South Dakota State University
Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange

Agricultural Experiment Station Technical Bulletins | SDSU Agricultural Experiment Station

1970

Predicting Seed Yield of Alfalfa Clones

M.D. Rumbaugh

W.R. Kehr

J.D. Axtell

L.J. Elling

North Central Regional Research Publication No. 207, June 1971

Predicting Seed Yield of Alfalfa Clones

Agricultural Experiment Stations of Alaska, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin, and the U. S. Department of Agriculture cooperating.

Technical Bulletin 38, June 1971
Agricultural Experiment Station
South Dakota State University, Brookings

CONTENTS

PROJECT: NC-83 Seed Production of Breeding Lines of Insect-Pollinated Legumes

COOPERATING AGENCIES AND PRINCIPAL LEADERS:

State Experiment Stations	Representatives
Alaska	* R. L. Taylor
Illinois	*D. A. Miller (for C. N. Hittle)
Indiana	*J. D. Axtell
Iowa	*I. T. Carlson
Kansas	*E. L. Sorensen
Michigan	*F. C. Elliott
Minnesota	*L. J. Elling
Missouri	*R. D. Horrocks
Nebraska	*W. R. Kehr
Ohio	*M. H. Niehaus
North Dakota	*P. C. Sandal
South Dakota	*M. D. Rumbaugh
Wisconsin	*E. T. Bingham
Administrative Adviser	F. W. Smith
U. S. Department of Agriculture	
Cooperative State Research Service	H. J. Hodgson
Agricultural Research Service	*C. H. Hanson
Primary Station, Nebraska	W. R. Kehr

*Voting members of NC-83 Regional Technical Committee

Sponsored by the agricultural experiment stations of South Dakota, Nebraska, Indiana, Minnesota, Kansas, Iowa, and the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture under the auspices of the NC-83 Technical Committee "Seed Production of Breeding Lines of Insect Pollinated Legumes."

SUMMARY

Five alfalfa clones from each of the breeding programs at the Agricultural Experiment Stations of Indiana, Iowa, Kansas, Minnesota, Nebraska, and South Dakota were vegetatively propagated and replicated in space-planted nurseries established in the six North Central states and in California and Idaho. The relationships among 18 plant characteristics measured in the North Central tests and seed yields in the western planting were evaluated by correlation and regression procedures. The objective of the experiments was to determine if associations among characters existed to a degree which would permit prediction of seed yields in the Western States' commercial seed producing regions from knowledge of plant morphology in the North Central seed consuming area.

Traits measured in the first year of growth which correlated consistently and highly with seed yields were: date of initial bloom, number of racemes per plant, flower color score, and number of coils per pod. The average magnitude of the correlations with second year data for the independent variables tended to be lower, and some characters shifted in relative importance. Characters that tended to exhibit consistent and relatively high correlations with first- and second-year seed yields in California and Idaho were in descending order of $\bar{r}$: (a) number of coils per pod, (b) flower color score, (c) number of seeds per pod, and (d) North Central state seed weight per plant.

The highest simple correlation coefficient of the 505 computed between attributes measured in the North Central trials and California and Idaho was $r = .81$ for first year number of coils per pod and second year California seed yields. No single independent North Central variable was sufficiently associated with seed yields to serve satisfactorily for prediction of seed yield potential in the western tests.

Multiple correlations based on all available information for each North Central state in each year resulted in values ranging from .53 to .94. Because independent variables were themselves mutually intercorrelated, several frequently could be deleted from the multiple regression equations with slight loss of predictive value. This was accomplished by backward stepwise regression in which the variable generating the standardized partial regression coefficient of lowest absolute magnitude was deleted from the function. The process was stopped at the arbitrarily selected end point of $R = .80$.

The independent variables which generated relatively high standardized coefficients rather consistently were: (a) number of racemes per plant, (b) flower color score, (c) number of stems per plant, (d) wet forage weight per plant, (e) percent fertile selfed florets, (f) number of open pollinated seeds per pod, and (g) number of coils per pod. Some variables in equations for predicting second year seed yields differed from those for the first year. Information from the Nebraska experiments, more than that from any other one station, seemed to represent the region as a whole.

Future research should be directed toward discovering other traits strongly associated with seed yield potential in the Western Region but not highly correlated with the independent variables measured in this study.

Predicting Seed Yield of Alfalfa Clones

By
M. D. Rumbaugh, W. R. Kehr, J. D. Axtell, L. J. Elling,
E. L. Sorensen, and C. P. Wilsie[2]

INTRODUCTION

Approximately two-thirds of the 30 million acres of alfalfa (*Medicago sativa* L., *M. falcata* L., and their hybrids) in the United States is grown in the 12 states comprising the North Central Region. Additional extensive but unreported plantings of alfalfa-grass mixtures are utilized for pasture and hay. Much of the alfalfa seed required to maintain the acreage in the North Central area is produced in the western states of California, Oregon, Washington, and Idaho (Figure 1).

A variety intended for forage production in the North Central Region must not only be well adapted in that region but also be suited for seed production in the western area. It would be advantageous if breeders examining alfalfa plants in North Central nurseries could predict the seed yield potential of those plants in commercial seed producing environments. This would enable them to discard undesirable genotypes early in the breeding program and ensure that any variety released for forage production in the North Central states could be sexually propagated successfully. Seeds of varieties with high seed yield potential usually have been less expensive than that of varieties with low seed yield potential. Therefore, experiments were conducted to determine: (a) whether associations between seed production potential and morphological- or physiological-plant characteristics exist, and (b) if such associations are of sufficient magnitude to use to identify plants having both desirable forage and seed production potential.

REVIEW OF LITERATURE

It has long been recognized that environmental variables such as air temperature, humidity, and soil moisture influence seed production by alfalfa plants. Grandfield (13) has pointed out that those environmental factors markedly affect the functioning of the reproductive parts of the plant as well as the nature and rapidity of top growth and the subsequent manufacture and storage of organic reserves. Some plants have been observed to be sensitive to unfavorable weather conditions and to exhibit a high degree of sterility (1). Other plants have seemed to be more stable and to produce seed freely under the same unfavorable conditions, apparently because an accumulation of genetic factors made them more favorable to seed setting.

Investigations of the relationships between control of predacious sucking insects and alfalfa seed yields (20) indicated inherent differences among alfalfa clones in seed production but that seed production was predominantly influenced by environmental factors prevailing during different growth periods and years. Insect attack consistently shortened internodes, reduced stem length, and caused more branches to be produced per stem. When alfalfa was protected from sucking insects, the seed yield increased as a result of more multiple podded rachises.

Plant diseases also strongly alter seed production. Black stem caused by *Aschochyta imperfecta* fre-

[1]Contribution from cooperative investigators of South Dakota State University, University of Nebraska, Purdue University, University of Minnesota, Kansas State University, Iowa State University, and the Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture under the auspices of the NC 83 Technical Committee "Seed Production of Breeding Lines of Insect Pollinated Legumes."

[2]Professor of Agronomy, South Dakota State University; Research Agronomist, Crops Research Division, ARS, USDA, University of Nebraska; Assistant Professor of Agronomy, Purdue University; Professor of Agronomy, University of Minnesota; Research Agronomist, Crops Research Division, ARS, USDA, Kansas State University; and Professor of Agronomy (deceased), Iowa State University.The authors gratefully acknowledge the assistance of R. E. Stucker, University of Minnesota, and G. L. Posler, Iowa State University, for obtaining a part of the data and to Dr. W. L. Tucker, South Dakota State University, for contributing to the statistical analyses.

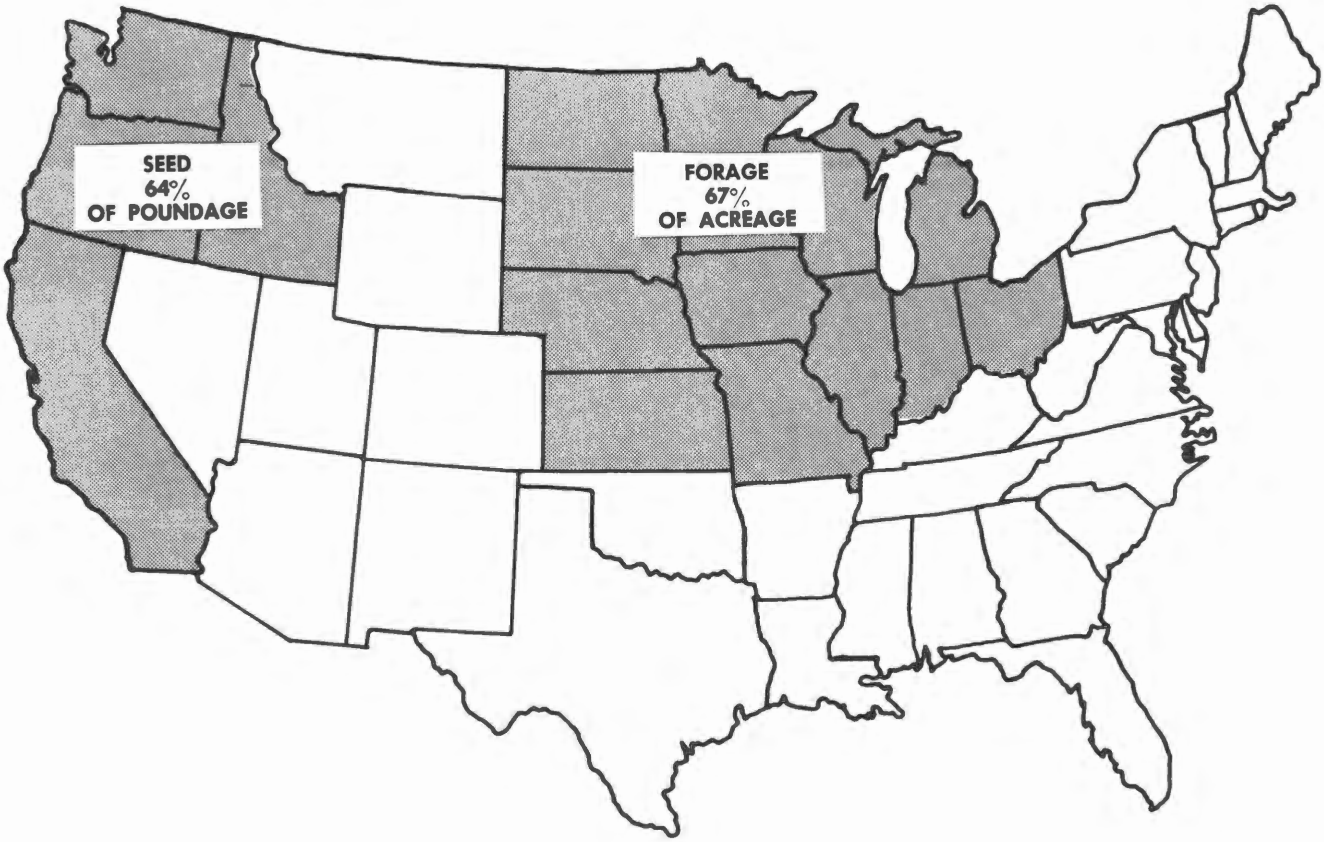

Figure 1. Alfalfa seed and forage producing regions in the United States. (Seed data based on S. Dak. Crop and Livestock Rept. Service Annual Seed Crop Summary, Dec. 26, 1968. Forage data based on U.S.D.A. Ext. Service annual reports, "Trends in Forage Crop Varieties," for the years 1962-1967.)

quently occurs on the inflorescence, where it is particularly destructive to seed (18). Genetic differences in clonal resistance to disease may be reflected by differences in seed yield potential in the presence of pathogens.

Tysdal (37) reported that less than 5% of alfalfa flowers set seed without tripping and that tripping by insects is necessary for successful seed production. A yield of 500 pounds of seed per acre was estimated to necessitate the tripping of at least 38 million flowers per acre (38).

Detailed observations on high and low seed producing clones after the flowers had been tripped to insure pollination revealed three reasons for seed production failure (5): (a) lack of fertilization even though pollen tubes were present, (b) failure of pollen tubes to reach all of the ovules, and (c) abortion of embryos at various stages of development. High seed setting plants produced an average of 1.25 seeds per flower tripped and 2.13 seeds per pod formed. The low yielding group produced 0.07 seeds per flower tripped and 0.99 seeds per pod. Meiosis and development of the macrogametophyte was similar in the two types of plants. Although all ovules appeared to be in a similar stage of development at the open flower stage, only 25% of those in the low seed setting group became fertile in contrast to 35% of the high seed producing plants. A high percentage of the fertile ovules failed to develop into mature seeds. An average of 3.1 ovules per flower in the high seed setting group was fertilized but only 1.25 seeds per flower were formed. In the low seed setting group the average number of fertile ovules was 2.5 but only 0.07 seed developed per flower. Many embryos aborted in early stages of maturation. Embryos developed more rapidly, cells were less vacuolated, and a lower percentage of abortion took place in the high than in the low seed setting plants.

A technique which employed the fluorescent properties of pollen tubes stained with aniline blue dye was used to determine the extent to which pollen tube growth, frequency of fertilization, and post fertilization ovule abortion influenced self and cross fertility in alfalfa (35). Selfing led to a lower frequency of fertilization and a higher incidence of ovule abortion than did crossing. The frequency with which fertilization occurred after both selfing and crossing apparently was determined by the number of pollen tubes which gained entry to ovaries, the depth of pollen tube penetration in ovaries, and the frequency with which pollen tubes entered ovules. The number of tubes which entered an ovary was controlled by the receptivity of the stigma to penetration by the tubes. None of these factors associated with seed set varied significantly when different pollen parents were used in pollinating a common female. Bolton and Fryer (1) found that high temperature accelerated pollen tube growth although individual plants reacted differently. Pollen tubes penetrated ovaries of two fertile plants within 7 hours after tripping whereas 9 hours were required in a sterile plant. Although variation in pollen viability has been eliminated as a cause of seasonal variation in pod setting, differences in viability of pollen from different plants were observed by Sexsmith and Fryer (36).

Rotar and Kehr (34) noted that self-fertility of 'Ranger' alfalfa clones was relatively independent of several agronomic characteristics of the clones and their polycross progenies. Highly significant differences for percentage of pollen abortion were obtained among florets, racemes, and cuttings of the same clone and cuttings of individual stems from different crown buds of the same clone. Possible reasons cited for the lack of repeatability of self-fertility studies were: (a) self-fertility was perhaps controlled by genes greatly influenced by environment, (b) self-incompatibility mechanisms were involved and their interaction with environment caused a large variation in self-fertility between dates; and (c) age of flower and different cuttings of the same clone may have influenced self-fertility indices.

Cross and self-fertility of 17 alfalfa clones were related to agronomic attributes of their progenies by Pedersen (26). Neither of the fertility values was found to indicate hay producing potential of the progeny. However, progeny seed production was correlated positively with cross fertility and seed production of the parents. Inbreeding has been observed to decrease self-fertility and vegetative vigor (39). Two generations of selfing resulted in a vigor loss of nearly 50% which is a more rapid decrease than expected of an autotetraploid. Miller and Schonhorst (22) also observed that numbers of seeds and pods produced and self-fertility decreased with inbreeding. No relationship was found among generations of inbreeding and numbers of racemes or flowers produced.

In one study six clones were compared for effects of complete and partial cross pollination of alfalfa on pod set seeds per pod, and pod and seed weight (28). When one-third of the flowers of a plant were cross pollinated, 66.4% of them formed pods weighing an average of 12.7 mg. When all the flowers were cross pollinated, 46.7% formed pods weighing an average of 11.3 mg. Heavier seeds and pod tissue rather than number of seeds per pod accounted for the difference in pod weight. Clones differed in pod set but behaved similarly at both high and low cross pollination intensities.

Because alfalfa is partially a cross pollinated species depending on insects for pollen transfer, attractiveness of the plants to insects is of major consequence for seed production. A number of studies indicated that alfalfa clones differed in attractiveness to honey bees (*Apis mellifera* L.). Boren, *et al.* (2) found that some bees recognized an unknown common characteristic among related clones and that some could distinguish among related clones. One honey bee foraging in a greenhouse containing 45 replicated, randomly arranged alfalfa clones showed complete specificity to a single clone during a long foraging trip.

Clement (4) studied honey bee activity on purple and white isogenic stocks of alfalfa and found that three of 17 individual bees preferred purple flowered plants, one preferred white and the remaining 13 showed no statistically significant flower color preference. Bees preferred purple to cream or yellow florets but that preference may have been related partly to the higher nectar production of the purple florets (23).

In another experiment involving 14 alfalfa clones, clones varied in their capacity to attract nectar collecting honey bees (24). Although subsequent research confirmed significant positive correlations between nectar production per plant and honey bee visitation (25), factors other than plant genotype were implicated in determining the amount of nectar produced (27). The honey bee attractiveness of 45 clones varied differentially with locations and years. Attractiveness of certain clones may remain high and that of others low. Conversely, conspicuous attractiveness alterations over seasons, years, and locations have characterized other clones (17).

An alfalfa clone that attracts honey bees does not necessarily attract other species of pollinating insects. Pedersen (31) noted that white flowered alfalfa was equal to colored flowered alfalfa in attracting nectar collecting honey bees, but was less attractive to pollen collecting leaf cutter bees (*Megachile rotundata* Fabricius). Efficiency of pollen transfer among alfalfa plants was different for leaf cutter than honey bees (32).

Application of light rates of 2,4,5-trichlorophenoxyacetic acid as a foliar spray on alfalfa during the early flowering stage increased seed yield by an average of 19% in 3 years (11). The treatment increased nectar volume, nector sugar concentration and seed set.

Several investigators examined relationships among environmental variables, alfalfa plant traits, and the seed yields of the same plants. Their findings are summarized in Table 1. Factors which explained at least 50% of the seed yield variation in any experi-

Table 1. Simple correlations (r) of alfalfa seed yield with other variables in investigations reported in 1969 and prior years.

Variable	r	Authority	Citation
Environmental variables:			
Soil moisture (atm)	.49**	Pedersen, *et al.*, 1959	(29)
	-.09	Hurst and Pedersen, 1964	(16)
Soil temperature (°F)	.58**	Pedersen, *et al.*, 1959	(29)[1]
	-.33*	Pedersen, *et al.*, 1959	(29)
Light (foot candles)	.48**	Pedersen, *et al.*, 1959	(29)
	-.33*	Pedersen, *et al.*, 1959	(29)
Relative humidity (%)	-.13	Pedersen, *et al.*, 1959	(29)
	.44**	Pedersen, *et al.*, 1959	(29)
Insect and disease variables:			
Chalcid (%)	.02	Pedersen, *et al.*, 1959	(29)
	-.00	Pedersen, *et al.*, 1959	(29)
Honey bees per unit area	.65**	Pedersen, *et al.*, 1959	(29)
	.56**	Pedersen, *et al.*, 1959	(29)
	.11	Hurst and Pedersen, 1964	(16)
Flowers per bee	-.38**	Pedersen, *et al.*, 1959	(29)
	.01	Pedersen, *et al.*, 1959	(29)
Yellow leaf blotch (score)	-.59**	Hurst and Pedersen, 1964	(16)

(continued on next page)

Table 1. (continued)

Variable	r	Authority	Citation
Morphological variables:			
Total plant weight (g)	.73**	Dann and Waldron, 1933	(7)
Vegetative vigor (score)	.51*	Busbice and Wilsie, 1966	(3)
Plant height (in)	.53**	Liang and Riedl, 1964	(19)
Stems per plant	.30**	Liang and Riedl, 1964	(19)
Stems per acre	-.47**	Pedersen, *et al.*, 1959	(29)
	.03	Pedersen, *et al.*, 1959	(29)
	.11	Hurst and Pedersen, 1964	(16)
Lodging (%)	-.62**	Pedersen, *et al.*, 1959	(29)
	+.36*	Pedersen, *et al.*, 1959	(29)
Profuseness of flowering (score)	.63*	Busbice and Wilsie, 1966	(3)
Bloom (%)	-.08	Hurst and Pedersen, 1964	(16)
Flowers per acre	.03	Pedersen, *et al.*, 1959	(29)
	.31*	Pedersen, *et al.*, 1959	(29)
	.20	Hurst and Pedersen, 1964	(16)
Flowers per plant	.15	Miller and Schonhorst, 1968	(22)
Racemes per stem	.50**	Pedersen, *et al.*, 1959	(29)
	.44**	Pedersen, *et al.*, 1959	(29)
	.13	Hurst and Pedersen, 1964	(16)
Racemes per plant	.54**	Dann and Waldron, 1933	(7)
	.13	Miller and Schonhorst, 1968	(22)

(continued next page)

Table 1. (continued)

Variable	r	Authority	Citation
Racemes per acre	.28	Hurst and Pedersen, 1964	(16)
Tripped flowers per raceme	.17	Hurst and Pedersen, 1964	(16)
Pods per raceme	.68**	Dann and Waldron, 1933	(7)
	.54**	Pedersen, et al., 1959	(29)
	.02	Pedersen, et al., 1959	(29)
	.10	Hurst and Pedersen, 1964	(16)
Pods per plant	.94**	Miller and Schonhorst, 1968	(22)
Seeds per pod	.57**	Dann and Waldron, 1933	(7)
	.48**	Hurst and Pedersen, 1964	(16)
Seeds per raceme	.44**	Liang and Riedl, 1964	(19)
Weight per seed	-.10	Hurst and Pedersen, 1964	(16)
	.23*	Liang and Riedl, 1964	(19)
Chaff (tons/acre)	.26*	Hurst and Pedersen, 1964	(16)
Physiological variables:			
Lateness of flowering	-.83**	Pedersen, et al., 1959	(29)
	.12	Pedersen, et al., 1959	(29)
Ease of tripping (score)	.44	Busbice and Wilsie, 1966	(3)
Self fertility	.02	Busbice and Wilsie, 1966	(3)
	.92**	Miller and Schonhorst, 1968	(22)

(continued next page)

Table 1. (continued).

Variable	r	Authority	Citation
Nectar sugar concentration (%)	.12	Pedersen, *et al*., 1959	(29)
	-.27	Pedersen, *et al*., 1959	(29)
	-.32**	Hurst and Pedersen, 1964	(16)
Root sucrose content (%)	.93**	Dobrenz and Massengale, 1966	(8)
Root glucose content (%)	.78**	Dobrenz and Massengale, 1966	(8)
Root fructose content (%)	.75**	Dobrenz and Massengale, 1966	(8)
Root starch content (%)	.94**	Dobrenz and Massengale, 1966	(8)
Root acid-hydrolyzable carbohydrates (%)	.93**	Dobrenz and Massengale, 1966	(8)
	.90*	Dovrat, Levanon and Waldman, 1969	(9)

[1/] Results from 2 experiments are reported in this reference. In all cases a single value or the first of two values which are reported in sequence are from a dryland experiment and the second value of a pair is from an irrigated experiment.

* $P < .05$
** $P < .01$

ment cited ($r^2 \geq 0.50$) include: (a) total plant weight, (b) pods per plant, (c) lateness of flowering, (d) self fertility, and (e) five different measures of root carbohydrate content. None of the studies associated a character measured in one environment with seed yield measured in a different environment.

Dann and Waldron (7) combined four independent variables total weight per plant, racemes per plant, pods per raceme, and seeds per pod—and computed a multiple correlation coefficient of $R = 0.84$ on weight of seed per plant. The most extensive use of multiple predictive equations reported to date was applied by Hurst and Pedersen (16) to alfalfa seed yields in Utah. After considering 14 factors associated with alfalfa seed production, they obtained a coefficient of determination of 0.74 by including 10 linear terms, three non-linear terms, and seven interaction terms in the model. Coefficients of the final model indicated that the factors which contributed most to increased seed yield included soil moisture tension and soil moisture tension squared, nectar sugar concentration and nectar sugar concentration squared, bees per square yard, racemes per acre by seeds per pod, yellow leaf blotch (*Pseudopeziza jonesii* Nannf.) score squared, and tons per acre chaff by blotch score interaction.

Phenotypic correlations have been found to be somewhat misleading (19). Plant height, seed size, fertility, and number of stems were positively correlated with seed yield in a greenhouse study. However, path coefficient analysis revealed that seed size exerted a negative rather than a positive direct influence on seed yield. Yield factors were found to be compensatory (30). When there were fewer stems per acre, there were more racemes per stem. An advantage in number of pods per raceme and seeds per pod was partially lost because the seeds were lighter in weight.

Attempts to breed for increased seed yield have been made in several environments and by using several breeding procedures. Maternal line selection applied over a 10-year period resulted in a strain with seed yield superior to that of Grimm, Ladak, and Cossack without a reduction in hay yield (12). Heinrichs (15) observed that polycross progeny lines tended to yield in the same rank in three successive years at one location. Seed yield of parental clonal lines and their polycross progenies measured in different years were not associated. Despite inconsistencies in seed yields between locations it was possible to form an 8-clone synthetic which was predicted to yield 30% more seed than the check.

A diallel cross among 11 random clones of Buffalo alfalfa provided evidence for significant general, specific, and maternal effects for seeds per pod, seeds per flower and percentage of flowers forming pods (33). Specific effects contributed most to variance for seeds per pod and seeds per flower, but general effects were more important for percentage of flowers forming pods. The authors suggested that the combination of effects found in their study could be used more efficiently with hybrids than with synthetic varieties.

In another investigation in which nine selected alfalfa clones were both polycrossed and intercrossed in a diallel series, four crosses significantly exceeded the check variety for seed yield (21). Increases over checks were considerably higher for seed than for forage yield. Busbice and Wilsie (3) noted that although ease of tripping was less strongly correlated with seed yield than was "profuseness of flowering," the relatively high heritability (.54) of the former character suggested the possibility of improving alfalfa for that characteristic.

Dade, *et al.* (6) conducted an experiment in which 23 alfalfa clones selected from the breeding program at the University of Kentucky were grown at Lexington, Ky., and at Prosser, Wash., in 1962 and 1963. Dates of bloom and seed yields were measured. Nonsignificant negative correlations between these characters at each location suggested a tendency for earlier flowering clones to be higher in seed yield. Seed yields were higher at Prosser in both years and differential clonal responses to the two locations were revealed. They concluded that yields from alfalfa clones grown in Kentucky could not be used to predict the reproductive capability of the same clones in environments favoring a more complete expression of seed yield potential. A correlation of $r = .86$ between the first and second yields at Prosser indicated that clones could be screened at that location in the first year.

MATERIALS AND METHODS

Five alfalfa clones were selected from each of the breeding programs of the Agricultural Experiment Stations of Indiana, Iowa, Kansas, Minnesota, Nebraska, and South Dakota to form the sample of 30 used in these experiments. Each clone was vegetatively propagated at the station of origin and bare rooted cuttings were distributed to the North Central sites in the early spring of 1966. Four replicate randomized complete block trials with three propagules per plot were established in spaced nurseries near Lafayette, Ind.; Ames, Ia.; Manhattan, Kan.; St. Paul, Minn.; Lincoln, Neb.; and Brookings, S. D. Similar four replicate tests with five plant plots were initiated near Fresno, Cal., in 1966 and Caldwell, Idaho, in 1967.[3] Bare-rooted cuttings were transplanted in Cali-

[3]The authors appreciate the cooperation of L. F. Arnold and H. L. Carnahan, Arnold Thomas Seed Service, and of R. R. Kalton and D. E. Brown, W. R. Grace & Co., who made the California and Idaho trials possible.

fornia. All clones for the Idaho test were started at Lincoln and rooted in peat pots for 4 to 6 weeks before they were transplanted to the field. These propagules were more uniform in root growth and, for many clones, were larger than those used in tests established in 1966. Plants were spaced at distances customarily used in each nursery as shown in Table 2.

Growing conditions were near normal at all sites. Precipitation and temperature data for 1966 and 1967 are shown in Table 3 and 4, respectively. Supplemental irrigation was used in Indiana in 1966 and in Nebraska during both growing seasons. At no time were any of the nurseries subjected to extreme moisture deficiency stress.

High concentrations of domestic honey bees in California and leaf cutter bees in Idaho provided the insect pollen vectors for those nurseries. Natural insect populations in the North Central nurseries were supplemented by the addition of honey bee colonies in the Nebraska and South Dakota locations.

The following independent variables were measured in one or more of the six North Central states in either the first or second year or both years of growth:

(1) Date of initial bloom: recorded as the numerical day of the year the first floret opened.

(2) Number of racemes per plant at full bloom. Data for this trait were not obtained in a uniform manner at all sites. In some nurseries all racemes on each plant were counted. In others the plants were quartered prior to counting and the total racemes computed.

(3) Raceme length (mm): included only the length of the flower bearing portion of the peduncle; i.e., from the distal end of the distal floret in the raceme to the proximal end of the proximal floret of the same raceme. Ten fully expanded racemes per plant were measured at one-tenth bloom stage.

(4) Raceme width (mm): the same 10 racemes per plant were used as in (3).

(5) Number of florets per raceme at full bloom: the same 10 racemes per plant were used as in (3).

(6) Flower color score: assessed on a numerical rating scale described in Table 5.

(7) Number of stems per plant at full bloom counted after the plant had been cut at the time of the first harvest.

(8) Length of longest stem (mm): measured with a meter stick from the soil surface to the distal end of the longest stem.

(9) Growth habit score: 1=upright, 9=prostrate.

(10) Vigor score: 1=strong, 9=weak.

(11) *Xanthomonas alfalfae* (bacterial leaf spot) score: 1=no disease, 9=severe disease.

Table 2. Plant spacings in nurseries at the eight test sites.

Location	Distance (inches)	
Location	Between rows	Within rows
Indiana	40	40
Iowa	40	24
Kansas	36	36
Minnesota	18	18
Nebraska	40	18
South Dakota	40	40
California	40	12
Idaho	36	24

(12) Wet forage weight (g): green weight per plant at the time of the first cutting.

(13) Dry forage weight (g): oven dry weight per plant at the time of the first cutting.

(14) Fertile open pollinated florets (%): computed from (5) after counting the number of pods borne on 10 racemes per plant.

(15) Fertile selfed florets (%): based on pods developing from florets that had been self fertilized in the field.

(16) Number of open pollinated seeds per pod: seed in 10 pods per plant were counted and averaged.

(17) Number of coils per pod: measured in gradations of one-tenth of full circles except that a minimum score of 0.5 was assigned to *Medicago falcata* L. type pods.

(18) Seed weight per plant (g).

The character of prime interest in California and Idaho was seed yield per plant although data on some other traits were recorded. In California pod set was visually scored twice each growing season and in Idaho seed set was similarly scored visually. These characters were assigned code designations X_{19} and X_{20}, respectively.

Disease, growth, pod set, and seed set scores were on a 1 to 9 scale in conformity with the suggestions of the "Report of the Committee on Genetics and Breeding Nomenclature" contained in the *Report of the Nineteenth Alfalfa Improvement Conference* of 1964. The analyses were based on all available information for the respective characters.

Not all propagules survived. Therefore, plant measurements were averaged within plots prior to analyses of variance. Statistical significance of differences among clonal means was tested by Tukey's *w*-procedure at a probability level of 0.05. When included in the tables, this estimate was indicated by $w_{.05}$. All correlation and regression statistics were computed from entry means rather than from plot values.

Table 3. Test environment data for the NC-83 objective 1 alfalfa clone seed study, May-October, 1966.

	Indiana	Iowa	Kansas	Minnesota	Nebraska	South Dakota
Soil Series	Fincastle	Clarion, Nicollet	Sarpy	Port Byron	Wabash	Vienna
Precipitation (inches)						
May	3.13 1/	4.81	1.48 2/	-----	4.74 3/	1.31
June	1.44	8.56	1.76	3.47	4.88	5.21
July	3.08	1.28	2.36	1.64	2.63	1.39
August	1.98	2.03	3.58	3.39	3.83	3.01
September	2.91	.25	.60	3.63	2.11	1.35
October	-----	.34	.78	-----	.45	.86
Ave. Max. daily air temp. (°F)						
May	66.8	70.7	80.3 2/	-----	74.5	65.6
June	82.6	80.2	85.5	81.3	82.7	77.9
July	89.5	87.6	95.7	87.6	91.2	87.4
August	81.1	81.3	85.9	79.5	82.4	79.3
September	75.7	74.9	78.1	73.0	73.9	71.2
October	-----	68.1	72.4	-----	68.5	59.8
Ave. Min. daily air temp. (°F)						
May	43.5	44.0	53.9 2/	-----	48.2	39.0
June	57.9	58.0	63.3	54.0	62.1	53.3
July	63.2	65.5	72.3	62.8	71.5	62.6
August	56.8	56.8	63.4	55.5	62.7	53.2
September	47.8	48.9	54.5	48.2	53.9	45.9
October	-----	38.3	42.8	-----	44.5	31.8

1/Supplemental irrigation used 3 times during season but amounts unknown
2/May 13-31 inclusive
3/Includes 3 inches of water sprinkle irrigated on May 5

Table 4. Test environment data for the NC-83 objective 1 alfalfa clone seed study, April 1 - October 15, 1967.

	Indiana	Iowa	Kansas	Minnesota	Nebraska	South Dakota
Precipitation (inches)						
April	3.43	2.78	5 02	4.76	7.63[1/]	2.02
May	3.85	2.48	2.95	.68	4.47	.82
June	1.07	10.21	9.96	8.63	12.93	8.90
July	1.16	1.93	3.10	3.08	3.99	2.06
August	2.65	1.45	1.20	2.80	1.91	2.36
September	1.42	1.53	7.97	.58	2.91	.66
October 1 - 15	1.09	1.41	2.56	1.43	1.45	.93
Ave. Max. daily air temp. (^oF)						
April	62.1	63.7	71.0	55.4	66.2	54.2
May	65.8	70.5	74.0	65.2	69.2	64.3
June	80.8	78.7	83.1	77.3	79.5	74.0
July	82.1	82.1	84.9	80.7	85.3	80.6
August	79.1	81.1	86.6	78.4	83.6	81.0
September	74.0	73.6	77.0	74.0	74.0	71.2
October 1-15	65.0	68.0	73.9	63.9	67.8	65.9
Ave. Min. daily air temp. (^oF)						
April	41.3	39.3	48.4	35.0	41.8	31.9
May	45.2	44.2	50.4	39.6	48.8	36.6
June	60.3	58.9	62.5	55.6	60.6	53.9
July	58.4	58.9	63.5	57.5	64.5	54.3
August	56.5	56.1	61.5	54.0	61.9	50.7
September	48.5	48.3	53.4	46.1	52.9	44.5
October 1-15	45.7	45.0	51.2	42.4	49.0	36.7

1/ Includes 6 inches of irrigation water

The repetitive process of deleting the independent variable generating the smallest standardized partial regression equation was arbitrarily stopped when the multiple correlation coefficient, R, was reduced to less than 0.80. A coefficient of multiple determination, R^2, of less than 0.64 was believed to indicate that the predictive value of the equation was too low for practical use in a breeding program.

Table 5. Scale for scoring of flower color.[1/]

Score		Flower color: Primary	Flower color: Secondary
1		White	
2		Purple, violet, lilac	
	2.1		Dark
	2.2		Moderately dark
	2.3		Light
	2.4		Very light
3		Cream	
4		Variegated	
	4.0		Purple variegated-dark
	4.1		Purple variegated-light
	4.2		Blue-dark
	4.3		Blue-light
	4.4		Maroon-dark
	4.5		Maroon-light
	4.6		Green-dark
	4.7		Green-light
	4.8		Yellow variegated-dark
	4.9		Yellow variegated-light
5		Yellow	
	5.1		Very light
	5.2		Light
	5.3		Moderately dark
	5.4		Orange

[1/] Scale developed by D. K. Barnes, Crops Research Division, ARS, USDA, Department of Agronomy and Plant Genetics, University of Minnesota. It has since been revised and current usage is described in "Report of the Twenty-First Alfalfa Improvement Conference", pp. 105-106. 1968.

RESULTS AND DISCUSSION

Character means and variations:

Plants were smaller and less vigorous in the first year of growth than they were in the second year of establishment. That was expected, based on other observations of propagules transplanted in nurseries in the North Central Region. When moved from greenhouses to the fields in May, 1966, the propagules of the different clones varied greatly in degree of development, especially with respect to the root system. That undoubtedly added to inherent genetic differences in phenology among clones and contributed to the significant clonal source of variation observed within tests in 1966. Most of these traits, however, differed significantly among clones in 1967 when propagule developmental effects were minimal. Morphological types among the 30 clones ranged from those typical of *M. falcata* L. (e.g. clones Ia. 1516 and Minn. 247) to many erect, broad leaved, purple flowered plants of the *M. sativa* L. form.

Initial propagule survival for all clones except one was excellent at all sites. The propagules for the exception were replaced in 1966 and in 1967 but measurements on that clone were not used in the regression and correlation statistics. Severe winter kill reduced the stand in the South Dakota test and second year data from that location were restricted to 20 of the hardier clones that survived.

The means of each clone for each trait measured in the North Central states for 1966 and 1967 are listed in Table 6 and 7, respectively. Both tables also show the ranges of the state means for each clone expressed as percentages of the corresponding means. Average date of initial bloom occurred on the 212th day of the year in 1966 (July 31) and on the 181st day in 1967 (June 30). The means of the number of racemes per plant, number of stems per plant, length of longest stem, forage and seed weights per plant all reflect the more advanced development of the plants in the second year. With two exceptions all characters exhibited a greater average range among state means in 1966 than in 1967. These exceptions were raceme width and percentage fertile open pollinated florets.

Examination of Tables 6 and 7 reveals that, with range of state means the criterion, certain traits were more variable than others. Large differences in ranges were observed between clones for the same character and some clones were less stable than others for most characters. Kansas 2311 tended to be less influenced by environmental differences than any other clone in each test year. Others which approached the same degree of stability were Iowa 46-1 and Minnesota 559. Minnesota 247, Nebraska 662, and South Dakota CK27-1 were more variable for most traits than the remainder of the clones in the experiment. The one attribute exhibiting a radical change in average range from the first to the second year was raceme length. The 1966 value was 105%. The corresponding 1967 value, 33%. The reduction in range for that trait is believed to be a result of increased awareness of personnel conducting the tests of the correct method to take the measurement.

Some characters were uniformly measured with about the same degree of precision in each location and year whereas others were not. This evaluation is based on the magnitudes of the coefficients of variation in Table 8. The coefficients for trait X_7, number of stems per plant, in the Indiana and South Dakota nurseries were approximately twice as large as those for the other four North Central states. In some instances a character was measured with greater precision in one year than in the other year at one location whereas at other locations the coefficients for the two years were very similar in magnitude. Number of racemes per plant in Indiana and in South Dakota provided one such comparison.

Tables 9 and 10 show the means of attributes measured on each clone in the first and second years of growth in California and Idaho. Significant differences among the clones were found for all traits in each year at each location. Number of seeds per pod, averaged over all clones, was consistently greater in California than in Idaho, perhaps because of differences in environments or in pollinating insect species. Honey bees were used in California and leafcutter bees were used in Idaho. It did not depend on the number of coils per pod, because that trait was nearly identical for both sites in each year. Seed weight per plant was considerably greater the first year of growth in Idaho than in California. This probably resulted from the use of larger and better rooted propagules in the Idaho planting. We do not believe it reflects other unrecognized biological or environmental factors. Hanson (14) noted that stage of growth, season, disease and other environmental conditions may be factors affecting the rapidity with which stem cuttings root and become established. He concluded that differences arising from the method of propagation decreased with time and appeared to have been largely dissipated by the second year following establishment.

Correlation of North Central Region Characters with Seed Yields:

The degree of association between independent variables and seed yields in the Western States was measured by computing simple correlation coefficients (r) for each North Central location. The coefficients were transformed to z values, averaged, and then decoded to obtain a mean correlation $(\bar{r})$ representing the association of the independent and de-

Table 6. Clonal grand means and range of test means in the North Central states 1966.

Clone	Date bloom(4)[1]		No.Racemes (5)		Raceme length(4)		Raceme width (4)	
	Mean	Range[2]	Mean	Range	Mean	Range	Mean	Range
Ind. 62-235	210	28	307	209	22	95	15	13
Ind. 62-237	212	33	400	196	16	19	15	7
Ind. 62-239	---	--	---	---	--	---	--	--
Ind. 62-247	214	35	371	242	23	117	14	14
Ind. 62-267	217	33	305	268	24	117	15	13
Ia. 918-2	223	39	299	183	26	138	16	38
Ia. 918-3	213	38	458	200	28	107	17	29
Ia. 46-1	208	33	323	172	28	93	16	12
Ia. 1317	206	33	438	158	25	108	17	12
Ia. 1516	219	34	174	236	25	124	16	19
Kans. 2313	213	34	434	203	25	100	15	13
Kans. 2314	208	34	750	159	22	114	15	20
Kans. 2315	204	33	769	197	23	87	17	6
Kans. 2316	206	32	427	273	29	86	15	13
Kans. 2311	206	34	441	210	24	88	15	13
Minn. 247	214	27	317	226	28	114	15	20
Minn. 559	210	33	303	241	22	73	15	13
Minn. 589	209	34	475	213	22	118	14	29
Minn. 1166	218	29	286	204	23	139	14	36
Minn. 1221	212	29	329	198	22	109	14	21
Nebr. 661	204	34	615	197	24	100	17	12
Nebr. 662	206	31	769	184	23	83	15	13
Nebr. 663	205	30	475	170	26	100	16	19
Nebr. 664	213	31	476	263	18	100	13	23
Nebr. 665	213	28	366	280	17	35	14	14
S.D. 1108	212	39	396	207	22	145	15	13
S.D. H2-8	217	35	249	214	20	135	13	38
S.D. H2-7	222	29	243	172	28	129	16	12
S.D. CK25-1	222	37	348	340	24	133	14	0
S.D. CK27-1	221	31	139	296	24	125	15	20
Average	212	33	403	218	24	105	15	17

1/ Figures in parentheses indicate the number of tests in which the trait was measured.
2/ All ranges are expressed as percentages of the corresponding means.

Table 6. (Continued)

Clone	No. florets(5) Mean	Range	Flower color(4) Mean	Range	No. stems(4) Mean	Range	Stem length(6) Mean	Range
Ind. 62-235	13	69	2.3	26	9	189	541	58
Ind. 62-237	11	82	3.5	54	10	140	558	65
Ind. 62-239	--	--	---	--	--	---	---	--
Ind. 62-247	13	54	2.6	69	11	145	537	84
Ind. 62-267	11	55	2.6	92	9	144	485	91
Ia. 918-2	11	64	4.4	14	9	156	657	97
Ia. 918-3	12	42	4.4	27	10	160	643	94
Ia. 46-1	14	43	3.3	58	10	160	634	60
Ia. 1317	12	50	2.8	64	9	156	573	69
Ia. 1516	11	82	5.3	0	9	133	575	119
Kans. 2313	13	54	2.8	46	12	133	476	70
Kans. 2314	12	75	2.4	21	13	138	489	46
Kans. 2315	15	40	2.4	0	11	136	594	56
Kans. 2316	12	50	2.2	0	12	125	635	55
Kans. 2311	12	75	2.3	0	10	130	508	65
Minn. 247	13	69	5.2	6	9	167	559	142
Minn. 559	14	64	2.9	66	12	117	574	81
Minn. 589	11	55	2.2	5	14	100	557	83
Minn. 1166	12	67	2.2	5	10	180	628	92
Minn. 1221	11	82	2.2	5	10	170	573	94
Nebr. 661	15	33	2.2	5	13	131	625	67
Nebr. 662	15	40	2.2	5	11	145	552	71
Nebr. 663	14	57	3.2	69	13	85	487	67
Nebr. 664	10	90	3.3	55	12	208	498	59
Nebr. 665	14	79	2.3	4	13	123	525	76
S.D. 1108	12	75	5.0	2	9	144	478	132
S.D. H2-8	10	50	3.9	31	9	144	505	146
S.D. H2-7	16	44	3.9	41	9	167	542	141
S.D. CK 25-1	14	29	3.6	42	9	200	525	113
S.D. CK 27-1	10	160	4.3	47	7	171	475	126
Average	13	63	3.2	30	10	150	552	87

Table 6. (Continued)

Clone	Dry weight per plant (3) Mean	Range	Fertile O.P. florets (4) Mean	Range	Number of seeds per pod (5) Mean	Range	Coils per pod (1) Mean	Seed weight per plant (4) Mean	Range
Ind. 62-235	71	34	35	89	3.1	97	1.2	.8	188
Ind. 62-237	68	65	37	81	2.6	96	1.6	2.1	205
Ind. 62-239	39	28	23	0	2.6	188	---	.2	150
Ind. 62-247	82	56	54	107	3.0	137	1.6	1.8	195
Ind. 62-267	55	82	23	122	1.8	206	1.1	1.0	280
Ia. 918-2	104	106	27	104	2.3	130	1.2	.6	217
Ia. 918-3	119	88	38	126	2.9	138	1.4	1.5	207
Ia. 46-1	69	55	51	49	3.3	167	1.4	3.2	181
Ia. 1317	88	56	52	133	3.9	149	2.9	3.1	223
Ia. 1516	69	101	40	120	2.8	179	.8	.5	267
Kans. 2313	62	61	23	100	2.3	243	1.1	.8	218
Kans. 2314	89	69	25	104	2.8	107	2.2	1.6	245
Kans. 2315	87	90	30	97	2.9	176	2.6	2.3	171
Kans. 2316	72	60	31	129	4.1	141	2.6	1.4	240
Kans. 2311	49	12	53	109	3.2	81	2.5	2.0	127
Minn. 247	67	90	43	93	2.2	177	.4	1.2	278
Minn. 559	61	67	42	107	3.1	132	2.0	1.8	192
Minn. 589	53	68	42	117	3.3	139	2.4	3.5	204
Minn. 1166	45	107	34	91	2.9	148	1.4	2.2	230
Minn. 1221	47	140	49	149	2.9	121	1.2	2.3	275
Nebr. 661	78	62	41	122	3.3	139	2.1	2.4	202
Nebr. 662	83	84	30	123	3.6	217	1.9	4.6	212
Nebr. 663	47	100	42	136	3.3	106	1.6	3.0	134
Nebr. 664	91	107	28	93	2.3	165	1.1	1.2	200
Nebr. 665	61	46	25	20	2.5	144	.7	1.4	218
S.D. 1108	67	87	46	150	3.7	116	1.3	2.2	162
S.D. H2-8	68	138	45	100	2.6	181	.5	1.0	176
S.D. H2-7	67	115	56	75	3.3	115	1.0	2.2	170
S.D. CK 25-1	57	125	40	102	3.5	120	1.1	2.7	268
S.D. CK 27-1	36	108	32	169	2.5	184	---	.3	233
Average	68	80	38	104	3.0	148	1.4	1.8	209

Table 7. Clonal grand means and range of test means in the North Central states in 1967.

Clone	Date bloom (4)[1]		No. racemes (5)		Raceme length (5)		Raceme width (5)	
	Mean	Range[2]	Mean	Range	Mean	Range	Mean	Range
Ind. 62-235	183	27	675	85	19	26	15	40
Ind. 62-237	181	29	1979	282	19	26	15	33
Ind. 62-239	194	13	855	169	19	11	14	21
Ind. 62-247	184	16	1416	149	21	14	15	27
Ind. 62-267	181	27	980	57	23	35	15	40
Ia. 918-2	184	29	860	115	22	18	15	40
Ia. 918-3	181	29	1016	128	21	24	16	38
Ia. 46-1	177	28	935	84	27	7	17	24
Ia. 1317	183	27	753	73	21	19	17	18
Ia. 1516	179	32	650	100	21	29	15	73
Kans. 2313	181	27	745	110	22	41	15	13
Kans. 2314	178	27	829	99	19	21	15	20
Kans. 2315	179	25	1132	98	21	43	16	31
Kans. 2316	178	27	813	128	27	30	15	33
Kans. 2311	180	28	667	124	22	18	15	33
Minn. 247	180	34	740	221	24	50	15	40
Minn. 559	178	26	1268	88	23	47	16	31
Minn. 589	179	26	806	46	17	76	14	29
Minn. 1166	184	28	728	148	18	61	15	46
Minn. 1221	184	26	734	162	20	25	15	46
Nebr. 661	178	26	985	105	21	28	17	41
Nebr. 662	181	26	868	209	18	39	14	36
Nebr. 663	179	26	767	145	21	43	17	35
Nebr. 664	184	29	546	58	18	72	14	29
Nebr. 665	180	25	1061	109	23	30	15	20
S.D. 1108	176	30	1509	130	18	28	15	47
S.D. H2-8	181	28	823	118	17	24	15	40
S.D. H2-7	184	27	752	203	22	18	15	33
S.D. CK 25-1	186	30	1094	164	19	42	14	29
S.D. CK 27-1	184	28	890	166	20	35	14	36
Average	181	27	929	126	21	33	15	34

[1] Figures in parentheses indicate the number of tests in which the trait was measured.
[2] All ranges are expressed as percentages of the corresponding means.

Table 7. (Continued)

Clone	No.florets(6)		Flower color(3)		No.stems(6)		Stem length(6)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Ind. 62-235	17	41	2.2	5	45	120	1046	96
Ind. 62-237	15	47	2.2	9	48	90	844	35
Ind. 62-239	15	60	1.0	0	23	230	504	146
Ind. 62-247	16	31	2.8	64	56	84	886	41
Ind. 62-267	16	31	3.5	51	47	119	933	47
Ia. 918-2	16	50	4.1	39	46	76	1143	94
Ia. 918-3	17	53	4.5	16	47	85	879	39
Ia. 46-1	19	26	4.3	2	57	81	938	22
Ia. 1317	17	65	2.9	62	36	114	956	47
Ia. 1516	12	33	5.2	2	47	100	523	130
Kans. 2313	17	71	2.3	4	37	108	363	81
Kans. 2314	18	44	2.2	0	46	124	369	60
Kans. 2315	19	26	2.3	9	44	89	838	43
Kans. 2316	18	39	2.2	0	39	113	921	52
Kans. 2311	18	33	2.3	0	32	106	629	138
Minn. 247	17	59	5.2	2	51	92	896	57
Minn. 559	19	53	3.6	28	78	69	907	32
Minn. 589	18	33	2.1	0	74	93	811	27
Minn. 1166	17	70	2.2	5	47	115	887	40
Minn. 1221	18	44	2.2	0	46	139	706	151
Nebr. 661	25	48	2.1	0	57	125	980	34
Nebr. 662	18	100	3.0	83	36	169	716	72
Nebr. 663	20	45	2.7	70	33	127	774	21
Nebr. 664	17	35	3.7	24	44	127	861	41
Nebr. 665	24	33	2.2	0	68	87	865	18
S.D. 1108	17	35	4.9	2	47	111	911	40
S.D. H2-8	15	53	2.7	79	48	108	857	48
S.D. H2-7	21	29	3.7	59	63	97	804	46
S.D. CK 25-1	20	45	4.1	15	54	98	829	41
S.D. CK 27-1	17	41	3.9	51	61	110	766	75
Average	18	45	3.1	23	49	110	811	60

Table 7. (Continued)

Clone	Wet weight per plant (4)		Dry weight per plant (1)	Fertile O.P. florets (6)		Fertile selfed florets (2)	
	Mean	Range	Mean	Mean	Range	Mean	Range
Ind. 62-235	1002	47	192	42	160	53	42
Ind. 62-237	1082	29	211	41	251	39	87
Ind. 62-239	306	166	80	23	261	28	107
Ind. 62-247	983	68	248	27	200	40	48
Ind. 62-267	726	111	216	19	153	10	0
Ia. 918-2	1093	73	202	24	200	18	139
Ia. 918-3	1284	66	246	35	203	33	24
Ia. 46-1	1221	41	200	41	93	54	37
Ia. 1317	716	141	228	34	218	38	92
Ia. 1516	581	106	81	25	188	30	70
Kans. 2313	513	74	136	25	160	7	200
Kans. 2314	831	41	140	17	212	12	108
Kans. 2315	806	96	196	20	215	29	179
Kans. 2316	748	10	94	21	162	17	118
Kans. 2311	343	34	198	33	118	44	25
Minn. 247	1191	60	237	27	200	28	186
Minn. 559	1296	78	246	19	226	12	92
Minn. 589	930	70	186	25	164	14	57
Minn. 1166	768	86	218	24	208	19	11
Minn. 1221	711	103	227	26	192	22	73
Nebr. 661	1172	51	160	25	120	39	87
Nebr. 662	682	141	190	18	200	13	108
Nebr. 663	685	121	120	20	230	10	27
Nebr. 664	1018	79	215	19	205	4	125
Nebr. 665	968	69	274	20	240	26	4
S.D. 1108	1135	84	210	20	135	14	21
S.D. H2-8	937	121	176	26	135	38	24
S.D. H2-7	907	19	180	32	153	62	76
S.D. CK 25-1	1350	98	156	19	153	20	40
S.D. CK 27-1	696	82	343	20	145	54	13
Average	889	79	194	26	183	28	74

Table 7. (continued)

Clone	Number of seeds per pod (6)		Number of coils per pod (4)		Seed weight per plant (5)	
	Mean	Range	Mean	Range	Mean	Range
Ind. 62-235	3.5	74	1.2	8	3.8	305
Ind. 62-237	3.2	97	1.6	25	3.9	308
Ind. 62-239	2.6	273	2.0	30	4.2	150
Ind. 62-247	3.3	82	1.9	42	3.1	190
Ind. 62-267	2.2	109	1.3	85	1.8	239
Ia. 918-2	3.1	142	1.2	25	3.8	234
Ia. 918-3	3.1	132	1.4	21	4.4	200
Ia. 46-1	4.0	50	1.9	21	8.8	119
Ia. 1317	4.0	158	2.7	33	6.0	183
Ia. 1516	2.3	161	1.0	110	1.1	245
Kans. 2313	2.5	64	1.5	13	2.9	203
Kans. 2314	3.5	51	1.8	78	4.3	153
Kans. 2315	2.9	86	2.4	29	5.5	160
Kans. 2316	4.7	72	2.5	60	2.7	152
Kans. 2311	3.5	63	2.2	41	3.1	155
Minn. 247	2.6	88	0.7	71	1.5	233
Minn. 559	3.6	111	2.2	20	4.1	171
Minn. 589	4.4	68	2.3	26	7.7	213
Minn. 1166	3.3	139	1.9	11	4.2	171
Minn. 1221	3.6	122	1.9	47	4.5	191
Nebr. 661	3.7	70	2.1	24	4.0	58
Nebr. 662	3.2	128	1.7	35	2.9	272
Nebr. 663	4.2	90	1.7	18	2.4	154
Nebr. 664	3.0	53	1.8	22	1.5	207
Nebr. 665	3.1	126	1.6	44	3.0	217
S.D. 1108	3.6	92	1.2	33	4.0	110
S.D. H2-8	3.3	88	1.7	29	3.1	174
S.D. H2-7	4.0	90	1.4	14	4.1	207
S.D. CK 25-1	3.7	81	1.3	23	5.2	179
S.D. CK 27-1	3.2	69	1.1	55	1.5	233
Average	3.4	101	1.7	36	3.8	193

Table 8. Summary of coefficients of variation (percent) of traits measured in the 8 states.

Character	Indiana		Iowa		Kansas		Minn.		Nebr.		S.D.		Calif.		Idaho	
	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967	1966	1967	1967	1968
X_1 Date initial bloom	2			1	1	1			2	1	4	3				
X_2 No. racemes/plant	46	84		25	53	13	42		24	32	53	55				
X_3 Raceme length (mm)	17	11		10	11	11			9	12	12	14				
X_4 Raceme width (mm)	14	11		11	25	7			6	8	12	7				
X_5 No. florets/raceme	19	16		12	18	9	24	16	17	15	22	17				
X_6 Flower color score	10	23	10				27					12				
X_7 No. stems/plant	41	46		15	15	10	26	21	22	18	38	49				
X_8 Stem length (mm)	12	34	15	6	9	8	17	10	8	8	14	82				
X_9 Growth habit score									10	12			21	19		14
X_{10} Vigor score													42			
X_{11} *X. alfalfae* score					15											
X_{12} Wet forage weight (g)				17		11			13	19		54				
X_{13} Dry forage weight (g)	27	40			20						35			30		
X_{14} Fertile O.P. florets (%)		56		21	25	18	38	42	40	45		105				
X_{15} Fertile selfed florets (%)		52							80	50						
X_{16} No. O.P. seeds/pod		17		16	14	10	28	28	23	18	96	85	23	17	12	15
X_{17} No. coils/pod						11		21		16	31	27	28	14	9	20
X_{18} Seed weight (g)/plant		122			65	25	59	53	32	45	200	128	35	39	18	33

Table 9. Clonal means of characters measured in the first year of growth in California and Idaho.

Clone	Number of seeds per pod		Number of coils per pod		Seed weight per plant(g)	
	Calif.	Idaho	Calif.	Idaho	Calif.	Idaho
Ind. 62-235	---	3.2	---	0.8	23.1	36.2
Ind. 62-237	4.4	3.3	1.4	0.8	22.7	35.8
Ind. 62-239	---	3.7	---	2.0	----	34.5
Ind. 62-247	3.6	3.4	1.6	1.9	48.5	42.0
Ind. 62-267	4.4	1.0	1.5	0.9	10.6	8.5
Ia. 918-2	3.0	3.2	1.2	0.8	8.0	14.8
Ia. 918-3	2.6	3.2	0.8	0.8	21.2	36.0
Ia. 46-1	5.3	4.2	1.6	1.6	24.3	45.5
Ia. 1317	4.2	4.2	1.6	2.3	22.2	41.2
Ia. 1516	2.8	2.2	0.5	0.5	1.6	14.5
Kans. 2313	1.6	1.6	1.4	1.4	9.5	18.0
Kans. 2314	4.0	2.9	2.1	2.2	26.5	23.0
Kans. 2315	3.6	2.8	2.2	2.2	31.8	33.5
Kans. 2316	5.9	3.0	2.4	1.9	21.8	33.0
Kans. 2311	4.6	3.2	2.5	2.2	34.6	37.2
Minn. 247	2.0	2.0	0.5	0.5	7.4	21.2
Minn. 559	3.6	3.1	1.6	1.8	16.4	27.0
Minn. 589	3.4	3.3	1.5	2.0	35.7	53.0
Minn. 1166	4.1	3.2	1.8	1.6	23.3	31.5
Minn. 1221	3.0	2.6	1.4	1.6	13.0	23.0
Nebr. 661	4.4	3.2	1.2	2.0	40.0	35.5
Nebr. 662	3.4	2.9	1.5	1.5	32.9	33.8
Nebr. 663	4.1	2.8	1.4	1.4	41.6	34.2
Nebr. 664	2.6	2.4	1.6	1.6	13.1	15.8
Nebr. 665	3.8	2.2	1.4	1.6	32.1	27.2
S.D. 1108	4.7	3.4	1.0	0.9	6.8	22.5
S.D. H2-8	3.2	2.8	1.7	1.7	10.5	20.2
S.D. H2-7	2.2	3.2	0.9	0.9	6.6	27.2
S.D. CK 25-1	3.4	3.8	1.0	0.8	12.2	29.2
S.D. CK 27-1	3.4	3.0	1.0	0.8	5.4	16.5
Average	3.6	3.0	1.4	1.4	19.7	29.1
$W_{.05}$	2.2	1.4	1.0	0.5	18.2	13.6
C.V. (percent)	23	12	28	9	35	18

Table 10. Clonal means of characters measured in the second year of growth in California and Idaho.

Clone	Number of seeds per pod		Number of coils per pod		Seed weight per plant (g)	
	Calif.	Idaho	Calif.	Idaho	Calif.	Idaho
Ind. 62-235	4.6	2.9	1.8	0.7	12.0	25.5
Ind. 62-237	4.4	2.6	0.7	1.0	14.8	26.8
Ind. 62-239	4.0	2.2	1.9	1.7	8.6	14.7
Ind. 62-247	4.0	2.2	1.6	1.8	24.8	20.0
Ind. 62-267	2.9	1.6	1.4	1.1	3.7	9.2
Ia. 918-2	3.7	2.2	0.7	1.0	15.0	11.2
Ia. 918-3	3.4	2.6	0.7	0.8	21.0	22.1
Ia. 46-1	4.2	4.0	1.4	1.6	40.8	34.7
Ia. 1317	6.1	3.3	1.8	2.2	32.7	30.1
Ia. 1516	2.4	2.3	0.5	0.5	7.9	4.4
Kans. 2313	1.9	1.9	1.0	1.5	14.8	14.3
Kans. 2314	3.8	2.6	2.0	2.0	32.1	25.8
Kans. 2315	2.8	2.4	1.6	2.2	46.8	26.5
Kans. 2316	5.3	3.5	1.9	2.1	39.3	27.2
Kans. 2311	3.0	2.5	1.8	2.4	61.9	20.4
Minn. 247	2.4	2.2	0.5	0.5	15.1	13.7
Minn. 559	4.8	2.0	1.8	1.4	40.2	25.8
Minn. 589	4.8	2.6	1.7	2.0	47.8	36.0
Minn. 1166	5.6	2.8	1.4	1.8	18.4	20.6
Minn. 1221	3.4	2.2	1.0	1.2	15.3	17.9
Nebr. 661	4.2	2.8	1.4	1.8	24.8	21.5
Nebr. 662	3.2	2.2	1.3	1.2	32.7	23.4
Nebr. 663	4.3	1.8	1.3	1.3	38.2	13.0
Nebr. 664	3.4	2.0	1.4	1.8	10.8	9.7
Nebr. 665	4.0	2.4	1.5	1.0	16.9	24.2
S.D. 1108	4.0	2.8	0.8	0.8	6.1	12.3
S.D. H2-8	4.2	1.9	1.4	1.3	16.8	12.8
S.D. H2-7	4.2	2.4	1.0	0.8	12.6	15.0
S.D. CK 25-1	4.8	3.8	0.9	1.0	15.0	15.4
S.D. CK 27-1	4.6	2.8	1.0	0.6	5.9	9.4
Average	3.9	2.5	1.3	1.4	23.1	19.5
$w_{.05}$	2.6	1.5	0.7	1.1	23.7	16.9
C.V. (percent)	17	15	14	20	39	33

pendent variables on a regional basis (Table 11). Not all traits were measured in all states in 1966, therefore the mean simple correlations are heterogeneous in that respect. The table shows the number of states with data contributing to each average correlation.

Well over half the values were statistically significant, although the magnitude of many that were significant was too low to be of practical benefit in a breeding program. The coefficient of determination, r^2, expresses the proportion of observed variation in a dependent variable accountable to variation in the independent trait. The same type of relationship holds for the $\bar{r}$ values. Although number of coils per pod showed the highest correlations, Table 11, it is clear that no one independent variable adequately explained the variation in seed yields among the clones when grown in California and Idaho. The relative magnitudes of the average coefficients for California and Idaho were similar for most of the independent traits. Number of racemes per plant and number of coils per pod generated slightly higher mean correlations with California than with Idaho data. Similarly,

Table 11. Average correlation ($\bar{r}$) of traits measured in the North Central Region in 1966 with seed yields in California (1966-67) and Idaho (1967-68).

1966 North Central trait	Number of values averaged	California 1966	California 1967	Idaho 1967	Idaho 1968
X_1 Date initial bloom	4	-.55**	-.59**	-.45**	-.49**
X_2 No. racemes/plant	5	.50**	.41**	.26**	.32**
X_3 Raceme length (mm)	4	.02	.27**	.11	.14
X_4 Raceme width (mm)	4	.13	.25*	.15	.16
X_5 No. florets/raceme	5	.21*	.18*	.20*	.19*
X_6 Flower color score	4	-.58**	-.45**	-.40**	-.52**
X_7 No. stems/plant	5	.42**	.32**	.26**	.30**
X_8 Length of longest stem (mm)	6	.13	.19*	.22**	.30**
X_{11} _X. alfalfae_ score	1	.33	.31	-.04	.06
X_{12} Wet forage weight (g)	1	.05	-.25	-.09	-.04
X_{13} Dry forage weight (g)	3	.10	.04	.06	.15
X_{14} Fertile O.P. florets (%)	4	.08	.21*	.41**	.22*
X_{15} Fertile selfed florets (%)	1	-.06	-.10	.26	.08
X_{16} No. O.P. seeds/pod	5	.21*	.25**	.41**	.36**
X_{17} No. coils/pod	1	.60**	.81**	.57**	.71**
X_{18} Seed weight/plant (g)	4	.44**	.41**	.52**	.41**

* $P < .05$

** $P < .01$

length of longest stem and percentage of fertile open pollinated florets provided somewhat greater correlation for Idaho than for California.

Several traits varied widely in magnitude of r values. This was not formally evaluated by tests of heterogeneity but is readily apparent by inspection of the statistics in Table 12. The ranges of the simple correlations for 1966 are indicated by the most negative and the most positive values computed for those North Central states where character data were obtained. One example of heterogeneity may be observed in the first line of the table. In one North Central state date of initial bloom provided a simple correlation value of -.65** which differs from .00 at a probability level of .01. In another of the four states in which that character was measured the correlation was -.24, a value that, although negative, is not significantly different from .00 when tested at a probability level of .05. Heterogeneity was strongly indicated even though a direct test of the difference between r values of -.65 and -.24 was not conducted. That type of interaction is most evident for length of longest stem. For example, the correlations of that character with second year California seed yield ranged from —.56** to .62**, both significantly different from zero.

Tables 13 and 14 show average correlations and ranges of the simple correlations for the 1967 North Central data, which differ from data in the previous two tables. Average correlations for date of initial bloom were greatly reduced in magnitude in 1967 compared with 1966. That is logical, because the relative degree of development of propagules when transplanted would affect both date of initial bloom and seed production pronouncedly the first year of growth, but the effect would be minimized during the second year, when the nurseries were established. The relationship between date of initial bloom and seed yield reported here was very similar to that observed in the Kentucky and Washington experiments (6). In 1966, the first cutting growth of plants in Indiana and Kansas was clipped and data obtained on the regrowth. Morphological data was obtained on the first growth in all other states in that year but was obtained on the regrowth in the second year of test at all sites. This change in technique probably influenced the results.

The importance of number of stems per plant in 1967 was greatly reduced in contrast to 1966. Characters with $\bar{r}$ values which mostly were significant in both years included: number of florets per raceme, flower color, score, number of open pollinated seeds per pod, number of coils per pod, and seed weight. Raceme width was more strongly associated with seed yield in the second than in the first year of growth. The remaining traits mostly were nonsignificant and did not appreciably shift in magnitude between years.

Correlation ranges for 1967 (Table 14) apparently exceeded the comparable values for 1966 (Table 12). This may in part be due to the inclusion of the computations for the South Dakota tests in which severe winter kill occurred. Correlations for that site in 1967 were based on only 20 of the hardiest clones measured in the test rather than on the 29 measured at the other experiment stations. Cursory examination of the r values (not shown here) supported that interpretation. For six of the 12 independent variables correlated with 1967 Idaho seed weight, the South Dakota coefficients were negative whereas those of the other states measuring the same variables were either all positive or predominantly positive.

Of the 504 simple correlation coefficients computed to measure the association of North Central Region independent variables with California and Idaho seed yields, the greatest magnitude attained was r .81. That was for the 1966 number of coils per pod in South Dakota and 1967 California seed production. The corresponding coefficient of determination is .66, cited to emphasize the concept that no single character included in these experiments correlated with seed yield in the western areas sufficiently to serve satisfactorily for predictive purposes and for selective screening of clones in the North Central Region alfalfa breeding programs.

With few exceptions, magnitudes of the correlations obtained in the experiments agreed with those found by previous investigators as listed in Table 1. Where the attributes were comparable but the correlations seemed markedly different, as for the total plant weight data of Dann and Waldron (7), it should be borne in mind that values in Table 1 are based on independent and dependent variables from the same plants, i.e. from one environment. Data reported in this bulletin relate traits measured on different plants of the same genotype but grown under extremely dissimilar environments.

Correlation of California and Idaho Characters with Seed Yields:

Table 15 shows simple correlations of first year growth traits in California with seed yields in that state and in Idaho. As with the data from the North Central states, many of the coefficients were statistically significant. However, the highest value for association of any two traits was .74 for first year seed yield in California with first year seed yield in Idaho. The corresponding r^2=.55. Thus, only slightly over one-half of the variation in seed yield in a given year and locality could be explained in the same trait in another environment and lesser amounts by associat-

Table 12. Range of correlations (r) of traits measured in the North Central Region in 1966 with seed yields in California and Idaho.

1966 North Central trait	Number of N.C. states	California 1966		California 1967		Idaho 1967		Idaho 1968	
X_1 Date initial bloom	4	-.71**	-.41*	-.63**	-.53**	-.65**	-.24	-.65**	-.33**
X_2 No. racemes/plant	5	.40*	.59**	.24	.55**	.20	.31	.26	.35
X_3 Raceme length (mm)	4	-.30	.26	-.12	.56**	-.18	.23	-.28	.33
X_4 Raceme width (mm)	4	.02	.20	.06	.42*	-.19	.37*	-.07	.26
X_5 No. florets/raceme	5	.01	.42*	.01	.34	-.03	.32	.04	.34
X_6 Flower color score	4	-.61**	-.53**	-.41*	-.48**	-.45*	-.32	-.60**	-.44*
X_7 No. stems/plant	5	.16	.58**	-.09	.51**	.07	.39*	.16	.49**
X_8 Length of longest stem (mm)	6	-.38*	.57**	-.56**	.62**	-.31	.51**	-.37*	.68**
X_{13} Dry forage weight (g)	3	-.21	.28	-.16	.18	-.17	.26	-.14	.35
X_{14} Fertile O.P. florets (%)	4	-.03	.23	.13	.32	.27	.47	.11	.26
X_{16} No. O.P. seeds/pod	5	.14	.34	.21	.32	.35	.51**	.28	.40*
X_{18} Seed weight/plant (g)	4	.33	.60**	.35	.48**	.43*	.61**	.33	.56**

* $P < .05$

** $P < .01$

ed characters. Table 16 includes similar correlations for the first year's data obtained in Idaho. The coefficient of greatest magnitude was generated by the 1967 and 1968 seed yields. Comparing traits common to the two tables, fall growth habit score, number of coils per pod and seed weight measured in Idaho seemed to be more closely related to California production than the converse, i.e., when those traits were measured in California and correlated with Idaho seed yield information. However, number of open pollinated seeds per pod measured in California did generate coefficients with Idaho seed yields that were slightly higher than those for the same character measured in Idaho and associated with California yields.

Tables 17 and 18 show coefficients for second year traits for California and Idaho, respectively. Several exceeded in magnitude the highest values for first year growth data (Tables 15 and 16). The second year information would seem to be equally well suited for understanding variation in western seed yields as first year data. Data for the second year of growth resulted in coefficients that were more consistent for a given character both for the state in which measured and for the other western site. For example, coefficients for number of coils per pod in California (Table 17) ranged from .41* to .67**. Coefficients for the same trait in Idaho (Table 18) were quite similar, ranging from .47** to .74**. Other characters common to both trials displayed similar relationships. However, it must be concluded here, as it was for data from the North Central states, that no one character would be adequate for seed yield predictions in those environments.

Table 13. Average correlation ($\bar{r}$) of traits measured in the North Central Region in 1967 with seed yields in California (1966-67) and Idaho (1967-68).

1967 North Central trait	Number of values averaged	California 1966	California 1967	Idaho 1967	Idaho 1968
X_1 Date initial bloom	4	-.08	-.20*	-.04	-.12
X_2 No. racemes/plant	6	.19*	.04	.14	.27**
X_3 Raceme length (mm)	5	.01	.22*	.04	.16
X_4 Raceme width (mm)	5	.25**	.30**	.24**	.25**
X_5 No florets/raceme	5	.30**	.19*	.20*	.34**
X_6 Flower color score	3	-.54**	-.37**	-.36**	-.50**
X_7 No. stems/plant	6	.00	-.03	.10	.20*
X_8 Length longest stem (mm)	6	.04	-.05	.07	.18*
X_{12} Wet forage weight (g)	4	-.09	-.21	.07	.09
X_{13} Dry forage weight (g)	1	-.03	-.19	-.01	.05
X_{14} Fertile O.P. florets (%)	6	-.05	-.02	.18*	.10
X_{15} Fertile selfed florets (%)	2	.03	-.01	.27	.11
X_{16} No. O.P. seeds/pod	6	.23**	.29**	.45**	.34**
X_{17} No. coils/pod	4	.45**	.60**	.45**	.55**
X_{18} Seed weight/plant (g)	5	.11	.22*	.38**	.40**

* $P < .05$
** $P < .01$

Table 14. Range of correlations (r) of traits measured in the North Central Region in 1967 with seed yields in California and Idaho.

1967 North Central trait	Number of N.C. states	California 1966		California 1967		Idaho 1967		Idaho 1968	
X_1 Date initial bloom	4	-.40*	.29	-.54**	.15	-.23	.18	-.49**	.24
X_2 No. racemes/plant	6	-.16	.48**	-.22	.44*	-.10	.27	-.16	.45*
X_3 Raceme length (mm)	5	-.12	.18	.04	.37*	-.31	.18	-.20	.35
X_4 Raceme width (mm)	5	-.25	.53**	.07	.46**	-.23	.46**	-.30	.52**
X_5 No. florets/raceme	5	.11	.44*	.04	.27	-.05	.35	-.06	.42*
X_6 Flower color score	3	-.54**	-.54**	-.41*	-.27	-.45*	-.21	-.60**	-.30
X_7 No. stems/plant	6	-.22	.25	-.29	.13	-.17	.28	.03	.44*
X_8 Length longest stem (mm)	6	-.23	.46**	-.30	.41*	-.26	.39*	-.21	.66**
X_{12} Wet forage weight (g)	4	-.28	.10	-.31	-.12	-.02	.16	-.03	.21
X_{14} Fertile O.P. florets (%)	6	-.34	.30	-.25	.19	-.03	.45*	-.20	.49**
X_{15} Fertile selfed florets (%)	2	-.09	.14	-.14	.13	.18	.35	.01	.21
X_{16} No. O.P. seeds/pod	6	.05	.39*	-.08	.47**	-.20	.64**	-.45*	.57**
X_{17} No. coils/pod	4	.18	.59**	.34	.71**	.17	.57**	.27	.64**
X_{18} Seed weight/plant (g)	5	-.22	.45*	-.02	.58**	.12	.64**	.06	.70**

* $P < .05$

** $p < .01$

Table 15. Simple correlations (r) among characters measured in California in 1966 and seed yields. Based on entry means.

	Seed Yield Test			
	California		Idaho	
Character	1966	1967	1967	1968
X_9 Fall growth habit score	-.46**	-.25	.08	-.44*
X_{10} Fall vigor score	-.50**	-.28	.08	-.28
X_{19} Early pod set score	.03	-.02	-.50**	-.14
X_{19} Late pod set score	-.10	.04	-.40*	-.09
X_{16} No. O.P. seeds per pod	.45*	.42*	.24	.45*
X_{17} No. coils per pod	.45*	.66**	.20	.49**
X_{18} California seed weight (g)	1.00**	.65**	.74**	.58**

* $P < .05$
** $P < .01$

Table 16. Simple correlations (r) among characters measured in Idaho in 1967 and seed yields. Based on entry means.

	Seed Yield Test			
	California		Idaho	
Character	1966	1967	1967	1968
X_9 Fall growth habit score	-.57**	-.48**	-.79**	-.53**
X_{20} Seed set score	-.51**	-.51**	-.33	-.51**
X_{16} No. O.P. seeds per pod	.29	.37*	.68**	.53**
X_{17} No. coils per pod	.63**	.73**	.47**	.58**
X_{18} Idaho seed weight (g)	.74**	.67**	1.00**	.83**

* $P < .05$

** $P < .01$

Table 17. Simple correlations (r) among characters measured in California in 1967 and seed yields. Based on entry means.

Character	Seed Yield Test			
	California		Idaho	
	1966	1967	1967	1968
X_{9} Growth habit score	-.65**	-.57**	-.39*	-.46*
X_{19} Early pod set score	.21	.03	-.07	.29
X_{19} Late pod set score	-.20	-.34	-.57**	-.28
X_{13} Dry forage weight (g)	.50**	.72**	.33	.42*
X_{16} No. O.P. seeds per pod	.21	.17	.45*	.45*
X_{17} No. coils per pod	.58**	.67**	.41*	.59**
X_{18} California seed weight (g)	.65**	1.00**	.67**	.66**

* $P < .05$
** $P < .01$

Table 18. Simple correlations (r) among characters measured in Idaho in 1968 and seed yields. Based on entry means.

Character	Seed Yield Test			
	California		Idaho	
	1966	1967	1967	1968
X_{9} Fall growth habit score	-.57**	-.50**	-.35	-.53**
X_{20} Seed set score	-.48**	-.38*	-.68**	-.50**
X_{16} No. O.P. seeds per pod	.06	.19	.49**	.50**
X_{17} No. coils per pod	.58**	.74**	.47**	.53**
X_{18} Idaho seed weight (g)	.58**	.66**	.83**	1.00**

* $P < .05$

** $P < .01$

Terminal Multiple Regression Coefficients

Standardized partial regression coefficients from multiple regression equations relating seed yields during the first and second years of growth in California and Idaho to traits measured in those western test sites as well as in the North Central Region are shown in Tables 19 to 26. With k independent variables there are 2^k possible equations to consider in predicting the dependent variable (10-Chapter 6). The most comprehensive experimental approach would be to compute and examine all equations. However, hopefully, not all k potentially important variables need be included to achieve the degree of precision desired in the predictive equation nor do all 2^k equations need be examined. Two basic schemes for searching the 2^k equations are forward and backward stepwise regression. For the experiments described here, the backward procedure was chosen. Initially, the full regression equation was computed. The variable producing the lowest magnitude standardized partial regression coefficient and thus also the least reduction in the residual sum of squares was then deleted from the linear function. The process was repeated until the value of the multiple correlation coefficient, R, dropped below .80. This end point was entirely arbitrary and reflects the authors' opinions that an equation of lesser predictive value is of little utility in a breeding program. The complete initial equations generated for the data in this study can be obtained from the authors.

Because not all independent variables were measured in each North Central state in each year, comparisons of the coefficients and equations are somewhat tenuous. However, certain features appear to be relatively consistent and marked. From Tables 19 and 20 relating first year California and Idaho seed yields to first year independent variables, it is readily apparent that, except for Nebraska and California, more input information was required to predict Idaho than California seed production. The importance of certain independent variables also can be discerned. Flower color score, for example, was negative and of sufficient magnitude to be retained in the equations for all states where measured. Traits with coefficients of plus or minus .50 or above in the equation for at least one North Central state include: number of racemes per plant, flower color score, dry forage weight, percent fertile open pollinated florets and seed weight per plant.

The next two Tables, numbers 21 and 22, show coefficients for first year independent variables and second year seed production in California and Idaho, respectively. For Kansas, Nebraska, and South Dakota less input information was required to predict, at the desired minimal level of precision, the dependent variable in California than in Idaho. For the other states, all independent variable data were used in both equations although some shifts in relative magnitudes of the coefficients can be noted. For example, Indiana flower color score data were about twice as important in predicting Idaho than California seed yield. Percentage of fertile open pollinated florets and seed weight per plant were less valuable in the equations for the second year seed yield predictions than the first year because no coefficient for those traits attained a magnitude of .50. Number of racemes per plant, flower color score and dry forage weight were of equal influence in the two predictive situations. Characters with coefficients less than .50 in magnitude for first year predictions (Tables 19 and 20) but greater than .50 for second year predictions (Tables 21 and 22) were: length of longest stem, *X. alfalfae* score, number of open pollinated seeds per pod and number of coils per pod.

Tables 23 to 26 present coefficients for the four cases in which second year independent variable data were used to generate equations for first and second year seed yields in the Western State's plantings. Examining those four tables, in contrast with the previous four would lead us to conclude that differences between comparable equations predicting California and Idaho yields were fewer when using second year, rather than when using first year, independent variable data. With the exception of the Indiana and South Dakota equation coefficients in Table 26, the four equations for each test site appeared to be relatively homogeneous. Statistical tests for heterogeneity were not conducted.

Judged by the criterion previously used, i.e. a coefficient with an absolute value of .50 or more in any equation, the more important independent variables for predicting first year seed yields were: (a) number of racemes per plant, (b) flower color score, (c) number of stems per plant, (d) wet forage weight, (e) percent fertile selfed florets, (f) number of open pollinated seeds per pod, (g) number of coils per pod, and (h) seed weight per plant. To predict second year seed yields, seed weight no longer met the criterion, but the other seven along with two additional traits—date initial bloom and length of longest stem —did.

In that the independent variables were not mutually independent and in that not all characters were measured in all North Central states each year, it was difficult to compare equations for those states with any great degree of assurance of biological validity. *In toto,* the coefficients from the equations for Nebraska, as given in each table, seem to represent the coefficients for all other equations in that table more consistently than do those from any other state. If that is true, it could be because the Nebraska site is more centrally located with respect to latitude than

Table 19. Summary of standardized partial regression coefficients from terminal equations predicting first year (1966) California seed yield from first year (1966 or 1967) data. Variables measured but not retained are indicated by -----. Terminal equations are those with R approximating .80 as closely as possible.

	Independent Variable	State							
		Ind.	Ia.	Kans.	Minn.	Neb.	S.D.	Calif.	Idaho
X_1	Date initial bloom	-----		-----		-----	-.3441		
X_2	No. racemes per plant	.5960		.5666	-----	-----	-----		
X_3	Raceme length (mm)	-----		-.2122		-----	-----		
X_4	Raceme width (mm)	-.2720		.4282		-----	-----		
X_5	No. florets per raceme	-----		-----	-----	-----	-----		
X_6	Flower color score	-.4909	-.4151		-.5159	-.1542			
X_7	No. stems per plant	-----		.2404	-----	.3133	.3793		
X_8	Length longest stem (mm)	-----	.3426	-----	-----	-----	-----		
X_9	Growth habit score					-.3210		-.3177	
X_{10}	Fall vigor score							-.2817	
X_{11}	_X. alfalfae_ score			.3547					
X_{12}	Wet forage weight (g)					.1372			
X_{13}	Dry forage weight (g)	-----		-.5337			-----		
X_{14}	Fertile O.P. florets (%)	.1970		-----	-----	.2929			
X_{15}	Fertile selfed florets (%)					-----			
X_{16}	No. O. P. seeds per pod	-----		.2454	-----	-----	-----	.2914	-----
X_{17}	No. coils per pod						.2863	.0046	.3709
X_{18}	Seed weight per plant (g)			_____	.5169	.2991	-----		.5639
	R	.7927	.6689	.7993	.7869	.7973	.7956	.6838	.8071
	R^2	.6283	.4475	.6390	.6192	.6357	.6330	.4675	.6513

Table 20. Summary of standardized partial regression coefficients from terminal equations predicting first year (1967) Idaho seed yield from first year (1966 or 1967) data. Variables measured but not retained are indicated by -----. Terminal equations are those with R approximating .80 as closely as possible.

	Independent Variable	State							
		Ind.	Ia.	Kans.	Minn.	Neb.	S.D.	Calif.	Idaho
X_1	Date initial bloom	-.0121		.0482		-----	-.4790		
X_2	No. racemes per plant	-.0938		.3617	.0819	-----	-.2351		
X_3	Raceme length (mm)	.3054		.1108		.1583	-.2116		
X_4	Raceme width (mm)	-.1173		.4176		-----	.2291		
X_5	No. florets per raceme	-.0353		.0110	-.1884	-----	.0760		
X_6	Flower color score	-.4312	-.1687		-.4523	-.2503			
X_7	No. stems per plant	.0322		.4198	-.0408	-----	.0432		
X_8	Length longest stem (mm)	-.2140	.4167	-.0243	.3176	-----	-.0226		
X_9	Growth habit score							-----	
X_{10}	Fall vigor score							.3675	
X_{11}	*X. alfalfae* score			.1909					
X_{12}	Wet forage weight (g)					.3096			
X_{13}	Dry forage weight (g)	.2654		-.4572			-.0812		
X_{14}	Fertile O.P. florets (%)	.3027		.5770	.2980	.4285			
X_{15}	Fertile selfed florets (%)					-----			
X_{16}	No. O.P. seeds per pod	.4914		.3964	.2222	-----	-.1561	-----	.6026
X_{17}	No. coils per pod						.2562	-----	.3185
X_{18}	Seed weight per plant (g)			-.3056	.2915	.5621	.3838	.9442	
	R	.7422	.5292	.7854	.7670	.7999	.7344	.8006	.7483
	R^2	.5509	.2801	.6168	.5882	.6399	.5393	.6410	.5600

Table 21. Summary of standardized partial regression coefficients from terminal equations predicting second year (1967) California seed yield from first year (1966 or 1967) data. Variables measured but not retained are indicated by -----. Terminal equations are those with R approximating .80 as closely as possible.

Independent Variable		State							
		Ind.	Ia.	Kans.	Minn.	Neb.	S.D.	Calif.	Idaho
X_1	Date initial bloom	-.0694		-.3534		-.3435	-----		
X_2	No. racemes per plant	.3299		.3853	.1701	-----	-----		
X_3	Raceme length (mm)	.0039		.2175		-----	-----		
X_4	Raceme width (mm)	-.1095		-----		-----	-----		
X_5	No. florets per raceme	-.1746		-----	.0232	-----	-----		
X_6	Flower color score	-.2294	-.2023		-.5595	-----			
X_7	No. stems per plant	.3446		-----	-.2032	-----	-----		
X_8	Length longest stem (mm)	-.0866	.5073	-----	.2117	-----	-----		
X_9	Growth habit score							-.0225	
X_{10}	Fall vigor score							.1323	
X_{11}	*X. alfalfae* score			.5164					
X_{12}	Wet forage weight (g)								
X_{13}	Dry forage weight (g)	-.0038		-----		-----	-----		
X_{14}	Fertile O. P. florets (%)	.0795		.3236	.1747	-----			
X_{15}	Fertile selfed florets (%)					-----			
X_{16}	No. O.P. seeds per pod	.1800		.1893	.1627	-----	-----	-.0735	-.0853
X_{17}	No. coils per pod						.8075	.5319	.5307
X_{18}	Seed weight per plant (g)			-.1869	.2429	.3523	-----	.4932	.3813
	R	.7783	.6419	.7939	.7229	.8025	.8075	.7797	.8254
	R^2	.6057	.4120	.6302	.5226	.6440	.6521	.6079	.6813

Table 22. Summary of standardized partial regression coefficients from terminal equations predicting second year (1968) Idaho seed yield from first year (1966 or 1967) data. Variables measured but not retained are indicated by -----. Terminal equations are those with R approximating .80 as closely as possible.

	Independent Variable	Ind.	Ia.	Kans.	Minn.	Neb.	S.D.	Calif.	Idaho
X_1	Date initial bloom	-.1170		.2390		-.2909	-.3019		
X_2	No racemes per plant	-.2297		.7661	.1655	-.1535	.0604		
X_3	Raceme length (mm)	.1653		.2636		-----	-.2729		
X_4	Raceme width (mm)	.0914		.2408		-----	.0616		
X_5	No. florets per raceme	-.0926		.1335	-.2851	.3687	.0266		
X_6	Flower color score	-.5064	-.1668		-.5838	-.4542			
X_7	No. stems per plant	.2293		.4804	-.0374	-----	-.2943		
X_8	Length longest stem (mm)	-.2054	.5918	-.0088	.4403	.4200	.5224		
X_9	Growth habit score					-----		-.2189	
X_{10}	Fall vigor score							.2448	
X_{11}	*X. alfalfae* damage score			.1619					
X_{12}	Wet forage weight (g)					-----			
X_{13}	Dry forage weight (g)	.2392		-.7309			-.1368		
X_{14}	Fertile O.P. florets (%)	.0453		.3187	.2310	-----			
X_{15}	Fertile selfed florets (%)					-----			
X_{16}	No. O.P. seeds per pod	.3210		.5674	.2314	-----	-.0739	.1328	-----
X_{17}	No. coils per pod						.3785	.2228	-----
X_{18}	Seed weight per plant (g)			-.4329	.0737	-----	.1020	.4249	.8280
X_{20}	Seed set score								-----
	R	.7774	.6982	.7607	.7401	.7891	.7934	.6647	.8280
	R^2	.6044	.4875	.5786	.5478	.6226	.6295	.4418	.6856

Table 23. Summary of standardized partial regression coefficients from terminal equations predicting first year (1966) California seed yield from second year (1967 or 1968) data. Variables measured but not retained are indicated by -----. Terminal equations are those with R approximating .80 as closely as possible.

Independent Variable		State							
		Ind.	Ia.	Kans.	Minn.	Neb.	S.D.	Calif.	Idaho
X_1	Date initial bloom		.2118	.0559		.3164	-----		
X_2	No. racemes per plant	.2628	.3201	.1699		.5945	-.2619		
X_3	Raceme length (mm)	-----	-.2369	-.1150		-----	-----		
X_4	Raceme width (mm)	-----	.2094	.2258		.4807	-.4940		
X_5	No. florets per raceme	-----	.1004	.3116	-.0383	-----	.5448		
X_6	Flower color score	-.5840				-.2966	-.3814		
X_7	No. stems per plant	-----	.1855	.0616	-.0358	-----	-.8343		
X_8	Length longest stem (mm)	.3592	.4003	-.1556	.1153	-.2354	-----		
X_9	Growth habit score					-.2853		-.4669	-.2470
X_{12}	Wet forage weight (g)		-.8117	.2492		-----	.5781		
X_{13}	Dry forage weight (g)	-----						-.0916	
X_{14}	Fertile O.P. florets (%)	-----	-.0471	.2326	-.0459	-----	-.2484		
X_{15}	Fertile selfed florets (%)	-.6899				-----			
X_{16}	No. O.P. seeds per pod	.4917	.1318	.0807	.0907	-----	-----	.1517	-.1812
X_{17}	No. coils per pod			.5411	-.5174	-----	.2712	.0307	.2720
X_{18}	Seed weight per plant (g)	.5106		-.5770	.1298	-----	-----	.4021	.2261
X_{20}	Seed set score								-.3430
	R	.8071	.6877	.7529	:6060	.7992	.8106	.7563	.7651
	R^2	.6513	.4729	.5668	.3672	.6387	.6570	.5720	.5853

Table 24. Summary of standardized partial regression coefficients from terminal equations predicting first year (1967) Idaho seed yield from second year (1967 or 1968) data. Variables measured but not retained are indicated by -----. Terminal equations are those with R approximating .80 as closely as possible.

Independent Variable		State							
		Ind.	Ia.	Kans.	Minn.	Neb.	S.D.	Calif.	Idaho
X_1	Date initial bloom		.2242	-----		.4085	-----		
X_2	No. racemes per plant	-.4291	.2655	.2582		.4533	-.4337		
X_3	Raceme length (mm)	-----	-.1206	-.1086		-----	-----		
X_4	Raceme width (mm)	-----	.2856	-----		.2230	-----		
X_5	No. florets per raceme	-----	-.2112	.3090	.1936	-----	-----		
X_6	Flower color score	-----				-----	-----		
X_7	No. stems per plant	.5184	.4373	-----	.1605	-----	-.5614		
X_8	Length longest stem (mm)	-----	.4076	-.4290	-.1178	-----	-.4621		
X_9	Growth habit score					-----		-----	-----
X_{12}	Wet forage weight (g)		-.7740	.3985		-----	1.0772		
X_{13}	Dry forage weight (g)	-----						-----	
X_{14}	Fertile O.P. florets(%)	-----	.1890	.4872	.3162	-----	-.2607		
X_{15}	Fertile selfed florets (%)	-----				.2889			
X_{16}	No. O.P. seeds per pod	.6751	.4814	.1812	.6016	.3993	-----	.4464	-----
X_{17}	No. coils per pod			.7512	.1984	-----	.6540	-.3587	-----
X_{18}	Seed weight per plant (g)	-----		-.2684	.0359	.3781	-----	.8704	.8280
X_{20}	Seed set score								-----
	R	.8315	.7322	.7949	.7700	.7936	.8088	.8199	.8280
	R^2	.6914	.5361	.6318	.5929	.6299	.6542	.6723	.6856

Table 25. Summary of standardized partial regression coefficients from terminal equations predicting second year (1967) California seed yield from second year (1967 or 1968) data. Variables measured but not retained are indicated by -----. Terminal equations are those with R approximating .80 as closely as possible.

	Independent Variable	Ind.	Ia.	Kans.	Minn.	Neb.	S.D.	Calif.	Idaho
X_1	Date initial bloom		-.0927	-.2549		-----	-.5712		
X_2	No. racemes per plant	-.4786	.4976	-.1114		.3898	-.9919		
X_3	Raceme length (mm)	-----	.3673	.1960		-----	-----		
X_4	Raceme width (mm)	-----	.3069	-----		-----	-.2165		
X_5	No. florets per raceme	-----	-.2532	-----	.1964	-.2617	-----		
X_6	Flower color score	-----				-----	-.3832		
X_7	No. stems per plant	.6167	.3015	-----	-.0600	-----	-.2704		
X_8	Length longest stem (mm)	-----	-.5219	-.2264	.1462	-----	-----		
X_9	Growth habit score					-.3827		-----	-----
X_{12}	Wet forage weight (g)		-.3769	-----		-----	.6882		
X_{13}	Dry forage weight (g)	-----						.5104	
X_{14}	Fertile O.P. florets (%)	-----	-.1219	-----	.3565	.2921	-----		
X_{15}	Fertile selfed florets (%)	-.5239				-----			
X_{16}	No. O.P. seeds per pod	.6244	.4713	-----	.2215	.2075	-----	-----	-----
X_{17}	No. coils per pod			.6530	.2747	.2556	.6475	.4360	.5432
X_{18}	Seed weight per plant (g)	-----		-----	.3170	-----	-----		.3527
X_{20}	Seed set score								-----
	R	.8486	.6891	.7993	,6510	.8024	.7973	.8111	.8059
	R^2	.7201	.4748	.6389	.4238	.6439	.6357	.6578	.6495

Table 26. Summary of standardized partial regression coefficients from terminal equations predicting second year (1968) Idaho seed yield from second year (1967 or 1968) data. Variables measured but not retained are indicated by -----. Terminal equations are those with R approximating .80 as closely as possible.

	Independent Variable	State							
		Ind.	Ia.	Kans	Minn.	Neb.	S.D.	Calif.	Idaho
X_1	Date initial bloom		.2777	.1768		-----	-----		
X_2	No. racemes per plant	-.3575	.3443	.3334		-----	-----		
X_3	Raceme length (mm)	.2392	.1348	-----		-----	-----		
X_4	Raceme width (mm)	.0169	.3760	.2144		-----	-----		
X_5	No. florets per raceme	-.2914	-.3878	-----	.1892	-----	-----		
X_6	Flower color score	-.2823				-.5066	-----		
X_7	No. stems per plant	.4198	.5007	.2990	.2879	-----	-----		
X_8	Length longest stem (mm)	.2816	.0540	-.3521	-.0482	-----	-----		
X_9	Growth habit score					-----		-.2070	-.4580
X_{12}	Wet forage weight (g)		-.4344	-----		.3532	.2900		
X_{13}	Dry forage weight (g)	.2107						-.0402	
X_{14}	Fertile O.P. florets (%)	-.0201	-.0716	-----	.2951	-----	-----		
X_{15}	Fertile selfed florets (%)	-.3721				-----			
X_{16}	No. O.P. seeds per pod	.5239	.5572	.2141	.4872	-----	-.4060	.3783	.5006
X_{17}	No. coils per pod			.5186	.0880	-----	.6977	.0123	.1785
X_{18}	Seed weight per plant (g)	.3176		-----	.1101	.4523	-----	.5079	
	R	.7441	.7422	.8033	.7530	.8002	.8279	.7694	.7651
	R^2	.5537	.5509	.6453	.5670	.6404	.6854	.5920	.5853

are the other five sites. Hence, clones well adapted to environments north and south of Nebraska could be moderately well adapted to the Nebraska environment. In contrast, clones well suited to the more northerly locations could be quite unsuited to the more southerly test sites included in the experiments, and conversely those suited to southern locations or originating from southern programs, would not fit the environments of the northern locations.

The Nebraska data were efficient predictors in that relatively few independent variables were required to be retained with $R=.80$. To some degree that was true of all North Central information. Table 27 summarizes the R^2 values and the numbers of independent variables in both the initial and terminal equations for each predictive situation. For example, line 1 of Table 27 shows that 11 independent variables were measured in Indiana in 1966 and functionally related to 1966 California seed yield. Utilizing all information available, the initial equation explained 69% ($R^2=.69$) of the variation in seed yield among the 29 clones when grown in California. Because independent variables were mutually interdependent, it was possible to delete seven of them by backward stepwise regression and still explain 63% ($R^2=.63$) of the variability. Future research of the type reported here should stress attempts to discover other attributes that, measured in the North Central Region, will have high predictive value but will not correlate with traits used in this investigation.

Influence of M. falcate Clones.

Three clones, Ia. 1516, Minn. 247, and S. D. 1108 possessed many morphological traits typical of *M. falcata*. Flower color scores of the three were equivalent to very light or moderately dark yellow in contrast to the purple and blue hues of ***M. sativa*** **or** ***M. sativa*** X *M. falcata* clones more commonly included in North Central Region breeding programs. The extent to which the inclusion of this *M. falcata* germplasm in the experiments influenced the predictive equations was evaluated by a critical examination of the 1966 Nebraska data.

Clone Ind. 62-239 was deleted from all equations because it failed to set seed in California in 1966. Four initial analyses were computed for data on the other 29 clones. Then clones Ia. 1516, Minn. 247, and S. D. 1108 were deleted and equations were computed for the set of 26. The orders of entry of the 14 independent variables measured in Nebraska and used in eight multiple linear equations are shown in Table 28. An order of entry rank of one meant that variation in that independent variable explained a greater proportion of variation in the dependent variable than did any of the remaining 13 predictors. A rank of 14 meant that the trait was the least valuable in explaining corresponding California or Idaho clonal seed yields.

Comparisons of the rankings between the two equations for each of the Western State seed production data sets revealed few major discrepancies in orders. Most of those occurred in the 1967 California seed yield predictions. Rank correlation coefficients computed for corresponding pairs of equations are included in Table 28. All were highly significant, indicating excellent agreement between the 26- and the 29-clone sets in ranking the 14 Nebraska traits according to predictive value. It was concluded that analyses based on all clones were representative for North Central Region alfalfa breeding stocks.

Table 27. Summary of R^2 values for initial and terminal equations predicting seed yields.

Source of independent variable data		Year and Location of Seed Yield Predicted							
		California				Idaho			
		1966		1967		1967		1968	
Year	State	Initial	Terminal	Initial	Terminal	Initial	Terminal	Initial	Terminal
1966	Indiana	.69(11)[1/]	.63(4)	.61(11)	.61(11)	.55(11)	.55(11)	.60(11)	.60(11)
	Iowa	.45(2)	.45(2)	.41(2)	.41(2)	.28(2)	.28(2)	.49(2)	.49(2)
	Kansas	.66(12)	.64(7)	.65(12)	.62(7)	.62(12)	.62(12)	.58(12)	.58(12)
	Minnesota	.71(8)	.62(2)	.52(8)	.52(8)	.59(8)	.59(8)	.55(8)	.55(8)
	Nebraska	.67(14)	.64(6)	.79(13)	.64(3)	.69(13)	.64(5)	.75(14)	.62(5)
	South Dakota	.74(11)	.63(3)	.81(11)	.65(1)	.54(11)	.54(11)	.63(11)	.63(11)
	California	.47(4)	.47(4)	.61(5)	.61(5)	.65(5)	.64(2)	.44(5)	.44(5)
1967	Idaho	.72(3)	.65(2)	.68(3)	.68(3)	.56(2)	.56(2)	.73(3)	.69(1)
	Indiana	.73(12)	.65(6)	.81(12)	.72(4)	.84(12)	.69(3)	.55(12)	.55(12)
	Iowa	.47(10)	.47(10)	.47(10)	.47(10)	.54(10)	.54(10)	.55(10)	.55(10)
	Kansas	.57(12)	.57(12)	.70(12)	.64(5)	.66(12)	.63(9)	.67(12)	.65(7)
	Minnesota	.37(7)	.37(7)	.42(7)	.42(7)	.59(7)	.59(7)	.56(7)	.56(7)
	Nebraska	.74(15)	.64(6)	.70(15)	.64(6)	.82(15)	.63(6)	.88(15)	.64(3)
	South Dakota	.70(13)	.66(8)	.65(13)	.64(7)	.82(13)	.65(6)	.89(13)	.69(3)
	California	.57(5)		.66(4)	.66(2)	.71(5)	.67(3)	.59(5)	.59(5)
1968	Idaho	.59(5)	.59(5)	.67(5)	.65(2)	.79(5)	.69(1)	.59(3)	.59(3)

1/ Numbers in parentheses are the number of independent variables included in that equation.

Table 28. Orders of entry of the 1966 Nebraska independent variables determined by reductions in variation of California and Idaho seed yields for sets of 26 and 29 clones.

Independent Variable		California				Idaho			
		1966 1/		1967		1967		1968	
		26	29	26	29	26	29	26	29
X_1	Date initial bloom	10	14	1	6	12	13	9	9
X_2	No. racemes per plant	1	1	14	11	6	5	10	10
X_3	Raceme length (mm)	13	10	6	3	9	8	13	12
X_4	Raceme width (mm)	12	13	12	10	7	7	8	6
X_5	No. florets per raceme	9	9	7	5	8	10	3	3
X_6	Flower color score	3	3	8	8	14	14	1	1
X_7	No. stems per plant	11	11	11	13	11	11	11	13
X_8	Length longest stem (mm)	6	8	13	14	13	12	2	2
X_9	Growth habit score	7	4	5	1	3	3	4	4
X_{12}	Wet forage weight (g)	8	7	10	9	5	4	12	11
X_{14}	Fertile O.P. florets (%)	2	2	2	4	4	2	7	8
X_{15}	Fertile selfed florets (%)	4	6	3	7	10	9	5	5
X_{16}	No. O.P. seeds per pod	14	12	9	12	1	6	14	14
X_{18}	Seed weight per plant (g)	5	5	4	2	2	1	6	7
	R	.76**	.79**	.91**	.91**	.88**	.88**	.88**	.87**
	R^2	.58	.63	.82	.82	.76	.77	.78	.76
	r_s 2/	.89**		.77**		.91**		.97**	

1/Clone Ind. 62-239 omitted from all equations because it failed to produce seed in California in 1966. Clones Ia. 1516, Minn. 247, and S.D. 1108 deleted to form the set of 26 clones.

2/ r_s is the rank correlation coefficient.

** $P < .01$

LITERATURE CITED

1. Bolton, J. L. and J. R. Fryer, 1937. Inter-plant variations in certain seed-setting processes in alfalfa. Sci. Agric. 18:148-160.
2. Boren, Roger B., Ralph L. Parker, and Edgar L. Sorensen. 1962. Foraging behavior of honeybees on selected alfalfa clones. Crop Sci. 2: 185-188.
3. Busbice, Thad H. and C. P. Wilsie. 1966. Heritability of 'ease of tripping' in alfalfa and its possible relation to seed setting. Crop Sci. 6:377-378.
4. Clement, William M., Jr. 1965. Flower color, a factor in attractiveness of alfalfa clones for honey bees. Crop Sci. 5:267-268.
5. Cooper, D. C., R. A. Brink, and H. R. Albrecht. 1937. Embryo mortality in relation to seed formation in alfalfa *(Medicago sativa)*. Amer. J. Bot. 24:203-213.
6. Dade, Eugene, Norman L. Taylor, and C. S. Garrison. 1967. Differential seed production of alfalfa clones at two diverse locations. Crop Sci. 7:663-664.
7. Dann, Berhard and L. R. Waldron. 1933. A statistical study of certain characters of the alfalfa plant concerned with seed production. J. Amer. Soc. Agron. 25:184-190.
8. Dobrenz, A. K., and M. A. Massengale. 1966. Change in carbohydrates in alfalfa (*Medicago sativa* L.) roots during the period of floral initiation and seed development. Crop Sci. 6:604-607.
9. Dovrat, A., D. Levanon and Miriam Waldman. 1966. Effect of plant spacing on carbohydrates in roots and on components of seed yield in alfalfa (*Medicago sativa* L.). Crop Sci. 9:33-34.
10. Draper, N. R. and H. Smith. 1968. Applied Regression Analysis. John Wiley & Sons, Inc. New York. 407 p.
11. Feltner, K. C. and R. G. Sackett. 1964. Effect of 2,4,5-trichlorophenoxyacetic acid on quantity and composition of nectar and seed production in alfalfa (*Medicago sativa* L.). Crop Sci. 4:560-562.
12. Fryer, J. R. 1939. The maternal-line selection method of breeding for increased seed-setting in alfalfa. Sci. Agri. 20:131-139.
13. Grandfield, C. O. 1945. Alfalfa seed production as affected by organic reserves, air temperature, humidity, and soil moisture. J. Agric. Res. 70:123-132.
14. Hanson, Clarence H. 1959. Clonal vs. seedling establishment as a factor affecting yield of alfalfa. Agron. J. 51:58.
15. Heinrichs, D. H. 1965. Selection for higher seed yield in alfalfa. Can. J. Plant Sci. 45:177-183.
16. Hurst, R. L. and M. W. Pedersen. 1964. Alfalfa seed production as a function of genetic and environmental characteristics. Advancing Frontiers in Plant Sci. 8:41-54.
17. Kauffeld, Norbert M., Edgar L. Sorensen, and Reginald H. Painter, 1969. Stability of attractiveness of alfalfa clones to honeybees under varying locations, seasons, and years. Crop Sci. 9:225-228.
18. Kernkamp, M. F. and G. A. Hemerick. 1953. The relation of *Aschochyta imperfecta* to alfalfa seed production in Minnesota. Phytopath 43:378-383.
19. Liang, George H. and William A. Riedl. 1964. Agronomic traits influencing forage and seed yield in alfalfa. Crop Sci. 4:394-396.
20. Medler, J. T. 1958. Seed production and certain growth characteristics of insect-free alfalfa. J. Econ. Ent. 51:729-733.
21. Melton, Bill. 1969. Comparative seed and forage yield in crosses of selected alfalfa clones as compared to polycross progeny. Crop Sci. 9:253-255.

22. Miller, M. K. and M. H. Schonhorst. 1968. Flowering and fertility of alfalfa as influenced by inbreeding and state of plant growth. Crop Sci. 8:522-524.

23. Pankiw, P. 1967. Studies of honeybee preference and behavior on normal and standardless alfalfa flowers. J. Apicult. Res. 6:105-112.

24. Pedersen, Marion W. and Frank E. Todd. 1949. Selection and tripping in alfalfa clones by nectar collecting honey bees. Agron. J. 41:247-249.

25. Pedersen, M. W. 1953. Seed production in alfalfa as related to nectar production and honey bee visitation. Bot. Gaz. 115:129-138.

26. Pedersen, M. W. 1953. Preliminary studies on breeding alfalfa for seed production in Utah. Agron. J. 45:179-182.

27. Pedersen, M. W. 1953. Environmental factors affecting nectar secretion and seed production in alfalfa. Agron. J. 45:359-361.

28. Pedersen, M. W., H. L. Petersen, G. E. Bohart, and M. D. Levin. 1956. A comparison of the effect of complete and partial cross pollination of alfalfa on pod sets, seeds per pod, and pod and seed weight. Agron. J. 48:177-180.

29. Pedersen, M. W., G. E. Bohart, M. D. Levin, W. P. Nye, S. A. Taylor, and J. L. Haddock. 1959. Cultural practices for alfalfa seed production. Bulletin 408. Utah A.E.S. pp. 31.

30. Pedersen, M. W. and W. P. Nye. 1962. Alfalfa seed production studies. Bulletin 436. Utah A.E.S. pp. 22.

31. Pedersen, M. W. 1967. Cross-pollination studies involving three purple-flowered alfalfas, one white-flowered line, and two pollinator species. Crop Sci. 7:59-62.

32. Pedersen, M. W. 1968. An interaction between pollinators and reciprocals in an alfalfa cross. Crop Sci. 8:107-109.

33. Rice, J. S. and Elmer Gray. 1969. General, specific, maternal, and reciprocal effects on seed set in a diallel cross among eleven clones from Buffalo alfalfa. Crop Sci. 9:307-308.

34. Rotar, P. P. and W. R. Kehr. 1963. Relationship of self-fertility, pollen abortion, and micronuclei number to agronomic performance in alfalfa. Res. Bulletin 209. Nebraska A.E.S. pp. 24.

35. Sayers, E. R. and R. P. Murphy. 1966. Seed set in alfalfa as related to pollen tube growth, fertilization frequency and post-fertilization ovule abortion. Crop Sci. 6:365-368.

36. Sexsmith, John T. and James R. Fryer. 1943. Studies relating to fertility in alfalfa (*Medicago sativa* L.) I. Pollen viability as affected by seasonal age of the plant. Sci. Agric. 24:95-100.

37. Tysdal, H. M. 1946. Influence of tripping, soil moisture, plant spacing and lodging on alfalfa seed production. Agron. J. 38:515-535.

38. Vansell, George H. and Frank E. Todd. 1946. Alfalfa tripping by insects. Agron. J. 38:470-488.

39. Wilsie, C. P. 1958. Effect of inbreeding on fertility and vigor of alfalfa. Agron. J. 50:182-185.