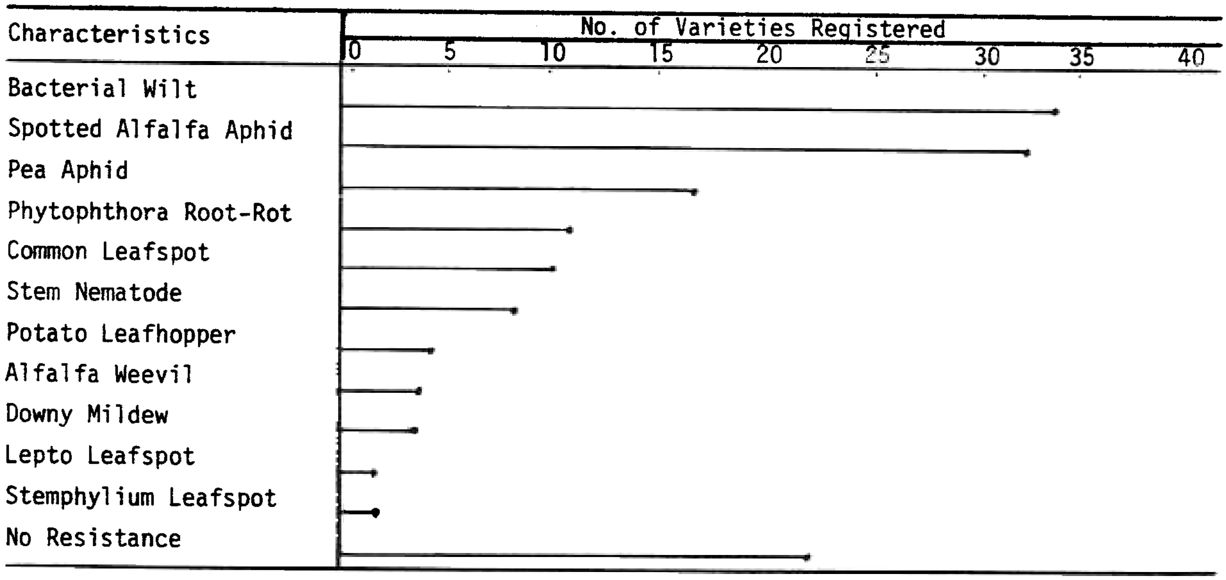
BREEDING OBJECTIVES FOR SEMI-HARDY AND HARDY ALFALFA

O. J. Hunt
Research Agronomist
ARS - Western Region
Reno, Nevada

We have seen a small but significant increase in forage yield of alfalfa every year for the past 20 years. Improved varieties have played a significant role in this increased production of alfalfa.

The development of pest resistant varieties has been the greatest contribution from plant breeding. The alfalfa crop, partly because of its perennial nature, is host to more pest problems than most crops. We recently indicated that there were 21 diseases, 10 insects and 3 nematodes which were major problems on alfalfa (1). It is not surprising, therefore, that most of our breeding advances have been in the area of pest resistance. Few pest problems have ever shown a complete lack of response to selection. We have sufficient basic knowledge on most of the important pests in alfalfa to conduct an efficient and successful breeding program for resistance. However, if we examine the characteristics of the varieties recommended for certification by the Alfalfa Variety Review Board during the past two decades, we find that these resistance principles have not been utilized very readily (Table 1).

Figure 1. Pest resistance characteristics of alfalfa varieties recommended for certification by the National Certified Alfalfa Variety Review Board 1960-1976.



A positive trend to multiple pest resistant varieties, however, is indicated in the descriptions of varieties submitted to the Board during the past 3 years. The average number of pest resistance characteristics described was about 1.5 per variety in 1974, 2.0 in 1975 and 3.0 in 1976.

Variety Development. One of the major reasons for this time lag in releasing varieties with the desired combined pest resistance has been the time consuming nature of the breeding process. Selection response to most pest resistance traits is predictable. A typical response to selection is illustrated in Figures 2 and 3. These figures indicate that only two cycles of recurrent phenotypic selection are necessary to achieve a high level of resistance to these nematodes. If resistance to both nematode species was desired in the same variety, however, the process would take 4 to 5 years.

A very common breeding practice is to select for resistance to a given trait until it is fixed at the desired level before starting on another trait. This is efficient if it is limited to two characteristics, beyond which it becomes very time consuming. Other methods in use employ some type of independent culling or successive elimination where plants selected for one trait are screened for a second trait and so on (2). This has been found to be efficient where selection can be practiced on mature plants. Many of our modern selection techniques, however, are practiced in the seedling stage of the plant. These independent culling or successive elimination methods could not employ seedling selection techniques for traits other than the first one in the sequence.

Figure 2. Five cycles of selection for resistance to stem nematode in Vernal and Lahontan alfalfa at Prosser, WA.

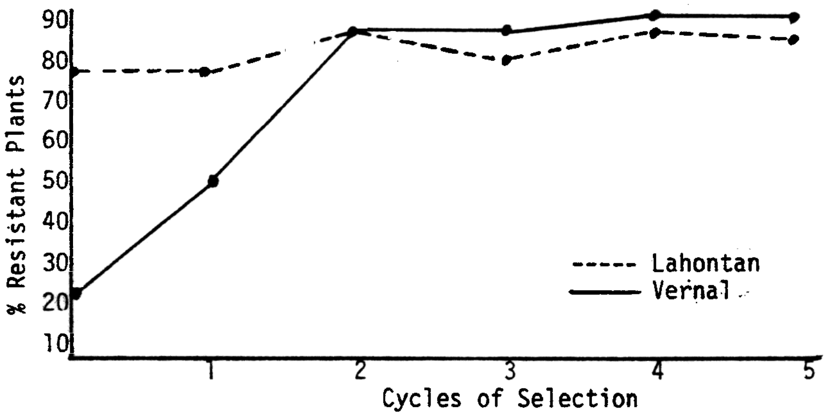
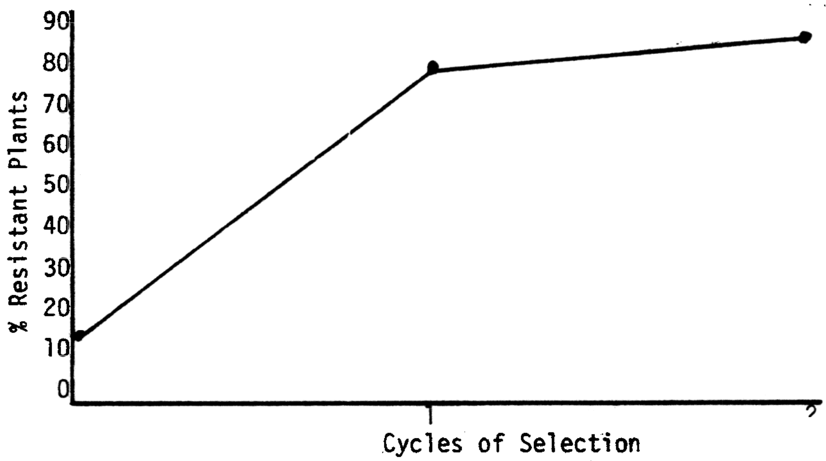


Figure 3. Two cycles of selection for resistance to northern root-knot nematode in a hardy alfalfa population at Reno, NV.



We are researching the idea of complementary strain crosses as a means of increasing the efficiency of variety development. Simply stated this involves crossing two strains or varieties each of which would contribute one or two traits to the resulting strain. Previous research has shown that the resulting strain or variety not only carries the desired resistance traits of each parent, but it also yields somewhat higher than either parent strain (3). Strains of more divergent origin would be expected to exhibit more hybrid vigor than those of similar origin.

The degree to which pest resistance traits are transferred in such crosses is illustrated by results of root-knot nematode resistance breeding experiments at Nevada (4). Vernal and Washoe clones were crossed initially to transfer root-knot resistance to Washoe. In subsequent generations of backcrossing and selfing, selection for the three major traits of Washoe, resistance to stem nematode, pea aphid and spotted alfalfa aphid, was not practiced; however, when advanced generations were tested, phenotypic expression for these traits was as high as in the parent variety, Washoe (Table 1).

Preliminary data (Table 2) from recent complementary strain crosses indicate that a high level of root-knot resistance can be transferred into a new strain in a similar manner. Other resistance traits are behaving similarly. These studies may also provide valuable information on the manipulation of multiple pest resistance in hybrid alfalfa.

Table 1. Maintenance of resistance to pea aphid, spotted alfalfa aphid and stem nematode in two experimental lines developed by backcross breeding Washoe and Vernal alfalfa.

	Pea Aphid	Spotted Alfalfa Aphid		Stem Nematode	Northern Root-Knot Nematode
	%	% Survival		% Resist.	% Resist.
Varieties	Survival	Ent A	Ent F	Plants	Plants
Synthetic WW	71.2	88.4	80.2	60.0	90.0
Synthetic XX	87.2	75.5	68.2	71.0	100.0
Washoe*	65.0	85.3	84.3	65.0	0.0
Caliverde (check)	0.0	0.0	0.0	--	--
Lahontan (check)	--	--	--	75.0	0.0

*Recurrent parent

Table 2. Development of multiple pest resistance by complementary strain crosses, Nevada 1977.

Variety	% Resistant Plants	Resistance Score*
Syn XX (Res. ♂ parent)	100.00	1.00
MSA CW_3 AN_3 (Sus. ♀ parent)	34.47	3.29
NMP-4 Syn 1	93.03	1.23
NMP-4 Syn 2	91.43	1.28
NMP-4 Syn 3	94.00	1.22
Dawson (Sus. check)	3.50	4.50

*1 = no nematode galls; 5 = heavily galled

Pest Resistance Requirements in Hardy and Semi-Hardy Alfalfa. Pest problems in alfalfa are seldom localized. Problems such as Phytophthora root-rot, bacterial wilt, stem nematode, root-knot nematodes and anthracnose can occur wherever alfalfa is grown. Most of the disease, insect and nematode problems can occur in several geographic regions and we see similar emphasis in breeding objectives in widely dispersed breeding programs. The Nevada program is emphasizing resistance to bacterial wilt, Phytophthora root-rot, stem nematode, southern anthracnose, pea aphid and spotted alfalfa aphid.

Foliar diseases have caused serious damage to alfalfa in many areas of the United States. In addition to reducing yield and quality of hay, they can cause a serious problem in general vigor and longevity of alfalfa stands. In colder climates foliar pathogens may be partially responsible for winter killing.

We have just recently begun research on common leafspot and other foliar pathogens. This general classification of diseases has been difficult to transmit and develop in laboratory or greenhouse studies. Field conditions, even in areas where the diseases are a serious problem, are unreliable for resistance screening. We have established a testing and screening site in the Salinas Valley which promises to provide the reliability required for an efficient program. Results of two year's research indicate rapid progress in developing resistance especially to common leafspot.

Yield Potential. The traditional method of breeding for increased forage yield performance in alfalfa has involved some form of progeny testing. These methods seriously limit the selection process to a very small representation of the population. Characters such as yield have a low heritability and require the evaluation of large numbers of plants to significantly increase the mean. In the absence of pest problems, the newer varieties of alfalfa show very little yield advantage.

A number of well organized efforts are now in effect to identify those physiological criteria which can be indicative of yield, to determine their heritability, and to devise techniques for large scale screening of alfalfa to improve those criteria. Yield potential is a complex trait, and it is unlikely that any one of these physiological criteria will individually influence yield potential significantly. Therefore, the benefit from this research will not be realized in the immediate future.

We have initiated research at Nevada to use recurrent phenotypic selection for yield potential in much the same manner that it is used in pest resistance breeding. The technique involves growing plants in a uniform medium and at a day length which will eliminate selection for dormancy. The program also includes selection under various day-night temperatures to determine if varieties can be tailored to specific environmental conditions. Preliminary data in the first cycle of selection for yield potential in one of our high yielding experimental populations indicates a normal distribution of plants with a range from very high yielding plants to a comparable number which are extremely weak and produce very little dry matter.

The program involves the selection of 10% of the population on each end of the yield distribution curve. These are intercrossed to begin a second cycle of selection as well as to evaluate the progress made in the first cycle. Preliminary results indicate that we are making progress in isolating vigor on a single plant basis. The stability of this vigor under normal stand competition remains unknown.

Selection for yield potential using some form of recurrent phenotypic selection procedure may eventually complement our pest resistance programs. A number of breeding programs are using recurrent phenotypic selection for pest resistance in varieties or populations and releasing varieties when the desired level of pest resistance is fixed. The yield advantage of these varieties is derived from pest resistance alone. There could be some significant advantage in selecting for vigor on a single plant basis as the last step before releasing the variety. Our yield potential research is designed to determine the advantage of such a procedure.

Summary. The technology for improvement of resistance to the major pest problems of alfalfa is sufficiently advanced to stimulate a continuous release of pest resistant varieties. New breeding technology to hasten the development of multiple pest resistant varieties is being developed. The first concentrated research efforts to improve yield potential in alfalfa are now underway at several locations.

Research in the genetics and breeding for seed yield potential is urgently needed. New research on old problems such as *Lygus* and chalcid could also be of great economic benefit to the seed industry. The clover root weevil (*Sitona sp.*) is an old problem, but damage to alfalfa by this insect is increasing in several regions of the United States. Host resistance appears to be the only practical control measure. Techniques for host resistance screening will be difficult to develop and will require a coordinated effort by entomologists and plant breeders.

References

1. Barnes, D. K., E. T. Bingham, R. P. Murphy, O. J. Hunt, D. F. Beard, W. H. Skrdla, and L. R. Teuber. 1976. Alfalfa germplasm in the United States: its genetic vulnerability, use, improvement and maintenance. USDA Tech. Bull. 1571.

2 Busbice, T. H., R. R. Hill Jr., and H. L. Carnahan. 1972. Genetics and breeding procedures. Alfalfa Science and Technology. ASA Monograph Series No. 15:283-318.

3. Hanson, C. H., H. O. Graumann, W. R. Kehr, H. L. Carnahan, R. L. Davis, J. W. Dudley, L. J. Elling, C. C. Lowe, Dale Smith, E. L. Sorensen, and C. P. Wilsie. 1964. USDA, ARS, Prod. Res. Rep. No. 83.

4. Hunt, O. J., R. N. Peaden, L. R. Faulkner, G. D. Griffin, and H. J. Jensen. 1969 Development of resistance to root-knot nematode (*Meloidogyne hapla* Chitwood) in alfalfa (*Medicago sativa* L.). Crop Science 9:624-627.