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Alfalfa Pollinators with Special Reference to Species Other Than Honey Bees

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ABSTRACT

Honey bees and many species of wild bees are the principal alfalfa pollinators. Over one hundred species of wild pollinators have been reported in the U. S. alone. The importance of wild bees depends upon their abundance, pollinating efficiency, and the local pollinating efficiency of honey bees.

In general honey bees pollinate alfalfa more efficiently in the warmer, drier parts of the world. Consequently wild bees are relatively important in cool or humid areas such as Canada, the northern United States, and most parts of Europe. They are relatively unimportant in the southwestern United States and most of Australia.

Bumble bees (*Bombus*) and leaf-cutting bees (*Megachile*) contain most of the important pollinators in North America and Europe. However, one or more species of other genera may be equally or more important in certain regions. *Nomia melanderi* (the alkali bee) is the most important wild bee in the Intermountain Region of the United States. *Andrena wilkella* is one of the most valuable species in the Great Lakes region. *Melitta leporina* and *Eucera longicornis* are important in Scandinavia. In parts of central Europe and Turkey, *Rhophites canus* is reported as responsible for most of the alfalfa pollination.

Establishment of alfalfa pollinators in new areas is strongly recommended. Such establishment should be easy in the case of *Bombus* and megachilids, but may be difficult in the case of solitary ground-nesting species.

Measures useful for preservation, increase, and better utilization of wild bees are as follows: (1) Locate seed fields where pollinators are abundant. (2) Time the bloom for the period of their greatest abundance. (3) Limit acreage in bloom at one time. (4) Reduce competing sources of pollen and nectar during blooming period of the seed crop. (5) Provide spring and early summer bloom for build up of long-season species. (6) Where possible, provide nesting sites or conditions suitable for nesting. (7) Search for nesting sites and keep them unaltered. (8) Avoid chemical insect control during bloom. If bloom stage treatments are necessary, use materials least harmful to bees and apply only when bees are not on the field.

The subject of alfalfa pollination was reviewed recently by Bohart (1957). The present paper emphasizes the activities of alfalfa pollinators (especially the wild ones) rather than plant responses. Problems of conserving, increasing, and making better use of wild pollinators are also discussed.

INSECTS OTHER THAN BEES

Alfalfa flowers are entered in several ways by various groups of insects. Thrips (principally *Frankliniella* spp.) enter the flowers bodily and reach the nectaries without tripping them or contacting the stigma. Besides taking some nectar, they rasp the floral tissues and cause a mottling of the petals. Their effect on pollination is therefore negligible or slightly harmful, depending upon their abundance. Moths and butterflies insert their long, slender tongues directly into the throat of the flowers without causing them to trip. From the standpoint of pollination they are merely nectar thieves, since they lower the attractiveness of the flowers to pollinating insects.

Pierids, nymphalids, lycaenids, and noctuids are the lepidopterous families most commonly attracted to alfalfa in Utah. Alfalfa butterflies (*Colias* spp.) are sometimes extremely abundant, especially in California. Noctuid moths of the genus *Autographa* sometimes become nearly as abundant in the evening. The effect such populations might have on the attractiveness of the flowers to pollinators has not been evaluated.

¹In cooperation with Utah Agricultural Experiment Station.

Meloid beetles (*Epicauta*) visit alfalfa racemes to feed on the flowers. The meloids often feed on the petals until the restraining mechanism is destroyed, thus allowing the flowers to trip. If the beetle is contacted when a flower trips, cross-pollination may result. However, damage to the flowers caused by indiscriminant feeding probably outweighs the advantage of occasional cross-pollination.

Cantharid beetles of the genus *Chauliognathus* have elongated gealeae which enable them to reach the nectaries through the throat of the flower. Such entry frequently results in tripping. However, the tripping rate is slow since the beetles usually crawl from raceme to raceme and often remain nearly motionless for long periods. Furthermore, they much prefer certain composites to alfalfa. Nevertheless, they have been rated as valuable pollinators in Nebraska by Tysdal (1940). Since *Chauliognathus* larvae are predatory on aphids and other harmful insects, they can be regarded as beneficial in this stage also. The possibility of increasing cantharids for release in alfalfa fields has apparently never been investigated.

Sphecid wasps in the genera *Bembix*, *Steniolia*, *Stictiella*, *Microbembex*, *Bicyrtes*, and *Sphex* are frequent visitors to alfalfa in some of the more arid regions of Utah. However, it is only rarely that they make a strong attempt to reach the nectaries. After searching for several hours near Delta, I found two individuals of *Stictiella pulla* (Handlirsch) tripping flowers regularly and accumulating a wet lump of pollen on the clypeus. A single individual of *Bembix connexa* Fox was seen tripping flowers on another occasion.

Scoliid wasps of the genus *Campsomeris* are apparently the only non-apoid Hymenoptera that trip alfalfa flowers consistently. Linsley (1946) stated that *Campsomeris pilipes* Cresson near Blythe, California, frequently trips flowers with its feet. I have observed several individuals of the same species in southern Utah tripping flowers regularly by thrusting their faces directly into the flowers. Because of their size and strength, they were able to trip flowers and reach the nectar easily. Pollen accumulated principally on the mandibles, clypeus, and maxillae. Unfortunately, *C. pilipes* females are rarely common enough on alfalfa to be important pollinators. Besides their value as pollinators, *Campsomeris* wasps are important enemies of scarabaeid larvae.

BEES

KINDS OF BEES INVOLVED

Honey bees are the most abundant and widespread alfalfa pollinators. In areas where they collect alfalfa pollen they are usually also the most important pollinators. However, their efficiency decreases sharply as the percentage of pollen collectors decreases. In areas where honey bees rarely collect alfalfa pollen, one or more of the other species of bees present on the field may be more important. In general, honey bees are most valuable in hot, dry areas. Wild bees are valuable wherever they are found in reasonable numbers on the field, but their relative importance increases in cooler climates where honey bees are usually less efficient.

Several hundred species of bees in about thirty genera are found in alfalfa seed fields of various parts of the world (Bohart 1957). The genera of widespread importance are: *Apis* (*mellifera* L.), *Bombus* (many species), and *Megachile* (many species). The following genera are of considerable importance in more limited areas: *Melissodes* (many species in western U.S.), *Eucera* (*longicornis* L. in western Europe and several species in central Asia), *Tetralonia* (*edwardsii* Cress. in Utah and Idaho and *tricincta* Eversm. in central Asia), *Florilegus* (*condignus* Cress. in Kansas and Nebraska), *Hemisia* (*rhodopus* Ckll.) in Arizona and southern Utah), *Melitturga* (*clavicornis* Latr. in central Asia), *Anthophora* (*magnilabris* Fedt. in central Asia and *urbana* Cress. in Utah), *Xylocopa* (several species in southwestern U.S. and Israel), *Osmia* (*seclusa* Sandh. in Utah and Idaho), *Halictus* (several species in western U.S. and central Asia), *Nomia* (*melanderi* Ckll. in western U.S. and *diversipes* Latr. in central Asia), *Rophites* (*canus* Eversm. in central and eastern Europe), *Melitta* (*leporina* Panz. in Europe and western Asia), *Andrena* (several species in northern U.S. and central Asia), and *Calliopsis* (*andreniformis* Smith in Nebraska). The remaining genera appear to be of little importance except on rare occasions or in very limited areas. However, surveys in

other important alfalfa-seed areas, such as Argentina and Australia, will undoubtedly show the existence of other important pollinators than those indicated above.

NECTAR COLLECTORS VS. POLLEN COLLECTORS

An individual bee may take nectar or pollen or both from alfalfa. Usually when it takes both, one food material is obviously the primary objective and the other is more or less accidental. Whether the bees are seeking pollen or nectar is the principal determinant of the effectiveness of their visits in terms of pollination. The percentage of nectar or pollen collectors found on an alfalfa field depends principally upon (1) the species and sex of the bees, (2) the needs of the nest, (3) the relative amounts and attractiveness of competing sources of pollen and nectar, and (4) the condition and variety of the alfalfa.

Apparently, male bees² and parasitic bees visit flowers for nectar only. Females of some species of nonparasitic bees always visit alfalfa for pollen and others always visit it for nectar. Most species fall somewhere between these extremes. In Utah species of *Halictus*, *Lasioglossum*, *Nomia*, *Nomadopsis*, *Andrena*, and *Colletes* apparently visit alfalfa for pollen only. Most species of *Megachile*, *Osmia*, *Hoplitis* and *Anthidium* do likewise, but a few individuals of some species can usually be seen collecting nectar. It is harder to generalize about anthophorids and apids. Some *Melissodes* and *Tetralonia*, for example, nearly always collect pollen when they visit alfalfa, but many species of *Anthophora* and *Bombus* frequently collect nectar. Under most conditions, as most of us know, the honey bee more often collects nectar than pollen from alfalfa. In general, solitary bees are more likely to collect pollen than social bees because they have no need to store supplies of nectar. Among the solitary bees, those that feed their young with the driest pollen mixes are the ones that make the highest percentage of pollen-collecting trips. Some bees collect little or no alfalfa pollen simply because their pollen host range does not normally include alfalfa, even though their nectar host range does. In Utah such bees include *Anthophora bomboides neomexicana* Ckll., *A. pacifica* Cress., and *Bombus fervidus* (F.).

According to many apiculturists the colony needs influence the relative number of bees foraging for pollen and nectar. Heavy brood rearing, for example, may lead to increased pollen collection. However, the effect of such needs is spread over many kinds of plants. The percentage of bumble bees collecting alfalfa pollen varies greatly from day to day and from hour to hour. Whether this variation is associated with colony needs, availability of more attractive pollen, or atmospheric conditions is not known. Alkali bees (*Nomia melanderi* Ckll.) usually complete one ball of pollen each day, and most of the nectar is added to it when the final molding takes place in the late afternoon. However, whether they take nectar principally at this time or merely store it in the honey stomach during the day until the proper time for regurgitation has not been determined.

Competing sources of pollen and nectar have a strong influence on the number of bees that collect pollen and nectar from alfalfa. Most species of bumble bees, for example, prefer red clover to alfalfa, especially as a pollen source. When a red clover field comes into bloom, both the total number of bumble bees and the percentage of pollen collectors decline on nearby fields of alfalfa. Hobbs and Lilly (1954) in Alberta found that only in dry summers, when almost no bloom occurred on the prairies, could effective numbers of bumble bees and *Megachile* be expected on alfalfa-seed fields. The effect of such wild bloom on the percentage of alfalfa pollen-collecting bees was not stated.

Only when competing pollen sources are nearly eliminated over a large area is the number of honey bees collecting alfalfa pollen noticeably increased. Less drastic elimination is required in the case of most wild bees. This may be related to the relatively low flower constancy of most species of bees. With the alkali bee another reason may be that alfalfa is one of its favorite host plants.

The condition of the alfalfa plants affects both the total number of bees visiting the field and the relative numbers of pollen and nectar collectors. A moderately well-watered field with large, well-spaced plants seems to be the most attractive to nectar-

²Male honey bees don't visit flowers. Except for stingless bees (Meliponinae), males of all other bees do.

collecting honey bees. Pollen-collecting honey bees seem to prefer more limited moisture and are even more partial to adequate spacing. Little is known about the preferences of other kinds of bees. Alkali bees like dense, well-watered growth better than dry, sparse growth. I have often seen alkali bees concentrate on small patches of luxuriant growth in an otherwise poor stand. Furthermore, they like to fly inside the dense growth, visiting the innermost racemes as freely as the outer ones. It is not surprising that growers in "alkali bee areas" believe they get the highest yields with dense plantings, whereas progressive growers in "honey bee areas" are convinced that well-spaced plantings give them the best yields.

Some varieties and strains of alfalfa are more attractive than others to certain kinds of wild bees. Vansell and Todd (1946) noted that a strain designated as C-11 was especially attractive to several species of leaf-cutting bees. Subsequent studies (Pedersen & Bohart, 1953) showed that it was also highly attractive to pollen-collecting bumble bees. A strain from Argentina was found to be highly attractive to several species of leaf-cutting bees at Logan, Utah, but it was not unusually attractive to bumble bees or honey bees. The subject of varietal attractiveness to wild bees has received little attention, although it may have important possibilities. Many wild bees are very specific in their flower preferences and a small change in the floral characteristics of a variety of alfalfa might greatly alter its attractiveness to certain species. I have frequently observed that, whereas bumble bees are not abundant in the agricultural areas near Logan, small plantings of hairy vetch or red clover can attract them from large areas and concentrate effective populations. Small fields of a highly attractive variety of alfalfa might achieve the same result.

POLLEN COLLECTORS

POLLEN COLLECTORS ON TRIPPED FLOWERS

Bees visit both tripped and untripped flowers. Those visiting tripped flowers do so for the pollen they can scrape from the exposed stamens. Small halictids, andrenids, and colletids unable or scarcely able to trip flowers are the principal visitors of the flowers that are already tripped. Such bees are seeking pollen and make no effort to obtain the nectar still available in small quantities. Honey bees on rare occasions visit tripped flowers for pollen and take some nectar as well. In general, populations of small nontripping bees increase on a field when the rate of tripping increases. It is usually assumed that they play little part in pollination, since the receptive surface of the stigma is pressed against the standard petal after tripping. However, several authors such as Linsley (1946) have suggested that they may be important in cross-pollinating flowers not cross-pollinated at the time of tripping. If they actually play such a role, it is conceivable that tripping machines might succeed in areas where the bees are abundant enough to invade alfalfa fields in large numbers following use of the machine.

The genera most commonly visiting tripped flowers in Utah are *Hylaeus*, *Lasioglossum*, *Halictus*, and *Nomadopsis*. *Halictus arapahonum* Ckll. is the species most often seen, although in local areas of Millard County several species of *Lasioglossum* (*Chloralictus*) are sometimes more numerous. Larger halictids, such as *Halictus ligatus* Say, *H. rubicundus* (Christ), and *Lasioglossum sysimbrii* (Ckll.) utilize tripped flowers when they find them, but they also trip their own flowers when necessary (although with considerable difficulty). The same holds true for *Nomadopsis scutellaris* (Fowler), which visits alfalfa only when little else is in bloom. This bee is very abundant in Utah and Idaho, but has been observed as an important pollinator only in the Howell Valley of northern Utah. Even at this locality it deserts alfalfa as soon as Russian-thistle (*Salsola pestifer*) comes into bloom.

POLLEN COLLECTORS ON UNTRIPPED FLOWERS

Bees visiting untripped flowers may or may not trip them. When seeking pollen primarily, they trip most of the flowers they visit and, except for the moderately small halictids and andrenids previously mentioned, have little difficulty in doing so. Most pollen collectors approach the flower facing the standard petal and insert their heads into the center of the throat or very slightly to one side. They usually use their

midlegs as braces against the wing petals while using head and mouth parts to apply a downward spreading pressure in the throat. This releases the sexual column from the enclosed keel petals and allows it to spring forward against the ventral side of the bee's head and glance off to the standard petal. Some of the smaller megachilids, such as *Megachile brevis* Say and *Osmia seclusa* Sandh., claw the keel apart with their forelegs and receive the blow from the stigma and stamens on their thoracic or even abdominal venter. Most pollen-collecting bees use their forelegs to scrape pollen from the stamens for a brief period during and immediately after the tripping process. In addition, they may get a general dusting from the small cloud of pollen released into the air by the force of the tripping. Thus, they can receive pollen by three routes. After visiting several flowers in rapid succession, the pollen gatherers take a brief "packing flight" to transfer the pollen from the receiving areas to the pollen-carrying apparatus.

Bees occasionally develop the habit of approaching the flowers over the standard petal, facing the keel. This is an individual rather than a specific characteristic. When a bee succeeds in tripping a flower in this manner, the blow from the sexual column lands on the front or top of its face.

Pollen-collecting bees probably take no nectar during most of their visits to alfalfa flowers. Although the tongue is in a position to take nectar while the flower is being tripped, it is rarely trapped against the standard petal by the sexual column. On the other hand, when nectar collectors trip flowers, they are commonly trapped in this manner. Perhaps the pollen collectors take a quick sip of nectar and retract the tongue in time to avoid being caught. Pollen-collecting bees in such genera as *Apis*, *Bombus*, and *Anthophora* often digress for various periods of time to take nectar by the normal methods described below for nectar collectors. *Megachile gemula* Cress. follows the same practice. However, most megachilids stay with pollen collecting although their honey stomachs often contain a little nectar, probably obtained during some of their pollen visits.

The tripping rate of pollen-collecting bees varies from less than 1 per minute for small bees such as *Halictus ligatus* Say to about 25 per minute for certain large bees such as *Xylocopa californica* Cress. and queens of *Bombus morrisoni* Cress. In general, the larger the bee the more rapidly it can trip flowers. However, megachilids seem to have a special knack for tripping alfalfa, and even small species such as *Osmia seclusa* Sandh. and *Megachile brevis* Say can trip about 14 flowers per minute as compared to 8 for honey bees, which are considerably larger. Large megachilids such as *Megachile dentitarsis* Sladen can trip about 20 flowers per minute.

NECTAR COLLECTORS

Nectar-collecting bees sometimes insert the tongue directly into the throat of the flower in the same manner as pollen collectors. More commonly they insert it from the side between the standard petal and the inrolled upper margin of the wing petal, or behind the wing petal at the margin of the standard petal. Occasionally they use an intermediate approach at the inner edge of the inrolled margin of the wing petal.

THE DIRECT APPROACH

Bees entering the throat of the flower between the wing petals nearly always trip it when they penetrate deeply enough to reach the nectar. Species of *Anthophora* with long, slender tongues and some of the long-tongued bumble bees are the only ones able to reach the nectaries through the throat without tripping a large percentage of the flowers. Some anthophorids can even take nectar without landing. Nectar collectors using the direct approach can usually be distinguished from pollen collectors by the absence of clawing movements and the relatively long time they leave the tongue extended. They may even fly from flower to flower without retracting it. Furthermore, they often fill up with nectar and return to the nest before the pollen-carrying areas are loaded. Sometimes nectar-collecting bees discard the pollen that strikes them, but more frequently they transfer it to their carrying areas. In the case of honey bees and bumble bees the pollen loads of nectar collectors are usually rather small and poorly formed.

Male bees and parasitic bees of certain genera sometimes use the direct approach. Males of *Nomia melanderi* orient their bodies in various ways but always try to enter the throat. More often than not they neither trip the flowers nor reach the nectar. Males of several genera of bees, such as *Anthophora*, *Diadasia*, *Agapostemon*, and *Halictus* are sometimes common in alfalfa fields but tend to be very "flighty" and rarely attempt to enter the flowers. When they do, they nearly always fail. However, males of the larger species sometimes learn to use the side approach successfully. Males of many species visit alfalfa even though females of the same species rarely or never do so—for example, *Agapostemon cockerelli* Crawford, *Diadasia enavata* (Cress.), and *Melissodes obliqua* (Say).

When the hairy-eyed cuckoo bees (*Coelioxys*) visit alfalfa, they brace their legs against the wing petals and force their heads against the base of the standard petal in much the same manner as their non-parasitic relatives, *Megachile*. However, they omit the clawing movements.

THE SIDE APPROACH

Bees using the side approach can reach the nectar quickly and easily and avoid contact with the sexual column. Furthermore, they don't have to spend time in pollen-packing flights. Experienced nectar-collecting honey bees are probably the most skillful users of the side approach. Depending upon various conditions, they trip from 0.2 to about 2.5 percent of the flowers visited. Some bumble bees are nearly as skillful. Nectar-collecting individuals of *Bombus huntii* Greene, for example, have been seen to visit as many as 30 blossoms per minute as against about 15 for honey bees. However, their rate of accidental tripping (caused by stray movements of the legs) is usually higher. Nectar-collecting bumble bees usually use the side approach. They insert the proboscis between the standard petal and the inrolled margin of the wing petals or even closer to the center, but never behind the wing petals.

Anthophora urbana Cress. is a very skillful side-worker. It visits flowers more rapidly than honey bees and, on the basis of limited observations, has at least as low a tripping rate. According to Franklin (1951), *Xylocopa virginica* Drury is just the opposite. Its body is so heavy and its tongue so broad that even when using the side approach it frequently causes tripping. Male bees in the families Apidae, Anthophoridae, and Megachilidae generally use the side approach. Male halictids and andrenids are more likely to use several approaches, most of them unsuccessfully.

WILD BEES

ADVANTAGES AND DISADVANTAGES

Most alfalfa-visiting species of bees pollinate alfalfa much more efficiently than nectar-collecting honey bees and somewhat more efficiently than pollen-collecting honey bees. When sufficiently abundant they can pollinate the flowers so rapidly that only a light bloom is evident on the field at any one time. Under these conditions the seed crop is less susceptible to damage by sucking insects and certain diseases than it would be with slower pollination. The grower who has had experience with pollination contracts also appreciates the fact that his wild bees are "free" and don't bother him in the field.

The shortcomings of wild bees as pollinators are obvious for the most part. They are usually too scarce for adequate service, their populations are too unpredictable from year to year and week to week for reliable service, and such measures as have been devised for their maintenance and increase are often contrary to accepted agricultural practices.

CONSERVATION

The problem of obtaining and maintaining adequate numbers of wild bees on a seed field can be approached from the standpoints of populations in the area and on the field. High populations in the area are usually favored by (1) providing plenty of wild land for nesting (broken terrain with bare areas, banks, and patches of shrubby growth is usually the most attractive to a wide variety of species); (2) providing sufficient bloom in the area throughout the season to attract and provide food for the species in the area; (3) having as many species as possible; (4) maintaining existing

nesting areas and establishing new ones; and (5) avoiding the use of insecticides during bloom (when unavoidable, using materials least harmful to bees and when bees are not on the field). High populations on the seed field are favored by (1) timing the bloom for the period of greatest abundance of the most important species, (2) limiting the acreage in bloom at any one time, and (3) reducing competing sources of pollen and nectar during the blooming period of the seed crop.

Declining numbers of wild bees in new agricultural areas may be more a matter of diluting the existing population over increasing acreage than reducing the overall population. Farmers in frontier areas often expand legume acreages rapidly to improve the soil. Much of that acreage is devoted to seed because of the high yields that usually occur on the first few fields in a new area. When the acreage of bloom increases, the overall population of wild bees may also increase, although benefit from the increased forage is more often than not offset by destruction of nesting sites and careless use of insecticides. It is only under exceptional circumstances that wild bee populations keep pace with expanding acreage of bloom. When areas become more settled, limitation of nesting sites and destruction of adult bees by insecticides become more serious than dilution of existing populations. In this phase of more intensive land use, limitation of blossoming plants is likely to reduce wild bee populations still further.

INCREASE OF ALKALI BEES

Pioneer farming practices are sometimes responsible for increasing both the forage and nesting site conditions of certain species of bees. When this happens the species in question may increase as rapidly as the acreage of seed alfalfa. Eventually, however, specific conservation measures become necessary to maintain the advantage gained. The alkali bee in the Northwest provides an outstanding example. When farmers first appeared, the nesting areas for alkali bees were limited to a few areas of natural seepage. Furthermore, only a few of the native plants were useful to them, and they were limited to small areas in the larger valleys where natural moisture was available. Irrigation greatly increased the suitable areas for nesting, and the introduction and spread of cultivated crops and foreign weeds such as alfalfa, sweetclover, Russian-thistle, and spearmint increased the available forage manyfold. Even such native host plants as bee flower (*Cleome serrulata*) were increased on wasteland and roadside areas.

In some areas, as pointed out by Bohart (1955), "improved" farming practices such as ditch lining and drainage of waterlogged areas have greatly reduced the populations built up by careless water use in the past. Furthermore, huge nesting grounds have been ploughed up to plant more alfalfa seed. In recent years alkali bees have been nearly wiped out in many areas by the use of such insecticides as parathion and dieldrin on blossoming alfalfa. The above measures have usually accomplished their immediate goal but in the end have depressed seed yields by "killing the goose that laid the golden egg." Fortunately, it is possible to maintain and even increase alkali bees without sacrificing good farming practices. Seepage areas can be prepared and maintained exclusively as nesting sites. Since alkali bees are highly gregarious (a million or more can nest in an acre of ground), the land devoted to their culture need not be large. Lieberman *et al.* (1953) have devised control programs for harmful insects that do not seriously reduce alkali bee populations. These programs have proved to be at least as successful in their primary objective as the programs that result in destruction of pollinators.

In the Riverton area of Wyoming, the Snake River Valley near Boise, Idaho, and the Yakima River Valley near Prosser, Washington, alfalfa-seed growers are already successfully preparing and maintaining nesting sites for alkali bees. Their ranks are increasing, and a few growers in other areas such as the Uintah Basin and Delta seed areas of Utah have signified their intention of preparing sites in 1957. This interest on the part of the more progressive growers is bringing to their neighbors greater awareness of the need for protecting bees.

At the present time alkali bees are largely responsible for high seed production wherever it occurs in the states of Washington, Oregon, Idaho, Wyoming, Montana, and northern Utah. Furthermore, there appears to be a great potentiality for increasing alkali bees and seed yields in many localities in these states.

INCREASE OF OTHER WILD BEES

According to reports alfalfa-seed growers in northern Manitoba have had some success in maintaining populations of *Megachile* and *Bombus* on their fields. This they have done by limiting the cultivated areas to relatively narrow strips surrounded by native aspen and cottonwood timber growth. The timber cleared from the fields is piled around the field margins. Beetles boring in the wood provide nesting places for *Megachile*, and rodents nesting in the brush piles provide nesting sites for *Bombus*. Additional trees in the surrounding forest are girdled to furnish more nesting places for *Megachile*. I have not seen the area in question, but it seems probable that the favorable conditions created will be difficult to maintain for many years.

INTRODUCTION OF POLLINATORS TO NEW AREAS

In many areas it should be practical to improve pollination by wild bees by the introduction of additional species. Apparently the only concerted efforts in this direction were made near the turn of the century when bumble bees were successfully introduced into New Zealand from England. Attempts during the same period to introduce bumble bees from England into Australia failed. Recently R. A. Cumber (1953) investigated the possibilities of introducing bumble bees from England to Australia, but was opposed on the grounds that parasites or diseases of honey bees might be introduced thereby. This fear, although understandable, was almost certainly groundless. Since only queens need be sent and these can be nematode-free individuals collected in the fall, there is little likelihood that parasites or diseases of either honey bees or bumble bees would be introduced. Mites might accompany the queens, but they are harmless scavengers in bumble bee nests and are in no way associated with acarine disease of honey bees.

Megachilids should be particularly well suited for introduction. The larvae develop well in confinement and are protected by cocoons in the overwintering stage. The cocoons could be inspected for evidences of parasitism and placed in split sections of hollow stems or drilled cylinders of wood (Levin and Haydak 1958) for shipment and release. Several species of *Megachile* have been accidentally introduced into eastern North America from Europe and one arrived in Hawaii from California. What man has done inadvertently, he should be able to do on a larger scale using purposeful methods. Other wood-inhabiting bees such as *Xylocopa* and *Ceratina* should be as easy to introduce as megachilids. Some of the *Xylocopa* are efficient alfalfa pollinators, but any species considered for introduction should be studied first to see if it damages structural timbers.

Many kinds of bees may prove to be difficult to transport and establish in new areas, but only actual trials will give us a clear picture of the problems concerned and lead us to the eventual solutions. There are many species to work with. Furthermore, many areas with similar climatic and soil conditions have entirely different bee faunas. Central Asia, being the homeland of alfalfa, is of particular interest as a source of alfalfa pollinators. Popov (1956) listed 22 species as being important alfalfa pollinators in central Asia. He gave special mention to *Melliturga clavicornis* Latr., a gregarious species nesting in open spaces of flat ground. Without doubt some of these species could be profitably introduced to various seed-growing regions. The alkali bee, an inhabitant of the intermountain areas of the West, would probably prosper in intermountain valleys of various parts of the world where alfalfa is grown.

WILD BEES IN THE FUTURE

The future for wild bees in agricultural areas is not necessarily so grim as it has been pictured. Some of the species that suffer from intensive agriculture may fare reasonably well if the present trend toward more pastures and soil banks continues. Species that are highly gregarious and also useful as pollinators can be maintained in special preserves by enlightened farmers. Indiscriminant bloom-stage applications of insecticides harmful to bees is one of the worst problems to be faced. Research has shown that we can develop satisfactory programs for the control of harmful insects with a minimum of damage to bees. Unfortunately, the importance of measuring both aspects of the problem by the same economic yardstick has not been widely accepted by the various organizations and individuals concerned.

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