As we approach the end of the 20th century, alfalfa improvement is happening at a very rapid pace. New varieties are being released at the rate of more than 30 per year. During the past 30 years, the roles of public and private research have changed significantly. Emphasis in public efforts has changed from variety development to basic research accompanied by an overall reduction in funding. Private industry, which released less than 20% of the new varieties prior to 1960, has released over 95% of the varieties since 1981. Funding of private research has increased dramatically during this period.

HOW FAR HAVE WE COME?

Diseases

Research over the past 20 years has very heavily emphasized multiple pest resistance. Several diseases we were not even aware of on alfalfa 20 years ago have been conquered by breeding efforts. These are Phytophthora root rot, anthracnose and Verticillium wilt. These diseases, in addition to bacterial wilt and Fusarium wilt, would cost U.S. producers over $2 billion a year in lost production if unchecked. That is 25% of the total value of the U.S. alfalfa crop. We don’t know that Verticillium wilt is present in Kentucky, but it has now been found in similar and warmer climates in the U.S.

You have probably heard of Aphanomyces. It is another disease known to seriously affect several alfalfa growing areas. Discovered as a problem in 1983 by Dr. Craig Grau in Wisconsin, breeders are already well on the way toward overcoming it through resistant varieties. Right now there are a half-dozen varieties available with good levels of resistance. We don’t know of its presence in Kentucky because, as far as I know, no survey has been done. Conditions favorable for Phytophthora also favor Aphanomyces.

Insects

In the past 20 years, we have made less progress breeding alfalfas that will withstand insect attack. By breeding, we have conquered the three aphids that can reduce yields, but only one of these, the pea aphid, is a nationwide problem and then only occasionally. We have made little progress in breeding for leafhopper and weevil resistance. Some of the newer varieties do yellow and stunt considerably less than others, but must still be sprayed under many conditions. Control of the alfalfa weevil through breeding has been even more difficult. Very rarely do we see any differences among varieties.
Yield and Persistence

The best newer varieties regularly beat Buffalo and Vernal in state yield trials by 15-25%, often because of a disease problem that eliminates part of the stand in the susceptible varieties. I believe that differences on the farm with good management are often greater than in state trials. Sometimes differences are closer to 100% when a partial stand failure necessitates early replacement. In the absence of specific pest problems, alfalfa yields have not been increased dramatically in the past 20 years.

Persistence is improved because of increased pest resistance.

WHERE ARE WE GOING?

Diseases

The work of the recent past may set the stage to concentrate more on other attributes in the future. However, we do still have a number of known disease problems to concentrate on. Sclerotinia and Rhizoctonia are two important diseases that breeders haven't done much about yet. I believe that through selection, Rhizoctonia resistance will be forthcoming in just a few years, if we give it the attention it deserves. We have already learned a great deal about how to select for resistance.

Sclerotinia is a different matter. Selection for resistance has proven extremely difficult. Progress has been hindered by lack of an effort which combines pathologist and breeder. Nevertheless, some progress is being made on understanding the disease. Dr. Rhodes at Ohio State University and a few others are adding to the current sparse body of knowledge on Sclerotinia. Small, but consistent, differences among varieties have been demonstrated. Biotechnology may also help on this one.

Just as in the past 25 years, when three important diseases that were already present were discovered as problems, observant pathologists will likely uncover others in the next 25 years.

There are at least 6 leaf diseases that we know cause significant yield and quality losses at times. There is a fairly good body of knowledge on these diseases, including methods to select for resistance. If given high priority, resistance to most leaf diseases is possible in the next 25 years.

Caution

Most progress in increasing pest resistance in the past has resulted from cooperation between public and private scientists. If federal and state programs continue to lose alfalfa scientists, progress will be slowed drastically.
Nematodes

We have known for some time that stem nematode and root knot nematode are problems on irrigated alfalfa in the western U.S. plus a few other isolated areas. More recently, several species of root pruning nematodes have been identified as causing stand and yield reductions in several areas of the country including the south, west and midwest. Dr. Don Barnes, USDA-ARS, and others at the University of Minnesota have concentrated on the lesion nematode. They have shown its dramatic effects, developed effective selection techniques and, in 1989, released resistant germplasm. In just a few years, many varieties with resistance will be on the market. It remains to be seen just how widespread lesion and other root pruning nematode problems occur, but many areas will likely benefit from resistant varieties. It appears that on vast acreages of corn where rootworm chemicals are used, nematode numbers are being held down. Any change in practices may result in nematode buildup.

Insects

This is an exciting area where progress will be phenomenal into the next century. Some of the progress will be a direct result of biotechnology, but weevil and leafhopper resistance may come from conventional breeding. The reason is glandular hairs. In a few years, varieties carrying these hairs with sticky glands on the tips will stop weevil larvae in their tracks. The leafhopper will also be controlled in the same manner.

Quality

We are hearing a lot about quality these days. Multileaf varieties are becoming available. At least 5 varieties have been or are being released in 1990. Only one of these has better quality than many newer conventional varieties. In the future, multileaf varieties can truly contribute to improved quality as we gain experience breeding for this trait. If we want greater digestibility and more protein, we may have to sacrifice some forage yield, lodging resistance and seed yield. Alfalfa quality is already high and many producers don’t want or need higher TDN, so higher quality is not the total answer.

Retention of more leaves through resistance to leaf diseases is a very effective way to improve quality. Digestibility of stems can be increased through breeding as it has been shown that a large amount of variability exists for stem quality among alfalfa plants. The current best way to improve quality lies with the producer and his management.

Yield

Small gains in forage yield will continue to be made, mainly as a spinoff of new genes for disease and insect resistance, stress tolerance and other new traits.
STRESS TOLERANCE

In addition to having higher yield, resistance to more pests, increased feed value and better persistence under "normal" conditions, varieties will be available that will perform better under particular stress conditions.

Winter Survival

Many factors can contribute toward maintaining an economic stand during unusually severe winters. The ability of plants to survive cold temperatures can be increased by selection.

More breeders are becoming aware of the need for greater cold tolerance in our varieties. We are also learning more about how to select plants which have more cold tolerance and how to evaluate varieties for cold tolerance.

Another aspect of winter survival is heaving. Under certain conditions, heaving can eliminate or severely weaken stands. Healthy roots which have additional branching are a little less prone to heave out of the ground. As breeders look at roots to evaluate disease reaction, there is the opportunity to select plants with increased branching, thereby gaining on both counts. Don Viands at Cornell University has selected plants with increased ability to regenerate new roots after severing of the taproot. Some of his populations show increased persistence after heaving has occurred.

The very dormant varieties with deep set crowns, rhizomatous roots or creeping roots have better winter survival. They also have lower yields and inadequate pest resistance. Efforts to break the relationship between dormancy and the spreading or creeping habit are still underway and pest resistance of these types of alfalfas is being strengthened.

Drought Tolerance

There is a definite need for varieties which will withstand periods of moisture stress. Parts of the south have droughty periods nearly every year and in the midwest we have just had two very dry growing seasons. Rumbaugh and others at Utah State and Melton and Currier at New Mexico State have been looking at ways to improve moisture stress tolerance of alfalfa. The variety 'Wilson', released from New Mexico, was bred to produce better under limited irrigation. Private industry is also involved in this type of research and is learning from public efforts.

Salinity Tolerance

For a number of years, researchers at Arizona (A. Dobrenz, S. Smith and others) have looked at alfalfa growth under saline conditions. They have selected populations that will germinate and grow under high salt concentrations. Others at Utah State,
Montana and California have also contributed to the present knowledge. Varieties with improved salinity tolerance will likely result if research continues.

**Flood Tolerance**

We have known for some time that varieties differ in their ability to withstand flooded conditions. For example, the old variety 'Narragansett' and varieties selected from it survive better under excess moisture situations in the absence of Phytophthora and Aphanomyces. Some research is continuing in this area.

**Grazing Tolerance**

Joe Bouton at the University of Georgia has led in the development of alfalfas which will withstand continuous grazing. In 1990, a variety will be released from this program. This alfalfa, in addition to tolerating continuous grazing, will yield similar to other varieties when cut for hay. This is a significant achievement and could increase the use of alfalfa in the southeast and possibly other areas as well.

**REDUCED INPUT ALFALFA**

There are several areas where opportunities exist to develop varieties which require less input from the producer.

**Nitrogen**

Research lead by Don Barnes, USDA-ARS at the University of Minnesota, has shown that it is possible to increase the N2-fixation of alfalfa. Their multidisciplinary effort over a 15 year period has produced a great amount of information relating to fixation and assimilation of nitrogen. They developed techniques to select plants that accumulate more nitrogen in the roots and forage. The variety 'Nitro' was released from these efforts. In the future, a range of dormancy types can be released which will fix more nitrogen and lower the requirement of applied nitrogen in the rotation.

**Phosphorus**

Research at New Mexico State and Minnesota has shown that it may be possible to breed varieties with lower phosphorus requirements. Producers would welcome a variety which required less dollars worth of fertilizer to get the same yield.

**Potassium**

Tomato selections have been made that require substantially less potassium. Limited research indicates the real possibility of doing the same with alfalfa. We do know that alfalfa forage on the average contains about six times as much potassium as cows require, so we do have room for selection as far as the animal is
concerned. On the other hand, we know that potassium is a very important element for winter survival of the alfalfa plant. We do not yet know if selection for lower potassium requirement will reduce plant potassium enough to affect winter survival. The savings to most producers would be very substantial if lower potassium requirement alfalfa becomes a reality.

**Lime and Low pH**

There are tens of millions of marginal acres where fertility and pH are not adequate to support alfalfa as we know it today. In the future, the breeder may be able to combine low requirement traits such as low potassium and low pH in varieties that require little or no soil amendments. Work by Elgin, USDA-ARS, Joe Bouton and others shows promise of breeding varieties which will grow productively at low pH. Cooperation with microbiologists will likely be needed in order to select rhizobia for these conditions.

**IMPACT OF BIOTECHNOLOGY**

Although biotechnology has not yet had the impact on the breeding of new traits that was predicted 10 years ago, significant developments are underway. Some of the areas where biotech may be helpful to the alfalfa breeder are:

2. Artificial seeds.
3. Resistance to Sclerotinia, mosaic virus and other diseases where conventional breeding has not been successful and cross protection.
4. Insect resistance.
5. Herbicide tolerance.
6. Increased food value through slower digestibility.

For over 20 years, scientists have sought bloat-safe alfalfa. In the past 10 years, nearly all efforts have been confined to a Canadian team of scientists including a breeder, Dr. Goplen. Millions of dollars have been spent in this team's relentless pursuit of nonbloating alfalfa. The best solution may come with "transformation" whereby a gene for tannin production is physically moved from trefoil or sainfoin to alfalfa.

One company is now field testing alfalfa plants containing a gene from another species for resistance to mosaic virus. Two companies are testing "genetically engineered" alfalfa with resistance to herbicides.

In other crops, the bacteria B.t. (*Bacillus thuringiensis*) has been used for a number of years as a natural bug killer. As we move away from pesticides, largely because of consumer safety concerns, B.t. type pesticides will increase in use. In the
future, rather than applying these naturally occurring bug killers, we will be able to purchase varieties with the B.t. type gene in the plant. This is already being done in other species and will surely be possible in alfalfa.

One of the best ways we can make alfalfa transfer more of its protein to the consuming cow is to slow down its rate of microbial breakdown in the rumen. Dr. Larry Satter, Director of the U.S. Dairy Forage Research Center, and others point out that high quality alfalfa is not as good a protein source as it could be if so much protein was not lost before reaching other parts of the intestines. Transfer of a gene such as one contained in the chicken for albumin may be an answer. Can you imagine growing alfalfa with a chicken gene in it? This and much more is likely to happen in the 21st century.

SUMMARY

There are many ways alfalfa breeding will benefit the producer in the 21st century. Progress will be made in yield, quality, pest resistance, lowered inputs and increasing tolerance to stress. Cooperation is needed between public institutions and the private sector. The decrease in funding of USDA-ARS and state programs is alarming and could defer important developments.