Research on Legume Pollination

George E. Bohart
Utah State University

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Recommended Citation
Symposium papers on contributions of research to the agriculture of the Intermountain Area together with the address made at the dedication ceremony of the Crops Research Laboratory and the Apiculture Research Laboratory Agricultural Research Service U.S. Department of Agriculture at Utah State University Logan Utah, October 26, 1961

Bulletin 431 · 1961
Utah Agricultural Experiment Station
A centennial event of the Land-Grant Colleges and Universities and the United States Department of Agriculture.
As has been reported by Dr. Keller earlier in this symposium, C. J. Sorensen and J. W. Carlson discovered in 1929 that lygus bugs seriously limited alfalfa seed production in Utah and elsewhere. In 1944 F. V. Lieberman, working in Millard County, established the value of DDT in controlling these bugs and in the ensuing few years developed a control program for them. Although lygus control was soon recognized as a “must” in seed production, yields still fell below the potential capacity of the plants to set and hold seed.

Federal Agronomist H. M. Tysdal suspected that lack of cross-pollination by insects was the major factor responsible for poor seed set on plants protected from insect damage. In Nebraska he demonstrated the value of several species of wild bees as alfalfa pollinators, but the usefulness of honey bees remained in question. He and others observed that most of the time honey bees visited alfalfa flowers for nectar and avoided the pollination mechanism. His interest in seed production problems in general and pollination in particular was instrumental in the establishment of federal legume seed laboratories.

The establishment of a legume seed research laboratory at Logan was stimulated by studies made in Millard County in the summers of 1943 to 1946 by G. H. Vansell and F. E. Todd. As a result of Tysdal's urging, these men were sent to Utah from California and Maryland, respectively, to study the alfalfa pollination problem. They found that in Millard County, in contrast to what had been observed in other areas, honey bees frequently collected alfalfa pollen and served as efficient pollinators. However, they found that the alfalfa pollen collecting behavior of honey bees varied from field to field and from time to time. Furthermore, the honey bee populations were generally lower than the alfalfa bloom would support. In publications serving as a basis for much of the subsequent research on alfalfa pollination, they concluded that honey bees, because of their widespread abundance, were the most important alfalfa pollinators. They recom-

Background material for this discussion was provided by E. R. Jaycox, M. D. Levin, and W. P. Nye. The material for the vegetable insect research was supplied by H. E. Dorst, Entomology Research Division.
mended that seed growers take definite steps to insure an adequate supply of honey bees and discussed possible methods of increasing honey bee efficiency by increasing the percentage of pollen collectors. They realized that many detailed problems relating to pollination by both honey bees and wild bees remained unsolved and consequently they recommended increased emphasis on pollination research.

**Assignments and personnel**

Two U.S. Legume Seed Research Laboratories were established in late 1946, one at Columbus, Ohio, to work primarily on red clover, and the other at Logan to work primarily on alfalfa. By June 1947 the Logan laboratory was staffed with two agronomists, J. W. Carlson and M. W. Pedersen, two entomologists from Forage Crop Insects Investigations, F. V. Lieberman and S. J. Snow, and three entomologists from Bee Culture Investigations, F. E. Todd, W. P. Nye, and G. E. Bohart. From the beginning close cooperation was established within this group and between it and various members of the experiment station staff.

Lieberman and Snow cooperated in the pollination studies by applying insecticides when needed to insure bloom and they were also full partners in several seasons of intensive investigations on the effects of insecticides on honey bees and alkali bees.

Pedersen had a particular interest in the attractiveness of alfalfa to pollinators and the responses of the plant to pollination. This led to several cooperative pollination projects. In addition, he worked with the Bee Culture group for the first two summers on wild bee propagation studies.

G. F. Knowlton of the Utah State University Entomology Department worked closely with the federal entomologists on the effects of insecticides on honey bees.

Todd served as leader of the Bee Culture group and he, with the assistance of Nye, took direct responsibility for the work with honey bees. Bohart concentrated his efforts on wild bees.

In the spring of 1950 Todd was transferred to Tucson, Arizona, to head the Southwestern Bee Culture Laboratory. Bohart assumed leadership of the group at Logan and M. D. Levin was brought in as an apiculturist to replace Todd. In 1956 we obtained the services of R. A. Nielsen, our only full-time subprofessional. The insecticide work was dropped at Logan from 1953 until 1959, when E. R. Jaycox was brought into the organization to make basic studies on the effects of insecticides on individual bees and colonies.

Cooperation with the Forage Crop Insects Investigations group was lost in 1955 when Lieberman was assigned to
other research. However, in 1959, after transfer to Bakersfield, California, he resumed cooperation with the Legume Seed Research Laboratory by testing Pedersen's high seed yielding alfalfa strains for spotted-alfalfa-aphid resistance.

A number of other federal and state researchers on the campus have taken active part in some of our projects. L. R. Hawthorn of Vegetable Seed Investigations has worked with us on carrot and onion pollination studies; Mark W. Martin, a federal plant geneticist, is aiding us in tomato pollination studies; and several members of the Chemistry Department have cooperated in various research projects over the years.

The foregoing sketch indicates some of the background for the pollination research at Logan and the various personnel assignments as they have affected the studies. It is apparent that cooperation has played a major role throughout. The Legume Seed Research Laboratory, although composed of personnel working under three different federal and one state organization, has always functioned as a unit on at least one major cooperative project. Whenever cooperative studies were needed, they were facilitated by the unified spirit of our organization.

**Pollination research**

Since our first season at Logan in 1947, the pollination research has been devoted principally to alfalfa. However, ramifications of this problem have led into such divergent fields as the effect of alfalfa insect control programs on honey bees, management of honey bee colonies, methods of breaking dormancy in alkali bees, bee visitation, and the host preferences of various kinds of solitary bees.

During the first four years, in cooperation with Lieberman and Knowlton, we devoted much effort to the effects of insecticides on honey bees and, to a lesser extent, alkali bees. We conducted field tests with all of the insecticides then recommended or considered for alfalfa insect control. Most of them were applied to alfalfa fields as dusts and sprays at the minimum effective dosages, and mortality to bees was measured at the hives and in the field. As a result of this work it was possible to recommend materials that could be applied under the proper conditions to blossoming alfalfa without excessive damage to pollinators.

In 1953 as a consequence of the development of several more recent materials, the testing program was resumed with materials such as endrin, heptachlor, and systox. Useful materials that can be applied safely in the bloom stage now included toxaphene, DDT, TEPP, and systox. These have proved adequate for control of all commonly encountered injurious in-
sects except the seed chalcid. An insecticide program compatible with pollination has yet to be developed for this pest.

Because the question of how insecticides affect bees inside the hive remained unanswered, Jaycox started work on this problem in 1960. His technique is to train individual bees to fly to feeders, mark them, give them poison, and observe their activities and fate after they return to a glass or screen-walled hive. He is also studying methods of confining bees to their hives during periods of insecticide application. A third project is the testing of systemic insecticides such as dimethoate by feeding bees measured quantities of nectar from treated plants.

From the beginning, agronomists and entomologists alike have taken part in cooperative projects involving alfalfa nurseries composed of plots treated in various ways to determine the relative importance and interrelation of factors affecting seed yields. In some of these studies pollination was controlled by eliminating or confining bees with large cages. In others we studied the effect on pollinator visitation of various agronomic treatments, alfalfa varieties, or combinations of both. In the earlier studies we were able to demonstrate the shortage of "natural"
pollination as compared to pollination in cages with colonies of bees. In later studies proper spacing and irrigation were seen to influence attractiveness of alfalfa flowers to pollinators. Genetic background also was shown to influence visitation by honey bees, bumble bees, and leaf-cutting bees. As might be expected, the strains most attractive to pollinators were those yielding the most seed.

In the most recent nursery we have tried to create conditions some of which would be attractive and others unattractive to pollen-collecting honey bees. This is the fourth year of our work with this nursery and the first one in which the conditions have approached our objectives.

One replication of a bee shade experiment planned to determine whether bees benefit by giving them shade when temperatures are above 95 degrees.

Many studies on the foraging behavior of honey bees have been made to determine how to increase their efficiency as alfalfa pollinators. We found that when different kinds of pollens were presented to the bees in dishes in the apiary a definite scale of attractiveness resulted. Alfalfa pollen ranked below the middle but not at the bottom. Studies of pollens taken from pollen traps on the hives showed that usually only a few colonies became oriented to alfalfa. However, the quantities of pollen available in the field and brought in from other sources bore no relation to the intake of alfalfa pollen. Negative results attended an attempt to increase the total pollen collected per hive by various changes in food and brood ratios. This left only plant condition as a major influence governing alfalfa pollen collecting.
Although we have formed a rough idea of the proper plant conditions as based on numerous observations, an understanding of the basic factors involved continues to elude us.

Other behavior studies have been concerned with the foraging range of bees under different conditions. Most of these studies have been made with genetically marked bees or bees fed with radioactive sirup. For one large-scale series of experiments Levin went to Bakersfield, California, where he could find large, relatively uniform fields provided with colonies in various densities and patterns of distribution. The results obtained helped us determine the best placement of colonies in and around alfalfa fields.

Seedsmen are concerned with the isolation distance necessary to insure maintenance of varietal purity. In 1958 Levin and Pedersen began a study in an isolated area near Logan to shed light on this problem. The first year two kinds of alfalfa, one with blue (dominant) flowers and the other with white (recessive) flowers were grown side by side. Contamination of the white type by the blue was measured in the progeny of the white at intervals in the field. In subsequent years a progressively greater gap was established between the fields. The size of the area covered by honey bees after they reached the field was studied by marking them with numbered plastic discs and locating them again over a period of days. Similar work was done with several kinds of wild bees.

Since 1947 Bohart has been conducting surveys of the wild species of bees that pollinate alfalfa. These surveys have included distribution, abundance, host preferences, efficiency as alfalfa pollinators, seasonal activities, nesting requirements, natural enemies, and possibilities for management. About 100 species have been found on alfalfa in Utah. Of these about 80 pollinate the flowers with reasonable efficiency but most of them are always too scarce to be significant in commerical seed setting. Even those that sometimes occur in goodly numbers are generally erratic in occurrence from place to place, day to day, and year to year. Nye's talent with a camera has been extremely valuable in the biological work with wild bees. We now have a series of photographs that say more than descriptions ever could.

Special attention has been directed to alkali bees (Nomia melanderi Ck11.), bumble bees (genus Bombus, and a small species of leaf-cutting bee (Megachile rotundata Fabr.). The alkali bee was recognized by Todd and Vansell in the early 1940's as a particularly valuable species. Studies over the years have shown that it is the pollinator responsible for nearly all of the high seed yields obtained in the Northwest and in several restricted
areas in Utah. As early as 1948 attempts were made to move these bees and create soil conditions favorable for their nesting. In that year blocks of soil containing overwintering larvae were successfully transferred from one area to another. In 1953 the first successful efforts to modify soil conditions to suit alkali bees were made under our supervision by Carroll Riggs, a seed grower in Wyoming. In 1954 individual larvae were successfully moved to new areas for re-nesting. Since then several improvements have been made on methods of moving individual larvae, and last year areas in California were successfully stocked with large larvae taken from Utah. In 1957 W. P. Stephen in Oregon developed a method for making "artificial" nesting sites for alkali bees. Improvements on this method have been made by our laboratory and by workers in Oregon, Washington, and Idaho. Farmers in several states are now using this information to build and maintain their own sites.

Bumble bees, although usually present in small numbers, are rarely abundant enough on large fields to be significant pollinators. In 1948 Pedersen and Bohart obtained acceptance by bumble bees of domiciles placed in the field for their convenience. In 1952 with the help of Svend Norgaard-Holm of
Denmark, we hibernated a number of queen bumble bees and induced spring-caught queens of several species to start nests in confinement. A great deal of information was learned about different bumble bees but none of it was encouraging enough for us to visualize bumble-bee keeping as a practical aid to alfalfa pollination on a field scale. In recent years Norgaard-Holm has continued bumble bee studies in Denmark with more promising species from the Old World.

The previously mentioned small leaf-cutting bee was accidentally introduced into this country about 25 years ago. It was first noticed in Utah in 1955, but was not identified until 1959. Since that time increasing attention has been paid to it. We have learned that it nests readily in blocks of wood drilled with holes and in soda straws. Prospects for management of this bee by seed growers are promising and we hope to have a practical bulletin ready for grower use before next season.

Many of the studies with wild bees have been made with the idea of learning how to handle them so that we could devise methods of transporting or shipping promising species of alfalfa pollinators from areas in southwestern Asia. From 1958 to 1960 we cooperated with J. W. MacSwain from the University of California in studies designed specifically for this purpose. These have included methods of inducing and breaking dormancy, rearing various species in enclosures, releasing adults or "planting" larvae, and devising shipping containers.

A growing share of our time is devoted to pollination of crops other than alfalfa. From 1952 to 1954 surveys were made of fruit pollinators in northern Utah. In 1956, with the assistance of Astrid Loken from Norway, we studied the foraging radius of pollinators in apple orchards. By radioactivating bouquets of apple blossoms and placing them in the orchards we were able to trace the subsequent range of some of the bees that visited the "hot" flowers.

In 1955 we started a cooperative series of vegetable pollination studies with L. R. Hawthorn. From 1955 to 1958 we studied carrot pollination, using large cages to control levels of pollinator activity. The results of these studies were published in 1959. From 1958 to 1961 we have been working on onion pollination, employing similar techniques. In this work we encountered an apparent relation between heat damage and high levels of pollinator activity. Our work in 1961 has been aimed primarily at clarifying this problem.

Interest in tomato pollination was stimulated by the observation that bumble bees visited tomatoes at the Greenville Farm, especially those adjacent to wild species of tomatoes.
grown for curly-top-resistance studies. Since hybrid tomato seed is produced with the help of hand pollination and sold for about $150.00 per pound, the possibility of substituting insect pollination seemed worth investigating. This year in our new greenhouse we grew potted tomato plants of several species and carried them to areas where known concentrations of various kinds of wild bees existed. Several species of anthophorid bees were particularly fond of the flowers and showed great skill in working them for pollen. It seems likely that if hybrid tomatoes could be grown adjacent to large nesting sites of these bees, insect pollination could become a reality.

In 1960 a project on tetraploid red clover seed production was initiated in cooperation with J. W. Carlson. A series of nurseries was established to compare seed yields under different conditions of pollination and with different degrees of potential contamination with diploid red clover pollen. Our phase in this first year of production was to study the populations and activities of the pollinators. Although far from complete, the project may be terminated after this year's results are studied because of Carlson's imminent retirement.

**Plans for the new apiculture research building**

Although we have not developed complete plans for the conduct of off-season projects in the new laboratory and greenhouse space, we are enthusiastic about the possibilities offered.

Already we have induced over 20 species of bees to nest in the large greenhouse section. We were pleased to find that alkali bees, emerging in the greenhouse in April instead of July as they customarily do, nested normally and foraged on the sweet clover provided. This means that we can carry on many life history, behavior, and propagation studies in the off-season instead of having to crowd them into the summer program with every other field project that demands attention.

In the large "bee-room" with its battery of fluorescent lights over the diffusion-screen ceiling we plan to conduct off-season experiments with honey bees. For example, it should be possible to test the effects of insecticides and learn the fate of every bee, whether contacted at the point of application or through food passed from field bees to nurse bees in the hive. When we complete the arrangements for temperature and humidity control in this room, we should be able to measure the effect on different aspects of honey bee behavior of various intensities of light, temperature, and humidity. Experiments in training bees to forage on
materials and floral food sources should be easier to interpret in such a simplified environment than in the field.

We have had little laboratory space in the past but have managed by crowding, by borrowing, and by making the field our laboratory whenever possible. Now however, we can conduct careful indoor research under much better conditions. Furthermore, we now have room for graduate students to carry out research in our fields of interest. This can be of tremendous assistance as we have already learned.

**Vegetable insects research field station**

The Federal Vegetable Insects Research field station was established on the campus of Utah State University in 1936 with Howard E. Dorst as station leader. All of the studies have been conducted in close cooperation with the Utah Agricultural Experiment Station.

W. E. Peay was station leader from 1941 to 1946 while Dorst was on military leave. Peay remained with the station until 1952.

Tomato fruitworm and beet leafhopper seriously reduced the yield of quality tomatoes in the Intermountain Area before 1936 when investigations were initiated to determine means of controlling these pests. Many insecticides and application methods and schedules were evaluated for their effectiveness in controlling the tomato fruitworm. The study encompassed the relation of the number of eggs deposited by the moth to resulting infestation of larvae in the tomato fruit. This method has provided a dependable means of determining the impending magnitude of the infestation. With this knowledge growers apply insecticides only when warranted.

Beet leafhopper studies on tomatoes and sugar beets have been conducted in Utah, western Colorado, and southern Nevada to determine the source and seasonal abundance of the leafhopper in the cultivated areas in relation to its movement from desert breeding grounds. Two sources of the spring movement of the beet leafhopper have been located: the local source from desert breeding grounds adjacent to Great Salt Lake and Utah Lake, and the long distance source from southern and western Arizona, southeastern California, southern Nevada, and southern Utah. Evaluation of such factors as climate, relative importance of various host plants, and numerical abundance of overwintering populations has provided an accurate and dependable basis to anticipate the time and intensity of yearly movement of