Legume Pollination Problems[1]

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During the past two decades there has been a gradual and consistent decline in the quantity and quality of the legume seed produced in the relative humid areas lying east of the Mississippi River. Legume seed production in Indiana has followed a similar trend, the yields during the last eight years having reached a very low level as shown in table I.

TABLE I. Acreages and yields of legume seed grown in Indiana.[2]

Year	Red Clover		Alfalfa		Alsike		Sweet Clover		Lespedeza	
	acres	bu.	acres	bu.	acres	bu.	acres	bu.	acres	bu.
1941	244000	.90	16800	.85	6000	1.20	5900	2.80	28000	3.83
1942	134000	.75	2000	.85	3000	1.10	6400	1.90	14800	3.17
1943	194000	.70	1500	.75	1800	1.20	4500	2.40	27000	2.58
1944	360000	.70	27000	.75	4000	.90	6800	1.50	33000	5.50
1945	180000	.70	8600	.70	3500	1.00	5000	2.00	18000	3.17
1946	420000	.70	8200	.50	5000	.90	4500	2.00	34000	3.38
1947	139000	.65	5000	.75	2000	1.00	3500	3.00	24000	4.58
1948	291000	.65	2000	.80	3000	1.00	1600	1.50	36000	4.41
Av. 1941—48	242250	.72	8887	.74	3537	1.03	4775	2.14	26850	3.51
Av. 1931—40	203100	1.01	7400	.96	..		4700	2.20	30000	2.13

There are many factors responsible for this situation. These include plant diseases, cultural practices, destructive insects, and lack of adequate pollination. Of the legumes grown for seed in Indiana, alfalfa and red clover offer the most serious problems in pollination.

In the past legume seed producers have depended on native bees to carry the burden of pollinating the legume flowers. The trend in recent years toward more intensive farming has resulted in the reduction of the types of areas in which native bees nested. Removal of heavy growth along fence rows, intensive pasturing of wooded areas and clearing of undergrowth, ditching and straightening of streams and rivers, and draining of low swampy areas have all contributed to a changing ecology

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[2] Justin *et al*, 1946 and 1948.

and the reduction of the native bee populations. Diseases of native bees, particularly the bumblebee, may also have contributed to this reduction. Not so many years ago it was a common occurrence to plow up bumblebee nests when fall plowing, an occurrence which is rare today. Unless care is used in applying the many new chemicals for weed control, further depletion of our native beneficial insects may occur through the destruction of such flowering plants as dandelions, wild asters, goldenrod, and smartweed, which are essential pollen and nectar sources for maintaining and increasing these insects. Since farming practices and other ecological factors have resulted in a diminishing native bee population over large areas of Indiana, interest has been focused on the use of the honeybee for the pollination of alfalfa and red clover.

Beard and Dunham (1) have shown that with an optimum stand, maximum production of flowers, and complete pollination, red clover is potentially capable of yielding 12 bushels of seed per acre. Other investigators put the maximum yield of alfalfa at 40 bushels per acre. We will probably never reach such yields, but in view of such potential yields we should certainly not be overly optimistic if we attempt to produce 3 bushels of red clover seed and 5 bushels of alfalfa seed per acre.

Few people appreciate the magnitude of producing 5 bushels of alfalfa seed per acre. There are on the average about 200,000 alfalfa seeds per pound or approximately 12,000,000 per bushel, according to statistics in the United States Department of Agricultural Yearbook for 1948. Since a single alfalfa flower will produce between 2 and 3 seeds per pod, a minimum of 4,000,000 flowers or 92 per square foot must be visited and pollinated to produce one bushel of seed. To produce an average of five bushels of seed, 20,000,000 flowers or 460 per square foot must be pollinated. If the 5000 acres harvested for alfalfa seed in 1947, Justin *et al* (7), had produced five bushels of seed to the acre, it would have been necessary to pollinate a total of one hundred billion flowers.

Red clover pollination requirements are even more startling. Each pound of red clover seed contains approximately 275,000 seeds, (USDA Yearbook 1948), or 15,500,000 per bushel. Since each clover flower produces only one seed, 15,500,000 pollinations are necessary to produce a bushel of red clover seed. An average clover head contains from 125 to 175 individual flowers. If we should obtain a minimum of 25 pollinations per head, it would require a total of 620,000 heads or 15 per square foot to produce a bushel of seed per acre. To produce three bushels of seeds, 46,500,000 flowers, 1,860,000 heads, or 45 heads per square foot will be needed. In Indiana in 1948 there were 291,000 acres of red clover harvested for seed, Justin *et al* (7). If each of these acres was to produce three bushels of seed, there would have to be a total of four trillion, five hundred ten billion, five hundred million flowers pollinated or one hundred eighty billion four hundred million heads containing 25 pollinations each.

Pollination of Alfalfa

In most areas of the more humid regions, honeybees are notoriously inefficient pollinators of alfalfa. This is due principally to the peculiar

structure of the alfalfa flower which makes it difficult for honeybees to obtain pollen. The reproductive parts of the alfalfa flower, commonly called the "sexual column," consist of the pistil and the stamens. This column is enclosed by the keel petals and is under a tension when the flower is fully opened. When pressure is exerted on the keel petals this sexual column springs forward with considerable force. The stigma of the pistil first strikes the pollinating insects followed by the anthers which dust the insect with pollen. This mechanism insures cross-pollination which is necessary to produce vigorous plants and good seed yields. This process of releasing the sexual column is known as "tripping" and very little if any seed will be produced if the flowers are not tripped. Honeybees collecting nectar soon learn to avoid tripping alfalfa flowers because of the force of the released column and secure the nectar from the side of the flower by inserting their proboscis between the wing and standard petals. Pollen collectors usually seek other sources of pollen when available. However, most investigators report that the honeybee while collecting nectar from alfalfa flowers will trip as high as four percent of the flowers by accident. Under average conditions the best estimates place the maximum tripped at two percent. Nectar collecting honeybees when present in large numbers will tend to compensate for their low efficiency of tripping and may be responsible for a considerable seed set. If honeybees can be induced to work alfalfa for pollen their efficiency is very high and they will be responsible for high seed yields.

In the western areas of the United States, where most of the alfalfa seed is produced, the honeybee is the main agent of pollination. These areas are largely isolated valleys which are under irrigation and where competing nectar and pollen plants are at a minimum. Hare and Vansell (**5**), found that at Delta, Utah, honeybees collected 32.4% of the pollen from alfalfa, 42.0% from greasewood, and 16.0% from corn, sweet clover, and cockle-bur. Since alfalfa was the main crop in this area, the low percentage of pollen from corn, sweet clover, and cockle-bur was probably due to the small numbers of these plants in the area. In the humid areas honeybees are rarely found collecting pollen from alfalfa flowers, as there are generally many other sources from which pollen can be more easily obtained.

The question arises can honeybees be of any value in producing alfalfa seed? A strong colony of honeybees will contain approximately 60,000 individuals. According to Park (**9**), about ⅓ or 20,000 of these will be field bees. Various authorities (**4, 9, 10**) estimate that from 2.8% to 5% of these field bees will be pollen collectors. This means that if we take 4% as a suitable average for pollen collectors, 96% or 19,200 bees from a colony of 60,000 individuals will be collecting nectar. Park (**9**) estimates that the average life of a field bee is 20 days during which it will make an average of 10 trips a day for nectar. If we take the average tripping efficiency of the nectar-collecting honeybee as 1.5%, each bee would have to visit 347 flowers per trip to cause sufficient tripping to produce five bushels of alfalfa seed. This would mean an average of 4 honeybees per square yard. If we assume that a minimum

of 350 alfalfa flowers are necessary to produce a bee-load of nectar, and if these nectar-collecting field bees could be confined to one acre, they could trip sufficient flowers to produce a 5 bushel yield of alfalfa seed.

Some experimental work has been done in the area east of the Mississippi river which has given definite indications that concentrated populations of bees in alfalfa will produce good yields of seed. Drake (2) reports the results of the use of bees in pollinating alfalfa in eastern Nebraska which corroborates the experimental results nearer Indiana. In this study, 256 colonies of bees were placed in a 250 acre alfalfa field. Parts of this field were cut for hay on each of three different dates with intervals of 8 to 10 days, which resulted in prolonging the period of bloom of the seed crop. As a result, he reports that 2050 bushels of cleaned alfalfa seed were harvested and 7 tons of extracted alfalfa honey was produced from these 250 acres. This averages a little more than 8 bushels of clean seed per acre, indicating that the honeybees collected some pollen from the alfalfa or that the nectar-collecting bees were augmented by sufficient native bees to increase the seed yield above five bushels. It would appear that honeybees may be able to do an adquate job of pollination in alfalfa.

The beekeeper who is willing to place his bees at the service of the alfalfa seed grower should keep in mind the following points, if a maximum amount of honey as well as a good seed yield is to be obtained.

1. Harmful insects must be controlled. Plantbugs when present in numbers as few as 7 or 8 per sweep can completely destroy the bloom of the alfalfa plants. Leafhoppers will also seriously affect seed yields. Wilson (12) in the vicinity of West Point, Indiana, found that one pound of DDT and one-half pound of Chlordane per acre, applied as a wettable powder spray at the prebloom stage of growth gave excellent control for a period of four weeks, and resulted in the best seed set. Insecticides if applied in the proper dosages at prebloom will not injure any pollinating insects.

2. Prolong the period of blooming by cutting parts of the field at least three different times, a week to 10 days apart. This will result in greater concentration of bees in the blooming part of the field with resultant increase in pollinations. The longer period of bloom will allow the colonies to build up with consequent heavier honey yields.

3. Hay cuttings of competing crops should be made where possible to reduce sources of more easily available nectar in the vicinity.

4. Not less than one colony per acre should be used and the bees should be located in the field or closely adjacent if possible. Best results would probably be obtained if the colonies were dispersed in the field, but the distribution will have to be adjusted to reduce the labor of examining the bees.

Pollination of Red Clover

The attraction of honeybees to red clover is the reverse of their attraction to alfalfa. Pollen-collecting field bees readily work red clover flowers, but the nectar-collecting bees are indifferent to them. This is

due mainly to a physical incompatibility between the bees anatomy and the anatomical structure of the red clover flower.

Measurements given by Martin (8), indicate that the average length of the corolla tube of a red clover flower is 9.2 mm. The tongue of the worker honeybee averages 7.37 mm. Since the nectar rarely rises over 1 mm. in the clover flower corolla it is obvious that the tongue of the worker honeybee cannot reach the nectar. Although some flowers may be slightly shorter than the average, these are not sufficiently numerous to make the clover plant attractive to nectar-collecting bees. Measurements of the quality of red clover nectar indicate that it compares favorably in sugar content to that of other flowers which do attract the honeybees. It seems apparent that the small quantity of nectar produced and its unavailability are responsible for this indifference on the part of nectar-collecting bees. Bumblebees, which are well known as pollinators of red clover have much longer tongues and can readily obtain the nectar from the flowers.

Attempts have been made to breed red clover varieties with shorter corollas. In every case the attempt has failed. It was found that short corollas are generally associated with inherent weaknesses in the plants or with peculiarities of environment. With the development of controlled breeding of honeybees through artificial insemination, it may become possible to breed a strain of honeybees with longer tongues. However, there is no information at present that the variability of tongue length in honeybees is sufficient to warrant an attempt to breed longer-tongued bees.

The problem of red clover pollination lies in the inability of nectar-collecting bees to obtain the nectar in the clover flowers, and the competition of other sources of pollen at the time the clover plants are in flower. Honeybees will readily collect pollen from clover blossoms and in so doing assure pollination of the flowers visited. Beard and Dunham (1), showed that in north-western Ohio, 82% of the clover pollination was accomplished by honeybees, 15% by bumblebees, and 3% by miscellaneous insects. The authors recommend growing red clover for seed in the vicinity of large colony sites, or enticing beekeepers to locate their yards near clover seed fields by offering free colony sites. They imply that honeybees can be depended on to pollinate red clover. However, since red clover in most years will not produce sufficient nectar available to honeybees, other inducements besides free colony sites will have to be offered. The beekeeper, no matter how altruistic and philanthropic he may be, is in the business to earn a livelihood, and depends on honey and associated products for his income.

Red clover must be cross-pollinated to produce seed, and since only pollen, collecting field honeybees will pollinate red clover flowers, the successful use of honeybees for this purpose will depend on a strong colony putting enough pollen-collectors in the field during the flowering period, to pollinate the number of flowers necessary for economic seed production. As stated previously, 46,500,000 flowers must be pollinated to produce three bushels of seed. Under the discussion of the use of

honeybees to pollinate alfalfa, it was estimated that a colony of 60,000 bees will put 20,000 bees in the field, of which approximately 4% or 800 will be pollen collectors. Using the estimate of 20 days for the life of the field bee and 8 pollen trips per day (Park, 9), each pollen-collecting field bee must visit 363 flowers on each trip to pollinate sufficient flowers to produce three bushels of seed per acre. Dunham (3), has stated that to obtain a full load of pollen, a bee must visit 346 florets. This figure is slightly less than the estimated requirements, but falls well within the limits of error in obtaining these estimates. By using several cutting dates for the hay crop to prolong the blooming period, one colony per acre should be able to pollinate sufficient red clover flowers to produce a yield of 3 bushels of seed.

Farmer and beekeeper opinions as reported by Martin (8), from Iowa show very diversified opinions as to the value of honeybees for red clover seed production. Martin states, "it is lamentable, (this diversified opinion), in view of what is being done in European countries where honeybees are well known to be of value in red clover seed production and are systematically and effectively used to increase yields to as much as 8 bushels in some countries. European red clovers are very similar in length of flowers and amount of nectar secreted to American clovers. The successful use of the honeybee to pollinate red clover in the United States has yet to be worked out." It appears that the problem is not insurmountable.

Since bees will only work red clover to obtain pollen, it is obvious that the beekeeper will not be interested in red clover seed production unless he receives some type of remuneration. There are several ways this may be accomplished depending on the localities and the individuals involved.

1. Direct rental payments at so much per colony. In such case written requests for such service and an agreement on payment should be made, as the grower assumes all risk for failure of his seed crop. Many factors other than inadequate pollination can cause seed losses.

2. Sharing seed yields with the beekeeper. Under such an arrangement the seed grower and beekeeper agree to share all seed above a base amount (usually one bushel) on a percentage basis, usually 50-50. This type of agreement is receiving serious consideration in many localities.

3. The seed grower agrees to plant some crop as a source of nectar supply for bees placed in the vicinity of his clover seed fields. Under this type of arrangement, the grower agrees to plant a specified number of acres of some nectar secreting crop in return for the services of the bees to pollinate the red clover crop. This would assure the beekeeper a honey crop as his payment and the seed grower would obtain the services of the pollen-collecting bees to produce a seed crop. The main point to be considered under such an arrangement will be to plant a nectar crop such as sweet clover or alfalfa which will not compete with the red clover as a source of pollen. If the use of honeybees should become widespread under such agreements, the disposal of the surplus

honey might become a problem. This type of agreement has been used extensively in Wood county, Ohio.

Injurious insects are a complicating factor in red clover seed production. Many more insects attack red clover than are at present injurious to alfalfa. Those attacking the roots and foliage weaken the plant or may completely destroy it, thus reducing stands and presenting a hazard to second crop seed production. Other insects attack the heads directly and present the problem of control without injury to pollinating insects. The use of DDT on any forage crop that may be fed to lactating animals and those being prepared for the market must be avoided in order to prevent the presence of DDT in milk products and in the fatty tissues of meat for human consumption. This means that if the grower treats his field for insect control as a step in seed production, failure of seed set from any other cause will not permit him to use the crop for hay or grazing, except under certain restrictions.

The use of honeybees for pollinating red clover then follows the same procedure as those for alfalfa with a few modifications.

1. Although the control of injurious insects on red clover by prebloom treatment is still in the experimental stages, it is recommended as a precautionary measure. Methoxychlor may be substituted for DDT, but should be used with chlordane to control plantbugs. The use of methoxychlor in place of DDT, makes possible use of the crop for forage in event of seed failure under present Pure Food and Drug rulings. If properly applied in correct dosages and at the prebloom stage of growth, no injury from insecticides will occur to pollinating insects.

2. Prolonging the flowering period of the red clover may be less desirable than in alfalfa, unless the bees have a source of nectar available to maintain colony strength. Colony strength may also be maintained by feeding, but this involves additional expense and labor. If an additional source of nectar is available, cutting the hay crop at intervals of 8 to 10 days will result in a greater concentration of bees in the clover in flower at any one time, and consequently a chance for a larger seed set.

3. Avoid competing crops as sources of pollen supply. The knowledge of the beekeeper should make possible the removal of competing sources of pollen, or if a crop is apt to compete some adjustment of planting or cutting time should be made to avoid competition.

4. Not less than one colony per acre should be used, and if possible locate the bees in the field to be pollinated or as close as practical. Shading of the colonies if necessary can be accomplished by the use of light frames and cloth, which can be removed for examinations of the bees.

The assistance of seed growers and beekeepers in experimental studies and the opportunity to make observations when bees are utilized for legume pollinations are greatly needed if we are to solve the problems of using honeybees as pollinating agents in legume fields, thereby creating more opportunities for beekeepers through a greater demand for honeybees.

Summary

Reductions in numbers of native pollinating insects throughout the greater portions of Indiana have resulted in decreased yields of legume seed, and have stimulated interest in the use of honeybees to pollinate alfalfa and red clover. These crops present the greatest problems in pollination.

Pollen-collecting honeybees will not work alfalfa flowers in this area as more easily available sources of pollen are usually present. However, the nectar-collecting bees readily work alfalfa flowers, and although only one to two percent efficient, there are sufficient nectar-collecting field bees in a colony of 60,000 bees, to trip the flowers necessary to produce approximately five bushels of seed per acre.

Although red clover nectar contains adequate amounts of sugar, honeybees usually cannot obtain it due to the length of the clover flower corollas which are approximately 2 mm. longer than the tongues of the honeybees. Pollen-collecting field bees will readily work red clover flowers. There is a sufficient number of pollen-collecting field bees in a colony containing 60,000 bees, to pollinate the flowers necessary to produce three bushels of red clover seed per acre. Since beekeepers cannot generally expect a honey crop from red clover, some method of remuneration for placing colonies of bees in red clover seed fields must be arranged. Such methods include direct rental, sharing seed crop, and providing nectar crop.

Points to be observed in the use of honeybees for pollinating legumes include prebloom treatment of the crop for injurious insect control; staggering of first crop hay cuttings to prolong the flowering period; elimination of competing crops as sources of nectar or pollen; and, using not less than one strong colony of bees per acre.

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