics are selected. They are increased vegetatively and planted in the clonal polycross nursery. In this nursery each clone (that is, each vegetatively propagated plant) is pollinated by natural methods. Pollen from the same clone or other clones in the nursery is carried to the flowers by insects. Because these plants are relatively self-sterile, it has been found that most of the seed so produced is out-crossed. Thus the seed from one clone or female parent derives its pollen or male parentage from many different clones. The progenies resulting from seed produced in this manner are known as polycrosses.

Tests comparing the combining ability of clones by the polycross method with the performance of the same clones in single crosses, or with their performance in a top cross, have shown that the polycross performance gives a reliable indication of their combining ability. It is much easier and cheaper to produce the polycross seed than to make all possible single crosses or to use a separate isolation block for each top-cross. By vegetative propagation, the original plants can be increased as much as is necessary to produce enough seed for thorough testing under various conditions in different parts of the country. The Eastern States depend largely upon the West and Midwest for their seed supply. It is, therefore, of prime importance to select plants whose progenies are adapted to relatively wide regional areas.

Besides showing the combining ability of clones, the polycross method makes it possible to obtain new superior combinations by natural crosses between selected clones in the polycross nursery. The term cumulative improvement is used to designate this phase of the program. In cumulative improvement it has been found that second-cycle material (that is, plants selected from the polycross progenies) is often better than the original parents. It should be remembered, however, that in cumulative improvement, precautions should be taken to prevent the basic stocks from becoming inter-related. This can be done by separating the various types in different polycross nurseries. It is also advisable to introduce new, unrelated selections into the program as often as possible.

When seed from the clonal polycross nursery is thoroughly tested, the original clones that show the best polycross performance in disease resistance, yield, etc., are increased vegetatively and paired in all combinations to produce single crosses. Single crosses are made by planting the two relatively self-sterile clones in alternate rows in an isolated field where they can be naturally pollinated without being contaminated with pollen from other sources. Very little alfalfa seed is produced without the tripping of the flowers by pollinating insects. During this process the pollen is carried by the insects from one clone to another. Thus, with relatively self-sterile clones, usually over 95 percent crossing is obtained.

The possibility of commercial production of hybrid alfalfa was first
proposed in November 1941. Since then a number of experimental hybrids have been produced in natural field crossing blocks. These have been tested in both forage and seed yield studies in comparison with the best standard varieties. In a 2-year test conducted at the Nebraska Agricultural Experiment Station, the better hybrids and polycrosses yielded from 4.16 to 4.34 tons an acre. In the same test, Grimm yielded 3.43 tons of cured hay to the acre. The hybrids showed a superiority of from 20 to 27 percent over Grimm. In a seed production test at the Utah Agricultural Experiment Station some of the hybrids yielded 660 pounds of seed to the acre, while Grimm produced 450 pounds an acre.

As I have said, many of these hybrids are resistant to bacterial wilt. Some also show resistance to attacks by the potato leaf hopper (*Empoasca fabae*). It has been found that alfalfa subjected to leaf hopper attacks (alfalfa yellows) is greatly reduced in carotene content. Carotene content is directly related to the vitamin A value of alfalfa hay. Tests under leaf hopper infestation have shown that more resistant hybrids have twice as much carotene (and thus vitamin A) as standard varieties. There is promise of producing hybrids more resistant to the leaf spot diseases. This would be important from the standpoint of increased quality of forage because the leaves of alfalfa contain approximately 66 percent of the protein and 75 percent of the carotene content of the plant. Leaf diseases destroy the leaves, and cause great losses in feeding value. Besides the usual hay types, the possibility of producing rhizomatous hybrids for grazing, for hay, and for erosion control is promising.

It may be possible to produce a double-cross hybrid alfalfa by planting seed of two high-combining single crosses in alternate rows for natural crossing. In that case the result would not be a 100-percent first-generation, or F1, cross because of some pollination within each single cross. Nevertheless, by using two single crosses that would produce an exceptionally good hybrid between them, the resulting progenies would prove high yielding and certainly much better than present standard varieties. As a matter of fact, yield tests have shown that as much as 25-percent selfed seed planted with the hybrid reduces the yield of the mixture very little below that of the pure hybrid. No doubt this is because in any field planting there are a large number of young plants that die from competition with more vigorous plants. In that event, the strong hybrids would crowd out the plants from selfed seed. In addition to the production of hybrid alfalfa in the above manner, the possible use of male sterility (sterile pollen) should be investigated as a means of producing hybrid alfalfa.

The same procedure outlined for the selection of high-combining clones for use in producing hybrids would be used for the development of superior synthetic varieties. A synthetic variety may be defined as a variety that is developed by crossing, compositing, or planting together two or
more unrelated strains or clones, the bulk seed being harvested and replanted in successive generations. By natural intercrossing the unrelated strains or clones are "synthesized" into a new variety. A synthetic variety can be increased through successive seed generations so long as the desired characteristics of the variety are retained. Some synthetic combinations have been tested in a preliminary way and have demonstrated their superiority over standard varieties. Thus if hybrids do not show a sufficient superiority to merit the extra labor involved, the same clones can be utilized in the production of synthetic varieties. The original clones would be maintained or increased vegetatively to form a source of pure foundation seed. The optimum number of clones to be used to produce a synthetic variety is being investigated.

Field tests have shown clearly that hybrid alfalfa has a definite place in alfalfa improvement. For the production of either hybrid or superior synthetic alalfas one of the essential features is the use of foundation materials that have high-combining value and therefore maximum hybrid vigor. This must be taken into consideration if maximum improvement in alfalfa is to be obtained.

The production of hybrid and synthetic alalfas is still in the experimental stages, but their utilization promises more certain production of higher quality forage and pasture. Since legumes might well be the keystone of a permanent and profitable agriculture, improved varieties of alfalfa, an important legume crop, would be of tremendous value for the needed expansion in acreage, for protection against soil erosion, and for furthering the livestock industries at lower production costs.

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