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THE DEPENDENCE OF AGRICULTURE ON THE BEEKEEPING INDUSTRY--A REVIEW

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INTRODUCTION

The principal role of the honeybee is not in the production of honey and beeswax, as is commonly supposed, but in the pollination of agricultural crops for the production of seed and fruit. Without insects to effect pollination, many species of plants will not set seed or produce fruit no matter how well they are cultivated, fertilized, and protected from diseases and pests.

Although the honeybee is the most important pollinating insect, it is but one of many species of bees necessary for the perpetuation of flowering plants. Various species of flies, beetles, and other insects also visit flowers and to some extent pollinate them. Whereas nectar and pollen are rarely the principal food of other pollinating insects, these substances supply the entire nourishment of both the young and adults of honeybees and wild bees.

Wherever a proper balance exists between plants and pollinating insects, both flourish. Agricultural development, however, has seriously interfered with this balance. It has demanded the growing of certain plants in enormous acreages and has unwittingly destroyed native pollinating insects as well as their nesting places. As a result the burden of pollination has been increased to such an extent that wild bees are no longer adequate or dependable, particularly where agriculture is highly developed. In many places the depletion of wild pollinators is so acute that honeybees have to be brought in especially for pollination, and so in practically all agricultural areas honeybees are now the most numerous of the flower-visiting insects. It is essential, nevertheless, to conserve our native pollinating insects, since some species of native bees are more efficient, bee for bee, than honeybees and will work under more adverse conditions. As yet, however, no agency, Federal, State or private, has assumed the responsibility for conserving wild pollinating insects.

The reduction in wild beneficial insects and the increase in acreage of crops requiring insect pollination have been gradual. While these changes were occurring, commercial beekeeping had its inception and fortunately so, since the presence of honeybees in some areas has helped to make

up the shortage of wild pollinators. Consequently, plant growers and farmers generally have not been greatly concerned about pollination simply because some beekeeper has relieved them of this worry by keeping his bees within flight range of their crops.

The service rendered to agriculture by the beekeeper in furnishing the public with pollinating insects has commonly been overlooked. In too many cases his only reward has been his honey crop, which, until war years, he often had to dispose of at depressed prices. In addition, his bees were frequently killed through the indiscriminate use of insecticides by the very man he was benefiting. Under such circumstances, since the beekeeper's interest was not safeguarded by sufficiently high honey prices, rentals, or a subsidy of any kind, the keeping of bees has declined in many communities, and this in turn has meant decreased yields for the grower of insect-pollinated crops.

The fertilization of flowers is so imperative that beekeeping must be carried on to maintain a profitable agriculture. Owing to conditions brought about by the recent war, of which increased acreage of insect-pollinated seed crops is but one, safeguarding the beekeeping industry has become doubly urgent. Beekeeping can be mastered only through years of experience. It cannot be learned as a trade is learned, and there is no floating population of persons seeking employment in beekeeping. The fact that bees have a propensity for stinging discourages many people from keeping them, and only certain individuals possess the proper temperament to be beekeepers. For these reasons every experienced beekeeper should be encouraged to continue with his bees. It may even become necessary to subsidize the keeping of bees, since there is no practical substitute for honeybees in the transfer of pollen from flower to flower and from plant to plant.

In the following pages literature is cited in support of the premise (1) that wild pollinating insects are deficient in number adequately to pollinate our agricultural crops, and (2) that at least 50 agricultural crops depend upon honeybees for pollination or yield more abundantly when bees are plentiful. 1/ The specific fruit and seed crops mentioned in these references are tabulated below:

Fruit Crops	Seed Crops	
Almond	Alfalfa	Kohlrabi
Apple	Asparagus	Muskmelon
Apricot	Broccoli	Onion
Avocado	Brussels sprouts	Parsnip
Blackberry	Buckwheat	Pepper
Blueberry and huckleberry	Cabbage	Pumpkin
Cherry	Carrot	Radish
Cranberry	Cauliflower	Rape
Cucumber	Celery	Rutabaga
Dewberry	Clovers (alsike, crimson, red, strawberry, white, and Ladino white)	Squash
Gooseberry		Sunflower
Grape		Sweetclover
Mango	Collards	Trefoil
Muskmelon	Cotton	Turnip
Peach and nectarine	Cucumber	Vetches
Pear	Flax	Watermelon
Persimmon, native	Kale	
Plum and prune		
Raspberry		
Strawberry		
Tung		
Watermelon		

POLLINATION REQUIREMENTS OF PLANTS 2/

Fletcher, S. W.
1941. Pollination. Standard cyclopedia of horticulture, by L. H. Bailey. v. 3, pp. 2734-2737. New York

p. 2734: ...it is well known that while the flowers of many plants may be readily fertilized by their own pollen, the offspring are stronger when pollen from another plant or another variety has had access to the flower. Sometimes pollen from a foreign variety

1/ These quotations are for the most part from plant specialists, with only a few from authorities on apiculture.

2/ The underlining in the references does not appear in the original citations but has been added for emphasis.

is absolutely essential to the best fruit-formation. This is particularly true of certain varieties of the pear. A poor quality of fruit can be prevented only by growing together different varieties. Again, although a plant may readily pollinate itself, yet the pollen from another plant or variety may be prepotent over its own. This is to say, if the plant be pollinated by its own pollen along with that of a foreign variety, that of the foreign variety will usually effect fertilization.

pp. 2734-5: The flowers of insect-pollinated plants, on the other hand, are usually showy, and have nectar or fragrance, or both. The pollen is more or less moist or sticky, so that it is not easily blown away... As the insect reaches down for the nectar, which is near the bottom of the flower, some parts of its body are sure to become dusted with pollen... Thus cross-pollination, or the transfer of pollen from the anthers of one flower to the pistil of another, is accomplished.

[Bees collecting pollen are just as valuable as those gathering nectar. In visiting large flowers they may be more effective, as they go directly to the reproductive organs.]

The value of crossing to plants was first clearly proved by Charles Darwin in 1859... From the observations of Kolreuter, Sprengel, Knight, and his own exhaustive experiments, Darwin showed that continued self-fertilization is likely to result in inferior offspring; while cross-fertilization, within certain limits, gives greater vigor to the offspring. Cross-fertilization between different flowers on the same plant usually has no appreciable advantage.

p. 2736: In the selection of a pollinizer, several points must be considered: (1) The two sorts must blossom approximately at the same time in order that cross-pollination may be possible. The transfer of pollen from one variety to another is performed mainly by insects. Waugh and Backhouse have shown that practically none of the pollen of the plum and other stone-fruits is carried by wind, it being moist and sticky. The same is true of pears, but apple pollen is somewhat drier and is wind-blown to a slight extent. The honeybee is the most important pollen-carrier. Hooper estimates that in England 80 per cent of the cross-pollination is done by the hive bee, 15 per cent by various wild bees, especially the bumble-bee, and 5 per cent by miscellaneous insects.

[If this was true for England with its large areas devoted to hedge-rows, woods, and small-scale farming with many wild areas suitable for the nesting of native bees, then in this country with its large blocks of clean cultivation, dwindling wild areas, its large sheep population and much greater use of arsenicals, the percentage of pollination effected by the honeybee must be even higher.]

pp. 2736-7: Orchard pollination, however, is a broader problem than the mere detection of varieties that are inclined to be unfruitful when planted alone, and discovering which are the best pollinizers for each of them. Experiments in crossing and observations in orchards indicate that nearly all varieties, whether self-sterile or self-fertile, will produce more or better fruit with foreign pollen than with their own... Yellow Newtown is distinctly self-fertile in Oregon, yet Lewis noted a decided improvement in the fruit when Jonathan and Grimes' pollen was used upon it. He concluded, "All varieties of pome-fruits, at least of apples and pears, even though they may be termed self-fertile, are benefited by having other varieties planted with them as pollinizers."

[A survey of the literature shows that the last statement is not confined to fruit but is applicable to many agricultural crops as well.]

MacDaniels, L. H.
1929. Pollination studies in New York State. Amer. Soc. Hort. Sci. Proc. 1928: 129-137.

p. 137: The value of having bees and good pollen varieties in the orchard is that in some seasons when there are only a few hours in which bees can fly, satisfactory cross-pollination will be effected whereas it would not have been accomplished if sources of good pollen and abundant insects were not close at hand. It is for such minimum conditions for cross-pollination that the grower should provide. It is also evident that in any region the lack of pollen carriers in the orchard at blooming time may be the limiting factor in the set of fruit and that in order to properly understand the pollination problem a study of the insects of the locality in their relation to pollination is necessary.

MacDaniels, L. H.
1930. Practical aspects of the pollination problem. N. Y. State Hort. Soc. Proc. 1930: 195-202.

p. 201: In the foregoing paragraphs much has been said of the limitations of bees in pollen distribution. It must be borne in mind, however, that for all that, bees are still the most effective pollen carriers there are and that they are the only insect that can be managed by the orchardist.

Marshall, R. E., Johnston, Stanley, Hootman, H. D., and Wells, H. M.
1929. Pollination of orchard fruits in Michigan. Mich. Agr. Expt. Sta. Spec. Bul. 188, 38 pp.

p. 38: The commercial fruit grower is almost entirely dependent on the common honey bee for the transfer of pollen from one variety to another.

There are not enough bees in many orchards to insure the setting of a full crop of fruit in years when weather conditions are not favorable for maximum insect activity at blooming time.

REASONS FOR INADEQUACY OF WILD POLLINATING INSECTS

Authorities universally admit the importance of wild insects in pollinating agricultural crops; yet no State or Federal organization is especially concerned with the conservation of beneficial insects. It is apparent, therefore, that the destruction of pollinating insects has not been fully recognized as the important cause of decreased seed and fruit production in many crops that are benefited by insect pollination.

In considering the part played by wild pollinating insects, it should be borne in mind that most species, with the exception of bumblebees, are solitary insects and reproduce slowly, and since the females have to fly in search of food they are subjected to such hazards as weather, fast-moving automobiles, natural enemies, etc. Many of the solitary bees are ground-nesting and are consequently easily destroyed in areas where agricultural practices demand frequent cultivation of the soil.

Certain species of flies, beetles, and other insects effect pollination but are considered of minor importance.

Megee, C. R., and Kelty, R. M.
1932. The influence of bees upon clover and alfalfa seed production. Mich. Agr. Expt. Sta. Quart. Bul. 14: 271-277.

p. 271: It is common observation that along with the decrease in the numbers of bumble bees and other wild bees there has been a decrease in the production of clover seed.

p. 277: Bumble bees are effective pollinating agents, but, due to their relative scarcity in the clover and alfalfa seed producing districts of northern Michigan cannot be depended on for pollination purposes.

Metcalf, C. L., and Flint, W. P.
1928. Destructive and useful insects; their habits and control. 918 pp. New York.

p. 264: Under farming conditions great changes take place in the character of the plants grown on the land. There are no longer a great number of species, generally intermixed, but a few species occupying the land in nearly pure stands of thousands and hundreds of thousands of acres. This affects the insect population of the land in two general ways. Many of those which depend on the plants of one family, or even on one species of plant, find their food supply

cut off, except in the small uncultivated areas and may nearly, or quite, disappear from the region, as certain species of the billbugs in drained bottom lands.

Vansell, G. H.
1942. Factors affecting the usefulness of honeybees in pollination. U. S. Dept. Agr. Cir. 650, 31 pp.

p. 2: The orchards were located on top of a ridge, which was flanked on both sides by uncultivated lands, including both timber and manzanita-ceanothus brush.

pp. 5-6: In the Camino district honeybees were the most common visitors to the blossoms, blowflies were next, and other insects were scarce. As a rule honeybees visit the blossoms of only one plant species on each field trip, while most other insects frequently shift from one species to another. For this reason no other insect compares favorably with the honeybee in pollen-distributing activity. Only honeybees and wild bees collected pollen for removal to their nests. Ants were surprisingly common in the orchard blossoms, feeding on nectar at temperatures well below that at which flying insects cease activity. Ants were observed working in early morning, late evening, and during cold rainy periods, but probably they do not often move from tree to tree. Pollen seemed to offer no special attraction to them, but nectar and possibly sap did, because frequently these ants were engaged in taking nectar and in biting into tender twigs and the tiny fruit before the petals had fallen away.

Bumblebees worked in the orchards during periods far too cold for the honeybee. Andrenids and other small bees were very sensitive to wind movement; they hung to leeward, and as a breeze increased to a gentle wind they disappeared. Honeybees were only slightly affected by a breeze of sufficient velocity to stop the andrenids. Wild bees were more in evidence near uncultivated lands. Blowflies were extremely active on pear blossoms, particularly for several hours before a rain. They also appeared on the sunny sides of tree trunks and limbs, and fed freely upon the fluid oozing from blight infections, where no honeybees were found. Syrphid flies evidently fed more or less on the pollen, but the chief interest of flies in general was in nectar.

... Note the abundance of the honeybee as compared with the other insects.

TABLE 2.--Comparison of insect visitors observed on apple, cherry, pear, and plum blossoms at Camino, Calif., during the seasons of 1932 and 1933

Insects	Number of insects	Percent of total visitors
Honeybees	10,774	82.3
Blowflies	926	7.1
Small wild bees	759	5.8
Syrphid flies	200	1.5
Bombyliid flies	164	1.3
Leaf-cutter bees	33	.2
Others	230	1.8
Total	13,086	100.0

Increased Areas under Cultivation

Cultivation of the land destroys the nests of beneficial insects and discourages rehabitation. The 1940 census reports a decrease in farm wood lots (nesting sites) of over 53 million acres since 1910.

Brittain, W. H.
1933. Apple pollination studies in the Annapolis Valley, N. S., Canada, 1928-1932. Canada Dept. Agr. Bul. 162, 198 pp.

p. 92: Observations were made by Hooper (1929 and 1931) over several years on the numbers of various insects visiting apple blossoms, and the numbers added up. The district contained many cherry, apple and other fruit plantations and numbers of hive bees were kept. The land not in orchard was either ploughed land or sheep pasture, not very suitable for pollinating insects. The counts on apple were as follows:

Hive bees	374	Beetles	104
Bumble bees	37	Ants	51
Halicti, etc.	21	Earwigs	3
Flies	23	Thrips	2

p. 93: Bumble bees are a variable quantity. They are numerous in the region of the North Mountain, and especially in certain seasons, as in 1930, were a decided factor in pollination of an orchard at Blomidon, but in 1931 were much less numerous. In 1932 there was an apparent increase at some points, but, taking the area as a whole, they

cannot be considered an important factor in apple pollination. There is considerable testimony to the effect that the bumble bee population has declined in recent years. Formerly, it is said that they were common in more or less damp meadows where hand mowing had to be resorted to, but are now much less frequently found, especially in the Valley proper. Whether this is actually the case, and whether, if true, it is due to limitation of breeding places, poisoning, or some other factor, cannot now be determined.

p. 96: Without pursuing this subject further, it may be pointed out that roadside banks, pastures and dykes do not represent exactly wild conditions, but are the product of human activity. However, neither are such locations intensively cultivated. Cultivated land and certain soil types, such as light sand or gravel, are not suited to nesting, which is one reason that the solitary bees are more numerous in such places as Long Island and along the North Mountain, than they are at many points situated in the middle of the Valley.

p. 108: In 1932 the number was less, corresponding to an apparent decrease in the solitary bee fauna from all stations. This observation may be correlated with a heavy mortality occurring among the solitary bees in the summer of 1931, apparently due to drowning in the nests following wet weather.

Hutson, R.
1926. Relation of the honeybee to fruit pollination in New Jersey. N. J. Agr. Expt. Sta. Bul. 434, 32 pp.

pp. 10-12: The difference in the number of insects present in the cultivated Triangle plot ... practically surrounded by tilled land, and in the cultivated Starr planting situated beside overgrown land is quite marked.

Family	Triangle	Starr
Chironomidae--midges	27	121
Bombidae--bumblebees	4	31
Syrphidae--syrphus flies	25	67
Scarabaeidae--beetles	--	4

p. 27: It has been generally demonstrated that insects, especially honeybees, are factors in the set of fruit.

Another factor is the comparatively high state of cultivation obtaining in the orcharding districts, which destroys hibernating places. The conditions do not obtain in the cranberry bogs which are surrounded by overgrown land, as cranberries do not bloom until July, giving ample time for breeding.

p. 29: The number of species of insects acting as fruit pollenators in southern New Jersey is small; the number of individuals other than honeybees is small, the lack of pollenizers being most serious in apple and pear orchards situated in cultured areas, less serious adjacent to uncultivated land, and not a problem at all on cranberry bogs, surrounded, as they are, with woodland, and blooming two months later than apple and pear.

Honeybees and bumblebees are the most important insect pollenizers in southern New Jersey. The ease with which honeybees can be supplied as needed is the deciding factor in making them the most dependable pollenizers.

Johnston, S.
1927. Pollination, an important factor in successful pear production. Mich. State Hort. Soc. Ann. Rpt. 1927: 196-199.

p. 199: Bees or other suitable insects are therefore necessary for pollen transfer. While other insects carry pollen to some extent, the honeybee has no equal in this respect. Unfortunately, tame bees have been greatly reduced in numbers throughout the State by foulbrood, a very serious disease of bees, while the wild bees have been greatly reduced in numbers through the extermination of our forests and the thoughtless cutting and robbing of bee trees.

Legasse, F. S.
1928. Proper pollination of fruit blossoms. Del. Univ. Agr. Ext. Bul. 15, 20 pp.

p. 5: Poor sets of fruit have long been associated with rainy weather during the blossoming season. We have learned that this is due to the fact that honey bees, particularly the domesticated ones, do not fly extensively during rainy, cool, and windy weather, rather than to the effect of the rain on the blossoms themselves. This is another condition over which we have little control. The only possible remedy lies in the harboring of greater numbers of certain wild insects, such as the wild honey bee, which fly under weather conditions that cause the domesticated bee to cling closely to the hive. However, the prevalent system of clean cultivation and cover crops, furnishes no nesting place for the wild bees and is not conducive to their multiplication in our orchards.

Murneek, A. E.
1930. Fruit pollination. Mo. Agr. Expt. Sta. Bul. 283, 14 pp.

p.1: Almost all fruit grown in Missouri are pollinated by insects. Wind is no factor in fruit pollination. When the orchard is small and there is a great deal of waste land in close proximity, enough wild bees, bumble bees and other insects may be present in the spring to be of benefit in pollination. But in a region where most of

the land is under cultivation, the common honeybee is the only insect to reply upon. They are the only pollenizer under the control of man.

Murneek, A. E.
1937. Pollination and fruit setting. Mo. Agr. Expt. Sta. Bul. 379, 28 pp.

p. 13: Of the various kinds of insects that visit flowers early in the spring, the common honeybee is by far in the majority. Moreover, it has been demonstrated in a convincing way that bees are of great value in pollination of apples, pears, cherries, plums and many other fruits. This is particularly true in sections where most of the ground has been put under cultivation with very little waste land left to harbor wild insects.

Phillips, E. F.
1933. Insects collected on apple blossoms in western New York. Jour. Agr. Res. 46: 851-862.

p. 861: It seems probable that the scarcity of wild insects on apple blossoms is due to a combination of factors incident to the agriculture of the fruit districts. The relatively high land values tend to reduce waste land and wood lots and also tend to eliminate the wide fence rows which are favored nesting places for some species. Cultivation reduces nesting and hibernating places, especially of solitary bees. Clean cultivation of orchards, where practiced, still further reduces the opportunities for the propagation of wild bees. It is possible that the efforts of fruit growers to control injurious insects in some degree serves to destroy individuals of those species which are beneficial. Beekeepers have observed that dusting destroys many honeybees, and it is probably equally disastrous to solitary bees.

Tysdal, H. M.
1940. Is tripping necessary for seed setting in alfalfa? Amer. Soc. Agron. Jour. 32: 570-585.

p. 583: The most effective pollinators in this study have been Megachile and Nomia bees, several species of which have been observed working on alfalfa. Other conditions being favorable, it would appear that one of the most effective means of insuring a seed crop of alfalfa would be a supply of these small, relatively harmless, hard-working insects. It should, therefore, be sound agronomic practice to encourage their presence in an alfalfa seed field. The writer has talked with alfalfa seed growers who have plowed through a large colony of these bees, which often make their home in the ground, and in some instances it has been known that such practices have destroyed the entire colony, or at least caused it to move.

p. 584: Entomologists who have observed the alfalfa pollinating insect population in Nebraska for many years unhesitatingly state

that there are fewer colonies of Nomia species and fewer of Megachile species than formerly. It is possible that cultivation and settlement has disturbed the wild bees and thus reduced their number. Hence, it is suggested that a decrease in the population of these beneficial insects, together with a possible increase in harmful insects, may be an explanation for the uncertainty in alfalfa seed production in formerly good seed-producing areas.

Concentrated Plantings

Wild pollinating insects apparently do not range widely for food, and since they do not store an appreciable amount of food, concentrated plantings of one crop are not favorable for their development.

Brittain, W. H.
1933. Apple pollination studies in the Annapolis Valley, N. S., Canada, 1928-1932. Canada Dept. Agr. Bul. 162, 198 pp.

p. 9: It should be emphasized, however, that a few colonies of bees placed in an orchard surrounded by large acreages devoid of bees is of little or no value. In such situations it may be necessary to have a concentration of from 35 to 50 colonies in order to ensure the pollination of the particular orchard in which the bees are placed. In districts where beekeeping is general, however, and neighbouring orchards are similarly supplied, one colony to the acre or even one colony to four acres may be sufficient. Owing to the many factors involved more exact figures cannot be given. It must suffice to point out that the provision of as many colonies as practicable is a useful measure of insurance against unfavourable weather, and a scarcity of wild pollinators, since it is only the hive bees that can be increased in numbers at will and placed where needed in the orchards. Unfortunately, at the present time, there is no adequate local supply; inexperience in beekeeping and the danger of poisoning prevents many from adopting this practice who would otherwise do so.

Hootman, D. H.
1930. The importance of pollination and the honey-bee in fruit yields. N.Y. State Hort. Soc. Proc. 1930: 49-58.

The location and size of the individual orchard are apparently the factors that determine whether or not bees are needed. Orchards not too large in size with varieties well mixed, located near woods, swamps or uncultivated land where wild insects can winter over in large numbers, usually set a satisfactory crop without additional bees. With the conditions that exist in commercial fruit sections where whole communities are engaged in fruit growing and where orchards have been planted by the square mile the wild insects are wholly inadequate to pollinate effectively the vast expanse of bloom. It is

in these locations especially that commercial fruit growers are largely dependent upon the honeybee—the only insect admirably adapted for pollinating fruit bloom that can be readily controlled by man.

Kearney, T. H.
1923. Self-fertilization and cross-fertilization in Pima cotton. U. S. Dept. Agr. Dept. Bul. 1134, 68 pp.

p. 49: Observation in Arizona has shown that the number of efficient pollinating insects differs greatly in different localities.3/ Bees and other active pollinators are normally abundant among the cotton flowers at Sacaton throughout the summer, and the entire surface of the stigmas is almost invariably well covered with pollen soon after the corolla has opened. On the other hand, observations in the Salt River Valley, at distances of 25 to 40 miles from Sacaton, have shown that insect pollination of cotton there is often much less rapid and complete. The probable explanation is that in recent years an extensive and almost continuous acreage has been planted to cotton, and the insect population is not large enough to insure thorough pollination of all the flowers.

Thus, on July 18, 1919, in a field situated near Tempe <u>in the heart of the cotton-growing district</u>, no pollen grains were observed upon the extrastaminal portion of the stigmas at 9 a.m. and very few at 10 a.m. Late in the afternoon of July 20, 1920, inspection of the same field showed the extrastaminal portion of the stigmas to be free from pollen in most of the flowers, while the remaining bore only a few insect-transported grains. None of the flowers examined showed thorough pollination of the whole stigmatic surface. Two other centrally located fields, one at Phoenix and one near Tempe, which were examined at 5 p.m. on August 5 and at 4 p.m. on August 6, showed similarly deficient pollination. On the other hand, <u>in fields situated on the outskirts of the valley</u>, at Litchfield and at Goodyear, which were examined at noon on the same days, <u>bees and other pollinators were abundant</u>, and the stigmas of the cotton flowers were found to be well covered with pollen.

p. 50: In the mean number of seeds per 100 flowers, a value which integrates the percentage of bolls matured and the mean number of seeds per boll, the increase due to artificial pollination amounted to 32 per cent, indicating <u>that a substantially greater crop both of seed and of fiber might be expected if bees were abundant in the Salt River Valley cotton fields during the blossoming period</u>.

3/ A pronounced difference in the abundance of pollinating insects at different localities in Arizona was noted by Cook, McLachlan, and Meade. "At the time of our visits to the fields at Yuma and Sacaton there was a notable difference in the activity of the insects at the two places. Several species of large wild bees that were industriously visiting the flowers at Yuma in September were not seen at all at Sacaton."

Luce, W. A., and Morris, O. M.
1928. Pollination of deciduous fruits. Wash. Agr. Expt. Sta. Bul. 223, 22 pp.

p. 21: Observations made at Wenatchee in the spring of 1926 and 1927 developed the fact that there are relatively few insects visiting the apple blossom in many orchards. These examinations showed that there was a lack of insect activity necessary to perform the cross-pollinizing in commercial orchards. In orchards where there were still plenty of trees of several different varieties the failure of a crop was apparently due to lack of insect activity at blossom time. Orchards nearest the foot hills or open country produced the heaviest set of fruit. The native bees and insects came in abundance from the rocky or hilly ground near these orchards. This condition has been known to prevail in many local districts for several different years.

Where wild bees and other insects are abundant, a minimum amount of help is needed from the honey bee, but in the large closely planted commercial sections, where there are very few wild bees and other insects visiting the blossoms, more honey bees should be provided.

Rail-Fence Elimination and Heavy Grazing

Rail fences constitute ideal nesting places for many species of pollinating insects. The replacement of rail by wire fences has destroyed such nesting places, for wire fences permit clean, close cultivation. The increase in the output of wire fences and their relative cheapness has facilitated the use of stock for cleaning up fence rows and out-of-the way patches of land which would otherwise harbor pollinating insects.

It is an axiom in beekeeping that bees starve on sheep ranges. The sheep trample the ground and eat the vegetation into the ground, leaving few flowering plants.

There has been an increase of more than 4 million head of sheep on farms since 1910.

The practice of pasturing sheep in woodlands is detrimental to the propagation of wild pollinating insects.

Sims, I. H., Munns, E. N., and Auten, J. T.
1938. Management of forest soils. U. S. Dept. Agr. Yearbook (Soils and Men) 1938: 737-750.

p. 744: The number of livestock grazing the farm woods in the Central States is estimated to be five times the actual carrying capacity and is maintained largely by supplementary feeding of crop feeds.

Spencer, D. A., and Potts, C. G.
1933. Sheep raising in U. S. has changed greatly since pioneer period. U. S. Dept. Agr. Yearbook 1933: 264-273.

p. 264: Sheep are also raised extensively in the grass-producing areas of the Eastern and Central States, particularly in rolling and hilly sections. Since sheep are fond of a great variety of weeds and underbrush which cattle and horses do not relish, they are useful in keeping fields and fence corners clean and in utilizing forage not so well adapted to other livestock.

p. 267: Except where flocks are kept to produce purebred stock, special crops are seldom grown for the sheep, which are generally turned onto pasture as soon as the grass begins to grow in the spring and remain there until the crops have been harvested, when they are usually given the run of the fields to graze and to clean up the weeds, and remain there until snow falls. They are then carried through the winter on hay and some of the unsalable roughage, with little or no grain.

Forest, Brush, and Grass Fires

Forest, brush, and grass fires destroy all kinds of wild life, including pollinating insects. The practice of burning fence rows, railroad right-of-ways, pastures, etc., is highly detrimental to wild pollinating insects, most of which nest in or near the ground.

Sims, I. H., Munns, E. N., and Auten, J. T.
1938. Management of forest soils. U. S. Dept. Agr. Yearbook (Soils and Men) 1938: 737-750.

p. 741: Heavy cutting has commonly been followed by fire, and examples of serious soil deterioration due to this combination of treatments can be found in practically every forest region of the country. Some 60 million acres of land have been so completely devastated by this combination that they are unlikely to reforest naturally and must be planted. The total is being swelled currently by the addition of 850,000 acres each year, three-fourths of which is land formerly occupied by conifer stands.

When cut-over land is burned the fire accomplishes in minutes the degree of litter removal that would be achieved naturally only after several years... This sudden removal of the litter and its living population sets in motion a chain of events leading directly to deterioration or loss of the soil.

p. 743: Extreme soil temperatures frequently develop during the great conflagrations and humus in the upper horizons is oxidized

immediately. The mineral soil has much the same appearance as samples ignited in a furnace. Accumulations of heavy debris burn with such intensity that the soil is sterilized for years.

The Automobile and Paved Roads

Fast-traveling automobiles kill large numbers of pollinating insects. For every slow, awkward female bumblebee killed in the spring there is one less nest of pollinating insects later in the year. Improved, well-kept roads offer little refuge for wild pollinating insects.

Pickles, W.
1942. Animal mortality on three miles of Yorkshire roads. Jour. Anim. Ecol. 11: 37-43.

p. 38: As with the Coleoptera, the Hymenoptera, chiefly bees, have met their deaths either by being crushed by the wheels of the vehicles, or in the manner indicated above.

p. 40: A busy road passing through a country district has a big effect on the animal life in its vicinity.

Throughout the year 1938, the total number of animals (insects) killed on the 3 miles of road under observation was 687... This is 229 per mile; of which 113.3 were Hymenoptera.

pp. 41-42: Altogether, there were 42 different species of animals killed on the roads. [The Hymenoptera included were as follows:]

Bombus terrestris L.	*Apis mellifera* L.
B. lapidarius L.	*Colletes succinata* L.
B. muscorum L.	*Andrena armata* Gmel.
B. agrorum F.	*Vespula vulgaris* L.
B. ruderatus F.	*V. germanica* F.

Poisoning from Insecticides

Thousands of colonies of honeybees are killed each year by arsenical sprays and dusts. Often the losses occur long after the insecticides have been applied, when brood is fed stored poisoned pollen. Under such conditions bees gradually dwindle and die, and often the owner is not aware of the true cause.

At one time poisoning of honeybees was confined largely to the fruit-blossoming period, when bees took poison from open blossoms, but now the poisoning continues throughout most the summer because many cover sprays are applied to control injurious insects, particularly the codling moth. Sprays and dusts falling on cover crops in orchards kill both honeybees

and native bees. The dusting of cotton, potatoes, and vegetables takes a heavy annual toll of bees.

From the knowledge of the habits of wild pollinating insects and the fact that the queens obtain their food directly from flowers, they would appear to be even more susceptible to insecticides than honeybees, since the queen's food is not nectar and pollen but royal jelly. Brittain made observations on this point, but came to no definite conclusions as to the over-all effect of the use of insecticides on wild pollinating insects. He did find, however, lethal amounts of arsenic in pollen in the nests of wild bees.

VALUE OF THE HONEYBEE IN POLLINATING CROPS

On the following pages will be found a few selected references to the value of the honeybee in pollinating crops, as mentioned in articles by recognized authorities in horticulture and agronomy.

Dietz, H. F.
1925. Pollination and the honey bee. Ind. Conserv. Comn. Pub. 52, 20 pp.

pp. 19-20: One thing is certain. The honeybee represents the highest point that has been reached in the insect world as a flower pollinator. Its own existence in both the larval and adult stage are dependent on either pollen or nectar. The habits that it possesses of working one kind of flower at a time make it a more effective pollinator than an insect that visits all flowers promiscuously...

And finally the honeybee is the only one of the insect pollinators that man has under his control or domesticated, so to speak. All the rest are subject to all the vicissitudes of nature, including unfavorable weather conditions, food shortage, which cannot be supplied, and the inroads of natural enemies, including Man. Man through his varied, often thoughtless and multitudinous activities, is the greatest disturber of the natural order of things, and what he does he must pay the price for in one manner or another. However, by studying the ways of nature he often corrects his errors and when he needs a general flower pollinator he has but to try the honeybee.

Vansell, G. H., and deOng, E. R.
1925. A survey of beekeeping in California and the honeybee as pollinizer. Calif. Agr. Expt. Sta. Cir. 297, 22 pp.

pp. 17-18: Of all the insects that visit flowers, bees are the best adapted by the structure of the body to act as carriers of pollen. The body and legs are covered with heavy, stiff hairs which are branched or featherlike. These catch and hold the pollen grains, until they are brushed into a "pollen basket" on the hind leg. In

this carrier the load of pollen is transported to the hive. However, all bees are not of equal value as pollinizers as some of them do not visit all types of flowers. The honeybee and the bumblebee, however, visit almost all flowers with little restriction except that they evidently confine themselves to a single species on any one trip.

We have many native species of bees such as bumblebees, carpenter bee, leaf cutters and others, but only in rare instances are any of these active during the early spring and then only in very restricted numbers.

The bumblebee is one of the earliest of the native bees to feed in the spring, but the entire colony, except the queen, perishes during the winter.

In the spring the whole responsibility of rebuilding the colony devolves upon the queen. She lays and incubates the eggs, seven to sixteen in number, feeds the newly hatched larvae and only after the first brood matures can she give her strength entirely to brood rearing. By fall the colony may have grown to a size of from one to five hundred individuals. Certain of the mining bees, Halictus, which nest in certain cliffs, have one or two generations a year. The spring generation consists of hibernating, fertilized females which give rise to a summer generation. The leaf-cutting bee, Megachile spp., apparently has but one generation a year and includes but a small number of individuals. The carpenter-bee, Ceratina dupla, has two broods a year which are very restricted in numbers.

These examples are typical of the life history of our common native species of bees that have from one to five or six brood cycles annually, while the number of individuals range from a score to a few hundred. Comparing this with the honeybee's record of from twelve to fifteen brood cycles a year, all the descendants of a single queen, which may reach a hundred thousand bees annually, or more, we realize the wonderful reproductive powers of this insect. It should also be noted that instead of the death of all the workers, the winter's mortality among honey bees is usually very slight. From five hundred to sixty thousand may be present in a single colony at the close of winter and two or more brood cycles may be reared in the spring before many of the fruit trees bloom.

Fruit Crops

Gould, H. P.
1939. Why fruit trees fail to bear. U. S. Dept. Agr. Leaflet 172, 5 pp.

pp. 3-4: Self-sterility is very common. It occurs in many varieties of apples, most varieties of pears, probably in all varieties of sweet cherries, in most if not all varieties of the native and

Japanese plums, and in some varieties of European or domestic plums and prunes. Sour cherries are considered largely self-fertile, although there is some evidence of partial self-sterility. Most peach varieties are self-fertile; the J. H. Hale and June Elberta (Mikado) are notable exceptions, as they require cross-pollination. Sterility in plums, cherries, and perhaps other fruits may sometimes be due to deformed or imperfect pistils. Some grape varieties must be cross-pollinated in order to be fruitful.

There is every conceivable degree of self-sterility, from one extreme where no fruit sets without cross-pollination to that where it is so slight as not to be a serious factor in fruit production. The opinion is commonly held that even the varieties considered to be self-fertile in a high degree will set a better crop of fruit if cross-pollination occurs. With self-sterility prevailing to so large an extent in common fruit varieties, the relation of weather conditions favorable to the greatest activity of honeybees becomes readily apparent, since it is on them that the fruit grower must depend very largely for the cross-pollination of his fruits.

When self-sterile varieties are planted and there are no other trees of different varieties of the same kind growing near enough to insure the passing of bees from one to the other, it will be found that trees blossom but do not set fruit.

When the tree to be cross-pollinated is in bloom secure some blossoming branches from a tree of another variety of the same kind of fruit and place them in a pail or other water container in the top of the tree. The bees, visiting the trees, will also visit the blossoms on the branches and will thereby transfer the pollen as they revisit the blossoms on the tree.

Murneek, A. E.
1930. Fruit pollination. Mo. Agr. Expt. Sta. Bul. 283, 12 pp.

p. 1: With proper care bees winter over in large numbers and are very active in the spring. They are especially well adapted to carry pollen. Their bodies and legs are covered with hairs to which the pollen grains adhere in large numbers. Moreover, the honeybee visits only one kind of flower, like the apple or the peach, at a time. Thus they are very effective agents in cross-pollination.

p. 9: It has been demonstrated in many orchards in a convincing way that bees are of great value for the pollination of apples, sour cherries, and other fruits. If the orchardist does not keep his own bees and there are none in the neighborhood, then most certainly it will pay to secure several hives.

Philp, G. L., and Vansell, G. H.
1932. Pollination of deciduous fruits by bees. Calif. Agr. Col. Ext. Cir. 62, 27 pp.

p. 4: The fruit grower has a pollination problem with almonds, cherries, plums and prunes, apples, pears, and berries. In general, apricots, peaches, and walnuts set well with their own pollen and hence present no difficulties from this standpoint. The J. H. Hale peach, however, is self-unfruitful and must be interplanted with some other variety. Recent studies indicate that some varieties of walnuts in certain years do not mature the staminate and pistillate flowers at the same time and therefore, under these conditions, cannot pollinate themselves.

p. 5: Bees are the most important insects for this work. The grower should therefore have plenty of bees in the orchard during the blossoming period.

[Honeybees are rented for the pollination of almonds, apples, avocados, cranberries, pears, plums, prunes and cherries, as well as cucumbers and alsike clover.]

Almond

Tufts, W. P., and Philp, Guy L.
1922. Almond pollination. Calif. Agr. Expt. Sta. Bul. 346, 35 pp.

p. 24: Pollenizing agencies, such as the honey bee, are necessary to the set of a good crop of fruit. One colony of honey bees should be provided for each acre of orchard.

Crane, H. L., and Reed, C. A.
1937. Nut breeding. U. S. Dept. Agr. Yearbook 1937: 827-889.

p. 872: The pollen of almond and tung trees is carried by insects.

Apple

Auchter, E. C.
1924. The importance of proper pollination in fruit yields. N. J. State Hort. Soc. Proc. 1924: 133-142.

pp. 140-141: The value of bees in pollination. The carrying of pollen from one variety to another is accomplished by wind and bees. It has been found, however, that pollen is carried only very short distances by wind, but that bees play a very important part in carrying the pollen.

In crossing into the blossoms to get the nectar, their bodies become dusted with the pollen. This pollen is then left on the stigmas of other blossoms when they are visited. In California the investi-

gators are recommending one hive of bees per acre for pollination purposes.

A few years ago, the writer helped to conduct a special test to prove the value of cross-pollination and bees in a bearing Rome Beauty orchard in West Virginia. This orchard consisted of approximately twenty acres and was planted at quite a distance from any other orchards. Although it blossomed well each year, the set was always very light. During the blossoming time for two years bees were placed under sixteen trees in the center of the orchard and blossoming limbs of other varieties were secured and placed in pails of water, which were hung in the Rome Beauty trees. The bees worked back and forth through these blossoms and an excellent set was secured each year on these sixteen trees. The rest of the orchard, at some distance from the bees, set only a light crop.

A similar test conducted in 1922 in a bearing Stayman Winesap orchard in Maryland where bees were placed in the orchard, together with blossoming branches of the York Imperial variety in pails of water, resulted in a fair crop of fruit being set, even though the season was unfavorable for pollination purposes due to some frosts and cold windy weather. In previous years, without bees or the York Imperial blossoms, very little fruit "set" although there were plenty of Stayman blossoms and the weather was favorable.

In 1923 with good pollination weather and Grimes blossoms placed about the bee hives, a good set of fruit was obtained in this orchard.

In some special tests at the Experiment Station in 1923, two trees, one a Grimes and one a Stayman Winesap, 40 feet apart, were inclosed in a large muslin frame 14 feet wide, 14 feet high, and 55 feet long.

A muslin partition was built through the center of the tent (long ways) so that one-half of each tree was on one side of the partition and one-half of each tree was on the other side. Bees were placed in one side of the tent, so that they could fly back and forth between the halves of the Grimes and Stayman Winesap trees. No bees were placed in the other side of the tent. In the side in which bees were placed, fruit set on the halves of both the Stayman Winesap and Grimes trees. In the other side of the tent without bees, no fruit set on the halves of the same Stayman Winesap tree, although the Grimes, being a self-fertile variety, did set some fruit. Apparently in the one-half of the tent, the Grimes pollen was carried by the bees to the Stayman Winesap, giving a set, while in the other half, the Grimes pollen did not reach the Stayman blossoms.

Another test of the value of bees was indicated in some experiments carried on at the College in 1923. Two hundred and fifty blossoms each of Baldwin, Lawyer, Stayman Winesap and Kinnaird were emasculated and left unbagged or open to cross-pollination. Apparently, because all of the petals had been removed by emasculation, the bees were not attracted to these blossoms. As a result, not a blossom on any of the emasculated blooms "set." Other unemasculated blossoms (with their petals expanded) on the same limbs were apparently visited by the bees so that cross-pollination took place. In these cases 21.4 per cent of the Lawyer blossoms, 6.4 per cent of the Kinnaird, 15.8 per cent of the Baldwin, and 5.3 per cent of the Stayman Winesap "set" fruit.

From the above experiments, it can be seen how important it is for orchardists to have several hives of bees scattered through their orchards. The last experiment also suggests that a great many bees might be killed if poisonous sprays are used when the petals of the blossoms are showing.

MacDaniels, L. H., and Heinicke, A. J.
1929. Pollination and other factors affecting the set of fruit, with special reference to the apple. N. Y. (Cornell) Agr. Expt. Sta. Bul. 497, 47 pp.

pp. 4-5: The flowers of the apple and of most of our fruit plants are adapted by their structure to insect pollination. The showy petals, the odor, and the nectar-secreting glands have the function of attracting insects which carry the pollen from flower to flower. The pollen itself is of the sticky type that adheres to the hairy coat of insects which visit the blossoms ... rather than of the light dry type that is adapted to wind dissemination. When it is appreciated that it would take approximately 400 apple-pollen grains placed side by side to reach from one end of a bee to the other, and that the number carried by a single bee might easily approximate 100,000, some idea of the possible effectiveness of insect pollination can be gained.

Overholser, E. L.
1927. Apple pollination studies in California. Calif. Agr. Expt. Bul. 426, 17 pp.

p. 15: The use of bees as a means of effecting pollination in an apple orchard greatly increased the set of fruit when contrasted with the normal set.

Cross-pollination increased the set of fruit, even with self-fruitful varieties like the Yellow Newtown.

Swinson, C. R., Weaver, F. P., Dadisman, A. J., Vernon, J. J., Gould, H. P., and Lincer, J. B.

1927. Factors influencing the yield of apples in the Cumberland-Shenandoah region of Pennsylvania, Virginia, West Virginia. U. S. Dept. Agr. Tech. Bul. 54, 25 pp.

p. 21: A number of growers attributed low yields to failure of fruit to set. It was commonly observed that the low yields of the Winesap and varieties of the Winesap family were ascribed to this factor. These varieties are largely self-sterile and must be cross-pollinated by some other variety. Self-sterile varieties should not be planted in solid blocks or isolated from other orchards. Where self-sterile varieties have been so planted the results may be improved by top-working every fourth or fifth tree in every fourth or fifth row with some variety that is a good cross-pollinizer. Bees are essential in any orchard and are effective in securing pollination even during cold, wet seasons.

Avocado

Stout, A. B.
1933. The pollination of avocados. Fla. Agr. Expt. Sta. Bul. 257, 44 pp.

p. 42: It is without doubt advisable (1) to interplant avocados on the basis of their flower behavior (2) to supply bees in abundance to effect pollination.

Traub, H. P., Pomeroy, C. S., Robinson, T. R., and Aldrich, W. W.
1941. Avocado production in the United States. U. S. Dept. Agr. Cir. 620, 28 pp.

p. 3: With some varieties, as Fuerte, there is sufficient overlap of the two sets of flowers to render them self-fertile; with other varieties, a sufficient percentage of single-cycle flowers (completing their anthesis in one opening) are produced to render self-pollination easy of accomplishment, the only requirement in each case being the activity of bees or other insects ... .

Keeping bees in or about the orchard is also considered a wise provision during the blooming period. Observations indicate that pollen is carried considerable distances by bees and doubtless by other flying insects.

Blackberry

Darrow, G. M.
1937. Blackberry and raspberry improvement. U. S. Dept. Agr. Yearbook 1937: 496-533.

p. 498: Normally the wild blackberries of the East are entirely

or nearly self-sterile, and those of the Pacific coast have male and female organs on separate plants. All need cross-pollination. In the clearings and pastures bees and other insects have crossed the blackberry species for the last 100 to 300 years.

Raspberry, Blackberry, Dewberry (Rubus)

Robbins, W. W.
1931. The botany of crop plants. Ed. 3, 608 pp. Philadelphia.

p. 340: Pollination. As a rule the anthers and stigmas mature simultaneously. There is abundant nectar secreted by a fleshy ring on the margin of the receptacle, inside of the stamens. Insects facilitate pollination. Better yields are secured, in the case of some dewberries, if they are planted adjacent to another variety so that cross-fertilization will result.

Blueberry and Huckleberry

Merrill, T. A.
1936. Pollination of the highbush blueberry. Mich. Agr. Expt. Sta. Tech. Bul. 151, 34 pp.

p. 33: Of much greater importance than self or cross-pollination, though it receives little space in this report, is the need of insuring some (any) sort of pollination. Mechanical aid is absolutely necessary to a good set, from self as well as from cross-pollination.

Bumble-bees and honey bees play a very active part in blueberry pollination.

Phipps, C. R.
1930. Blueberry and huckleberry insects. Maine Agr. Expt. Sta. Bul. 356, pp. 107-232.

p. 116: In conclusion, then, the investigations thus far have shown: (1) that various species of insects, especially honey-bees, bumble-bees and other bees, collect blueberry pollen; (2) that such insects undoubtedly exert a marked influence on blueberry pollination since their exclusion affects yields so strikingly.

Cherry

Lagasse, F. S.
1928. Proper pollination of fruit blossoms. Del. Univ. Agr. Ext. Bul. 15, 20 pp.

p. 10: The experimental results obtained in different sections of the country on the sour cherry with respect to its self-fertility do not entirely agree. The majority of evidence, however, indicates that most varieties will set commercial crops thru the use of their own pollen. Shoemaker ... has recently shown that the set of Montmorency is increased under Ohio conditions by the use of early Richmond pollen, but it is doubtful whether the increased set will compensate for the space occupied by the trees of the inferior pollinating variety. Interplanting of several varieties, better cultural practices, and the placement of bees in the sour cherry orchard is recommended for increasing the set of fruit.

Schuster, C. E.
1925. Pollination and growing of the cherry. Oreg. Agr. Expt. Sta. Bul. 212, 40 pp.

p. 23: With fruit so dependent upon cross-pollination as are cherries, the agents responsible for this transfer of pollen need to be considered. The number and presence of wild insects can be controlled very little, but the honey-bee can be controlled to a great extent. It is becoming the practice for cherry growers either to keep their own bees or to hire stands of bees during the blooming season. One hive to one or two acres of cherries is sufficient if the stands of bees are strong.

The sour cherry may be self-sterile, self-fertile, or partly self-fertile, depending on the variety.

Tufts, W. P., and Philp, G. L.
1925. Pollination of the sweet cherry. Calif. Agr. Expt. Sta. Bul. 385, 28 pp.

p. 26: Pollinizing agencies, such as honey bees, are necessary to set a good fruit crop.

At least one stand of bees should be provided for each acre of orchard.

Cranberry

Darrow, G. M., Franklin, H. J., and Malde, O. G.
1924. Establishing cranberry fields. U. S. Dept. Agr. Farmers' Bul. 1400, 37 pp.

pp. 9-10: Results of investigations by the Massachusetts Agricultural Experiment Station indicate that in that State cranberry blossoms are pollinated by bees. Bumblebees and honey-bees seem to be the chief agents of pollination. As the former are not always

abundant many growers keep small apiaries.

Bees are not common in the cranberry region of Wisconsin, and experiments and observations by representatives of the Wisconsin Agricultural Experiment Station indicate that though they help in pollination they are not necessary in that State under normal conditions. The cranberry blossoms there seem to be practically self-fertile. After the flower bud opens ... the pistil grows past the anthers and may be fertilized then or later as the flower is jostled by the wind. Even in Wisconsin bees may be of great value in hastening pollination, thus insuring uniformity in the time of setting and maturing the fruit. Without insect aid the pollination is apt to extend over a long period and the fruit likely to mature unevenly.

Cucumber

Beattie, W. R.
1942. Cucumber growing. U. S. Dept. Agr. Farmers' Bul. 1563, 25 pp.

pp. 12-13: Pollination, or the setting of fruit, on cucumber vines is dependent upon some outside agency such as bees. Two kinds of flowers are found on every fruiting cucumber plant--the male ones ... which supply the pollen, and the female ones... which produce the cucumbers. They can be readily distinguished, as the female flower is borne on the outer end of the little cucumber. Usually the male flowers appear in great abundance in advance of the female flowers, which leads to the erroneous notion that the cucumbers are failing to set fruit. Later, the female flowers appear, and fruit is formed. Cucumbers grown in the field are pollinated by either tame or wild bees from the neighborhood. Under favorable conditions, cucumbers grown in frames may be pollinated by natural agencies, but the sash-cucumber growers of the Norfolk district provide hives of bees near their frames when the cucumbers are setting, in order to insure perfect pollination. Without proper pollination the cucumbers are deformed, or at least a considerable percentage of nubbins are produced. In localities where bees are scarce it is advisable for the growers of cucumbers in fields to keep bees, in order to insure pollination.

Gooseberry

Hooper, C. H.
1939. Hive bees in relation to commercial fruit production. Southeast. Agr. Col. Jour. 44: 103-108, illus.

p. 106: There is an opinion that blossoms that have been pollinated resist frost better than those that have not been pollinated ... In England a Cambridgeshire grower who had a large acreage of gooseberries and had hives of bees placed among them, in a year in which frost damaged his neighbours' crops, had a good crop which he attributed to his bees.

Gooseberry and Currant

Robbins, W. W.
1931. The botany of crop plants. Ed. 3, 608 pp. Philadelphia.

p. 307: Pollination.--Gooseberries and currants are cross-pollinated for the most part. Insects are the chief agents in pollination.

Almeria Grape

Olmo, H. P.
1943. Pollination of the Almeria grape. Amer. Soc. Hort. Sci. Proc. 42: 401-406.

p. 405: Einset (1) stated that no female grape varieties are grown commercially in this country because natural cross-pollination is inadequate to obtain good yields. The Almeria in California is an exception to this rule. This fact brings up the question as to whether grape breeders should continue to discard all female varieties without further tests of their qualities. The experience with the Almeria in California suggests that other female varieties, if they should possess particularly desirable qualities, might be grown commercially with profit <u>if adequate cross-pollination is provided. Since it has been observed that bees do work on grape flowers, it appears that more adequate cross-pollination may be provided for by introducing hives in commercial plantings to supplement wind pollination</u>.

Grape

Fletcher, S. W.
1941. Pollination. Standard cyclopedia of horticulture, by L. H. Bailey. v. 3, pp. 2734-2737. New York

p. 2736: Of one hundred and forty-five varieties of grapes tested by Beach, thirty-one were self-fertile, forty-one self-sterile, and seventy-three uncertain.

Snyder, E.
1937. Grape development and improvement. U. S. Dept. Agr. Yearbook 1937: 631-664.

pp. 639-40: The blossoms of <u>Vitis</u> are arranged in a pyramidal, loosely branched cluster known as a panicle. In the wild state some vines may bear only male or staminate flowers, while others bear perfect or hermaphrodite flowers that have both stamens and pistils. American native species bear male flowers and hermaphrodite flowers on separate vines, while most European vines of <u>Vitis vinifera</u> bear

only hermaphrodite flowers.

The hermaphrodite blossoms range from flowers having reflexed, very poorly developed stamens ... to perfect flowers with upright stamens ... Varieties with reflexed stamens usually do not set fruit, or set only very loose clusters, unless they are cross-pollinated, either naturally or artificially.

The pollen grains are deposited on the stigma through natural or artificial means.

Dearing, C.
1938. Muscadine grapes. U. S. Dept. Agr. Farmers' Bul. 1785, 36 pp.

p. 17: The pollen is carried from the male to the pistillate flowers almost entirely by insects.

While the honeybee is a less-effective pollinating insect for muscadine than for fruits with sticky pollen, such as apples, it appears to have sufficient value to warrant placing stands of bees in large vineyards during the blossoming season.

Mango

Popenoe, W.
1917. The pollination of the mango. U. S. Dept. Agr. Bul. 542, 20 pp.

p. 4: In spite of the close proximity of anther and stigma, the transfer of pollen from the former to the latter does not seem to be accomplished easily. Both the stamen and the pistil retain an erect position throughout, and the pollen as it is shed usually falls upon the base of the ovary or upon the disk rather than upon the stigma.

The normal method of transferring the pollen from the anther to the stigma must be through the agency of insects.

p. 6: The industry with which the honeybee goes from flower to flower, systematically working over the surface of the disk with its proboscis to obtain all the nectar present, at the same time turning its body around in a circle and almost of necessity coming in contact with the anther in its circuit of the disk, makes this insect one of the most effective pollinating agents.

Muskmelon

Beattie, W. R.
1926. Muskmelons. U. S. Dept. Agr. Farmers' Bul. 1468, 38 pp.

p. 21: Growers frequently inquire why the early blossoms on their muskmelons do not set fruit. Muskmelon blossoms are of two kinds, staminate and pistillate, or male and female. Following the

natural tendency of all vine crops, a large number of male blossoms appear in advance of the vines to set fruit. At the base of the pistillate or female blossom is located the small embryonic melon formed before the blossom opened, and it is necessary that the pollen from the male flower be transferred by bees or other insects to the female flower. Where melons are grown in greenhouses or in closed frames it is essential that provision be made for the entrance of bees in order that the pollen be transferred.

Peach and Nectarine

Cullinan, F. P.
1937. Improvement of stone fruits. U. S. Dept. Agr. Yearbook 1937: 665-748.

p. 675: The nectarine was formerly thought to be a different species from the peach. It is now known that the nectarine is simply a smooth-skin peach. The trees differ in no respect from the peach, and it is impossible to tell a peach tree from a nectarine tree.

p. 695: Most varieties of peaches are self-fruitful. Occasionally failure to produce crops may be due to pollen sterility, which is exhibited in a few commercial varieties, such as J. H. Hale, Halberta, Candoka, Mikado, and Chinese Cling.

Marshall, R. E., Johnston, Stanley, Hootman, H. D., and Wells, H. M.
1929. Pollination of orchard fruits in Michigan. Mich. Agr. Expt. Sta. Spec. Bul. 188, 38 pp.

p. 29: A J. H. Hale peach orchard favorably located on the Friday Bros. Farm near Coloma and containing a few scattering trees of other varieties had produced but a few fruits since planting in 1917. When it was learned that this variety was self-sterile, South Haven and Elberta trees were planted in the vacancies as pollinizers for the J. H. Hale. In spite of this provision the orchard produced less than 10 bushels of peaches in 1926. Before the succeeding blossoming period, 20 colonies of bees were located in the orchard and it produced the first crop of fruit in 11 years.

Pear

Kinman, C. F., and Magness, J. R.
1940. Pear growing in the Pacific Coast States. U. S. Dept. Agr. Farmers' Bul. 1739, 38 pp.

p. 24: That cross-pollination is advantageous to setting fruit of practically all varieties is now generally conceded. Provisions for cross-pollination should be made, notwithstanding the fact that such varieties as Bartlett, Anjou, and others may, under favorable

conditions, set fair crops when planted alone.

One tree is considered sufficient to pollinize eight others if bees are provided to carry the pollen.

Tufts, W. P., and Philp, G. L.
1923. Pear pollination. Calif. Agr. Expt. Sta. Bul. 373, 36 pp.

p. 35: Pear fruits resulting from cross-pollination do not appear to exhibit the same tendency to fall after the June drop as do those resulting from self-pollination.

Pollinating agencies such as honey bees are necessary to set a good crop of fruit.

Persimmon, Native

Fletcher, W. F.
1942. The native persimmon. U. S. Dept. Agr. Farmers' Bul. 685, 22 pp.

pp. 3-4: The trees are generally dioecious; that is, the pollen-bearing and fruit-producing flowers are borne on separate trees. The pistillate or fruit-producing flowers are borne singly, whereas the staminate or pollen-bearing flowers are generally produced in threes. The pollen is very light and powdery, and, although it is generally distributed by bees that frequent the trees in great numbers during blossoming time, it can also be carried to great distances by the wind.

Plum and Prune

Hendrickson, A. H.
1918. The common honey bee as an agent in prune pollination. Calif. Agr. Expt. Sta. Bul. 291, pp. 215-236.

p. 236: The results of the two seasons' work seem to warrant the following conclusions: Both the French and Imperial prunes may be aided in setting fruit by the use of bees in the orchard during the blossoming period, provided the trees are in a normal, healthy condition.

The absence of bees in the orchard may mean a low percentage of set with both of these varieties.

Hendrickson, A. H.
1922. Further experiments in plum pollination. Calif. Agr. Expt. Sta. Bul. 352, pp. 247-266.

p. 266: The presence of honey bees materially aided in setting heavy crops on the following combinations of varieties: Formosa and Wickson; Beauty and Santa Rosa; Diamond and Grand Duke. Observations, furthermore, showed that many other combinations were also benefited by these insects.

Hendrickson, A. H.
1919. Plum pollination. Calif. Agr. Expt. Sta. Bul. 310, pp. 1-28.

p. 27: A comparison over a number of years between trees where there was an abundance of bees flying and trees where bees were scarce, emphasized the desirability of having bees in the orchard. Even self-fertile varieties were immensely benefited by the presence of bees as an agency for distributing pollen.

Kinman, C. F.
1931. Plum and prune growing in the Pacific States. U. S. Dept. Agr. Farmers' Bul. 1372, 57 pp.

p. 25: The presence of bees in the plum orchard at blossoming time has been demonstrated to be almost an economic necessity.... Poor crops or perhaps failures may be expected of self-sterile varieties where no bees are present, and even with self-fertile varieties the presence of bees has caused a decided increase in the crop.

Strawberry

Darrow, G. M.
1937. Strawberry improvement. U. S. Dept. Agr. Yearbook 1937: 445-495.

p. 455: Pollen is carried by bees and other insects, but it is also thrown out of the stamens as the anthers crack open ... or it is jarred out and blown by the wind and falls on the pistils. A variety having perfect or hermaphrodite flowers can produce fruit when planted by itself, but one with pistillate flowers cannot set fruit unless perfect-flowered plants are nearby to furnish pollen through the agency of bees or other insects.

Robbins, W. W.
1931. The botany of crop plants. Ed. 3, 608 pp. Philadelphia.

p. 347: Fertilization and Development of the Fruit.--Strawberries are protogynous, that is, the pistils of a flower mature before its stamens. Hence cross-fertilization is secured; and this usually by insects. Non-fertilization or incomplete fertilization is usually indicated by berries with hard, greenish, undeveloped apices, so-called "nubbins."

Tung. See Almond.

Watermelon

Goff, C. C.
1937. Importance of bees in the production of watermelons. Fla. Ent. 20(2): 30-31.

From these observations it is quite evident that the size of the melon crop may be greatly influenced by the bees. Observations in Florida and elsewhere show that certain days are favorable for setting melons while a very poor set will occur on other days, due to weather conditions. If the favorable days are few and the supply of bees small, the yield may be small.

It is therefore important that a good set be obtained from the earlier flowers and to insure this an adequate supply of bees should be present. Thus, in certain areas at least, the earliness and size of yield may be increased by keeping honeybees near the field during the flowering season. In large fields, the best results should be obtained by having a hive near the center of the field.

Seed Crops

Alfalfa

Tysdal, H. M.
1940. Is tripping necessary for seed setting in alfalfa? Amer. Soc. Agron. Jour. 32: 570-585.

p. 582: One factor ... is the effect of constant visits of honey bees to the same flower. When the bees are extremely numerous the same flower may be visited a great many times, and in this way a higher percentage of flowers are tripped than shown in Table 10. Actual counts have shown honey bees to trip as much as 12 percent of the flowers of a given raceme during the course of two or three days. This would indicate that honey bees in abundance might be beneficial for seed setting. It has also been observed that certain honey bees are much more apt to trip alfalfa flowers than others, thus indicating rather wide differences among individuals in the same species. Plants also differ in ease of tripping.

Tysdal, H. M., and Westover, H. L.
1937. Alfalfa improvement. U. S. Dept. Agr. Yearbook 1937: 1122-1153.

p. 1139: The ability of the honey bee (Apis mellifera L.) to trip alfalfa flowers is not so easily clarified. Piper et al. found that honey bees tripped only from 0.3 to 4.7 percent of the flowers visited and many visits to the flower were required before tripping was effected. Dwyer ... of Australia, has found that honey bees cause a considerable amount of tripping and has suggested the use of honey bees in cages in breeding work. Michigan workers have also

found the honey bee to be effective when confined to small areas. Helmbold ... states that honey bees collecting pollen cause tripping and attributes more tripping to them than to bumblebees.

Asparagus

Robbins, W. W.
1931. The botany of crop plants. Ed. 3, 608 pp. Philadelphia.

p. 244: Pollination.--Common asparagus is almost entirely insect-pollinated. The nectaries are small and concealed at the base of the perianth. Staminate flowers are first to open.

Brassica

Magruder, R.
1937. Improvement in the leafy cruciferous vegetables. U. S. Dept. Agr. Yearbook 1937: 283-299.

p. 283: According to most botanists, cabbage, cauliflower, broccoli, green-sprouting broccoli, brussels sprouts, kale, collards, and kohlrabi are very closely related, being horticultural forms of the species Brassica oleracea L.

p. 291: By planting in alternate rows strains that are self-compatible but cross-fertile, hybrid seed will result through the action of insects in carrying the pollen from one strain to the other. Bud pollination of a few flower clusters of each strain results in enough seed to perpetuate the strains for later crops. Bees have been found to be very effective agents in the cross transfer of pollen, and by enclosing the individuals or groups of plants under cheesecloth cages the bees may be used in working out the problem of obtaining desirable crosses between different strains or increasing the seed of a number of desirable crosses for preliminary commercial tests ... .

Broccoli

Pearson, O. H.
1932. Incompatibility in broccoli and the production of seed under cages. Amer. Soc. Hort. Sci. Proc. 29: 468-471.

p. 469: The results given here indicate that the use of small numbers of bees under cheesecloth cages is a possible method of producing small quantities of broccoli seed, if the compatibility situation is such that seed can be produced with the pollen available.

Buckwheat

Leighty, C. E.
1919. Buckwheat. U. S. Dept. Agr. Farmers' Bul. 1062, 24 pp.

pp. 21-22: It is not advisable to grow buckwheat for use by bees alone. Commercial beekeeping in buckwheat-growing sections is advisable, as bees can make use of the flowers produced and may in turn be of use in fertilizing the flowers. Many buckwheat growers, in fact, believe that the weight per bushel of the seed is heavier where the crop has been worked largely by bees.

White, J. W., Holben, F. J., and Richer, A. C.
1941. Experiments with buckwheat. Pa. Agri. Expt. Sta. Bul. 403, 62 pp.

p. 57: Buckwheat plants are a valuable source of nectar, and since the common varieties are highly self-sterile, bees are of great value in bringing about cross-pollination.

Cabbage

Pearson, O. H.
1932. Breeding plants of the cabbage group. Calif. Agr. Expt. Sta. Bul. 532, 22 pp.

pp. 4-5: Insects visit the flower (Brassica oleracea) freely. Honeybees, although usually plentiful, often fail to be very efficient, because they do not work at temperatures below 60° F. Bumble-bees are not very plentiful in California, but usually a few of them are collecting pollen in nearly every field.

p. 7: Cross-pollination which is the rule in Brassica is usually brought about by insect visitation. Bees are the active pollinating agents.

Carrots

Robbins, W. W.
1931. The botany of crop plants. Ed. 3, 608 pp. Philadelphia.

p. 510: The flowers are mostly insect-pollinated.

Umbelliferea (Carrot Family)
(Carrot, Parsnip, Celery)

Robbins, W. W.
1931. The botany of crop plants. Ed. 3, 608 pp. Philadelphia.

p. 504: The umbellifers are usually insect-pollinated. Protandry is common.

Clover, Alsike

Megee, C. R., and Kelty, R. H.
1932. The influence of bees upon clover and alfalfa seed production. Mich. Agr. Expt. Sta. Quart. Bul. 14 (4): 271-277.

p. 277: The honeybee was found to be a very effective pollinating agent for June and alsike clovers and for alfalfa and the presence of large numbers of bees resulted in marked increases in the seed crops of these legumes.

United States Department of Agriculture.
1942. A much larger harvest of hay crop seeds needed in 1942. U. S. Dept. Agr., Food for Freedom Program, Background Information Series, No. 7, 5 pp.

p. 3: The placement of one hive of honeybees per acre adjacent to or in an alsike field will materially increase seed production.

Clover, Crimson

Hollowell, E. A.
1938. Crimson clover. U. S. Dept. Agr. Leaflet 160, 8 pp.

p. 8: Crimson clover is a prolific seed-producing plant and yields of 5 to 10 bushels per acre are common, depending upon the thickness of the stand, the amount of growth that is produced, and the care exercised in harvesting the seed. The florets are self-fertile, but bees are effective in tripping and transferring the pollen, with a consequent increase in the number of seed per head. The placing of colonies of honeybees adjacent to blooming fields will effectively increase pollination.

Clover, Ladino White

Hollowell, E. A.
1942. Ladino white clover for the Northeastern States. U. S. Dept. Agr. Farmers' Bul. 1910, 10 pp.

p. 10: Because cross-pollination is necessary for seed formation, it is advisable to move hives of honeybees adjacent to the fields before the plants bloom. A minimum of one hive per acre materially increases seed production.

Clover, Red

Hollowell, E. A.
1932. Red-clover seed production in the Intermountain States. U. S. Dept. Agr. Leaflet 93, 7 pp.

p. 7: The dependence of seed setting on the number and activity of honeybees and bumblebees is not realized by most farmers who grow red-clover seed. The red-clover flower is practically self-sterile; that is, the pollen of a flower will not fertilize any other flower on any head of the same plant. Therefore, before fertilization can occur, it is necessary that the pollen be transferred between flowers on different plants. This cross-pollination is done principally by honeybees, bumblebees, and other kinds of bees, whose presence in large numbers at the time red clover is blooming is essential for large yields of seed. If other nectar and pollen producing plants more liked by the bees than red clover are available, the honeybees in particular will work the other plants in preference to the red-clover flowers. If only the second growth is saved for seed, the time of cutting the first growth may be regulated so that the second growth will be in full bloom when other flowering plants are scarce and then large numbers of bees are present. There is reason to believe that in sections where an increase in acreage has been accompanied by declining yields of seed, the introduction of additional colonies of honeybees would prove profitable. Bumblebee nests should not be destroyed, and every effort should be made to provide desirable nesting places for queen bumblebees.

Pieters, A. J., and Hollowell, E. A.
1937. Clover improvement. U. S. Dept. Agr. Yearbook 1937: 1190-1214.

p. 1199: Bees visit the red clover floret for nectar and pollen or both, tripping the florets and transferring pollen from plant to plant, thus constantly maintaining the condition of mixed inheritance in the species. Other insects, such as moths, are constantly seen on red clover heads, but they do not come in contact with the pollen and therefore do not effect cross-pollination.

There has been considerable controversy as to the extent to which pollination can be accomplished by honeybees. Discussion has centered upon the fact that the tongue of the honeybee is not long enough to reach the nectar. The literature on this subject is voluminous and cannot be reviewed here. More recent investigations clearly indicate that honeybees visit red clover principally for pollen and seldom obtain nectar, but regardless of what is obtained, pollen is transferred and cross-pollination is effected.

United States Department of Agriculture.
1942. A much larger harvest of hay crop seeds needed in 1942. U. S. Dept. Agr., Food for Freedom Program, Background Information Series, No. 7, 5 pp.

p. 3: A lack of sufficient pollination insects when red clover is blooming is one reason for low seed yields. Honeybees, one of the principal pollinators of red clover, are the only kind that can be readily increased and moved. The placement of one hive of honeybees per acre adjacent to or in a red clover field when blooming will increase seed production.

Clover, Strawberry

Hollowell, E. A.
1939. Strawberry clover. U. S. Dept. Agr. Leaflet 176, 8 pp.

p. 6: The blossoms of strawberry clover are visited by honeybees. Apparently they obtain considerable nectar, which indicates that this is a good honey plant.

Clover, White

Hollowell, E. A.
1936. White clover. U. S. Dept. Agr. Leaflet 119, 8 pp.

p. 7: White clover is naturally a free-blossoming plant in all parts of the United States, but only in a few sections has seed production developed as a farm enterprise. ... Even when blossoms are abundant, moist, cloudy weather is unfavorable to bee activity, and necessary cross-pollination is, therefore, restricted and seed production reduced. The presence of colonies of honeybees in the immediate vicinity of clover-seed producing fields usually insures a maximum of cross-pollination.

Cotton

Allard, H. A.
1910. Preliminary observations concerning natural crossing in cotton. Amer. Breeders' Mag. 1: 247-261.

pp. 256-257: Honeybees are among the most frequent visitors of cotton blossoms, but, at the same time, they are very generally visitors of the outer involucral nectaries alone. ... Nearly all bee visitors show a marked tendency to pass from plant to plant up and down the rows rather than across.

p. 258: These casual records are sufficient to show the enormous number of blossoms a single bee is capable of visiting

in a few hours, and the probabilities of intercrossing a great number of these all over the field. Almost before day, bees are forcing their way into the expanding buds, and an examination of these reveals many whose stigmas have been pollinated long before the flowers are fully opened. The writer has observed that in the near vicinity of domestic hives in northern Georgia the number of honeybee visitors is enormously increased.

p. 261: In cotton fields of northern Georgia the demonstrated proportion of crossed blossoms is at least 20 per cent, with strong probabilities that approximately 40 per cent of the blossoms are crossed. Although crossing may be very detrimental in unselected cotton, in selected cotton it is probably beneficial.

Kearney, T. H.
1923. Self-fertilization and cross-fertilization in Pima cotton. U. S. Dept. Agr. Dept. Bul. 1134, 68 pp.

p. 36: There is little doubt that natural cross-pollination in cotton is effected almost solely by the agency of insects. The nature of the pollen grains of Gossypium is unfavorable to their transportation by currents of air.

p. 37: Various Hymenoptera are the most efficient carriers of cotton pollen at Sacaton, Ariz., as is probably the case wherever cotton is grown. The honeybee and the wild bees (Melissodes spp.) are the most important cotton pollinators in this locality.

The honeybee (Apis mellifica L.) is very assiduous in its visits to cotton flowers, although sometimes preferring the extra-floral nectaries to those with the flower. Nevertheless, this insect probably holds first rank at Sacaton, Ariz., as a conveyor of cotton pollen, especially among Pima flowers. As was noted on a preceding page, honeybees entering and emerging from the flowers when the petals are just beginning to unfold almost invariably come in contact with the reproductive organs.

Meade, R. M.
1918. Bee keeping may increase the cotton crop. Jour. Hered. 9: 282-285.

p. 285: No effort was made to exclude insects, and the weather-conditions during the course of the investigation were not unfavorable to their activities. It is evident from the increased yield of bolls secured in the long-pistiled Durango variety through artificial pollination that the presence of additional pollinating insects would aid in reducing the high percentage of shedding. The value of honey

bees in this connection is recognized in some localities, and it would seem that growers of long stapled varieties might find bee-keeping a distinct advantage to the cotton crop.

Cruciferous Root Vegetables

Poole, C. F.
1937. Improving the root vegetables. U. S. Dept. Agr. Yearbook 1937: 300-325.

p. 310: The cruciferous root vegetables—turnips, rutabagas, and radishes—have relatively large flowers, which are insect-pollinated.

Onion

Jones, H. A.
1937. Onion improvement. U. S. Dept. Agr. Yearbook 1937: 233-250.

p. 239: Most of the pollen is shed between 9 a.m. and 5 p.m. Pollination is effected mainly by insects that go from flower to flower and visit the nectaries at the base of the three inner stamens. Interpollination among flowers of the same umbel is no doubt of frequent occurrence, as the same insect has been observed to visit many flowers on an umbel before leaving. In the onion, however, cross-pollination is the rule.

Pepper

Odland, M. L., and Porter, A. N.
1941. A study of natural crossing in peppers (Capsicum frutescens). Amer. Soc. Hort. Sci. Proc. 38: 585-588, tables.

p. 588: The pepper flower is rather inconspicuous and non-fragrant, a fact that would suggest pollination not very likely. Erwin ... found that the flowers produced nectar and that insects did at times visit them. The writers are of the opinion that honey bees are largely responsible for the cross pollination that takes place. This insect has been found working on the pepper plant rather often. The presence of the bee is rather spasmodic, however, as they are found only on certain warm bright days. The presence of bees in the vicinity may have a bearing on the amount of cross pollination.

Flax

Gubin, A. F.
1945. Cross pollination of fibre flax. Bee World. 26:30-31.

p. 30: Among all insects which pollinate flax flowers the honeybee occupies a significant place ... . The honeybee constitutes 93.8 percent of all such insects.

p. 31: Cross-pollination of flax by bees increased the yield, as measured by quantity of grain, 28.57 percent; as measured by weight of seed, 31.01 percent and raised the absolute weight of 1000 grains from 5.0372 to 5.1329 gm. Consequently, the development of seeds with self-pollination proved to be somewhat depressed. Usually with a smaller quantity of seed and fruit they grow larger in size; in the given case the reverse was observed--the resultant yield with cross-pollination was higher in respect of both quantity and quality.

On the open plot where the number of visits was only 67.8 percent of the number of flowers, the increase of the yield of flax proved to be less significant; the number of grains from 500 bolls rose from 2688 to 3050, that is 13.47 percent; their weight rose from 13.5934 to 15.8878 gm. or 16.88 percent; the weight of 1000 grains rose from 5.0576 to 5.2095 gm.

Radish

Crane, M. B., and Mather, K.
1943. The natural cross-pollination of crop plants with particular reference to the radish. Ann. Appl. Biol. 30: 301-308.

p. 307: As the radish is self-incompatible each plant must receive pollen from another plant to produce seed. In these experiments the pollen could come from a sister plant of the same variety or from a plant of a different variety. As shown in Figs. 4-6, 25 hives of bees were maintained close to the experiments. Thus, the bee population was much higher than in most cases where crops are grown commercially for seed, and the number of bees visiting the plots during the flowering period was extremely large. The seed crop was heavy throughout the plots, indicating that cross-pollination had been effectively carried out.

Kremer, J. C.
1945. Influence of honey bee habits on radish seed yield. Mich. Agr. Expt. Sta. Quart. Bul. 27: 413-420, illus.

p. 419: Figure 4 illustrates a typical example of the effective radius of commercial bee yards located in a radish seed area, where radish seed fields were located without regard or knowledge of their existence.

All the fields located within the circles or the 2-mile radius produced from 400 to 450 pounds of seed per acre, while those on the border of this radius or beyond averaged 200 to 300 pounds of seed per acre. One field located within the flying radius of two of these bee yards averaged 600 pounds per acre. No other colonies

of bees were known to exist in this area, though possibly there were some wild swarms present.

Sunflower

Rudnev, V. Z.
1941. [The effect of pollination by bees on yield of sunflower seeds.] Soc. Zern. Hoz. No. 2. 134-40. [Abstract in Imp. Bur. Pastures and Forage Crops, Herbage Abs. 14:55-56, 1944.]

p. 55: Field tests with sunflower plants, which were either completely or partially covered with gauze to prevent pollination by the bees, indicated that percentage of settings was 77.7 to 85.9 in the insect-pollinated and 25.0 to 25.7 in the self-pollinated flowers. Trials in field conditions (when a number of beehives was placed at varying distances from several observation plots 100 m^2 each in a large sunflower plantation) showed that, with the increase from 500 to 1250 m. of the distance of a beehive from the plantation, the number of bees visiting each plot daily fell from 100 to 61, the weight of ripe seeds dropped from 6,000 to 3,700 grm., and the weight of empty seeds rose from 110 to 200 grm.

Sweetclover

Pieters, A. J., and Hollowell, E. A.
1937. Clover improvement. U. S. Dept. Agr. Yearbook 1937: 1190-1214.

p. 1207: Pollination of sweetclover under natural conditions is effected principally by honeybees, except insofar as the species, varieties, or individuals are spontaneously self-fertilized.

United States Department of Agriculture.
1942. A much larger harvest of hay crop seeds needed in 1942. U. S. Dept. Agr. Food for Freedom Program, Background Information Series, No. 7, 5 pp.

p. 3: ... lack of sufficient pollination lowers seed yields. Honeybees are the most valuable pollinators. A minimum of one hive of honeybees per acre located close to a blossoming field of sweet clover will increase the quantity of seed set.

Trefoil

McKee, R., and Schoth, H. A.
1941. Birdsfoot trefoil and big trefoil. U. S. Dept. Agr. Cir. 625, 13 pp.

p. 5: The general conclusion of investigators who have studied seed setting in Lotus species is that both birdsfoot trefoil and big trefoil are practically self-sterile. Silow ... who has more

recently given the subject consideration draws the following conclusion:

"Lotus corniculatus is practically self-sterile, but occasional plants set a few seeds after self-pollination. Plants of L. major Smith (= L. uliginosus Schk.) are, on the whole, incapable of spontaneous self-pollination, but after artificial self-pollination practically all plants are self-fertile, some to a very high degree. Thus these two perennial species are almost entirely dependent upon insect visitors for seed formation."

Vetches (Vicia)

Schelhorn, M.
1942. Blütenbiologische Studien an der Zottelwicke. Pflanzenbau. 18: 311-320.

Hungarian (Vicia pannonica) and hairy vetch (V. villosa) were screened to exclude bees. In the former 38 percent of the flowers produced seed but only 3.5 percent of the latter. Hairy vetch was found to be self-fertile but to require bees to transfer the pollen. The author concluded that seed production in hairy vetch is almost entirely dependent on the visits of bees to effect the transfer of pollen. [Abstracted from translation by Carlo Zeimet.]

Vicia villosa
(Hairy, Hungarian, Russian, Siberian, or Villous Vetch)

Robbins, W. W.
1931. The botany of crop plants. Ed. 3, 608 pp.

pp. 411-412: There are five to eight pairs of leaflets, and many (about thirty) violet-blue, rarely white, flowers in one-sided racemes. Cross-fertilization is necessary for the normal production of seeds. Bees are the chief agents in the dissemination of pollen.