BREEDING ALFALFA FOR TOMORROW

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Alfalfa is a low income crop planted over large acreages. Unlike high income crops such as lettuce or cotton, growers cannot afford to spend large amounts of money to treat alfalfa for control of plant pests. Other ways had to be found to control plant pests as economically as possible. Developing resistant varieties seemed the best way to do this.

Because alfalfa is a low income crop, it, like wheat, barley, and other forage crops, is often planted in the poorer, more marginal agricultural areas. This results in new problems such as impermeable soils, high soil salinity, or a fluctuating water table. New alfalfa varieties must be developed which will be adapted to adverse conditions as well as be resistant to diseases and insects.

In this report I will try to cover most of the important alfalfa problems we see today and see for the near future. In doing this it seems appropriate to mention some of the progress made in the past as well as the work in progress. This report will cover work conducted by many groups or individuals both public and private. However, examples will be drawn largely from University of California work because it is more familiar and it eliminates any possible reporting problems.

Insect Resistance

Considerable progress has been made in the biological control of insects through the development of resistant varieties. A new nondormant variety (Moapa) with resistance to the spotted alfalfa aphid (SAA) (*Therioaphis maculata*) was developed about three years after the pest was found in the United States. Since then, more than 30 varieties have been developed with resistance to this insect. All varieties of alfalfa grown in Southwestern United States must have resistance to the SAA. In addition, since many unadapted alfalfa varieties are grown in California for seed production, these varieties should also have some resistance to this aphid. Good germplasm and breeding methods are available making breeding varieties with resistance to the SAA almost routine in many programs.

One year after Moapa was released aphid types called biotypes were found which were capable of attacking some of the parent plants of Moapa and weakening its SAA resistance. Later, additional virulent biotypes of the spotted alfalfa aphid were found which further weakened the resistance of Moapa and other varieties. Alfalfa varieties with resistance to these new biotypes had to be found.

At present the SAA is still considered a very important insect pest. Aphid populations are being monitored for new biotypes. Resistance is being incorporated into additional variety types and strengthened in other materials. Where new biotypes are important, resistance to them is being developed.

The pea aphid (*Acyrthosiphon pisum*) was a pest of alfalfa long before the SAA was introduced into the United States. However, the first varieties resistant to the pea aphid were not released until 1966. Development of these varieties was made possible by using techniques learned from resistance work with the SAA. Efforts to place pea aphid resistance into alfalfa varieties is continuing, but the work is often given a low priority because other, more important pests are given preference.

The blue alfalfa aphid (BAA) (*Acyrthosiphon kondoi*) is a new pest of alflafa in Southwestern United States. Since identified in California in

1975 it has been found in large areas in the mid and southwestern parts of the United States. In addition, it has also been found in New Zealand, Australia, and Argentina. Damage has been heavy in many areas where it has been found, but it is still a new insect and too early to know if it will be an important pest of alfalfa over the wide areas where it has been found.

Breeding methods used for the SAA and pea aphid have been used to develop varieties resistant to the BAA. Good resistance has been found, and considerable effort is being placed in developing varieties with BAA resistance for areas where it has been an important pest.

The alfalfa weevil (Hypera postica) and the Egyptian alfalfa weevil (H. brunnepennis), unlike the aphids, are chewing insects and have been very important insects in most areas where they are found. Work has been conducted for more than ten years on developing varieties with resistance to these two insects. Varieties with resistance to the alfalfa weevil have been developed and released. Experimental varieties with resistance to the Egyptian alfalfa weevil have been developed. However, resistance in these materials has been low and variable. Support to continue this work on weevil resistance has been variable and poor, but the work has been continuing at several diverse locations at relatively low levels. The development of high levels of resistance to these two weevils seems distant. However, I feel this is very important work because once the techniques and breeding methods can be worked out for the weevil, we will be able to make advancements in breeding for resistance to many of the other chewing insects.

Varieties of alfalfa have been released with resistance to the meadow spittlebug (Philaeuus spumarium) which is not found in the Southwest and to the potato leafhopper (Empoasca fabae) which can be important at times in the low desert valley areas. However, the variety with resistance to the potato leafhopper is dormant and not adapted to the desert Southwest. Essentially no resistance work is being done on these insects in the West.

Of the 14 important insects attacking alfalfa in Southwestern United States, resistance has been reported for eight. Varieties have been released which are resistant to three. Little work is now being done on 11 of these insects. This is unfortunate because plant resistance is the best and, I believe, highest form of biological control. Once it has been incorporated into a variety, the resistance will protect the variety when the insect attacks. This protection against insect attacks is purchased with the seed, and it has proven to be relatively inexpensive when available.

Root Rot Diseases

Root rots seem to be the most important diseases in the Southwest. This may be because almost all alfalfa is irrigated sometime during the year and, when sufficient water is available, there is a tendency to overirrigate. This overirrigation plus occasional unexpected rainfall can create severe root rot problems.

There are three main root rots important in the West: Phytophthora root rot (Phytophthora megasperma), flooding injury commonly called scald, and Rhizoctonia root canker (Rhizoctonia solani). Of these three problems Phytophthora root rot seems to be the most important. Good sources of resistance and breeding techniques have been found for this disease. Varieties with resistance to Phytophthora root rot have been developed and released in most areas of the country including the low desert valley areas. Plant breeders are now in the process of strengthening this resistance in their materials. Varieties with increasingly better resistance to this disease can be expected.

Scald is a very important disease in the low desert valley areas because its action is much more rapid and severe during hot summers. However, this same disease is commonly found in other areas, but it is usually much slower in developing because the air temperatures are generally cooler. This disease is never called scald or associated with the disease known as scald in the low desert valley areas. Instead, it is referred to as "drowning out" or "killed from standing water." Treatment (less water, better land leveling, and improved drainage) is the same in the cooler areas as in the low desert valley areas. No good breeding methods have been developed to artifically develop resistance to this disease. Some varieties used in the low desert valley areas have been labeled as moderately resistant to scald, but our tests are imprecise. Rigid, side by side comparisons are unavailable. More work on development of breeding techniques and identification of germplasm is needed.

Rhizoctonia crown rot and root canker are often thought of as being two diseases caused by the same organism. The crown rot phase is widely distributed through the United States and, as the name implies, attacks primarily the crown of the plant. Rhizoctonia root canker, on the other hand, is found primarily in the low desert valley areas of the Southwest. It develops during the hot summer months and is aggravated by excessive soil moisture. This disease seems important in eliminating large portions of a stand and also in gradually thinning stands. No good breeding techniques are available for selection for the root canker phase, but limited screening procedures are available for the crown rotting phase. Germplasm with only relatively low levels of resistance is available. More work is needed on this destructive disease.

Leaf and Stem Diseases

Leaf and stem diseases tend to be of limited importance in the Southwest because there is usually little rainfall during the producing seasons. Many of these leaf and stem diseases can be problems, however, during the winter and spring periods when rainfall is expected. Generally, the coastal areas where there is more rainfall and higher humidities will have more problems with leaf and stem diseases. Problems with these diseases will be least in the low desert valley areas.

Downy mildew (*Peronospora trifoliorum*) is one of the most common, widely distributed leaf diseases. Symptoms are large, circular light-colored spots on the leaves. It also has a systemic phase which distorts the plants and results in light green leaves. These leaves may later turn grey in color as spores form. This disease can be found in most Southwestern areas sometime through the year. Light infestations may have limited economic value. Good selection procedures are available for this disease and considerable improvement can be made with a single cycle of selection. Most varieties have some resistance to this disease. Resistance is being upgraded in successive releases of most varieties.

Southern anthracnose (*Collectotrichum trifolii*) and common leaf spot (*Pseudopeziza medicaginis*) are also important diseases in California. Their areas of distribution overlap but, generally, common leaf spot is more important in the cooler, Northern areas whereas anthracnose appears to have a greater importance in the South, including the desert areas. Germplasm with good resistance and good breeding techniques are available for both diseases. Considerable work is being done to get resistance to anthracnose into many variety types. This effort is succeeding. Released varieties with this resistance should be available soon. Varieties with varying levels of resistance to common leafspot are available. Higher levels of resistance to this disease are needed in Central California but priorities for developing this resistance have been low.

Stemphylium leaf spot (*Stemphylium botryosum*) and Stagnospora crown root rot, and leaf spot (*Stagonospora meliloti*) are two diseases which appear important. Research on these problems is relatively new and little information is available. However, more information and, hopefully, resistant varieties should be available sometime in the future, perhaps seven to 10 years.

Wilt Diseases

Bacterial wilt (Corynelbacterium insidiosum) is one of the first diseases for which resistant varieties have been developed. It is an important disease in most of the United States, but at present it seems to be of secondary importance in Southwestern United States, especially in the low desert valley areas. Good sources of resistance and breeding methods are available. Varieties with resistance are available for Central and Northern California and the higher elevations in Arizona and Nevada. Very limited or no resistance is available in the highly nondormant varieties grown in the low desert valley areas. Efforts are underway to develop nondormant varieties with high resistance. If nondormant varieties were available with wilt resistance, seed exports to countries with bacterial wilt problems such as Argentina and Australia might be easier.

Fusarium wilt (Fusarium oxysporum) is a disease with a variable reputation. It has usually been considered a minor disease in California but thought to be a more important disease of alfalfa in neighboring states. Some breeding and selection methods as well as resistant germplasm are available. The best resistance to the disease is found in highly nondormant varieties where no planned selection procedures were used. Only very limited planned selection for resistance to this disease is being conducted at present.

Dwarf, Mosaic and Witches' Broom

Three diseases of relatively unknown or minor importance in the Southwest are alfalfa dwarf, alfalfa mosaic, and witches' broom. Alfalfa dwarf was an important disease at one time in California. A resistant variety, California Common 49, was developed in 1949. The disease seemed to decrease in importance after that and does not appear to be a problem at the present time.

Alfalfa mosaic and witches' broom can be seen almost every year under the correct conditions. The importance of these diseases on stand depletion or stand decline is unknown. Limited breeding procedures and little germplasm with any type of resistance are available. Priorities for work on these diseases may remain low.

Smog

Areas near large cities such as Los Angeles, Phoenix, Bakersfield, and San Diego frequently have problems with smog. The economic importance on alfalfa in most areas can be debated because data are usually available from only the Los Angeles area in Western United States. However, it is likely that smog may intensify and spread in the future. In addition, it may be necessary to develop varieties with high resistance and test them with present varieties before smog damage can be assessed.

We have been cooperating with Drs. W. H. Isom and C. R. Thompson to obtain resistant plants for development of a resistant variety. Plants have been selected primarily from Isom Polycross, a variety previously selected for vigor and appearance in the western end of the Los Angeles basin. Other material was also used to obtain some selections. Three germplasm pools have been selected. They will be tested under smog conditions as soon as possible.

Soil Salinity

Alfalfa is naturally adapted to soils which are neutral to basic in pH. It will grow well in soils which have low to moderate levels of soil salinity. However, many soils in Southwestern United States where alfalfa is grown contain relatively high levels of salinity. In addition, since alfalfa is a low income crop, it is often grown on marginal land while the high income crops are produced on the best land. Obtaining resistance in the seedling stage or, more importantly, through the life of the stand would widen the adaptation and increase the productivity of alfalfa in the West.

Interest in breeding crop varieties with resistance to increased levels of soil salinity is high in most crop plants. Alfalfa is no exception. In cooperation with Dr. F. E. Robinson, Department of Land, Air, and Water Resources, University of California, Davis, we are conducting work in three areas: laboratory seedling experiments, greenhouse studies, and field selections.

Laboratory experiments were conducted to study the effect of two levels of salinity and three temperatures on four alfalfa varieties. Selections were saved from certain varieties and used as material to develop resistant germplasm. The data from these experiments are being analyzed, and it is too early to provide any results. However, one selection (UC 124) made for resistance to soil salinity using laboratory and greenhouse tests was included in the experiments. It appeared to react positively to salt concentrations in these tests, but it is too early to know if this is due to resistance to salinity or some factor increasing vigor.

A second series of experiments was conducted on potted plants in the greenhouse. The objective of this study was to observe several alfalfa characteristics on two or three varieties irrigated with three levels of salinity. In this work we were trying to identify characteristics which might be used in identifying plants with resistance to salinity. This data which included one experiment with UC 124 has not been analyzed. The greenhouse was also used to apply EC = 15 mmho/cm irrigation water to plants originating from salinity selections made in the seedling stage of growth. Survivors from this treatment were used as parents of a new synthetic variety.

The third type of work with soil salinity involved the field approach to selecting for resistance to salinity. One field in which we are working had soil salinities of approximately EC = 7, EC = 8, and EC = 9 mmho/cm, respectively, in the first, second, and third foot of soil. The area was planted to a breeding mixture of alfalfa seed in the fall of 1975. The stands thinned severely from 1975 to 1978 due to natural selection for many characteristics, one of which might have been high soil salinity. Seed was harvested in the fall of 1978 and called UC 150. This material will be tested for reaction to salinity and other factors. Plant selections were also made in very saline fields located near Blythe, California. These plants were combined into a synthetic which will be tested. Second cycles of selection for resistance to salinity will be made in some of the germplasm.

Nondormancy

Alfalfa growers in the low desert valley areas as well as growers in other areas with special situations like green-chopped alfalfa are interested in obtaining as much forage as possible through the entire year. In addition, there are areas in the world such as the tropics and irrigated desert regions that might purchase more seed if better adapted varieties were available.

We have been observing introductions and germplasm in the breeding program for increased nondormancy. One group of introductions we have tested is from the Arabian Peninsula. This material seems to have rapid recovery after cutting and good summer growth. It seems this material when crossed with elite germplasm from the low desert valley areas might result in unique useable types. However, a disadvantage with this Arabian Peninsula germplasm is that it is highly susceptible to leaf diseases, even in desert regions. In addition, it might also be susceptible to most other common diseases and insects. Because of this, it may require extra time to obtain useable germplasm from these Arabian introductions. Other germplasm with increased winter growth may come from Mexico, Venezuela, and the tropics. We are observing this also.

This past year we found extra tall plants in some germplasm in our breeding program. The tall plants were an average of about 25% taller than neighboring plants in one winter measurement. The tall plants were saved and used as parents of a tall plant synthetic which will be tested during the coming year.

Genetic Vulnerability and Increased Adaptation

Planting crop plants in pure stands of very closely related material makes excellent conditions for the development of diseases and insects. In addition, the danger is increased when all fields in a particular area are planted to varieties with essentially the same genetic background or varieties that may have obtained a characteristic like aphid resistance from a single parent.

In 1970 southern corn leaf blight damaged a large portion of the nation's corn crop because male sterility in most corn could be traced to a single source of cytoplasm. Since that time, most plant breeders have been trying to broaden the germplasm base used in their breeding programs. Alfalfa breeders have been doing this also but for a longer period of time. In addition to protecting alfalfa from genetic vulnerability, a broad germplasm base also seemed to give slightly better varieties with a broader adaptation and seemingly better pest resistance. Use of broadbased alfalfa varieties were generally accepted by all parts of the alfalfa industry, probably because we were working with a forage crop that was already quite heterogenous.

Alfalfa breeders from private companies have been as responsible as anyone for introducing new germplasm into old variety types. Unlike University employees with narrow geographic responsibilities, for example, the private plant breeder wants his material to be resistant to problems in both the hay and seed producing areas which are often in widely separated geographic locations. He is also constantly traveling over much of the United States and has a greater opportunity to see and select a wide variety of germplasm.

The U. S. Department of Agriculture has a program of mixing a wide range of varieties and variety types into very wide germplasm pools. The main objective of this type of work is to get a large number of characteristics in one seed lot. Theoretically, this seed lot can then be screened when a new, damaging pest is found and the chances of finding resistance there is expected to be good. Of course, these broadbased germplasm pools also contain a range of dormancy types which is obvious when observed under certain conditions. Parts of the University of California have this same type of objective, but the genetic base of the California germplasm pools is usually narrower and new germplasm (usually less than 20%) is often introduced.

According to Barnes et al. (1977), varieties developed prior to 1930 were primarily from a single source of germplasm. Between 1941 and 1960 two to three sources were used. Between 1961 and 1970 varieties often used three or four sources, and since 1971 some varieties have used material from all nine of the germplasm sources they recognized in their publication. It seems we can continue to expect to see more varieties being released with a broad genetic base.

Yield

Yield is one character we are constantly measuring and are continuously improving by various means such as use of resistant varieties, better soil fertility, and improved land leveling. However, all of these improvements are on factors which affect yield and not on yield as a character. Most of the work being done now on yield as a character seems to be in the form of basic studies where activity centers on studies which deal with subjects such as cell components, photosynthesis, and reaction to carbon dioxide. One reason plant breeders have not been working on yield may be because we are making significant progress in improving yield through work in other areas and, therefore, do not receive pressure to improve yield per se. A more important reason may be that there is no time left to do this work after funds and time have been allotted to resistance work and other important problems that must be solved now. My hope is that one of international organizations that has helped with the wheat, rice, and vegetable programs will also set up a forage research center where all aspects of the world's important forages will be studied. A research center of this type could be expected to look at all components of yield and offer predictions or suggestions on where improvements in yield might be most likely to occur and how the problem might be approached. The factors affecting forage yield in alfalfa are much different than those for wheat, rice, cotton, and sorghum because in alfalfa we utilize the vegetative portion of a plant grown in a solid stand.

Quality

Quality, perhpas like yield, is a character we watch and try to do as much as we can in the hay making processes, but genetic research has been largely limited to a few specific characters like saponins. Part of the reason for this may be that most interest has been in emergency-type work like breeding for resistance to the spotted alfalfa aphid, root rots, and the blue alfalfa aphid. In addition, work on quality is expensive and there has been little demand for improving quality by plant breeding. Breeding alfalfa for improved quality is important, but at this time significant increases in this type of work seem unlikely. It may take increased consciousness on the part of the alfalfa user before improvements in quality through plant breeding will occur.

Hybrid Alfalfa

Hybrid alfalfa was an important topic of conversation at most alfalfa meetings about 10 to 20 years ago. The theory seemed very good and worthy of a serious effort. Considerable work was done on searching for methods capable of making some system work. Some hybrids (none in the low desert valley areas) were released but, in general, they have had difficulty competing with the open-pollinated varieties. Work being done on hybrids now seems to have a relatively low priority.

Species of Medicago

Species of *Medicago* might be called the close relatives of alfalfa (*Medicago sativa*). Bur clover (*M. polymorpha*) which is commonly found in winter lawns in the low desert valley areas is one of these relatives. It is a relatively short-lived, small plant of wide distribution. An opposite of this might be tree alfalfa (*M. arborea*) which is a shrub four to six feet tall that may live many years in its relatively narrow area of adaptation near the Mediterranean. Generally, most of the true species of *Medicago* will have difficulty in crossing and this tends to keep them distinct.

To date alfalfa research workers have been unable to cross and effectively utilize germplasm in crosses between the real species in *Medicago*. Efforts have been made to do this in the past. Everytime a new, damaging alfalfa pest is found, the *Medicago* species are tested and a few resistant lines are usually found. However, use of these resistant factors is usually blocked because we are unable to make species crosses. Some work on this subject is generally in progress in the United States or Canada because of its great value, but the amount of work being done is limited. I feel it would be a significant breakthrough if a way could be found to utilize the *Medicago* species. More work is needed on this problem.

The World Collection of Alfalfa Seed

The United States Department of Agriculture maintains a collection of alfalfa varieties, lines, and species at its Regional Plant Introduction Stations. This collection is commonly called the World Collection because the material in it comes from around the world. The Introduction Stations are located at Geneva, New York; Pullman, Washington; Experiment, Georgia; and Ames, Iowa. Most of the seed for the perennial alfalfas is held at Ames. Materials in these collections are grown, classified, and seed is increased. This seed is then available to qualified research workers in the United States.

The World Collection is used by alfalfa breeders to obtain specific characters, broaden the germplasm base with which they are working, and obtain material for special experiments. This has proven to be a very useful program.

With the increased consciousness for endangered species and the environment, this World Collection program seems to have obtained a small amount of additional support. Some facilities are being improved, data is being organized, and future collection trips are being discussed. There are now an estimated 1,500 to 1,600 collections of *Medicago*. This is small compared to the more than 12,000 rice lines in the U.S. World Collection. More work should be done.

Conclusion

Progress in breeding improved alfalfa varieties has been good. Work on developing varieties with resistance to spotted alfalfa aphid is usually used as an example of the progress that can be made in insect resistance. Progress can also be fast. Parent plants of a new variety (CUF 101) with resistance to the blue alfalfa aphid were being planted in a seed block about eight weeks after it was identified as a new plant pest Large quantities of seed of this new variety were available in about 2½ years after the pest was identified.

In disease resistance excellent methods have been developed for mass screening of diseases attacking all parts of the plant. Developments are also being made over a wide range of other problems.

The caliber of the individual research worker in alfalfa breeding programs is high. He knows his subject matter, and I am sure he will continue to try to give the grower varieties which are as good as possible and he will try to do this as soon as possible.

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