HOW ALFALFA VARIETIES ARE DEVELOPED

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ABSTRACT

A variety, also called a cultivar by the breeders, is a group of plants distinct for specific traits which remain uniform for these traits through generations of multiplication. Therefore, in alfalfa cultivar development, breeders simply try and increase or add those traits (genes) which enhance the value of the final cultivar. The trend in breeding alfalfa has been to develop synthetic cultivars for improved multiple pest resistance and proper fall dormancy. This has been very successful during the past 2 decades with the current Alfalfa Council's List now recording 276 cultivars into 9 dormancy groups for up to 12 pest resistance ratings. More recently, breeders are introducing more complex traits such as grazing tolerance, high nutritive quality, and salt tolerance into these multiple pest, dormancy specific cultivars. The next step for alfalfa breeders will be transgenics or the addition of genes via genetic engineering.

Key Words: alfalfa, breeding, cultivar, genetics, synthetics, transgenics, variety.

INTRODUCTION

You say variety and I say cultivar! In most situations, the two terms are interchangeable. To agronomists and breeders, however, there is this distinction: variety is the old botantical term which was applied to material collected in nature and directly propagated for man's use, while cultivar is the more modern term meaning "cultivated variety" and refers to material directly developed by breeders using modern genetic princples. For the remainder of this paper, I will use the term cultivar.

By definition, a cultivar is a group of plants distinct for specific traits which remain uniform for these traits through generations of multiplication. In its purest form, a cultivar is the package or vessel contains a collection of favorable genes and a minimum number of unfavorable genes. Therefore, in cultivar development, plant breeders simply try and increase or add those genes which increase the value of the package or vessel. Breeders manipulate genes and alfalfa breeders are no exception!

HISTORY OF ALFALFA CULTIVAR DEVELOPMENT

The history in alfalfa cultivar development has been to introduce alfalfa germplasm from other parts of the world and then develop improved varieties of them once they are in widespread use by producers. When first introduced, the initial material was simply called 'Common'. From these commons, "breakthrough" varieties were developed which helped defined the positive benefits of important traits such as bacterial wilt and even defined the next generation of improved varieties. The first breakthrough varieties were developed by public breeders employed by State Experiment Stations or the USDA and included 'Buffalo', 'Vernal', 'Ranger', 'Moapa', 'CUF 101', etc. That these

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same varieties are still recognized by producers and that some are still used today in our cultivar performance trials as checks demonstrates how successful they were.

Cultivar development in alfalfa took a dramatic change in the early 1970s with the passage of the Plant Variety Protection Act (PVP). This gave a level of legal protection for cultivars in the marketplace. Due to this protection, there was a great increase in the number private breeding programs and in the total number of cultivars released. Today, nearly all alfalfa cultivars are developed and marketed by private breeding companies and the total number of cultivars are truly staggering - nearly 276 cultivars on the 1998/99 Alfalfa Council's List!

The trend in breeding the more recent cultivars of alfalfa has been for improved multiple pest resistance and proper fall dormancy. Since insects and diseases are numerous in alfalfa, development of a cultivar with the proper fall dormancy and a broad genetic base for resistance to many pests is felt to give more persistence and higher yield. One has only to consult performance trials in their respective state or region to see that most of the new, multiple-pest resistant cultivars currently on the market are outperforming the old public checks (sometimes as much a 30 to 40% in yield).

In the seed industry, alfalfa cultivars are also grouped into different types based on their fall dormancy. Fall dormancy means the ability to cease growth in the fall of the year and protect itself for the upcoming winter weather. This is an important trait where winters are severe. Conversely, nondormant types will continue some growth during the winter (winter active growth), so they have to be planted where the climate is warm and the winters not quite as severe. Therefore, the current Alfalfa Council's List records the 276 varieties into 9 dormancy groups and for up to 12 pest resistance ratings.

There has been a movement lately to introduce more complex (from a genetic point of view) traits into these multiple pest, dormancy specific cultivars. Cultivars with traits such as grazing tolerance, high nutritive quality, and salt tolerance are now marketed.

THE CULTIVAR DEVELOPMENT PROCESS

In its most simplistic form, the alfalfa cultivar development process can be outlined as five distinct steps: 1) establishment of objectives and goals, 2) collection and development of parents, 3) selection and breeding to develop elite lines and experimental cultivars, 4) testing to identify the best elite lines and experimental cultivars, and 5) release, dissemination, and commercialization of the best cultivars. Steps 2 and 3 are probably considered the essence of plant breeding and are the most identifiable steps to other agricultural scientists and farmers alike. Although in many ways the most creative steps in the process, these steps are simply the breeder asking the questions do I have enough natural genetic variation for the trait or traits and can I enhance this variation into an acceptable germplasm? It is actually step 4 which requires the most resources in terms of time, labor, supplies, and money. Finally, these steps are very time consuming and can take the breeder up to 12 years to complete them for each cultivar.

Step 1. Establishment of objectives and goals

It is surprising how many breeders approach their work without clearly defined goals and objectives.

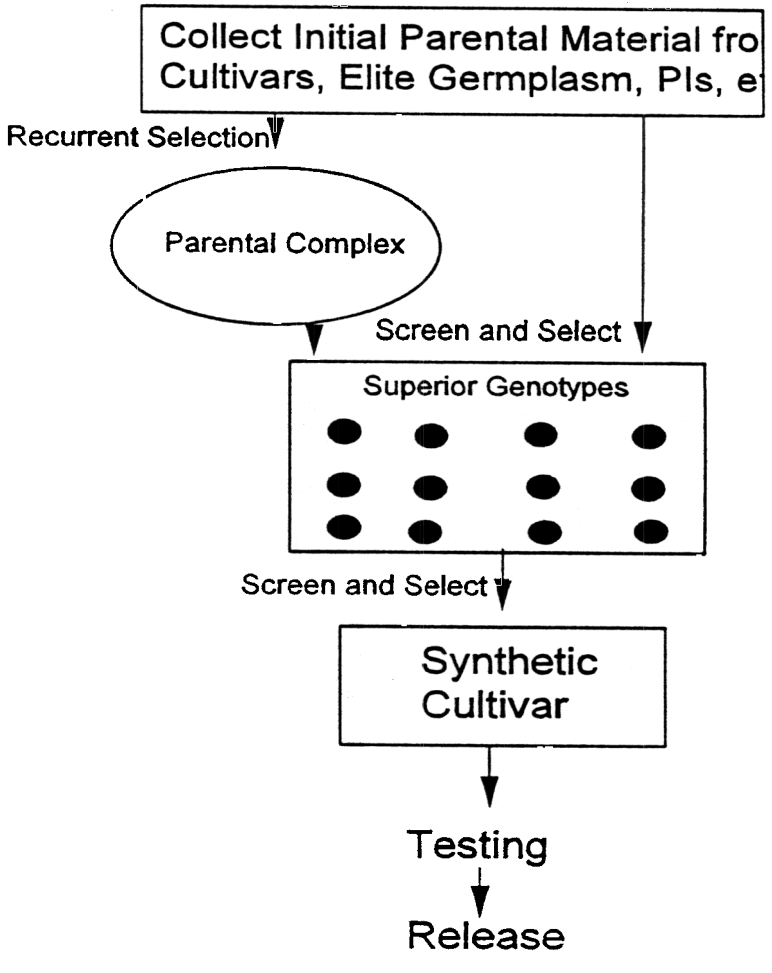
Their goals should be formulated based on sound principles of alfalfa management and utilization, knowlege of the species' the morphology, physiology, and genetics, and forage economics. As mentioned previously, alfalfa breeding for the past 20 years has concentrated on producing cultivars in all fall dormancy groups which contain as high a level of resistance as possible for a minimum of 6 different disease or insect pests and this will not change in the immediate future. However, selection for newer value added complex traits (grazing tolerance, high nutritive value, salt tolerance, etc.) and even introgression of transgenes (herbicide resistance) via genetic engineering seems to be the objectives of the future.

Step 2. Collection and development of parents

This is one of the most important decisions in the breeding program because the end product will only be as good as the parents which originally went into process. Two keys for success: One must have clear ideas of what traits which need to be changed and one must have variation and diversity for these traits.

The best sources of parental germplasm are currently used and successful commercial cultivars, elite breeding lines breeding, lines from other breeders, plant introductions from government germplasm collection and curation agencies (in the USA, the National Plant Germplasm System), and related species and subspecies (Figure 1). These can be obtained by several means from buying (commercial cultivars) to gifts from other breeders and government agencies (freely available elite germplasms and plant introductions) to actually collecting the material yourself (ecotypes, land races, etc. in this country as well as other countries).

Figure 1. Development of synthetic cultivars in alfalfa.



The approach used by most alfalfa breeders has been to use commercially successfully or elite material as much as possible. This then allows one to capitalize on all the good agronomic traits already in this material. If not possible in elite material, then most breeders progress to plant introductions and related subspecies and species, but are aware that you

will probably introgress several unacceptable traits when this material is used. A good example of this has been the recent introduction of potato leaf hopper resistance via glandular hairs into cultivated alfalfa from the related subspecies (*spp. glutinosa* and *spp. glandulosa*). The original material was weak and not acceptable from an agronomic point of view but did possess the glandular hairs from the subspecies which were felt to be responsible from a insect deterrence point of view. Several years of breeding and reselection were necessary to develop this material into the acceptable cultivars on the market today.

Finally, if the trait is not present in your parental material, you may have to create it with somaclonal variation or mutation breeding or possibly find the genes in other organisms and use transformation technologies to incorporate them into your material. When the transformation approach is taken, the value of the crop must be very high in order to justify the expenditure of required resources.

Step 3. Selection and breeding to develop elite lines and experimental cultivars
A breeder must be able to identify the trait of interest within the parental germplasm and then select plants containing the trait. To do this, one must have a good method of identifying plants containing the trait. Therefore, one must have a good screening procedure to do this (Figure 1).

Good screening procedures have the following characteristics: 1) The procedure must measure a real trait; there needs to be a direct relationship between the trait for which you are screening and the trait the farmer or grower is interested in. Example: yield - one can simply measure yield in large farmer type blocks or research plots with equipment similar to the farmers equipment or measure a trait that directly effects yield like photosynthesis on leaves in the greenhouse (e.g. must have good relationship between leaf photosynthesis and yield). 2) The procedure must be reliable and repeatable and one MUST have good checks or controls as part of the protocol. 3) The procedure must be rapid and cost effective. 4) The procedure must be capable of handling large numbers of entries.

After the best plants are identified through screening, they will need to be composited into an experimental cultivar. Nearly all alfalfa cultivars are synthetic cultivars, so the approach taken is to identify using the screening procedures the individual plants (e.g. genotypes) which contain the genes of interest (see Figure 1). These genotypes are viewed as parents and are then composited via replicated random mating (allowing all possible of crosses with all possible parents) in isolation into the first generation synthetic seed (syn 1). After its final release (see step 5 below), each further generation (Syn2, Syn 3, Syn 4, etc.) of seed increase of the synthetic is then done in isolation and random mating is assumed. It is up to the breeder to then decide which generation will be breeders, foundation, or certified.

Step 4. Testing to identify the best elite lines and experimental cultivars
After the best material is composited into an experimental synthetic cultivar, it is important these experimentals are tested in the field in order to support the claims to be made for the cultivar and to determine its overall worth to the producer (Figure 1). One must use the best available cultivars as checks and account for the influence of environment. Determining environmental effects usually means testing over as many years and locations as possible but especially over the environments contained in the potential marketing area of the cultivar. This testing over locations and years is why

this step consumes so many resources in terms of money, time, labor, etc.

When testing, the breeder should use appropriate and acceptable procedures of field plot testing as determined by scientists working in the management of the crop. This is another reason why knowledge of the basic principles of forage management and utilization is so important to the forage breeder. Specific things to be considered include: 1) knowledge of the site to be used including soil heterogeneity, slope and drainage, and previous cultural practices, 2) need to use fertilizers, weed control, grazing systems, and other cultural practices which are normally used by the farmer, 3) when testing in small plots one should use proper experimental designs and should eliminate border effects wherever possible, and 4) data collection and analyses need to be done in line with proper statistical methods.

Step 5. Release, dissemination, and commercialization of the best cultivars
If one or more of the experimental synthetic cultivars shows promise during testing, it can be released for commercialization (Figure 1). During release, the breeder gets involved in a series of events which can best be summarized as "Paperwork! Paperwork! And More Paperwork!". However, this final result is what most breeders have been striving for so the paperwork is usually a labor of love.

This paperwork includes (but is not limited to) the following: 1) a release document which includes all data and supporting information for presentation to the decision makers within your organization to justify the actual release; 2) an application for Plant Variety Rights or other forms of patenting; 3) applications for certification including applications to have the cultivar placed on a countries' "Approved List"; 4) scientific and popular articles describing the cultivar and its best management practices.

THE FUTURE

The future for alfalfa cultivar development will surely be in the area transgenics or the addition of genes via genetic engineering. Transgenics involve the movement of specific and useful genes even between two unrelated organisms and has been referred to as genetic engineering. It was previously has great promise and has already shown success in making crop plants resistant to insects, viruses, and herbicides. In fact, at this symposium there will be a paper presented by Mark McCaslin on "The Implications of Roundup Resistance in Alfalfa". Therefore, with the introduction of genes for resistance to the herbicide Roundup, alfalfa cultivar development, like major row crops such as corn, cotton, and soybeans, is now becoming a sophisticated undertaking involving high investment, but with the potential to bring producers new high value cultivars.