The Process of Breeding New Alfalfa Cultivars[1]

Alfalfa breeding is a relatively new area of plant improvement. Its development can be traced through a series of significant events: (1) Plant Introductions-'Spanish' types in mid 1800's, winter-hardy types in 1858 - 1910; moderately winter-hardy types in 1898 - 1910; Flemish types in 1947; (2) Prior to 1925 - identification and selection of winter-hardy cultivars; (3) 1925 to 1955-development of cultivars combining winterhardiness with resistance to bacterial wilt; (4) 1955 to present-development of multiple-pest resistance in cultivars varying in winterhardiness. The "boom" period in alfalfa improvement started in the mid 1950's. Prior to 1955, 33 recognized cultivars were available in the U.S. and Canada. By 1975, the number of cultivars increased to 160, and today the number of cultivars developed and/or offered for sale in the U.S. may be as high as 600! Obviously, alfalfa breeding is a productive and dynamic area of science. A lot of this productivity can be attributed to the development of the private seed industry since the mid 1950's. In 1956, only 20% of the new cultivars were developed by private industry but in 1993, all 48 new cultivars were from the private sector. Less than 20% of the certified cultivars now available originated from public agencies. Competition in the seed industry has resulted in more and better cultivars for producers to choose from but has also changed the public programs from applied to basic research. The public programs have contributed to progress in recent years by identifying new production problems, developing testing procedures and germplasm sources. Emphasis on forage quality and increased yield has also originated in public programs. However, these accomplishments do not involve the total program of alfalfa improvement. The science of plant breeding can still be taught in the classroom and laboratory but the art, the philosophy and the organization of a plant breeding program can only be learned by participating in a total program which goes from germplasm development, cultivar synthesis, seed production, testing to certification. The most serious question at the present time is--Where are we going to get the next generation of alfalfa breeders?

Before the processes of alfalfa improvement can be described, "alfalfa" itself must be defined. Alfalfa is a cross pollinated, polyploid, perennial grown primarily for a vegetative product. This means that alfalfa is a heterozygous, continually segregating population in which every plant is genetically different. Polyploidy further complicates the picture by providing more than two homologous chromosomes and, subsequently more than two genes at a loci. Alfalfa is a vast reservoir of genetic diversity but is very resistant to giving it up. The perennial nature of alfalfa slows down the process as plants must be evaluated over time. The vegetative product slows progress as compared to crops in which the seed is the primary economic product. Vegetative traits simply do not change to the same degree as seed traits.

To further complicate the issue, an alfalfa cultivar needs to be defined. An alfalfa cultivar is a random, interbreeding population of plants with a characteristic frequency of

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traits. It is not a uniform population. In fact, performance, in many instances, depends on diversity or nonuniformity.

The process of alfalfa breeding starts with the identification of geographic (adaptive) areas that are to be served and the types of germplasm that are to be used. This is usually accomplished by correlations of cultivar (germplasm) performance with climatic areas and soil types. The third step is the determination of levels and types of pest resistance required in order to produce a superior or competitive cultivar. It is essential that these factors are well defined otherwise the program loses direction and becomes wasteful of time, money and manpower. Find Something That Does Not Need To Be Done and Then Don't Do It! Start the program with the best germplasm available!

Alfalfa breeding is basically a cyclic system in which successively improved populations are developed by intermating selected plants until the desired levels of performance are attained. Extreme care must be taken to maintain an effective population size to avoid inbreeding and prevent random changes in traits not subjected to selection. Genetic diversity also is important to prevent inbreeding and to prevent progress limitations.

Germplasm is usually incorporated into a breeding program through (1) field selection nurseries, (2) selections from pest resistance and dormancy tests, and (3) strain crossing. Selections are then placed into a mating system determined by objectives, progress desired and time or money constraints. The mating systems usually used includes: (1) Phenotypic Recurrent Selection within a population, (2) Phenotypic Recurrent Selection in an open system, or (3) Genotypic Recurrent Selection. Phenotypic selection is normally used for the simple traits and genotypic selection for the more complex traits.

Multiple objectives require a lot of decision making as to the order of selection and selection intensities. The process starts with a knowledge of the germplasm being utilized and how the various objectives fit into the breeding procedure selected. Do you concentrate on the rarest traits and risk inbreeding and genetic drift for other traits or do you select for the more frequent traits and then concentrate on the rare traits? This becomes a major part of the Art of Plant Breeding.

When the desired levels of pest resistance and fall dormancy are attained, the more time consuming and expensive field yield tests are conducted. The Variety Review Board requires a minimum of 6 location years with at least 2 locations. Most breeders would prefer 3-5 locations with 3 years of data from each location. Stand persistency data are usually taken after the third harvest year.

Cultivar synthesis is most often through population seed increases in which the seed of the experimental population is planted in isolation and the resulting seed harvested in bulk. True synthetics are formulated by intercrossing highly selected individual plants (4 to 50) in a random fashion will equal quantities of seed from each parent bulked to form the Synthetic 1 generation. Strain crossing is also an effective system of varietal synthesis that results in an average performance level between two or more parents but may alleviate inbreeding and increase yield in some cases. With narrow based material, it is also important to evaluate

generations equivalent to Foundation and Certified seed classes as performance may be reduced in these advanced generations.

Based on the accumulation of data on pest resistance, fall dormancy, forage yield and persistency, the breeder makes a decision on which entries should be considered for release and certification. In public agencies, these data are reviewed by Varietal Release Committees and final decisions are made. Similar groups are usually present in most private agencies. The breeder then designates the generations to be used as breeder seed and is usually responsible for production of this seed for the life of the variety. A seed increase organization i.e. Crop Improvement Association or its equivalent group with a private agency, is then responsible for seed increase through Foundation and Certified Seed, processing and distribution.

The National Alfalfa Variety Review Board is a committee representing all groups involved in the alfalfa breeding process. Its function is to review data submitted by the developing agency to determine if the cultivar is accurately described. The Review Board requires data on germplasm origin, breeding procedure, methods of seed increase, fall dormancy, forage yield, persistency and at least 6 pests. If approved by the Review Board, a cultivar is eligible for certification.

A look back at the process shows the following time table:

Year 1 -	Define objectives and select germplasm for improvement
Year 2 to 8 -	Selection of plants to fit objectives, intercrossing and repeated cycles, until desired levels of performance are attained.
Year 9 to 11 -	Field Testing
Year 12 to 14 -	Seed Increase

What has this expenditure of time, money and manpower accomplished? A look at some benchmark cultivars is self explanatory:

1	1942	Ranger, winter-hardy with resistance to bacterial wilt
		Buffalo, moderately winter-hardy with resistance to bacterial wilt
2.	1953 -	Vernal, very winter-hardy with resistance to bacterial wilt.
3	1954 -	Lahontan, semidormant with resistance to stem nematode, bacterial wilt and spotted alfalfa aphid.
4	1957 -	Moapa and Zia, nondormant and semidormant with resistance to spotted alfalfa aphid, bacterial wilt and Fusarium wilt.

Now - Over 50 new cultivars each year in 9 fall dormancy categories with resistance to up to 12 different pests.

This not only allows producers to select cultivars to specifically fit their needs but also is a heavy contributor to environmental protection, sustainable agriculture, and minimum input agriculture.