POLLINATION STUDY ON SOYBEANS USING HONEYBEES AND LEAFCUTTER BEES

By

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CHAPTER I

INTRODUCTION

The soybean (Glycine max (L.) Merr.) is one of the most important agronomic crops in the United States today. Its oil and protein are valuable for human and animal consumption as well as for industrial uses. In these times of ever expanding urban development, farm acreage is becoming limited. Greater yields per unit area are increasingly more important to today's farmer.

Soybeans exhibit a high degree of flower and pod abortion with the greatest percentage occurring within the first seven days after flowering. Generally, the first and last few flowers to bloom are those which abort most readily (26). The cause is not definitely known. If abortion could be inhibited, yields should increase.

Flower abortion may be due, in part, to a failure in pollination. Soybeans are highly self-fertilized with usually less than 1% natural crossing. If successful self-pollination could be assured or if cross-pollination could be induced, the abortion might be decreased. This might be accomplished through the use of bees. The success could then be measured by observing differences in yield. Decreasing the percentage of flower and pod abortion should increase seed yield. The objectives of this study were (1) to determine if a failure in pollination could be a factor in the spontaneous abortion of soybean flowers and

pods, (2) to determine which type of bee would reduce abortion to a greater extent, and (3) to determine differences in yield and other agronomic characters of the three varieties tested.

CHAPTER II

LITERATURE REVIEW

Soybean (Glycine max (L.) Merr.) is the most important oilseed crop in the United States. In 1969, over 41 million acres of farmland were planted in soybeans (24). Acreage, especially in the southern states, has been steadily increasing in soybean production over the past two decades, although soybeans are adapted for production from southern Canada to the Gulf of Mexico and other areas of the world (7).

Nationwide effort is being made to increase soybean productivity. This is the major goal in most research programs (6). According to Erickson (11) one method may be through the use of honeybees to improve pollination. He obtained higher yields from two out of three varieties using honeybees as pollinators.

Several researchers (3, 16, 30, 31, 33, 34) have found that many of the flowers of a soybean plant abscise without forming pods. Abortion of reproductive plant parts can be quite extensive with some cultivars ranging from 30 to 85% of the total flowers and pods produced. They conclude that if shedding could be decreased, yields might increase. Hansen and Shibles (16) agree there is a great yield potential in soybeans. In their opinion, the factors involved in flower and pod loss require much more attention.

Research to determine the factors involved in flower and pod abscission was conducted by van Shaik and Probst (30). They found that

a considerable degree of genetic control is involved but that environmental conditions played the biggest role (31). They discovered that the percent abortion increased with increases in temperature and photoperiod. A lack of pollen was not found to be a factor. Struckmeyer (29) agrees that the environment has a definite effect on the favorable development of blossoms and pods.

Extensive research involving histological observations of flowers and pods has been conducted by Kato et al. (20, 21, 22) and Abernethy et al. (1). Abortion was found to occur at any stage of development from bud initiation to cotyledon development. Not only did entire ovaries abort but single ovules as well, without loss of the whole pod. In two varieties tested Abernethy et al. (1) found only 7.0 to 8.9% of the aborted flowers were due to failure in fertilization. They concluded that a failure in pollination played a minimal role in the flower and pod abscission of soybeans.

Sionit and Kramer (28) studied the response of 'Ransom' and 'Bragg' cultivars to water stress. They observed flower shedding when plants were stressed during the flowering period. Brevedan et al. (3) also noticed relatively high rates of abortion in soybeans and found that increasing the nitrogen supply during flowering increased soybean yield.

Environmental relations to soybean flowering were examined by Hardman (17). He discovered that pod set was much higher in flowers produced early in the season than in those formed later. He attributed this to cooler temperatures and lower radiation levels during that time.

Wiebold et al. (34) studied the abscission levels of 11 determinate soybean varieties, including 'Forrest' and 'Essex.' They found that the production of young pods was lowest in Essex and that Forrest produced

the lowest number of pods at the time of harvest. Maturity groups V - VIII had the highest rates of abortion and they surmised that there were genotypic differences among cultivars. Hansen and Shibles (16) and Breveden (3) studied a few indeterminate types and, in contrast, found a greater percentage of flowers in the lower canopy regions. This was possibly due to a greater penetration of sunlight allowed by this type of growth habit.

Early studies by Wiebold et al. (33) concerned carbohydrate deficits in soybeans as related to pod shed. He concluded that a low carbohydrate supply lowered the levels of indolacetic acid in the pods, resulting in their abscission.

It is well known that soybeans are highly self-fertile. Natural hybridization occurred less than 1% of the time, depending on the variety, region and season (8, 15, 32, 35). This opens the door for increasing cross-pollination, possibly through insects.

Free (14) stated that the most important pollinating insects are solitary bees, bumblebees and honeybees. The female alfalfa leafcutter bee, a type of solitary bee, is a very efficient pollinator of alfalfa. The honeybee is particularly useful because it will visit and pollinate many of the economically important plant species. According to Free (14), a common method for studying insect pollination on a particular crop is by enclosing an area in screen cages with the insect pollinator. He suggests that comparisons can be made when three treatments are involved. They include (a) caged with bees, (b) caged without bees, and (c) not caged where the crop is visited by all natural pollinators.

Sheppard et al. (27) discussed two roles the honeybee plays in soybean production. They may increase yield by pollinating the flowers,

and they may serve in the production of hybrid soybean seed. Self-pollination cannot occur in cases when the timing of pollen release and stigma receptivity is not synchronized or if the pollen viability is short or impaired. Bees could therefore introduce pollen and increase seed set.

A study conducted on alfalfa by Butler (5) revealed that 80 leaf-cutter bees (Megachile concinna Smith) were as effective as a small colony of honeybees. They are excellent pollinators of alfalfa, however they benefit few other plants (24). Abrams (2) noted soybeans were frequently visited by honeybees but seldom by the leafcutter bees. He also reported higher yields and a greater percent of cross-pollination when using honeybees.

Erickson (12) reported increases of 5-20% in yields of soybeans with bees both in caged trials and in the open field. However, he did find some negative effect on yield due to the cages and suggested they should not be used in southern climates.

The attractiveness of soybeans to bees is questionable. According to Free (14) the amount of nectar secreted by soybeans can be quite small and its attractiveness to bees can vary from year to year. Honeybees have been reported collecting pollen and nectar from soybeans (4, 13, 19). However, Milum (25) obtained no differences in yield between soybeans grown in cages with bees and those without cages. He concluded there was little nectar available to attract the bees. Cutler (8) surrounded soybean plots with cheesecloth, which was open at the top, and placed honeybee hives nearby. Unlike Milum, he observed many bees working the soybean flowers. Caged soybean studies conducted by Caviness (7) disclosed 7.7% cross-pollination induced by honeybees with

none occurring in cages without bees.

Some varieties were highly attractive to bees, but this may fluctuate with region, time of flowering and environmental conditions (10, 11, 23). Jaycox (18) concluded that selecting strains of bees which are more attracted to the desired variety will produce more successful yields.

CHAPTER III

MATERIALS AND METHODS

This study was conducted at the Agronomy Research Station, Perkins, Oklahoma during the 1980 growing season. The soil was a Teller loam, of the Udic Arginsolls family.

Three varieties commonly grown in Oklahoma were chosen for this study. They included Forrest, Essex, and 'Crawford.' Forrest and Essex are classified in maturity group V and have determinate growth habits. Crawford is classified as an indeterminate type belonging in group IV.

Honeybees (Apis mellifera) and leafcutter bees (Megachile pacifica) were chosen as the pollinators. One hive was placed in each cage of the honeybee treatment. Brood was added to the hives two weeks later. To sustain the hives, fresh water was provided along with a supplementary feeding program which began one month after the start of the experiment. The feeding material consisted of a 1:1 solution of sugar and water. This continued until harvest. Leafcutter cocoons or cells were introduced to the cages designated for that treatment as the adults were beginning to emerge. Shelters were provided in the upper southwest corners of the cages for the bees to nest. The shaded nesting blocks consisted of pieces of wood with small holes drilled almost through their thickness. Leafcutter bees chew off small oblong pieces of leaves to construct new cells along the length of the holes. This results in a degree of leaf damage to the soybeans although no appreciable damage

was observed.

Design and Field Layout

The experimental design was a randomized complete block with a split plot arrangement of treatments and four replications. The main plots included caged plots with no bees added, caged honeybees, caged leafcutter bees, and check plots (no cage, no bees). The subplots consisted of two rows of each soybean variety.

Two rows of each variety plus two rows of guard at each end were planted in plots measuring 12 x 20 feet. Planting occurred on June 3, 1980. Seed was planted at a rate of 6 - 7 seed per foot row. Rows were 12 inches apart. Irrigation was provided when necessary. For the first few applications, water was applied using garden sprinklers and later, when the plants were taller, by flooding. Cages were built over the designated plots on July 9 and 10 when flowering began. Bees were introduced to the specified cages several days later. The cages were left on the field until the soybeans were almost ready to harvest. Harvest occurred on October 28, 1980. The rows were shortened to eight feet in length and harvested by hand. Each variety within a whole plot was harvested and threshed individually.

Characters Investigated

Data were collected on each cultivar within a whole plot. The following characters were measured and recorded.

Height

Plant height was measured in centimeters as the distance from the

soil surface to the tip of the main stem. Several plants in each sub-plot were randomly selected, measured, and the average recorded.

Shattering

Pod shattering was estimated on a percent basis.

Lodging

Plant lodging was evaluated on a scale from one to five; where one represented no lodging and five represented severe lodging.

Yield

Seed yield was measured in grams per plot and number of seed per plot and converted to kilograms/hectare.

Weight of 100 Seed

The weight of 100 seed was recorded in grams.

Plants Per Plot

The number of plants of each variety were counted.

Seed Per Plant

The number of seed per plant was calculated by the following formula:

$$\frac{\frac{\text{gms/plot}}{\text{gms/100 sd}} \times 100}{\text{number of plants per plot}}$$

Seed Per Pod

The number of seed per pod was obtained from an average of ten pods.

Pods Per Plant

The number of pods per plant was calculated by the following formula:

$$\frac{\text{number of seed per plant}}{\text{number of seed per pod}}$$

Statistical Analysis

Analyses were made by the Statistical Analysis System at the Oklahoma State University Computer Center. An analysis of variance was conducted for each character to determine significant differences among whole plot treatments and among subplot treatments. LSD was used to compare the means of the varieties for each character.

CHAPTER IV

RESULTS AND DISCUSSION

The results of the analyses of variance for the characters tested are presented in Table I (see Appendix for Tables). This table indicates no significant differences due to treatments for yield and its components. The treatments with bees did not significantly increase yield over the treatments without bees. Height, at the 0.05 level of probability, is the only character which showed significant difference due to treatment. Significant difference due to variety is seen at the 0.01 level of probability for height, lodging, kilograms per hectare, grams per plot, plants per plot, seed per pod, and 100 seed weight. Lodging at the 0.01 level of probability, is the only character which had significant difference due to treatment by variety interaction.

Seed Yield

The analysis of variance for seed yield and its components indicate no significant difference due to treatment (Table I). The means for yield in grams per plot are compared in Table II and those for yield in kilograms per hectare are presented in Table III. Using LSD at the 0.05 level of probability for comparing treatment means reveals no significant difference between any caged treatment when compared to the check. The bees did not increase yield; therefore flower and pod abortion was not reduced. The mean yield of the honeybee treatment is greater than

that of the leafcutter bees. However, the mean yield of the caged plots with no bees is even greater. No conclusion can therefore be made as to which bee reduces abortion to a greater extent. Honeybees have been shown to increase yield on soybeans (12), however in southern climates, cages had a negative effect. The 1980 growing season was unusually hot and dry. More positive results might have been obtained had there been normal weather conditions during that summer. The analysis of variance for grams per plot and kilograms per hectare indicate a significant difference due to variety at the 0.01 level of probability (Table I). The means for yield in grams per plot and kilograms per hectare are compared in Tables II and III, respectively. Forrest yielded significantly higher than did Essex when comparing variety means averaged over treatments using LSD at the 0.05 level of probability. Likewise, the yield of Essex is significantly greater than that of Crawford. These observations were not unexpected since Crawford, a Group IV variety, is not as well adapted to Central Oklahoma as are Forrest and Essex (Group V varieties).

Height

The analysis of variance for height indicates a significant difference due to treatment at the 0.05 level of probability (Table I). A comparison of means for height of the three cultivars and four treatments may be observed in Table IV. The LSD at the 0.05 level of probability (11.83 cm) indicates a significant increase in height of each caged treatment over the check. No significant difference can be seen between the means of any two caged treatments indicating that the presence of the cages was the factor affecting height rather than the

bees. The cages may alter the environment by reducing wind movement, increasing temperature and humidity, and providing some shade. These conditions stimulate vegetative growth producing taller plants than those grown without cages.

The analysis of variance for height due to variety is significant at the 0.01 level of probability (Table I). Table IV provides the means of each variety averaged over the four treatments. The LSD at the 0.05 level of probability is 7.59 cm. Crawford is significantly taller than Forrest or Essex. Forrest is intermediate in height and Essex is the shortest variety. These data are in agreement with previous observations of these varieties grown in Oklahoma.

Lodging

The analysis of variance for lodging indicates a significant difference due to treatment by variety interaction at the 0.01 level of probability (Table I). This indicates there is differential response of the varieties to the treatments. The means for this character are presented in Table V. The LSD is used to make comparisons between two varieties within the same treatment and between two treatments on the same variety. The values for these are 0.68 and 1.28 respectively. Significant difference is observed between Forrest and each of the other two varieties within each caged treatment. Forrest lodged significantly less than Essex or Crawford. However, significant difference is observed between Essex and Crawford in any treatment except the caged honeybees. In the check treatment, no significant difference is seen between any two varieties. When comparing two treatments on the same variety, no significant difference is observed between any two

treatments on Forrest. On Essex, significant difference is found only between the caged leafcutter bees and the check. On Crawford each caged treatment is significantly different from the check while no difference is observed between any two caged treatments. In general, Forrest lodged significantly less than either Essex or Crawford when grown in the presence of cages but no difference is observed between any two varieties when cages are not present. The cages also significantly increased the rate of lodging on Crawford over uncaged conditions. The differences observed are apparently due to the environmental changes induced by the cages in relation to the susceptibilities of the varieties to lodge.

Shattering

The analysis of variance for shattering indicates no significant difference due to treatment, variety or treatment by variety interaction (Table I). Table VI lists the means for shattering of the three varieties and four treatments. The LSD at the 0.05 level of probability is 4.98 for comparing treatment means and 6.21 for comparing variety means. Shattering was not decreased by any treatment when compared to the check and no variety shattered differently from any other.

Plants Per Plot

The analysis of variance for plants per plot indicates no significant difference due to treatment (Table I). A comparison of means for plants per plot is presented in Table VII. The means indicate a reduction in plant number in the presence of cages. However, using LSD at the 0.05 level of probability for comparing treatment means averaged

over varieties, no difference is observed between any caged treatment and the check.

The analysis of variance due to variety indicates a significant difference at the 0.01 level of probability (Table I). Significant differences are observed using LSD at the 0.05 level of probability for comparing variety means averaged over treatments (Table VII). Forrest has a significantly higher number of plants per plot than Essex, which is significantly higher than Crawford. The planting rates for each variety were identical, therefore this might be explained by differences in germination and seedling vigor. These data correlate with those concerning seed yield (Tables II and III). Forrest had the highest number of plants per plot and yielded the highest while Crawford was the lowest in both of these characters.

Seed Per Pod

The analysis of variance for number of seed per pod indicates no significant difference due to treatment (Table I). Table VIII lists the means for number of seed per pod of the three varieties and four treatments. The LSD for comparing treatment means is 0.18 seed per pod. Neither caged bee treatment is different from the check and no significant difference is observed between any two caged treatments. Neither type of bee, therefore increased the number of seed per pod.

The analysis of variance indicates a significant difference due to variety at the 0.01 level of probability (Table I). The LSD at the 0.05 level of probability is used to compare variety means averaged over treatments (Table VIII). Crawford has a significantly higher number of seed per pod than either Forrest or Essex. However, no significant

difference is observed between these two varieties. This does not correlate with the data concerning yield because Crawford is the lowest yielding variety. Forrest would be expected to have the highest number of seed per pod because it yielded the highest.

Pods Per Plant

The analysis of variance for pods per plant indicates no significant difference due to treatment, variety, or treatment by variety interaction (Table I). The means for this character are listed in Table IX. The number of pods per plant is not significantly increased by the presence of cages or bees and no significant difference is observed between varieties. Any increase due to bee treatments would have indicated a reduction in pod abortion. No favorable conclusion can be made from these results.

100 Seed Weight

The analysis of variance for the weight of 100 seed indicates no significant difference due to treatments (Table I). The means for this character are compared in Table X. The LSD value at the 0.05 level of probability is 0.5 grams for comparing treatment means averaged over varieties. No significant difference is observed between any two treatment means. Neither type of bee had any effect on seed weight.

The analysis of variance due to variety indicates a significant difference at the 0.01 level of probability (Table I). Using the LSD for comparing variety means (Table X), significant differences are observed between Crawford and Forrest and Between Crawford and Essex. No significant difference is observed between Forrest and Essex.

Crawford has a greater seed weight than either Forrest or Essex. This data, along with that concerning the number of seed per pod (Table VIII) does not correlate with the data concerning yield (Tables II and III). Crawford yielded the lowest of the three varieties yet it has the highest number of seed per pod and the highest seed weight. The low yield might be explained by its low number of plants per plot (Table VII).

CHAPTER V

SUMMARY AND CONCLUSIONS

Soybeans (Glycine max (L.) Merr.), which are highly self-fertile, have a natural tendency to abort a certain amount of flowers and pods. This study was conducted to determine if a failure in pollination could be a factor. Honeybees (Apis melifera) and leafcutter bees (Megachile pacifica) were used to insure that either self-pollination occurred or that cross-pollination was induced. It was believed that if the abortion could be reduced, increases in yield would be observed. The objectives of this study were (1) to determine if a failure in pollination could be a factor in the spontaneous abortion of soybean flowers and pods, (2) to determine which type of bee would reduce abortion to a greater extent, and (3) to determine differences in yield and other agronomic characters of the three varieties tested.

The experiment was conducted during the 1980 growing season at the Agronomy Research Station at Perkins, Oklahoma. The experimental design was a randomized complete block with a split plot arrangement of treatments having four replications. Three soybean varieties, Forrest, Essex and Crawford, were grown in two-row plots collectively in whole plots measuring 12 x 20 feet with two border rows at each end. The treatments consisted of caged whole plots with no bees added, caged honeybees, caged leafcutter bees, and a check (no cage, no bees). The characters investigated were height, shattering, lodging, seed yield, 100 seed

weight, plants per plot, seed per plant, seed per pod, and pods per plant. Analyses of variance were calculated for all the traits and LSD at the 0.05 level of probability was used to compare means.

Analyses of variance for variety indicate significant differences at the 0.01 level of probability for height, lodging, kilograms per hectare, grams per plot, plants per plot, seed per pod, and 100 seed weight. However, no significant differences are observed due to treatment for any characters investigated except height at the 0.05 level of probability. This difference in height is believed to be due to environmental conditions favorable to vegetative growth produced inside the cages. Lodging, significant at the 0.01 level of probability, is the only character showing significant difference due to treatment by variety interaction. This is believed to be caused by the increased height of the plants inside the cages as well as the varied susceptibilities of the cultivars. Yield, the character most important in the outcome of this study, shows no significant difference due to treatment. The highest yields observed for cultivars Forrest and Crawford occurred with the treatment having cages but no bees. However, when using LSD at the 0.05 level of probability they were not significantly different from their checks. The highest yield of Essex occurred under the honey bee treatment, although, none of the caged treatments were significantly different when compared to the check.

Since treatments did not affect yield and its components, it is impossible to conclude that the presence of bees on soybeans reduced the instance of flower and pod abortion. Using LSD at the 0.05 level of probability, there is no significant difference between the yields of the honeybee treatments and those of the leafcutter bee treatments for

each cultivar. It is, therefore, also impossible to determine which type of bee would reduce abortion to a greater extent. Highest yields were observed on cultivar Forrest, with Essex and Crawford following respectively. This is seen in the treatments without bees as well as those with bees. The analysis of variance for yield shows significant difference at the 0.01 level of probability due to variety. Differences in yield and other agronomic characters of the three cultivars can therefore be determined. Forrest yielded the highest with Crawford and Essex following respectively. Yield is substantiated by data concerning height, lodging, and the number of plants per plot. Forrest is intermediate in height, lodged the least and has the highest number of plants per plot. No significant differences are observed for shattering and the number of pods per plant. However, Crawford has the highest number of seed per pod as well as the greatest seed weight. Forrest and Essex are not significantly different for these characters. Generally, Forrest is superior in yield while Crawford is superior in some of the components of yield. Essex is intermediate in all characters.

The 1980 growing season was unusually hot and dry. Perhaps these conditions masked any yield differences which might have resulted due to treatments. Further study is necessary to determine the role that failure in pollination might have on the flower and pod abortion of soybeans.

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APPENDIX

TABLE I

MEAN SQUARES FOR HEIGHT, SHATTERING, LODGING, KILOGRAMS PER HECTARE, GRAMS PER PLOT, PLANTS PER PLOT, SEED PER POD, PODS PER PLANT, AND 100 SEED WEIGHT FOR THREE VARIETIES AND FOUR TREATMENTS

Source of Variation	d.f.	Height	Shattering	Lodging	Kg/Ha	Gms/Plot	Plants/ Plot	Seed/ Pod	Pods/ Plant	100 Sd. Wt.
Rep.	3	311.23	46.13	1.13	2949970	260720	267.17	0.03	128.7	2.62
Trt.	3	647.81*	100.08	4.69	194584	17197	397.17	0.10	513.9	0.07
Error (a)	9	164.06	29.11	1.58	714921	63185	288.00	0.03	417.6	0.34
Var.	2	5115.47**	27.77	9.75**	4117811**	363935**	1664.08**	0.24**	311.5	38.54**
Trt. x Var.	6	171.74	12.74	1.00**	141692	12522	57.58	0.06	165.9	0.78
Error (b)	24	108.32	72.39	0.21	190539	16840	92.46	0.03	205.7	0.74
CV(Error a)		19.86	104.86	46.78	24.42	24.42	29.99	7.59	40.56	3.98
CV(Error b)		16.14	165.37	17.26	12.60	12.60	16.99	6.77	28.46	5.81

*Significant at the 0.05 level of probability.
**Significant at the 0.01 level of probability.

TABLE II

COMPARISON OF MEANS FOR GRAMS PER PLOT OF THREE VARIETIES AND FOUR TREATMENTS GROWN AT PERKINS, OKLAHOMA IN 1980

Treatment	Forrest	Essex	Crawford	Mean
Cage, No Bees	1257	1020	942	1077
Caged Honeybees	1130	1114	866	1036
Caged Leafcutter Bees	1186	1022	852	1020
No Cage, No Bees	1083	1066	807	985
Mean	1164	1058	867	1030

LSD .05 = 232 grams for comparing treatment means averaged over varieties

LSD .05 = 95 grams for comparing variety means averaged over treatments

TABLE III

COMPARISON OF MEANS FOR YIELD (KG/HA) OF THREE VARIETIES AND FOUR TREATMENTS GROWN AT PERKINS, OKLAHOMA IN 1980

Treatment	Forrest	Essex	Crawford	Mean
Cage, No Bees	4228	3465	3169	3621
Caged Honeybees	3800	3747	2911	3486
Caged Leafcutter Bees	3990	3436	2865	3430
No Cage, No Bees	3643	3586	2712	3314
Mean	3916	3559	2915	3463

LSD .05 = 781 kg/ha for comparing treatment means averaged over varieties

LSD .05 = 319 kg/ha for comparing variety means averaged over treatments

TABLE IV

COMPARISON OF MEANS FOR HEIGHT (CM) OF THREE VARIETIES AND FOUR TREATMENTS GROWN AT PERKINS, OKLAHOMA IN 1980

Treatment	Forrest	Essex	Crawford	Mean
Cage, No Bees	66.04	48.26	83.82	66.04
Caged Honeybees	68.58	48.26	99.06	71.12
Caged Leafcutter Bees	60.96	50.80	86.36	66.04
No Cage, No Bees	55.88	40.64	60.96	53.34
Mean	63.50	48.26	83.82	63.50

LSD .05 = 11.83 cm for comparing treatment means averaged over varieties

LSD .05 = 7.59 cm for comparing variety means averaged over treatments

TABLE V

COMPARISON OF MEANS FOR LODGING[1/] OF THREE VARIETIES AND FOUR TREATMENTS GROWN AT PERKINS, OKLAHOMA IN 1980

Treatment	Forrest	Essex	Crawford	Mean
Cage, No Bees	2.00	3.25	3.75	3.00
Caged Honeybees	1.75	3.00	4.25	3.00
Caged Leafcutter Bees	2.00	3.50	3.50	3.00
No Cage, No Bees	1.50	2.00	1.75	1.75
Mean	1.81	2.93	3.31	2.69

[1/] Lodging Score - 1 = no lodging, 5 = extreme lodging.

LSD .05 = 0.68 for comparing two variety means within the same treatment

LSD .05 = 1.28 for comparing two treatment means within the same variety

TABLE VI

COMPARISON OF MEANS FOR PERCENT SHATTERING OF THREE VARIETIES AND FOUR TREATMENTS GROWN AT PERKINS, OKLAHOMA IN 1980

Treatment	Forrest	Essex	Crawford	Mean
Cage, No Bees	1.00	3.75	4.50	3.08
Caged Honeybees	2.75	6.76	5.75	5.08
Caged Leafcutter Bees	1.25	3.25	5.00	3.17
No Cage, No Bees	9.75	11.25	6.75	9.25
Mean	3.69	6.25	5.50	5.15

LSD .05 = 4.98 for comparing treatment means averaged over varieties

LSD .05 = 6.21 for comparing variety means averaged over treatments

TABLE VII

COMPARISON OF MEANS FOR NUMBER OF PLANTS PER PLOT ON THREE VARIETIES AND FOUR TREATMENTS GROWN AT PERKINS, OKLAHOMA IN 1980

Treatment	Forrest	Essex	Crawford	Mean
Cage, No Bees	60	48	42	50
Caged Honeybees	72	60	43	58
Caged Leafcutter Bees	61	59	45	55
No Cage, No Bees	74	62	55	64
Mean	67	57	46	57

LSD .05 = 16 plants/plot for comparing treatment means averaged over varieties

LSD .05 = 7 plants/plot for comparing variety means averaged over treatments

TABLE VIII

COMPARISON OF MEANS FOR NUMBER OF SEED PER POD OF THREE VARIETIES AND FOUR TREATMENTS GROWN AT PERKINS, OKLAHOMA IN 1980

Treatment	Forrest	Essex	Crawford	Mean
Cage, No Bees	2.75	2.55	2.77	2.69
Caged Honeybees	2.50	2.70	2.75	2.65
Caged Leafcutter Bees	2.52	2.35	2.85	2.57
No Cage, No Bees	2.37	2.47	2.60	2.48
Mean	2.53	2.52	2.74	2.60

LSD .05 = 0.18 seed/pod for comparing treatment means averaged over varieties

LSD .05 = 0.13 seed/pod for comparing variety means averaged over treatments

TABLE IX

COMPARISON OF MEANS FOR NUMBER OF PODS PER PLANT OF THREE VARIETIES AND FOUR TREATMENTS GROWN AT PERKINS, OKLAHOMA IN 1980

Treatment	Forrest	Essex	Crawford	Mean
Cage, No Bees	57	62	59	59
Caged Honeybees	48	48	49	48
Caged Leafcutter Bees	60	51	41	51
No Cage, No Bees	45	53	33	44
Mean	52	53	45	50

LSD .05 = 19 pods/plant for comparing treatment means averaged over varieties

LSD .05 = 10 pods/plant for comparing variety means averaged over treatments

TABLE X

COMPARISON OF MEANS FOR 100 SEED WEIGHT OF THREE VARIETIES AND FOUR TREATMENTS GROWN AT PERKINS, OKLAHOMA IN 1980

Treatment	Forrest	Essex	Crawford	Mean
Cage, No Bees	13.7	14.3	16.4	14.8
Caged Honeybees	13.3	14.7	16.3	14.7
Caged Leafcutter Bees	13.7	14.5	16.7	14.9
No Cage, No Bees	14.0	13.5	17.0	14.8
Mean	13.7	14.2	16.6	14.8

LSD .05 = 0.5 grams for comparing treatment means averaged over varieties

LSD .05 = 0.6 grams for comparing variety means averaged over treatments

VITA[2]

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