The effect of strain and cultural treatment upon the seed production of birdsfoot trefoil, and a preliminary study of pod shatter-proofing
by Howard Rhoads

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Agronomy
Montana State University

Abstract:
Ten strains of birdsfoot trefoil were evaluated for seed and forage yielding ability when cut for seed. No significant difference existed. Differential ability to withstand late spring freezes was observed between strains and susceptibility ratings assigned.

The effect of several cultural treatments upon seed yields and forage yields when cut for seed was studied using Empire strain. Width of row and rate of seeding did not affect seed yields; significantly better yields were obtained where 2,4,D was employed to control weeds.

In this test, row spacing did not affect forage yield; best forage yields were obtained where the seeding rate was 6 lbs. per acre. Hay yields were superior, where 2,4,D was applied, over yields where early mowing was used to control weeds.

The extreme variability of rate of maturation of pods was substantiated. A relationship between length of pods and percentage shattering was apparently lacking; color of pods and shattering percentage was significantly correlated. The relationship between age of pods, percentage shattering, color of pods, weight of seeds, and germination percentages of seeds of different ages was studied.

A preliminary evaluation of the possibilities for shatterproofing by chemical methods was made. Para-chlorophenoxyacetic acid was apparently effective and the reaction was quite stable for all concentrations used and on all dates of harvest. Some concentrations of 2,4,D, methylcellulose gum, naphthaleneacetic acid, and p-chloro-phenoxyacetic acid appear to be more effective than other concentrations. Certain concentrations of 2,4,5,T, and 2,4,D may result in increased shattering. Interaction evaluations indicate that certain chemicals react differently on different dates of harvest following spraying and that some concentrations of various chemicals react differently on different harvest dates.

THE EFFECT OF STRAIN AND CULTURAL TREATMENT UPON THE SEED PRODUCTION OF BIRDSFOOT TREFOIL, AND A PRELIMINARY STUDY OF POD SHATTER-PROOFING

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ABSTRACT

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The effect of several cultural treatments upon seed yields and forage yields when cut for seed was studied using Empire strain. Width of row and rate of seeding did not affect seed yields; significantly better yields were obtained where 2,4,D was employed to control weeds. In this test, row spacing did not affect forage yield; best forage yields were obtained where the seeding rate was 6 lbs. per acre. Hay yields were superior, where 2,4,D was applied, over yields where early mowing was used to control weeds.

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INTRODUCTION

It has long been thought that a long-lived, high quality pasture legume would be desirable for certain areas in Montana and elsewhere.

Although observations and experimental trials have indicated that adapted strains of Lotus corniculatus L., commonly known as birdsfoot trefoil, possess qualities which would be desirable in such a legume, their use has thus far been limited due to the high price of seed as compared with other pasture legumes. This high price of seed can largely be attributed to scarcity, which is the result of poor seed yields. The most serious cause of poor seed yield is probably the high loss of seed due to shattering and this loss has been observed to be as much as 61 per cent at Bozeman. It has been observed that failure to set seed in quantity may also be a factor causing poor seed yields.

In view of the fact that harvested yields of birdsfoot trefoil seed are often low, it was decided to test the effect of strain and several cultural treatments upon the seed yield of birdsfoot trefoil at Bozeman in 1951. At the same time it was postulated that plant growth regulators applied at harvest time might somehow delay the shattering of pods thereby making it possible to harvest a larger proportion of the seed crop. It was further suggested that viable seed might be obtained by harvesting before the pods were sufficiently mature to permit shattering. A preliminary study of stage of maturity as a means of prevention of shattering and of chemical pod shatter-proofing was made during 1951.

REVIEW OF LITERATURE

MacDonald (7)[1] has indicated that birdsfoot trefoil is a cross-pollinated crop and that the most important pollination agents are probably bees. Pellet (10, 11) cites evidence that honey bees are good pollinators since good seed set was shown where frequent bee visitation was observed.

According to several writers (4, 7, 8, 14), the earliest reports concerning birdsfoot trefoil have listed the high degree of shattering as one of the most important limitations to its extensive use as a forage legume. McKee and Schoth (8) report that uneven ripening complicates the harvest problem but that cutting at night may serve to keep shattering losses to a minimum. The problem is further complicated by the fact that the plants are green when the pods are fully ripe. They believe that the average yield of clean seed in the U. S. is about 100 lbs. per acre.

MacDonald (7) presents data to show that as maturity advances shattering percentage increases, and weight per 1000 seeds increases until a certain stage of maturity is reached, as does also percentage of mature plump seed and percentage of live seed. He based his maturity rating upon color of pod and other morphological differences. Willson (15) found that for red clover there was essentially no difference in shattering due to maturity of blossoms. Yield was apparently

[1] Figures in parenthesis refer to "Literature Cited", page .

associated with weather conditions at the time of flowering. Seed that matured late in the season was lighter in weight than seed that matured early.

MacDonald (7) has studied the effect of strain upon seed yields in New York. The data indicates that there may be differences due to strains, but the results are inconclusive since several years results were not consistent.

The effect of cultural treatment upon seed set has been studied. The results indicate that the effects may not be the same for different areas. MacDonald (7) presents data that indicates that in New York a nurse crop, sparse top growth, and taking the first crop for seed may be desirable practices while lodging is considered undesirable. He does later state, however, that sometimes better yields are obtained by clipping or grazing before the end of May and taking the second growth for seed (6). Schwanbom and Fröier (12), in a review of Scandinavian literature, found that rate of seeding, row spacing, use or non-use of a nurse crop, clipping treatments, and weed control by cultivation have all been cited as factors affecting seed yields. Kolar (5) found that a high fertility level and luxuriant top growth adversely affects seed yields in Czechoslovakia.

No reports of attempts to shatter-proof seed pods by chemical methods have been found in the literature.

Growth regulators have been found to be useful in the prevention of pre-harvest fruit drop (1,2,3,9). Gardner, Marth, and Batjer (2,3), using various plant hormones, established that preharvest drop of apples could be controlled. Mitchell and Marth (9) have estimated that 75,000 acres of apples are sprayed annually in all major apple producing regions of the U.S. as insurance against damage or loss by premature fruit fall. In general, dilute concentrations of 5-10 ppm were thought to be most effective for most chemicals. Avery, Johnson, Addoms, and Thompson (1) found, in an extensive literature review, that various hormones have been used to prevent fruit drop of apples, pears, cherries, plums, apricots, oranges, peaches, and grapes. Holly and a few other ornamental evergreens have been treated to delay leaf and berry fall for several days. It is thought that the hormone treatments delay the formation of the abscission layer, thus facilitating a longer harvest period in addition to prevention of preharvest fruit drop.

It is not known if the suture line of legume pods and the abscission layer of leaf and fruit petioles are closely related. Since a legume pod is considered to be a modified leaf, there may or may not be a relationship between the two.

MATERIALS AND METHODS

Ten strains of birdsfoot trefoil were planted in the spring of 1950, using three replications and a randomized block design. It was originally intended to make an evaluation of the strains for forage yielding ability, hence they were planted in 6" rows at a 12 lb. per acre rate. In 1951, it was decided to evaluate the strains for both seed and forage yielding ability, with primary emphasis being given to the effect of strain upon seed yielding ability.

Some plants in the strain trial had commenced blooming by May 26. On May 29, 30, 31 and June 1 freezing temperatures occurred and the relative ability to withstand late spring frosts was recorded for the strains. One irrigation was applied. The first growth was cut for seed on September 4. Shattering had commenced in all plots at the time of cutting and the mowing was done in the evening after dew had started to form. All plots were mowed the same day.

To study the effects of several cultural treatments upon seed yields, a planting of Empire strain of birdsfoot trefoil was made in the spring of 1950. The cultural treatments studied were: 1. Rate of seeding (one, three, and six pounds per acre); 2. Width of row spacing (six, twelve, and eighteen inches); 3. Early mowing vs early spraying with 2,4,D for control of weeds; and 4. Interactions between the above.

The clipping treatment was made on June 1. The 2,4,D treatment consisted of 1/4 lb. of methyl amine of 2,4,D per acre applied as a spray on June 5. The weather conditions prior to spraying were cold, windy, and dry. It commenced raining the evening of the date of spraying. No check was employed for either the clipping treatment or the 2,4,D treatment. Notes upon the effects of 2,4,D upon the trefoil crop and various weeds present were obtained on several dates following the spray treatment.

Drought conditions prevailed throughout the summer and although one irrigation was applied it is doubtful if seed yield was increased since ample water to facilitate an irrigation could not be obtained until very late in the growing season.

Both seed and forage yield data were obtained upon harvesting for seed on September 15. Harvest operations were done in the evening after dew had started to form. Shattering had commenced in all plots prior to mowing. The plot size harvested was 5' x 18'.

The relationship between age of pods, percentage shattering, color of pods, weight of seeds, and germination percentages of seeds was studied. Beginning June 18 and at successive three day intervals twenty clusters of flowers were tagged. For sake of uniformity in selection of clusters at a similar stage of maturity an arbitrary stage of growth was established. At this stage, one flower in the cluster had completely opened but was apparently not yet pollinated as indicated by turgidity of flower parts.

At each tagging date, several clusters from previous tagging dates were examined to determine the degree of uniformity of maturation. All clusters were harvested on August 11, at which time shattering had commenced on some of the clusters tagged June 18.

Since many pods were broken off during the period of study, it was necessary to group the data obtained for each date of tagging into three samples for comparison purposes between age of pods and percentage shattering exhibited. It was arbitrarily decided that each sample within each date should consist of not less than ten pods. Shattering percentages were determined by dividing number of pods shattered by total number observed and converting to percentage. The observations were made after the harvested pods had been dried at room temperature for several weeks.

A preliminary study to evaluate the possibility of shatter-proofing pods by chemical methods was conducted. On August 31, about forty clusters of pods were sprayed with three different concentrations of each of the following chemicals: 1. Sure-set (Dow Chemical Co.); 2. Stem-tite (Dow); 3. Methocel (Dow); 4. Fruitone (American Chemical and Paint Co.); 5. 2,4,5 - Trichlorophenoxypropionic acid (American Chemical and Paint); 6. Methyl amine of 2,4,D; 7. 2,4,5 Trichloro-phenoxyacetic acid.

The spray was applied directly to the cluster of pods. Each cluster was given one complete stroke of spray solution from a small spray pump similar to a windex sprayer. No attempt was made to select for color differences of pods. The only criterion for selection was apparent maturity as indicated by the sound of seeds rattling upon shaking.

On September 2 and three successive two day intervals ten clusters of pods that had been sprayed with each concentration of each chemical were harvested along with an unsprayed check sample of ten clusters. After harvest the clusters were placed in bags in a warm room (75°F. ± 20°F.) for thirteen days, after which the percentage of shattered pods was recorded. The shattering percentage of the first eight clusters of pods observed for each concentration of each chemical was statistically compared with the shattering percentage of a check harvested the same day and a statistical comparison of all concentrations of all chemicals on all dates was made.

Skoog, et al (13) have listed the relative activity ratings of several growth regulating substances, based upon the ability of the substances to regulate growth of slit pea stems. They found that equal quantitative concentrations of different growth regulators would not produce the same growth reaction. From this viewpoint, the concentrations used in the present study may not have been relative between the different chemicals. The companies furnishing the chemicals also recommended that they be tried at certain concentrations and on the basis of these recommendations, a concentration thought to be relatively high, medium, and low was prepared.

The chemical components of the brand name products listed above and used in the study, and the concentrations used are as follows:

1. Sure-set is a 0.16% solution of p-Chlorophenoxyacetic acid.

   The concentrations used were:

Sure-set	I	=	50 c.c. per liter.
"	II	=	25 c.c. per liter.
"	III	=	5 c.c. per liter.

2. Stem-tite is a 1.75% Sodium 1-Naphthaleneacetate powder. The concentrations used were:

Stem-tite	I	=	29 grams per liter.
"	II	=	0.58 grams per liter.
"	III	=	0.145 grams per liter.

3. Methocel is a 15 cps, powdered, water soluble gum known as methyl cellulose. The concentrations used were:

Methocel	I	=	5 grams per liter.
"	II	=	2.5 grams per liter.
"	III	=	0.1 grams per liter.

4. Fruitone is a powder containing naphthaleneacetic acid. The concentrations used were:

Fruitone	I	=	29 grams per liter.
"	II	=	0.58 grams per liter.
"	III	=	0.145 grams per liter.

5. The concentrations of 2, 4, 5 trichlorophenoxypropionic acid (powdered form) used were:

2,4,5 TP	I	=	0.5 gram per liter.
"	II	=	0.02 gram per liter.
"	III	=	0.005 gram per liter.

6. The concentrations of 2,4, dichlorophenoxyacetic acid used were:

2,4,D	I	=	100 ppm.
"	II	=	20 ppm.
"	III	=	5 ppm.

7. The concentrations of 2, 4, 5 trichlorophenoxyacetic acid were:

2, 4, 5 T	I	=	100 ppm.
"	II	=	20 ppm.
"	III	=	5 ppm.

All of the above chemicals were applied as a spray and mixed with water. With the exception of Methocel, a detergent was used as a spreader.

EXPERIMENTAL RESULTS

Strain Trial Results

The seed yields of ten strains of birdsfoot trefoil at Bozeman during 1951 are reported in Table I. The analysis of variance of the seed yields of the strains is given in Table II. No significant differences due to strains or replications exist.

Table I. Seed yields of birdsfoot trefoil strains in pounds per acre, at Bozeman, 1951.

Strain	Yield in Pounds per Acre in Replication I	II	III	Average Pounds per Acre
F.P.I. 187101	158	89	128	125
Cascade	276	59	153	163
Granger	242	301	209	251
New York E. 494	150	180	178	166
New York E. 491	94	122	187	134
Montana Early	214	220	112	182
Empire, N.Y.	231	103	334	223
Narrow leaf, N.Y.	271	210	142	208
Viking	155	177	192	174
Italy Imported	125	448	172	248

Table II. Analysis of variance of seed yields of birdsfoot trefoil strains at Bozeman, 1951.

Variation due to	d.f.	M.S.
Replications	2	372
Strains	9	5,736
Error	18	7,715
Total	29	

The hay and straw yields of the ten strains of birdsfoot trefoil when cut for seed are reported in Table III. The analysis of variance of the hay and straw yields is given in Table IV. A highly significant difference due to replications is shown.

Table III. Hay and straw yields of birdsfoot trefoil strains when cut for seed at Bozeman in 1951. Yield is reported in tons per acre at 12% H_2O.

Strain	Yield in Tons per Acre in Replication I	II	III	Average Tons per Acre
F.P.I. 187101	3.64	1.88	4.23	3.25
Cascade	3.55	0.77	2.64	3.32
Granger	3.35	3.13	3.40	3.29
New York E. 494	3.36	2.93	3.43	3.24
New York E. 491	2.02	2.12	2.93	2.36
Montana Early	3.99	3.75	3.65	3.79
Empire, N.Y.	3.22	0.93	4.20	2.78
Narrow leaf, N.Y.	4.13	2.83	2.58	3.18
Viking	2.73	2.67	2.95	2.78
Italy Imported	3.81	2.94	3.82	3.52

Table IV. Analysis of variance of hay and straw yields of birdsfoot trefoil strains when cut for seed at Bozeman, 1951.

Variation due to	d.f.	M.S.
Replications	2	3.2439 **
Strains	9	0.6928
Error	18	0.4928
Total	29	

**F-value is significant at 1% level.

The relative ability of the various strains to withstand late spring freezing temperatures was recorded. Arbitrary susceptibility rating standards were assigned. The susceptibility rating reported is the average of three replications. The observed ratings are reported in Table V.

Table V. Susceptibility rating of ten birdsfoot trefoil strains to late spring freezing temperatures.

Strain	Susceptibility Rating
F.P.I. 187101	3.67
Cascade	4.33
Granger	3.67
New York E. 494	4.33
New York E. 491	5.00
Montana Early	1.00
Empire, N.Y.	3.33
Narrowleaf, N.Y.	1.00
Viking	3.00
Italy Imported	1.67

A rating of:
1 - denotes resistance
3 - denotes medium susceptibility
5 - denotes susceptibility

Cultural Treatment Results

The average seed yields of Empire strain birdsfoot trefoil showing row spacing used, seeding rate, and weed control method are given in Table VI. The average seed yields for each of the weed control treatments are given in Table VII.

Table VI. Average seed yields in pounds per acre of three replications of birdsfoot trefoil when several cultural treatments were employed.

Row Spacing in inches	Seeding Rate in lb/A.	Yield when weed control method was Mowing	2,4,D
6"	6	13.51	78.96
6"	3	19.20	47.66
6"	1	19.57	36.99
12"	6	17.50	80.59
12"	3	14.41	24.61
12"	1	17.64	71.35
18"	6	11.41	48.73
18"	3	22.76	39.44
18"	1	8.89	51.93

Table VII. Average seed yield in pounds per acre when using two weed control treatments.

	Weed Control Method Used Mowing	2,4,D
Average Yield in lb./A.	16.08	53.36

The analysis of variance of the seed yields of Empire strain birdsfoot trefoil when grown under several cultural treatments is shown in Table VIII. Using error term (d), a significant difference due to rows and a highly significant difference due to weed control method or treatment is shown to exist.

Table VIII. Analysis of variance of seed yields of birdsfoot trefoil when several cultural treatments were employed.

Variation due to	d.f.	M.S.
Rows	2	115.825
Columns	2	157.745
Row-Spacing	2	287.035
Error (a)	2	63.920
Total	8	
Rows	2	115.825
Columns	2	15,335.880
Seeding rates	2	1,252.425
Error (b)	2	1,914.785
Total	8	
Rates x Spacing	4	379.760
Error (c)	8	1,350.946
Total	26	
Treatments	1	18,810.240**
Rows	2	115.825*
Error (d)	2	48.060
Total	5	
Treatments x Spacing	2	65.890
Treatments x Rates	2	1,078.550
Treatments x Rates x Spacing	4	1,634.130
Error (e)	16	6,281.968
Total	53	

* F-value is significant at 5% level.
** F-value is significant at 1% level.

The average hay yields of Empire strain birdsfoot trefoil when cut for seed, showing row spacing used, seeding rate, and weed control method are given in Table IX. The average hay yield for each of the weed control treatments is given in Table X. The average hay yield for each of the seeding rates, irrespective of weed control treatment and row spacing, is reported in Table XI. The analysis of variance of the hay yields of Empire strain grown under several cultural treatments and cut for seed is given in Table XII. A highly significant difference due to rows and a significant difference due to weed control treatments is shown for error (d), while a significant difference due to rows and due to rates is shown for error (c).

Table IX. Average hay yields in tons per acre of three replications of birdsfoot trefoil when cut for seed and several cultural treatments were employed.

Row Spacing in inches	Seeding Rate in lb./A.	Yield when weed control method was Mowing	2,4,D
6"	6	1.16	1.44
6"	3	0.93	1.06
6"	1	0.81	0.71
12"	6	1.08	1.63
12"	3	0.97	0.89
12"	1	0.77	1.05
18"	6	0.70	1.40
18"	3	1.20	0.93
18"	1	0.66	0.84

Table X. Average hay yields of all plots within each weed control treatment.

	Weed Control Method	
	Mowing	2,4,D
Ave. Yield in Tons/A	0.92	1.15

Table XI. Average hay yields of all plots within each rate of seeding.

	Seeding Rate in lb. per Acre		
	6	3	1
Ave. Yield in Tons/A	1.23	0.99	0.80

Table XII. Analysis of variance of hay yields of Empire strain when cut for seed and several cultural treatments were employed.

Variation due to	d.f.	M.S.
Rows	2	1.145
Columns	2	0.050
Row-Spacing	2	0.055
Error (a)	2	0.235
Total	8	
Rows	2	1.145*
Columns	2	0.400
Seeding Rates	2	0.830*
Error (b)	2	0.025
Total	8	
Rates x Spacing	4	0.103
Error (c)	8	0.386
Total	26	
Treatments	1	0.510*
Rows	2	1.145**
Error (d)	2	0.010
Total	5	
Treatments x Spacing	2	0.030
Treatments x Rates	2	0.290
Treatments x Rates x Spacing	4	0.400
Error (e)	16	0.530
Total	53	

* F - value is significant at 5% level
** F - value is significant at 1% level

The germination percentage of 100 seeds harvested from the area where 2,4,D was applied to control weeds and of 100 seeds from an unsprayed area is reported in Table XIII.

Table XIII. Germination percentages of 100 seeds harvested from the area sprayed with 2,4,D and of 100 seeds from an unsprayed area after 13 days in the germinator.

Treatment	%Dead Seed	%Normal Sprouts	%Hard Seeds	%Live Seed
2,4,D	13	14	73	87
None	8	13	79	92

Notes taken several days following spraying revealed that while some curling and twisting of stems was in evidence, very few trefoil plants were injured severely by the 2,4,D application. Growth was retarded for several days but recovery was evident after ten days. Very few weeds were actually killed by the spray application although varying degrees of damage was noted for the weeds and crop mixtures present.

Results of Stage of Maturity Study

Field notes revealed that maturity does not progress at a uniform rate for flowers of the same age. The range of variability of color and length of pods of different ages at harvest is given in Table XIV. The analysis of variance of the number of pods attaining apparent maturity from tagging date until harvest date is shown in Table XV. No significant differences between tagging dates are shown.

Table XIV. Range of variability of color and length of pods of different ages when harvested.

	Age of Pods in Days						
	55	52	49	46	43	40	37
Color Range*	Gr-Dk Br.	Gr-Br.	Gr-Dk Br.	Gr-Br.	Gr-Br.	Gr-Br.	Gr-Br
Length Range-mm.	15-31	15-35	10-30	5-36	10-31	10-31	5-30

*Color abbreviations: Gr.= Green, Br.= Brown, Dk.= dark, Lt.= light

Table XV. Analysis of variance of number of pods attaining maturity by harvest date from seven flowering dates. Based on first 15 clusters harvested per flowering date.

Variation due to	d.f.	M.S.
Between Dates	6	2.263
Within Dates	98	3.193
Total	104	

The shattering percentages of birdsfoot trefoil pod samples for seven different ages of pods are given in Table XVI. The samples upon which the percentages are based consist of no less than 10 pods. The analysis of variance of shattering percentages of pods of different ages is given in Table XVII. A significant difference between ages is shown.

Table XVI. Shattering percentages of pods of different ages.

	Age of pods in days						
Sample No.	55	52	49	46	43	40	37
1	58	85	62	88	75	76	29
2	100	75	86	69	75	75	50
3	55	92	50	81	81	84	44
Ave. %.	71	84	66	79	77	78	41

Table XVII. Analysis of variance of shattering percentages of pods of different ages.

Variation due to	d.f.	M.S.
Between Ages	6	628.20*
Within Ages	14	184.11
Total	20	

*F - value significant at 5% level.

The shattering percentages of pods and average length of pods in six shattering classes are reported in Table XVIII. A relationship between shattering percentage and length of pods is apparently lacking.

Table XVIII. Shattering percentages of pods and average length of pods in six shattering classes.

No. Clusters Observed	Shattering Class	Ave. Length of Pods
50	100%	22 mm.
2	76-100	23
9	51-75	21
8	26-50	20
2	1-25	24
30	0	20

The shattering percentages of pods in seven color classes are given in Table XIX. A highly significant positive correlation between color classes and average shattering percentages was shown to exist. The coefficient of correlation was 0.46313 for 100 degrees of freedom.

The regression of Y (average shattering percentage) on X (coded color class) is shown in Figure 1.

Table XIX. Shattering percentages of pods in seven color classes.

No. Clusters Observed	Color 2/ Class	Ave. % Shattering
25	1	24.00
4	2	68.75
25	3	59.33
2	4	100.00
41	5	78.59
1	6	100.00
4	7	75.00

2/ Color Class Code:

1 = Green
2 = Green to greenish brown
3 = Greenish brown to light brown
4 = Light brown
5 = Brown
6 = Brown to dark brown
7 = Dark brown

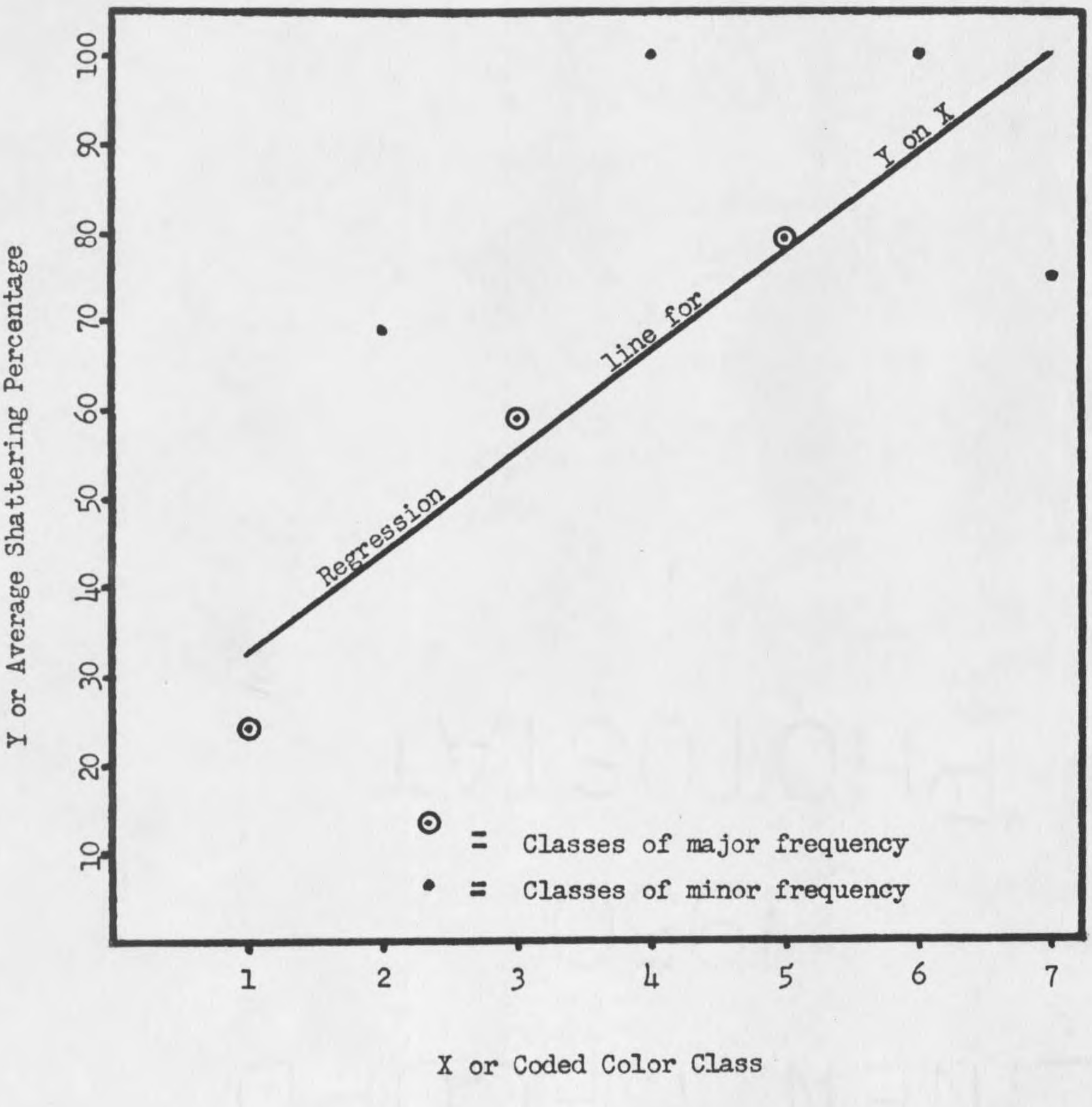

Figure 1. The regression of average shattering percentage (Y) on coded color class (X). $Y = \bar{Y} + [(11.58)(X-3.48)]$.

The germination percentages and weight per 100 seeds of seed from pods of different ages is given in Table XX.

Table XX. Weight per 100 seeds and germination percentages of seed from pods of different ages.

Age in Days	Wt/100 seeds in Mg.	% Dead Seed	% Normal Sprouts	% Hard Seed	% Live Seed
55	100	7	8	85	93
52	95	19	10	71	81
49	95	33	8	59	67
46	100	29	9	62	71
43	95	20	9	71	80
40	95	19	11	70	81
37	85	15	3	82	85
32	62	42	0	58	58

Chemical Shatter-proofing Results

The overall analysis of variance of shattering percentages present when seven chemical sprays were used as possible shatter-proofing agents is given in Table XXI. Highly significant differences due to chemicals, concentrations of chemicals, days elapsing between spraying and harvesting, and for interactions are shown.

Table XXI. Analysis of variance of shattering percentages for the various chemicals used in the shatter-proofing study.

Variation due to	d.f.	M.S.	F-value
Chemicals	6	1,468.94	5.310**
Concentrations	2	1,853.97	6.702**
Harvest Dates	3	2,337.63	8.450**
Chem. x Dates	18	1,270.57	4.593**
Conc. x Dates	6	1,902.97	6.879**
Chem. x Conc.	12	22,660.61	81.917**
Chem. x Conc. x Dates	36	3,433.71	12.413**
Error	588	276.63	
Total	671		

**Significant at 1% level