THE EFFECT OF THE HONEY BEE, *Apis mellifera* (L.) ON THE SEED SET, YIELD AND HYBRIDIZATION OF THE CULTIVATED SUNFLOWER, *Helianthus annuus* L.

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by

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ABSTRACT

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THE EFFECT OF THE HONEY BEE, *Apis mellifera* (L.) ON THE SEED SET, YIELD AND HYBRIDIZATION OF THE CULTIVATED SUNFLOWER, *Helianthus annuus* L.

Plot investigations at The University of Manitoba and field investigations in the sunflower growing area of Manitoba were conducted to determine what effect populations of honey bees had on the seed set, yield, and hybridization of cultivated sunflowers.

The per cent seed set and the yields of the open-pollinated plots were considerably higher than those of the mesh-bagged and kraft-bagged plots. Data are given to show the relative populations of a number of pollinators which visited the plots.

Sunflowers were found to be attractive to honey bees in spite of buckwheat competition.

Sunflower seed yields were significantly decreased as the distance from the honey bee colonies was increased. Unpopulated fields showed no significant differences between the yields at the various distances.

Commercial crossing block fields populated with honey bees had substantially more hybrids than the unpopulated fields.

There also appears to be an increase in the oil content in the immediate first generation seed of the crossing block fields populated with honey bees.

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INTRODUCTION

Cultivated sunflowers have been grown in Western Canada since the beginning of the twentieth century. For many years the crop, except for a negligible portion which was harvested for the roasted seed market, was generally used as ensilage. About 1936, when the wheat market was depressed and glutted, breeding programs were initiated to produce a variety of sunflower having seed with a high oil content for extraction purposes. During World War II a Federal subsidy encouraged the production of this type of seed to meet the great demand for vegetable oils.

In Manitoba, the sunflower was first grown on a commercial scale in 1943. The acreage increased until 1949, when 60,000 acres of sunflowers were cultivated. This acreage was reduced as quickly as it had increased, and by 1952, only 3,500 acres of sunflowers were cultivated.

The two main factors causing this reduction in acreage were low yields and low prices. The low yields were effected by combinations of disease, weather conditions, poor seed set and insect attacks. The low prices were

brought about by the removal of the governmental subsidy and by other competitive vegetable oils. Since the sunflower is considered a cross-pollinated crop, the poor seed set and the resulting lower yields were believed to be caused by a lack of insect pollinators.

The investigation described here was carried on in 1952 and 1953 and is concerned with (a) the study of the effect of honey bee populations on seed set, (b) the effect on seed yields by populating commercial sunflower fields with honey bees, and (c) the effect on hybridization and production of Advance hybrid seed by populating sunflower crossing block fields with honey bees.

REVIEW OF LITERATURE

A review of the literature reveals very little quantitative information concerning the activities of honey bees on sunflowers. This is probably because the sunflower has become a commercial oil seed crop only within the last decade.

Several workers (1, 4, 9, 12) have shown that the sunflower is a cross-pollinated crop. Hurt (4) and Sivori (12) reported that the morphology of the sunflower floret makes it practically self-sterile. Putt (9) demonstrated that the crop was not highly wind pollinated. He also found, in a three year bagging experiment, that open-pollinated heads greatly exceeded both kraft-bagged heads and tiffany-bagged heads in percentage of seed set. Other workers (1, 8) have substantiated these results. The various workers (1, 4, 8, 9, 12) concluded that the pollination of the sunflower was largely dependent on pollinating insects.

Both Hambleton (3) and Edgecombe (2) list the sunflower among those seed crops which are either dependent on honey bees for their production, or which yield considerably more when honey bees are present. Stephen (13) using caged plots, found that the plots populated with honey bees produced an estimated 250 per cent increase in yield compared to those from which honey bees were excluded.

Rozov (10) studied the role of honey bees as "pollen

carriers" in promoting fertilization of ovules and increasing sunflower seed yield. He found that honey bees not only can replace the wild pollinators, but also can increase the pollination and the seed set between 25 and 30 per cent. This author stated that:

> The quantity of bees required for the pollination of a crop of sunflower is equal to the expression: a.b/c.d.e, where a- is the quantity of flowers on a given area, b- the number of times bees must visit a flower in order to effect its pollination, c- the number of times bees leave the hive in the course of a day, d- the length of a single spell of visiting the flowers (i.e. the time during which a bee remains out in the field), e- the rate of visiting the flowers. Dividing the quantity obtained by the quantity of bees working from one hive (10-15 thousand), we obtain the number of hives necessary for the pollination of the flowers on a given area.

Rozov (10) also reported that the flowers in the antheral stage of inflorescence secreted more nectar, and were visited three to five times more often than those in the stigmatic stage of inflorescence. He concluded that the honey bees visited the sunflower chiefly for nectar. Large areas sown with sunflowers must be provided with apiaries for pollination. At least one colony of honey bees is necessary for one hectare (2.5 acres) of crop.

Pellett (7) stated that the cultivated sunflower is of little, if any value for honey. Vansell and Griggs (15) stated that the sugar concentration of nectar is an important factor in plant visitation by honey bees. Vansell (14) lists the average sugar concentration of

sunflower nectar at 31.6 per cent compared to 41.1 per cent and 35.8 per cent for alfalfa and white sweet clover respectively.

Mitchener (5) found that a scale colony in the sunflower area gained almost as much (104 pounds) in the fifteen day period between August 23 to September 6, 1950 during the sunflower flowering period, as it had gained (114 pounds) over a period of fifty days between June 29 to August 17. He concluded that the need for a crop to yield a late nectar flow may be met by the sunflower since the sweet clover flow had been steadily decreasing during August since 1934. Other papers (4, 6) comment on the honey available from the cultivated crop, but do not give a great deal of quantitative information.

MATERIALS AND METHODS

This investigation, consisting of a number of plot studies and field experiments, was carried out on the clay textured, black earth soils of the Red River Valley.

The plot investigations were initiated in 1952 at The University of Manitoba. Seed of the variety Advance was used in the plot studies. The purpose of the plot studies was to compare the percentage of seed set and the yield of open-pollinated heads with heads which excluded certain insect pollinators, particularly the honey bee. The plots were seeded at a rate of five pounds per acre, in rows thirty-six inches apart. Each day during the flowering period counts of the insect visitors were made on twenty selected sunflower heads at intervals of two hours (nine A.M. to five P.M.). Many other heads were tagged as they began to flower, and the date of tagging recorded for each head. When they completed flowering they were bagged to protect them from bird damage. Five separate heads were bagged with eleven-mesh netting just before they began flowering. These heads were used as checks. When the heads were mature they were all carefully harvested and hand-threshed. Accurate counts were made of the number of filled seeds, the number of hollow seeds, and the number of insect-damaged seeds of the peripheral twenty rows per head.

The plot trials were continued in 1953. A bagging

experiment was conducted consisting of nine plots. The seed was planted with a corn planter at six inch plant spacing, and thirty-six inch row spacing. The plants were thinned to the desired stand when they reached a height of six inches. Three plots were left open to natural pollination. Just before the heads began to bloom, the heads in three of the plots were covered with kraft bags, and the heads in three of the plots were covered with eleven-mesh netting. When the crop was mature, the heads were carefully harvested, and the seed was cleaned and weighed.

Commercial fields planted to the varieties Advance, Advance-Sunrise mixture, and Sunrise-S37-388 (crossing block) were selected for the field trials because of their economic importance. The field experiments were conducted at eight locations: four crossing blocks located at Homewood 21-7-3, Homewood 13-7-4, Myrtle 16-5-3, and Plum Coulee 35-2-3; two Advance fields located at Roland 27-5-4, and Altona 12-2-2; and two Advance-Sunrise mixture fields located at Roland 19-5-4, and Plum Coulee 5-3-3. The fields in this experiment were seeded at a rate of five pounds per acre in rows thirty-six inches apart. An attempt was made to locate fields in which the seeding dates were as nearly as possible the same. Two crossing blocks, one Advance field, and one Advance-Sunrise mixture field were populated with honey bees as soon as the flowering period commenced. Honey bees were used as pollinating

agents because of their large numbers, and the ease by which they may be managed to fit the needs of the crop. Honey bees of the common Italian race were employed. These honey bees were utilized at a population density of approximately one colony per acre. The colonies were slightly weaker than average but were all in the proper condition for pollen gathering since each colony was rearing brood. The honey bee colonies were situated along one edge of each field, usually on the east side. A populated field is illustrated in Figure I. The four unpopulated fields were isolated at least three miles from honey bee colonies.

Two of the sunflower fields which were populated with honey bees, and which were within one mile of buckwheat fields were visited at two dates during the latter portion of the flowering period. Honey bees were picked up at random as they entered their respective hives, and placed in vials. The stopper in each vial had been previously treated with ethyl acetate. The vials were taken to the laboratory, and the hind tarsi of each honey bee individually mounted on glycerine covered slides and examined through a microscope for sunflower pollen. The percentage of honey bees carrying sunflower pollen was noted. In this way the attractiveness of the sunflower crop to the honey bees in competition with buckwheat was determined.

When the plants became mature in the fields, rod-row

Figure 1. Typical sunflower field populated with honey bee colonies.

samples in triplicate were taken at intervals of 200 feet from both the populated and the unpopulated fields. Eighteen samples were taken from each populated field, the first three samples coming from that edge of the field on which the honey bee colonies were situated. Fifteen samples were taken from each of the unpopulated fields, the first three samples coming from the east side of each field.

Each sample was individually bagged, labelled, and taken to the laboratory. The diameter and the non-productive area of the heads in each sample were measured, and the heads classified as Advance or S37-388. The classification was based on mature head characteristics, such as size and shape, as well as seed characteristics such as size, shape, color and markings. The heads were then carefully threshed by a single head, drum-type thresher, and the seed cleaned and weighed.

Four 40 gram samples of seed from each of the crossing block fields and two 40 gram samples of seed from each of the commercial fields were prepared and oil content determinations obtained.

Samples of medium Advance seed from five widely distributed sunflower fields were acquired from the Cooperative Vegetable Oils Ltd., Altona. Randomized portions were planted in the greenhouse on August 4, 1953. Following

a method being developed by Stefansson,[1] the seedlings were classified as hybrid or inbred.

This procedure was repeated on randomized samples of seed from the crossing blocks in the field experiment. The seed from each field was bulked, and two randomized samples taken. The first series of samples from each field was planted in the greenhouse on October 24, 1953. The second series of samples was planted on December 2, 1953. In each case the samples were classified by Stefansson's (loc. cit.) method.

Where data from this investigation were subjected to statistical analysis, the methods described by Snedecor (11) were used.

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1. Unpublished data by B. S. Stefansson, Division of Plant Science, The University of Manitoba, Winnipeg. 1953.

RESULTS AND DISCUSSION

1. Reaction of the Sunflower to Populations of Honey Bees, and Their Effect on Seed Set and Yields

Seed Set

Observations made in the plots during the flowering period indicated that the open-pollinated heads passed through the flowering process in a shorter interval than the bagged heads. The florets on the bagged heads remained fully extended for many days, with divided stigma lobes slowly curling, but not withering and receding as those on the heads which were open-pollinated. These observations also indicated that this reaction was a result of the flowers on the bagged heads not being fertilized.

The bihourly counts made in the plots disclosed that there was an average of 17.19 ragweed plant bugs, Chlamydatus associatus (Uhl.)[1], 7.27 honey bees, Apis mellifera (L.)[2], 2.32 tarnished plant bugs, Lygus oblineatus (Say)[3], 1.35 syrphid flies[4], and 0.83 bumble bees[5] present in the plots per twenty heads, per count. The average percentage of seed

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1 Family Miridae, Order Hemiptera.

2 Family Apidae, Order Hymenoptera.

3 Family Miridae, Order Hemiptera.

4 Family Syrphidae, Order Diptera.

5 Family Bombidae, Order Hymenoptera.

set of the open-pollinated and the bagged heads is shown in Table I.

Table I

Summary of sunflower seed set on open-pollinated heads and mesh-bagged heads

Condition of seeds	Open-pollinated 40 heads	Mesh-bagged 5 heads
Number filled seeds	46,297	2,315
Number hollow seeds	7,266	4,816
Number insect-damaged seeds	426	35
Per cent seed set*	86.34	32.22

NOTE:* Insect-damaged seeds counted as filled seeds

The percentage of seed set of each open-pollinated head is shown in Appendix A, and each bagged head in Appendix B.

The per cent seed set of the open-pollinated heads was considerably higher than the bagged heads, an increase of 267.97 per cent. It is important to note that the average open-pollinated head contained only 10.65 insect-damaged seeds, compared with 181.65 hollow seeds. The counts made also showed a decrease in the percentage of seed set during the latter portion of the season. (See Appendix A) This decrease coincided with a similar trend of decreased numbers of insect visitors. (See Appendix C)

The data indicate that the abundance of the ragweed

plant bugs and the tarnished plant bugs had little effect on the seed set because the mesh of the bagged heads was large enough to allow these plant bugs, and other possible small pollinators through to the flowers. On the other hand the mesh prevented the larger pollinators from visiting the flowers. The difference in seed set between the open-pollinated and the bagged heads denotes the important role of the larger pollinating insects, particularly the honey bee, since the honey bee was by far the most numerous visitor.

Yield

In view of the results obtained in 1952, another bagging experiment was designed in 1953 to obtain actual yield data. The results are shown in Table II.

The yields of the open-pollinated plots greatly exceeded those of the kraft-bagged, and the mesh-bagged plots. The open-pollinated plots showed a yield increase of 477.26 per cent over the kraft-bagged plots and 212.34 per cent over the mesh-bagged plots. The latter difference would have probably been greater except that a large number of the mesh-bagged heads developed to the extent where the inner florets protruded through the mesh before they were noticed. While the bags were being adjusted, many honey bees and bumble bees were observed gathering nectar and pollen from the florets pressed against the mesh. It seems plausible to assume that during this period many ovules were

Table II

Comparative yields between open-pollinated and bagged sunflower plots at Winnipeg, 1953.

Method of treatment	Plot number	Number of heads	Yield in grams	Per cent increase over kraft bag	Per cent increase over mesh bag
Kraft bag	3	30	246	------	------
	5	30	321		
	7	30	273		
Mesh bag	2	30	750	224.76	------
	6	30	598		
	9	30	531		
Open-pollinated	1	30	1330	477.26	212.34
	4	30	1429		
	8	30	1250		

fertilized which normally would not have been fertilized.

Another small bagging trial to study the seed yields of the varieties Advance and S37-388 under different bagging materials gave similar results. This is shown in Table III.

Table III

Summary of seed yields of five Advance and five S37-388 heads using different bagging materials at Winnipeg, 1953.

Method of treatment	Yield	
	Advance grams	S37-388 grams
Kraft bag	24	20
Mesh bag	123	100
Open-pollinated	433	305

It is noteworthy that the difference in yield between the two bagging treatments was considerable, but the varieties did not exhibit a differential response. It was observed that bagging plants with kraft bags affected the condition of the heads, leaving them pale green, misshapen and quite pulpy. This was not observed on the mesh-bagged heads. The latter material is believed to have had little or no effect on the microclimatic conditions about the heads, and therefore should not have affected the yields.

It has already been pointed out that the difference in seed set indicated the important role of the larger pollinating insects, particularly the honey bee. By

excluding this insect and preventing the cross-pollination which it affords, seed set and yields are greatly reduced.

2. Effect on Seed Yields by Populating Commercial Sunflower Fields With Honey Bees

Sunflowers attract honey bees

Observations made on two of the honey bee populated sunflower fields indicated that numerous honey bees were visiting the sunflower crop. Examination of the honey bees which were collected from the hives on these fields revealed that many of the honey bees carried sunflower pollen. This is shown in Table IV.

The flowering period of these two fields extended from the last week in July to the third week in August. During the early portion of the bloom period, alfalfa competed with the sunflower for honey bee attention. During the latter portion of the bloom period, when the collections were made, buckwheat was in full bloom. Recorded observations in both cases show a decrease in honey bee activity on the sunflower fields as the flowering period progressed. The data also indicate that the sunflower is attractive to the honey bees in spite of buckwheat competition.

Honey bees, when visiting the sunflower became coated with pollen. The head and the ventral portion of the honey bee especially were observed to be covered with pollen. This is illustrated in Figure 2, page 20. Because of this feature the majority of the nectar gatherers, as well as the pollen gatherers pollinate a considerable percentage of the

Table IV

Determination of the type of pollen carried by honey bees collected at the hive entrances of colonies on two fields at two dates in 1953

Type of pollen carried	Date honey bees collected			
	August 13		August 17	
	Field A	Field B	Field A	Field B
Sunflower pollen	15	12	25	18
Other pollen	9	12	25	32
Per cent sunflower pollen	62.5	50.0	50.0	36.0

Figure 2. Honey bee, densely covered with sunflower pollen.

flowers by accident.

Plant stand and head size

The measurements which were taken of the heads before the heads were threshed revealed that the productive area of an average sample from the populated fields was 563.28 square inches, and the average number of heads per rod-row sample was 19.25. (See Appendix D) The productive area of an average sample from the unpopulated fields was 484.74 square inches, and the average number of heads per rod-row sample was 17.16. (See Appendix E) In general, an increase in stand is usually accompanied by a decrease in head size. In view of the fact that this did not occur in this experiment, it may be plausibly assumed that the pollination afforded by the honey bees increased the productive area of the heads by increasing the seed set and decreasing the non-productive area.

Seed yields

The yields in grams of the individual samples which were taken from the populated fields are shown in Appendix F. The yields in grams of the individual samples which were taken from the unpopulated fields are shown in Appendix G. The fields populated with honey bees consistently yielded more than the unpopulated fields. The total difference in yield was very pronounced. Sixty rod-row samples of seed from the populated fields weighed 89.88 pounds, compared

with only 60.73 pounds from the unpopulated fields. This marked increase in yield compared favorably with the results obtained by Rozov (10).

The average yield in pounds from populated and unpopulated fields at various distances from the honey bee colonies or the edges of the fields is illustrated in Figure 3.

The average yield of the populated fields decreases as the distance from the honey bee colonies increases. An analysis of variance (Table V) showed this decrease to be significant at the one per cent level. The differences may

Table V

Analysis of variance of fields populated with honey bees

Source of variation	D.F.	S.S.	M.S.	F.	.05	.01
Distance	5	707,082	141,416	4.56	2.90	4.56
Fields	3	2,819,745	939,915	30.33	3.29	5.42
Interaction	15	416,841	30,989			
Error	48	1,098,800	22,891			
Total	71	5,090,468				

be accounted for by the different densities of honey bee activity at the various distances, or by the so-called "border effect."

The average yield of the unpopulated fields does not decrease as the distance from the edges of the fields

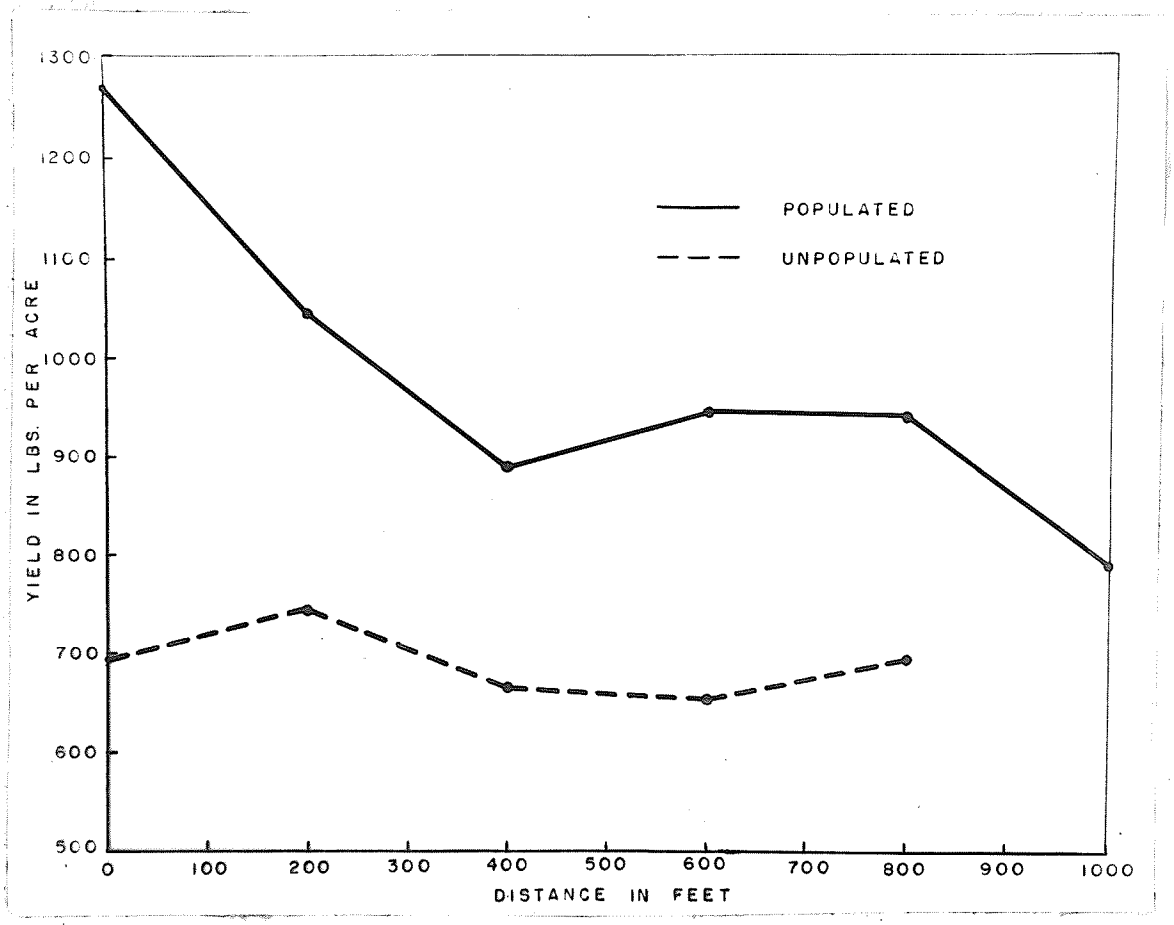

Figure 3. Average yield in pounds from populated and unpopulated fields at various distances from the honey bee colonies or the edges of the fields.

increases. An analysis of variance (Table VI) showed no significant difference between distances.

Table VI

Analysis of variance of fields unpopulated with honey bees

Source of variation	D.F.	S.S.	M.S.	F.	.05	.01
Distance	4	22,873	5,718			
Fields	3	600,458	200,153	21.41	3.49	5.95
Interaction	12	112,115	9,346			
Error	40	620,402	15,510			
Total	59	1,355,888				

Since no significant difference was obtained in the unpopulated fields, the differences in yields in the populated fields must have been due to the influence of the honey bee populations.

The results of this field study strongly suggest the importance of populating commercial and crossing block sunflower fields with honey bees to obtain greatly increased yields. The results also suggest that approximately one colony per acre is sufficient to obtain these increases. The colonies should be placed in rows across the field about 300 to 400 yards apart, the first row preferably on the east edge of the field.

3. Effect on Hybridization and Production of Advance Hybrid Seed by Populating Crossing Block Fields with Honey Bees

Hybridization of commercial crossing blocks

Observations made in the plots at The University of Manitoba during the seedling stage clearly showed the "seedling markers" which were described by Stefansson (loc. cit.). The five samples of Advance medium seed which were obtained from the Co-op. Vegetable Oils Ltd. and planted in the greenhouse on August 4, 1953 were carefully classified as hybrid or inbred in the seedling stage on August 29, 1953. This is shown in Table VII.

Table VII

Per cent hybrids determined by using "seedling markers"

Character	Field A	B	C	D	E
Number hybrid	26	39	57	54	52
Number inbred	57	57	63	59	57
Per cent hybrid	31.3	40.6	47.5	47.8	47.7

The average percentage of hybrids determined was 42.98. These results compared favorably with other results obtained by Stefansson (loc. cit.) of a commercial sample of Advance seed. It is of interest to note that this is a low hybrid percentage for seed which is considered hybrid.

The same procedure was repeated on the randomized

samples of seed from the crossing blocks in the field experiment. The results are shown in Table VIII.

Table VIII

Percentage of hybrids obtained from populated and unpopulated crossing blocks

Treatment	Field	Series 1 Per cent hybrid	Series 2 Per cent hybrid	Mean
Populated	A	51.00	53.66	53.01
	B	48.96	58.40	
Unpopulated	C	32.00	40.65	28.17
	D	20.00	20.00	

The seed samples were planted in two series because of a shortage of space in the greenhouse. The two series show that the fields that were populated with honey bees had approximately 87 to 92 per cent more hybrids than the control fields.

It should also be noted at this time that the seed which was taken from the plot trials rated 0.0 per cent hybrid under the kraft bags, and only 9.4 per cent hybrid under the eleven-mesh netting.

In any case, the difference in the percentage of hybrids obtained from the populated and unpopulated fields gives strong support to the view that the presence of honey bee populations is necessary to increase the cross-pollination of the sunflower.

Per cent oil on a dry matter basis

The oil content determinations of seed submitted to the Grain Research Laboratory proved to be of great interest. The oil content determinations of the seed from the crossing blocks are shown in Table IX.

Table IX

Per cent oil content of various samples of sunflower seed from a number of crossing blocks

Sample	Crossing blocks			
	Populated		Unpopulated	
	A	B	C	D
Random sample 1	30.2	30.8	31.3	28.6
Random sample 2	30.7	32.1	30.4	28.9
Sample at 0 feet	33.2	33.2	30.7	28.3
Sample at 800 feet	30.2	32.1	29.9	28.1
Mean	31.10	32.05	30.33	28.48

NOTE: Each value represents the mean of duplicate determinations.

The data show that the oil content of the samples of seed taken adjacent to the honey bee colonies appear to be higher than that of samples of seed taken 800 feet from the colonies. This difference is not as striking in the unpopulated fields.

The data also show that there appears to be an increase in the oil content in the immediate first generation seed of the fields populated with honey bees compared to that

of the unpopulated fields. This increase also appears to be somewhat related to the percentage of hybridization. This is shown in Table X.

Table X

Comparative averages of the hybridization and the oil content of seed from various crossing blocks

Character	Fields			
	Populated		Unpopulated	
	A	B	C	D
Average per cent hybrid	52.33	53.68	36.33	20.00
Average per cent oil	31.10	32.05	30.33	28.48

Since the oil content of the hybrid is greater than that of the two parents, the increase in oil content with an increase of hybridization would be expected in the immediate first generation seed.

Oil content determinations were also obtained from the commercial Advance, and the Advance-Sunrise mixture fields. These are shown in Table XI.

When the heads were classified before threshing, fields A, B and C were classified as containing 39.0, 37.6 and 29.1 per cent inbreds respectively. Field D on the other hand had only 4.10 per cent inbred heads. It should be noted that this field was an Advance-Sunrise mixture field as was field B. Perhaps this low percentage of inbred heads accounts for the high oil content of the seed.

Table XI

Oil content of various samples of sunflower seed from a number of commercial fields

	Commercial field			
	Populated		Unpopulated	
	E	F	G	H
Random sample 1	30.9	31.7	28.8	33.7
Random sample 2	31.6	29.2	30.0	34.4
Mean	31.35	30.80	29.40	34.04

NOTE: Each value represents the mean of duplicate determinations.

SUMMARY AND CONCLUSIONS

Plot and field investigations were carried out in the sunflower growing area of Manitoba to determine the effect of populations of honey bees on sunflower seed set, yield and hybridization.

The plot investigations were carried out at The University of Manitoba. In 1952 a bagging experiment was undertaken to determine the percentage of seed set of open-pollinated and bagged heads. During the time that the heads were in the flowering stage, insect counts were made five times a day at two-hour intervals. The heads were hand threshed and counts made of the number of filled seeds, the number of hollow seeds and the number of insect-damaged seeds. In 1953 bagging experiments using kraft-bagged, mesh-bagged and open-pollinated plots were conducted, and the total weight of seed determined for each plot.

The field experiments were carried out in 1953 in the Altona, Homewood, Plum Coulee and Roland areas. The eight commercial fields in the study were planted to the varieties, Advance, Advance-Sunrise mixture and S37-388-Sunrise (crossing block) at normal seeding rates. Four of the eight fields were populated with honey bees at a density of approximately one colony per acre. The attractiveness of the sunflower to honey bees in competition with buckwheat was determined by

collecting and examining honey bees for sunflower pollen. At harvesttime three rod-row samples were taken from each field at intervals of 200 feet. The samples were threshed, and the seed cleaned, and weighed. Randomized samples of the female parent seed from the crossing blocks were planted in the greenhouse, and the seedlings classified as hybrid or inbred. Determinations of the oil content were also obtained of replicated samples of seed from each field.

The per cent seed set of the open-pollinated heads was notably higher (267.97 per cent) than the mesh-bagged heads.

The yield of the open-pollinated plots was higher (212.34 per cent) than the mesh-bagged plots, and considerably higher (477.26 per cent) than the kraft-bagged plots. These increases in seed set and yields may be ascribed to the presence of the larger pollinating insects, particularly the honey bee, since the honey bee was by far the most numerous visitor of the larger pollinators.

Sunflowers can compete with buckwheat for honey bee attention. The data showed that between 36 and 62 per cent of the honey bees examined carried sunflower pollen.

Sunflower seed yields were significantly decreased as the distance from the honey bee colonies was increased. Unpopulated fields showed no significant differences between the yields at the various distances.

Commercial crossing blocks populated with honey bees had approximately 87 to 92 per cent more hybrids than the unpopulated fields.

There appears to be an increase in the oil content in the immediate first generation seed of the crossing block fields populated with honey bees. There is also an indication that the oil content of the samples of seed taken adjacent to the honey bee colonies is higher than that of the samples of seed taken 800 feet from the colonies.

It may be concluded that populating commercial sunflower fields with honey bees at approximately one colony per acre is sufficient to increase yields significantly. These experiments also indicate that populating crossing blocks with honey bees will increase the percentage of hybridization.

Since the climatic conditions throughout the summer and fall of 1953 were well adapted for sunflower production, this study showed what effect honey bee populations had on the sunflower seed set, yield, and hybridization under almost ideal production conditions. Because this phase of research on the sunflower crop is still in its initial stages, and because of its extreme value to the grower, this study should be repeated and expanded in order to take into account varying climatic conditions, various honey bee population densities and also yields of honey.

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LITERATURE CITED

1. CONDON, P. U. Sunflower studies. Jour. Amer. Soc. Agron. 14:69-72. 1922.

2. EDGECOMBE, S. W. The pollination of fruits, seed crops and other plants. A paper presented before the American Beekeeping Federation at Biloxi, Mississippi. January, 1950.

3. HAMBLETON, J. I. The dependence of agriculture on the beekeeping industry. U.S.D.A. Circ. E-584. Rev. 1946.

4. HURT, E. F. Sunflower. Faber and Faber Ltd. London. 1948.

5. MITCHENER, A. V. Honey bees and sunflowers. Ann. Con. Man. Agron. 27. 1950.

6. _____Nectar and pollen producing plants in Manitoba. Sci. Agr. 28:478-480. 1948.

7. PELLETT, F. C. American honey plants. Orange Judd Publishing Company, Inc., New York. 1947.

8. PRYCE-JONES, J. Bees and sunflowers. Overseas Food Corporation. Report for 1949-1950: 93-94 and Appendix 5 (Part 2) :105-109. 1950. Original not seen.

9. PUTT, E. D. Observations on morphological characters and flowering processes in the sunflower (Helianthus annuus L.) Sci. Agr. 21(4):167-179. 1940.

10. ROZOV, S. The role of the honey bees in the cross-pollination of the sunflowers. Comptes Rendus De L'Academie des Sciences De L'U.R.S.S. Nouvelle Serie. 6:303-305. 1933.

11. SNEDECOR, G. W. Statistical methods. Iowa State College Press. 4th Ed. 1946.

12. SIVORI, ENRIQUE. M. Biologia floral de girasol. Rev. Argentina Agron. 8(2):150-154. 1941.

13. STEPHEN, W. P. Sunflower insects. Research Report. International Great Plains Conference of Entomologists 25:36. 1952.

14. VANSELL, G. H. Factors affecting the usefulness of honey bees in pollination. U.S.D.A. Cir. No. 650. 1942.

15. _____and W. H. GRIGGS. Honey bees as agents of pollination. The Yearbook of Agriculture. U.S.D.A. 88-107. 1952.

APPENDIX A

The seed set of 40 open-pollinated sunflower heads in the order of succession in which they flowered at Winnipeg, 1952.

Head number	Number of seeds	Number filled	Number hollow	Number insect-damaged	Per cent filled
1	1028	885	130	13	87.35
2	1572	1361	209	2	86.70
3	1505	1378	119	8	92.09
4	955	831	122	2	87.23
5	1240	1040	195	5	84.27
6	773	614	156	3	79.82
7	1274	1074	197	3	84.54
8	1461	1323	129	9	91.17
9	1548	1327	215	6	86.11
10	1866	1850	284	32	84.78
11	1203	991	200	12	83.37
17	1581	1218	349	14	77.93
21	1530	1373	152	5	90.07
22	1463	1285	164	14	88.79
23	1393	1185	207	1	85.14
26	1262	1086	148	28	88.27
27	1701	1433	254	14	85.08
29	1208	1068	130	10	89.24
33	1451	1246	194	11	86.63
34	1373	1207	155	11	88.71
36	1417	1294	113	10	92.03
37	1239	1075	155	9	87.49
40	1686	1553	123	10	92.70
47	1038	928	107	3	89.69
48	1395	1221	166	8	88.10
55	1032	906	123	3	88.08
56	1040	908	122	10	88.27
60	1382	1208	169	5	87.77
61	1541	1371	157	13	89.81
62	1386	1186	191	9	86.22
63	1307	1116	177	14	86.46
64	1079	986	83	10	92.31
65	1315	1116	184	15	86.01
67	1504	1180	301	23	79.99
70	1322	1145	165	12	87.52
71	1033	773	260	0	74.83
72	1226	985	240	1	80.42
74	1342	1041	258	43	80.78
77	1712	1528	170	14	90.07
79	1306	1002	293	11	77.57
Total	53,989	46,297	7,266	426	86.23

APPENDIX B

The seed set of five mesh-bagged sunflower heads in the order of succession in which they flowered at Winnipeg, 1952.

Head number	Number of seeds	Number filled	Number hollow	Number insect-damaged	Per cent filled
1	1412	434	972	6	31.16
2	1409	138	1264	7	10.29
3	1592	738	846	8	46.86
4	1535	638	895	6	41.69
5	1218	371	839	8	31.12
Total	7166	2315	4816	35	32.79

APPENDIX C

Average populations per 20 head count of a number of insect pollinators on the sunflower plots at Winnipeg, 1952.

Period ending	*Chlamydatus associatus* (Uhl.)	*Apis mellifera* (L.)	*Lygus oblineatus* (Say)	Syrphidae	Bumble bee	Total number of visitors
August 5	25.71	5.64	.93	2.00	.36	34.64
August 10	16.73	6.00	1.33	.93	.47	25.46
August 15	15.44	9.96	1.52	2.08	.92	29.92
August 20	17.13	12.07	1.93	1.80	1.20	34.13
August 25	16.24	8.88	2.29	1.76	1.41	30.58
August 30	16.35	5.35	4.41	.53	.82	27.46
September 4	12.75	3.00	3.81	.33	.63	20.52
Grand Average	17.19	7.27	2.32	1.35	.83	28.96

APPENDIX D

The average number of heads, average yield per head, average productive area per sample, and average yield per rod-row of samples taken from populated fields

Field	Average number of heads per sample	Average yield per head grams	Average productive area per sample square inches	Average yield per sample grams
A	15.94	28.96	415.24	405.00
B	19.83	26.15	493.16	518.78
E	19.14	47.23	692.89	870.81
F	22.10	37.66	651.82	791.48
Average	19.25	35.00	563.28	646.52

APPENDIX E

The average number of heads, average yield per head, average productive area per sample, and average yield per rod-row of samples taken from unpopulated fields

Field	Average number of heads per sample	Average yield per head grams	Average productive area per sample square inches	Average yield per sample grams
C	13.93	26.68	357.62	349.47
D	15.87	29.71	412.23	449.07
G	14.11	30.23	611.15	391.83
H	24.73	26.11	557.97	622.20
Average	17.16	28.18	484.74	453.14

APPENDIX F

The yields in grams of the individual rod-row samples at various distances from honey bee colonies

Distance in feet	Field			
	Crossing block		Advance	Advance-Sunrise
	A	B	E	F
0	480	580	1,168	1,145
	497	630	1,019	1,276
	526	603	998	1,210
Total	1,503	1,813	3,185	3,631
200	288	536	1,005	702
	409	875	545	838
	511	578	1,238	849
Total	1,208	1,989	2,788	2,389
400	424	409	613	636
	514	589	952	724
	437	443	653	733
Total	1,375	1,441	2,218	2,093
600	543	449	883	451
	387	508	870	539
	345	533	826	1,298
Total	1,275	1,490	2,529	2,288
800	542	572	672	795
	296	551	911	817
	254	413	825	904
Total	1,092	1,536	2,408	2,516
1000	277	352	854	438
	207	400	891	688
	356	317	1,004	543
Total	840	1,069	2,749	1,669
Field Total	7,293	9,338	15,877	14,586
		Grand total		47,094

APPENDIX G

The yields in grams of the individual rod-row samples at various distances from the edges of the unpopulated fields

Distance in feet	Field			
	Crossing block		Advance	Advance-Sunrise
	C	D	G	H
0	403	535	356	846
	449	191	364	330
	332	530	520	693
Total	1,184	1,256	1,240	1,869
200	321	520	482	719
	370	399	487	710
	259	442	409	799
Total	950	1,361	1,378	2,228
400	401	517	319	698
	322	405	453	604
	424	308	303	575
Total	1,147	1,230	1,075	1,877
600	422	297	455	423
	267	315	453	439
	419	721	361	665
Total	1,108	1,333	1,269	1,527
800	290	509	359	518
	283	345	411	812
	380	705	400	502
Total	953	1,559	1,170	1,832
Field Total	5,342	6,739	6,132	9,333
		Grand total		27,546