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Comparison of Selection Methods for Autotetraploids. II. Selection for Disease Resistance in Alfalfa[1]

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ABSTRACT

One generation of selection based on selfed progeny test, selfed family, polycross progeny test, polycross family, and indlvidual phenotype was conducted for resistance to *Uromyces striatus* Schroet. var. medicaginis (Pass.) Arth., *Phoma herbarum* West var. *medicaginis* Fckl., and *Stemphylium botryosum* Wallr. in alfalfa (*Medicago sativa* L.). Selected individuals from each method with each pathogen were intermated separately. The resulting populations were compared experimentally to evaluate relative effectiveness of the selection methods.

Each method of selection produced a significant increase in resistance to *U. striatus*. Selfed progeny test and selfed family selection gave similar responses and were the most effective methods. Polycross progeny test and polycross family selection also gave similar responses, but were the least effective methods for *U. striatus* resistance. Response with individual selection was intermediate to responses with selfed and polycross methods. Each of the progeny test and family methods produced similar and significant increases in resistance to *P. herbarum*. Individual selection for resistance to *P. herbarum* was not effective. No method of selection produced a significant increase in resistance to *S. botryosum*.

Additional index words: *Medicago sativa* L., Family selection Mass selection, Progeny test.

A THEORETICAL study (Hill and Haag, 1974) indicated that selfed progeny test and selfed family selection should give equal response and should be among the most effective methods of selection in autotetraploids. Polycross progeny test selection was the next most effective method, and polycross family was the least effective method of selection. Response with full-sib family and individual selection was always intermediate between response with polycross progeny test and polycross family selection.

Theoretical studies alone have limited practical value to plant breeding without experimental evidence to support the theoretical findings. Polycross progeny test and individual selection have been used extensively in alfalfa (*Medicago sativa* L.) breeding. Selfed progeny test selection has been used to a much lesser extent. Family selection has not been used extensively, although Graumann (1952) recommended use of polycross family selection. Most of the comparisons of selection methods in the literature have dealt with parent-offspring correlations and rankings of the parents by different methods of progeny testing. Critical comparisons of the relative effectiveness of different methods of selection seem to be lacking in most crop species (Sprague, 1966).

Foliar disease resistance in alfalfa provides an excellent means of comparing selection methods. Resistance to a number of foliar diseases is needed in many alfalfa cultivars. A wide range of heritabilities can be found in several alfalfa cultivars (Hill and Leath, 1972). Inoculation procedures have been developed that permit evaluation of a large number of plants with relatively little effort. These considerations led to a comparison of several methods of selection for resistance to three foliar pathogens of alfalfa.

MATERIALS AND METHODS

A random sample of 300 plants of 'Beltsville 2-An4' (Devine et al., 1973) was established in pots in the greenhouse during the summer of 1970. Selfed and polycross seeds were produced on each plant by hand pollination. Polycross seeds were produced by intercrossing plants using a bulk sample of pollen from each plant in the population. The 144 plants that produced sufficient selfed and polycross seeds were chosen for further evaluation. Eight plants each of the selfed progenies, polycross progenies, and vegetative propagules of the parents were established during the spring of 1971. The plants were established in standard greenhouse flats, with 12 rows of eight plants in each flat. Each row contained a single progeny type. A bulk sample from seeds of the original population was planted in 12 flats at the same time as the progeny types. The four populations, selfed progenies, polycross progenies, vegetative propagules, and bulk population, were evaluated as if they were four separate experiments. Each population occupied the same amount of space, and required approximately the same amount of labor.

The populations were inoculated with *Phoma herbarum* West var. *medicaginis* Fckl., *Stemphylium botryosum* Wallr., and *Uromyces striatus* Schroet. var. *medicaginis* (Pass.) Arth. during the spring and summer of 1971. Inoculation procedures were the same as those used by Hill and Leath (1972). Plants were inoculated with the pathogens in the order given above. The plants were cut, and residual plant material was removed from the flats with a vacuum cleaner between each inoculation. A visual scale of 1 to 4 based on lesion size, with one representing resistance-type flecks and four representing large fruiting lesions, was used in rating the plants.

A total of 21 populations was formed from plants selected for reaction to each of the three pathogens as follows:

1. All plants in the most resistant six polycross families.
2. All plants in the most resistant six selfed families.
3. The parents of the most resistant six polycross families.
4. The parents of the most resistant six selfed families.
5. The parents of the most resistant 48 polycross families.
6. The parents of the most resistant 48 selfed families.
7. The most resistant 48 individuals from the bulk population.

Each of the selected groups of plants was intercrossed by hand with a bulk sample of pollen from all plants within the group during the fall and winter of 1971-72. Selections for resistance to any one pathogen were made independent of the reaction to the remaining two. Thus, some clones or families were represented in more than one of the selected groups.

The 21 selected populations plus Beltsville 2-An4, 'MSA-C4,' and 'MSB-C4' (Hanson, 1969) were established in greenhouse flats in the spring of 1972. A total of 24 replications was used, each consisting of two flats with 12 rows of eight seedlings per

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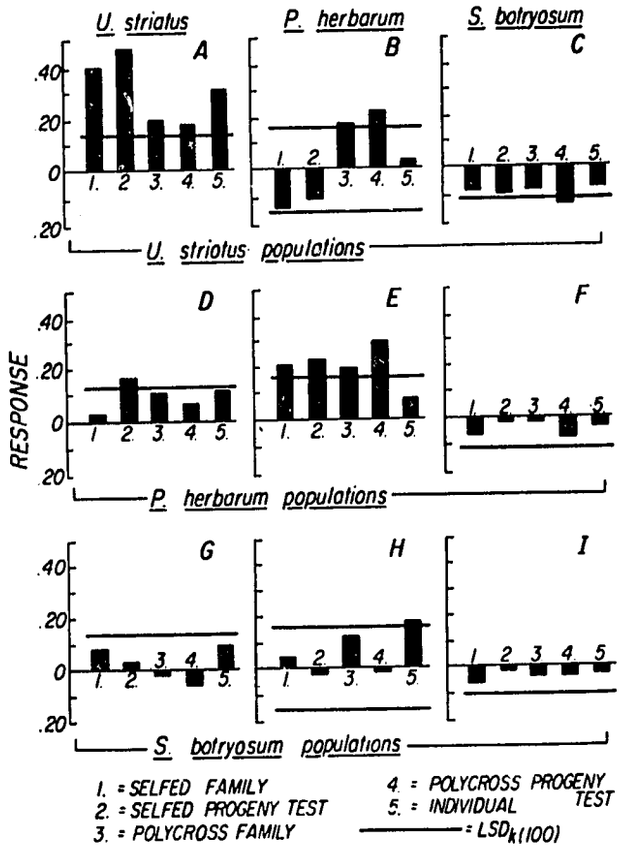

Fig. 1. Response to selection for resistance to the indicated pathogen with various methods of selection. Response is expressed as deviation from the mean of an unselected sample of Beltsville 2-An4 (*U. striatus* = 3.67, *P. herbarum* = 3.47, and *S. botryosum* = 3.78).

flat. Each row in a flat contained a single entry. The same order of inoculation, methods of inoculation, and score scale that were used in the selection phase of the experiment were used in the evaluation of the improved populations.

RESULTS

A significant increase in resistance to *U. striatus* was obtained with each of the selection methods based on six families and with individual selection (Fig. 1A). Selfed progeny test selection was the most effective method, but it was only slightly more effective than selfed family selection. Responses with polycross progeny test and polycross family selection were almost identical, and these were the least effective methods of selection for resistance to *U. striatus*. Response with individual selection was intermediate between that of the selfed and polycross methods. Individual selection was significantly less effective than selfed progeny test selection, but differences between individual and the remaining methods of selection were not significant.

Polycross progeny test and polycross family selection for resistance to *U. striatus* resulted in a significant increase in resistance to *P. herbarum* (Fig. 1B). A decrease in restance to *P. herbarum* accompanied selfed family and selfed progeny test selection for resistance to *U. striatus*, but the differences were not

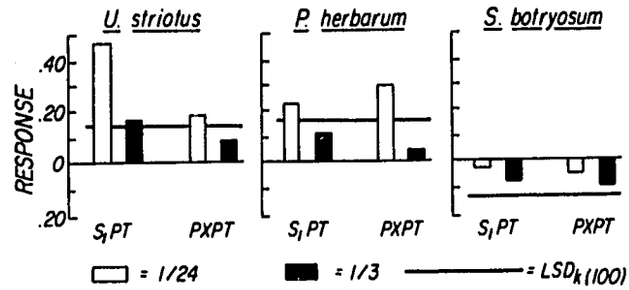

Fig. 2. Effect of the proportion of the population selected with selfed and polycross progeny test selection for resistance to three foliar pathogens of alfalfa.

statistically significant. Almost no change was observed in mean scores for reaction to *P. herbarum* with individual selection for resistance to *U. striatus*.

Selection for resistance to *U. striatus* with each of the methods of selection resulted in a decrease in resistance to *S. botryosum* (Fig. 1C). The only significant decrease in resistance to *S. botryosum* was with polycross progeny test selection, however.

A significant increase in resistance to *P. herbarum* was obtained with each of the selection methods except individual selection (Fig. 1E). Differences among the progeny test and family methods of selection were not significant.

Selfed progeny test selection for resistance to *P. herbarum* resulted in a significant increase in resistance to *U. striatus* (Fig. 1D). Although not significant, resistance to *U. striatus* increased with selection for resistance to *P. herbarum* by each of the other selection methods. Decreases in resistance to *S. botryosum* accompanied selection for resistance to *P.* herbarum with each method, but the differences were not significant (Fig. 1F).

No method gave a significant response to selection for resistance to *S. botryosum* (Fig. 1I). The fact that all responses to selection for resistance to *S. botryosum* were negative indicates that the results are not entirely determined by chance variation. All comparisons in Fig. 1 are expressed as deviations from the mean of Beltsville 2-An4. Sampling variation or some unknown environmental factor may have caused the *S. botryosum* score mean for Beltsville 2-An4 to be lower than the true value. If this were true, the *S. botryosum* results may be interpreted as random deviations from zero, because the mean of Beltsville 2-An4 was lower than it should have been.

A significant increase in resistance to *P. herbarum* accompanied individual selection for resistance to *S. botryosum* (Fig. 1H). The remaining correlated responses in reaction to *P. herbarum* were generally small and not significant. All correlated responses in resistance to *U. striatus* with selection for resistance to *S. botryosum* were small and not significant.

Increasing the proportion of the parents selected with progeny test selection from 1/24 to 1/3 (6 to 48 parents, respectively) drastically reduced the response to selection (Fig. 8). The only significant response with the lax progeny test selection was with selfed progeny test selection for resistance to *U. striatus*.

DISCUSSION

A range of heritabilities was found for reaction to the three pathogens of this study in 'Saranac' alfalfa, which is directly related to Beltsville 2-An4. Heritability for resistance to *U. striatus* was high, and those for resistance to *P. herbarum* and *S. botryosum* were low (Hill and Leath, 1972).

The responses obtained with selection for resistance to *U. striatus* agreed reasonably well with theoretical expectations for a character with relatively high heritability (Hill and Haag, 1974). Selfed progeny test and selfed family selection gave approximately equal response and were the most effective methods; response with individual selection was intermediate; and response with polycross family selection was among the least effective methods. The only disagreement with theoretical expectations was that response with polycross family selection was about the same as that of polycross progeny test selection, not one-half as expected.

On first inspection, response to selection for resistance to *P. herbarum* does not appear to agree with the theoretical expectations for a character with low heritability. Were resistance not recessively inherited and gene frequency low, theory indicates that differences among the family and progeny test methods would be small (Hill and Haag, 1974). Selfed methods should be superior to polycross methods when resistance is recessively inherited. If, in addition, heritability was extremely small, family and progeny test methods of selection would have an advantage over individual selection. Thus, experimental results with selection for resistance to *P. herbarum* do not strongly disagree with theoretical expectations.

Experimental results with selection for resistance to *S. botryosum* indicated that little or no genetic variance was present in the base population, or that our methods of evaluation were subject to extremely large environmental variation. No method of selection resulted in an increase in resistance to *S. botryosum*.

The theoretical results indicated that polycross family selection would seldom be recommended, because it was always the least effective method (Hill and Haag, 1974). Experimental results did not entirely support theoretical findings, however. Theory indicated that polycross family selection should be half as effective as polycross progeny test selection, but response with polycross family selection was never very different from response with polycross progeny test selection. We have no explanation for this discrepancy. Our results indicate, however, that use of polycross family selection should not be discounted by alfalfa breeders, at least until additional information is gathered that supports the theoretical findings.

The comparison of two selection intensities illustrated one of the dilemmas associated with progeny test selection. None of our experimental populations was highly resistant to disease, a result indicating that no method of selection is likely to achieve the desired level of resistance in one generation of selection. If a large enough number of parents is selected with progeny test selection to preserve the genetic variability of the population, response to selection is practically eliminated. Our results indicate that family selection is probably a better method than progeny test selection when heritability is low and where two important criteria are selection response and preservation of genetic variability for yield and other agronomic traits. Progeny test selection may be desirable in the later stages of a breeding program, when preservation of genetic variability is less important.

The results with correlated responses to selection in this study were inconclusive. The only significant negative correlated response was with *S. botryosum*, when polycross progeny test selection was conducted for resistance to *U. striatus*. The correlated responses with progeny test selection were subject to sampling errors, because only six parents were selected with each progeny test method. Most of the correlated responses with family or individual selection were positive or very small, and few of them were significant.

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