1950

Pollination (in Growing Alfalfa for Seed in Utah)

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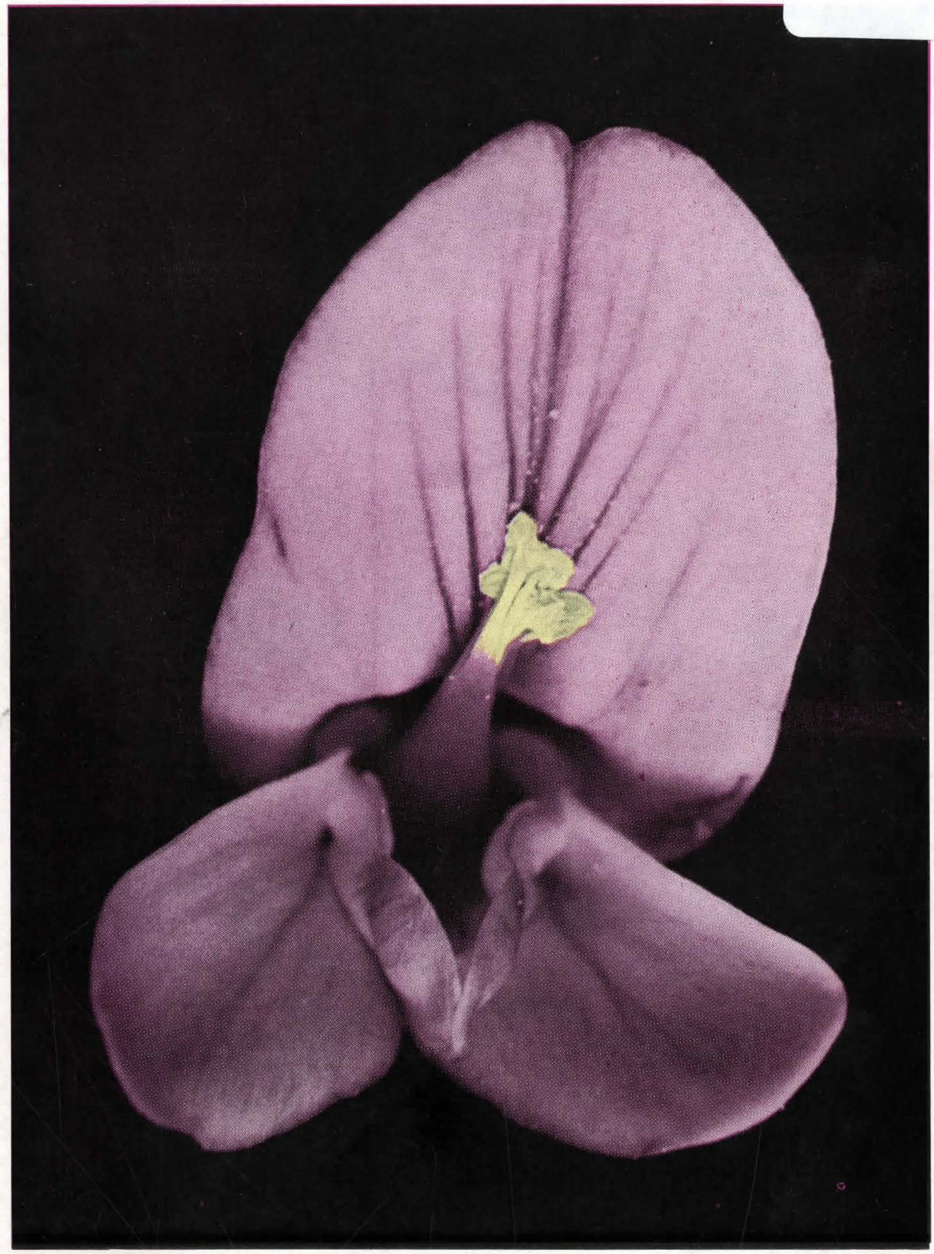
Recommended Citation
Todd, F. E., G. E. Bohart, and W. P. Nye. 1950. Pollination. In Growing Alfalfa for Seed in Utah. Utah Agr. Exp. Sta. Circ. 125. p. 44-71.

CIRCULAR 125

Growing Alfalfa for Seed IN UTAH



UTAH AGRICULTURAL EXPERIMENT STATION
IN COOPERATION WITH THE
U. S. DEPARTMENT OF AGRICULTURE

Growing Alfalfa for Seed in Utah

Circular 125

UTAH AGRICULTURAL EXPERIMENT STATION
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U. S. DEPARTMENT OF AGRICULTURE

THE AUTHORS

This circular was prepared by research workers at the Utah State Agricultural College. Most of these men are affiliated with the Legume Seed Research Laboratory. They have all cooperated in conducting research on the problems of alfalfa seed production.

AGRONOMIC STUDIES

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STUDY OF HARMFUL INSECTS

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STUDY OF POLLINATING INSECTS

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FOREWORD

DIFFICULTIES encountered by farmers in obtaining satisfactory yields of alfalfa seed first came to the attention of the Utah Agricultural Experiment Station in 1925. Since that time experiments have been conducted in many areas of the state and studies made of many factors thought to affect seed production. These have included cultural methods, irrigation, harvesting, studies of pollinating insects, and studies of the life history and control of injurious insects. Some of these studies have been conducted cooperatively with the Bureaus of Plant Industry, Soils, and Agricultural Engineering and Entomology and Plant Quarantine, U. S. Department of Agriculture.

In order to give more impetus to the research a special appropriation by Congress in 1947 provided funds for establishment of the Legume Seed Research Laboratory at the Utah State Agricultural College. The work of this laboratory is done on a cooperative basis by the Agricultural Experiment Station, the Bureau of Plant Industry, Soils, and Agricultural Engineering, and the Bureau of Entomology and Plant Quarantine. Since the establishment of this laboratory, increased emphasis has been given to the study of alfalfa seed production problems.

The results of experiments conducted under this research program, together with those from other areas, and the experience of seed producers constitute the basis for the recommendations made in this circular.

R. H. WALKER
Director

June 1950

RECOMMENDATIONS FOR CONTROL OF ALFALFA SEED INSECTS

1. LYGUS BUGS. When alfalfa is in bud, apply 20 pounds of 10 percent DDT dust per acre or 1.5 pounds of actual DDT per acre as a spray. When full recommended dosage is used, second treatment will usually be unnecessary. When rcinfestation warrants a second treatment, apply 20 pounds of 10 percent toxaphene dust per acre or 1.5 pounds of actual toxaphene per acre as a spray. Apply this treatment 3 to 4 weeks after the DDT treatment and only after 7 p.m. or before 7 a.m. when bees are not visiting the blossoms.

2. ALFALFA WEEVIL. The control given for lygus is usually adequate for weevil. Growers having difficulty in controlling weevil by that method alone can apply 1.5 pounds of actual chlordane per acre as a water-emulsion spray when the first-crop shoots are 1 to 2 inches long.

3. SEED CHALCID. Feed or destroy chaff stacks and screenings before May 1. Prevent volunteer alfalfa and red and crimson clover from forming pods. To control this pest grow all first-crop or preferably all second-crop seed, but not both in the same locality. Cultivate seed fields in fall or spring to bury as many infested seeds as possible. Clean all seed promptly.

4. GRASSHOPPERS. When the plants are blooming, use only toxaphene at the rates given for lygus control in blooming alfalfa. Before the plants bloom either toxaphene or chlordane may be used.

5. MITES. Apply 10 to 25 pounds of dusting sulfur per acre twice (10 days apart) before the plants bloom. A 10 percent DDT dust containing at least 50 percent sulfur can be used to combine the second application for mites with the bud stage application for lygus bug control. Do not apply DDT more than once on the same crop of seed.

6. APHIDS, THRIPS, LEAFHOPPERS, AND ARMYWORMS. These minor pests are usually adequately controlled by the DDT application recommended for lygus.

7. Do not feed chaff from crops treated with DDT, chlordane, or toxaphene to dairy animals, to meat animals being fattened for slaughter, or to poultry.

SUMMARY

ALFALFA is the most important cultivated crop in the Intermountain area and is one of the most important forage crops in the nation. Utah was the major seed-producing state in the late twenties, but by the early thirties yields were so reduced that seed production became unprofitable.

As a result of intensive studies in this state and elsewhere, many of the essentials for successful alfalfa seed production can now be outlined. Briefly summarized, they are as follows:

1. Normal growth should be encouraged. The best yields may be expected on soils of fertility adequate to produce plants of maximum size. Irrigation should be used to prevent wilting but should not be heavy.

2. Harmful insects should be controlled. It is usually necessary to control alfalfa weevil by cultural or chemical means in order to obtain normal vegetation. It is almost always necessary to control lygus bugs with insecticides in order to obtain normal flowering and response to pollination. Seed chalcids should be kept at a minimum with recommended cultural practices.

3. Bees must be present on the fields in abundance during the blossoming period. Increase in the number of colonies of honey bees in or near seed-producing fields should result in increased seed production. Wild bees are particularly efficient as pollinators and they should be protected and encouraged whenever possible.

4. Community approach to such problems as uniformity of cultural practices, control of injurious insects, and improvement of pollination is desirable.

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Growing Alfalfa for Seed in Utah

INTRODUCTION

A STABLE SUPPLY of alfalfa seed is essential to the welfare of American agriculture. During the last decade over 70 million pounds of cleaned seed have been required each year to maintain hay fields and pastures. If acreage planted to legumes were increased to the extent advisable for soil conservation and a balanced agricultural economy, the annual need for alfalfa seed would increase to more than 100 million pounds.

In recent years seed production has been increasing and it is not unlikely that in the future annual yields will be consistently above 100 million pounds. If lower prices result, the successful growers will be those who can produce higher acre yields than are now common.

Many areas where alfalfa can be successfully grown for hay and pasture are unfavorable for consistent seed production. Consequently, the seed supply for the entire nation is concentrated in a few areas where conditions of soil and climate are relatively favorable. However, even in these areas, yields fluctuate widely from year to year and from field to field. Utah, which appears to be one of the most favorable areas, has been no exception in this wide fluctuation of yields.

Research here and elsewhere during the past few years has succeeded in separating a few of the more important factors from among the multitude influencing seed yields. By utilizing knowledge of these factors, Utah has an opportunity to become one of the most profitable seed producing areas of the country. To attain this goal, however, it will be necessary to produce seed of varieties in demand by other areas and to maintain purity and quality in the seed produced.

This circular discusses various phases of seed production and emphasizes factors of known importance, particularly pollination and damage by insects, over which the grower has some control. Its aim is to stimulate the seed industry of the state and to encourage growers to increase their yields.

AGRONOMIC PRACTICES

The Seed

Varieties of Alfalfa

UTAH Common, Grimm, Ladak, Cossack, and Hardigan have been the common varieties of alfalfa grown in Utah during the past fifty years. At present the wide-spread distribution of wilt is making these varieties unproductive after the third or fourth year

Fig. 1. Relative height of Ranger (left) and Utah Pioneer (right) alfalfas in the third year of cropping for hay. Average yield: Range 5.21 tons per acre; Utah Pioneer 3.25 tons per acre

of cropping. Consequently they are being replaced by new varieties, especially Ranger (fig. 1) and Buffalo, developed primarily for wilt-resistance at the state and federal alfalfa breeding stations. Both Ranger and Buffalo are well adapted to the alfalfa growing regions of Utah and compare favorably in seed production with Utah Common and Grimm. Data obtained from seed productivity tests at Logan are given in table 1.

Table 1. *Comparative seed yields of alfalfa varieties*

Varieties	Seed in pounds per acre				
	1945	1946	1947	1948	Means*
Ranger	387	362	332	280	340
Buffalo	314	224	226	128	222
Atlantic	302	336	243	247	282
Grimm	448	443	294	257	360
Utah Common	266	244	260	223	263

*Differences are not statistically significant.

There is a demand also for seed of varieties meeting special requirements. Among these are Atlantic and Narragansett, which are especially adapted to New Jersey and Rhode Island conditions where wilt is not a serious factor. Williamsburg is another variety developed for resistance to fungus diseases prevalent in Virginia. Limited areas infested with stem nematode need seed of the variety Nemastan which is highly resistant to nematodes. Consuming areas for these varieties, except Nemastan, are not suitable for seed production.

Although Common alfalfa is not fully adapted to the eastern and northern regions of the United States, its seed continues to be used in regions where winter killing is not a limiting factor. Demand for it is likely to lessen as the supplies from better adapted varieties become cheaper and more plentiful.

Breeding for Seed Production

Plant breeders have succeeded in developing cold and wilt resistant varieties of alfalfa. Seed production can also be improved by breeding.

Seed productivity studies with single plant selections and varieties of alfalfa indicate that high seed production is dependent to an appreciable extent upon hereditary characters in the alfalfa plant (table 2). Alfalfa plants differ widely. Selection and hybridization for superior types seem, therefore, to be a promising method of improving alfalfa seed production. Furthermore, yields of progenies from selected high-seeding plants have been found to be superior to the variety from which they were selected. And strains that were high in seed production in the initial year of the test have been high in succeeding years. Seed production is affected by the complex interaction of many genetic factors such as number of seeds per pod, plant size, pods per raceme, sterility, attractivness to pollinators, and resistance to insects and diseases.

Table 2. *Efficiency in response to pollination and seed productivity of low and high seeding alfalfa plants (Petersboro plots—Utah Agricultural Experiment Station,* 1946)

Character of the genotype	Flowers forming with type of pollination		Seed per acre
	Natural	Cross*	
	percent	*percent*	*pounds*
Low seeder			
Utah Grimm 12	28	42	133
High—very high seeders			
Nebraska 1226	21	69	758
Nebraska 1255	25	83	856
Utah Ranger 7	45	78	1039

*Hand tripped and cross pollinated to determine potential response to insect pollination

From 25 to 60 percent of the variation in seed yields has been found to be associated with plant size. Healthy, vigorous, large plants are essential to high seed yield.

Seed Certification

The introduction and release of new alfalfa varieties, developed as a result of careful breeding work, require new certification procedures in order to maintain their genetic purity, disease resistance, winter hardiness, and other characteristics. Certification of these new varieties is limited to three generations or classes of seed, namely; foundation, registered, and certified. Registered seed is the progeny of foundation seed. Certified seed is the class of seed intended for use in planting fields for hay production and is not eligible for further certification. The limited number of generations, isolation, and other necessary restrictions for certified seed have retarded the rapid increase of the new alfalfa varieties. Believing that a shortage of foundation seed was a limiting factor in their rapid increase, state and federal agencies have recently initiated a national foundation seed increase program. Financial backing by a lending agency of the federal government should make it possible to build up quickly and maintain foundation seed stocks for use in the production of registered and certified seed.

For details of certification regulations and procedures, consult the Utah Crop Improvement Association, Utah Agricultural Experiment Station.

Selection and Preparation of Seedbed

Alfalfa seed can be successfully grown under dry land conditions when soil moisture is not too limiting a factor. Soils best adapted to alfalfa on dry land are those that are deep, of a loam to clay loam or even a silty loam texture, located in areas where the rainfall is not less than 12 inches annually, and where the growing season is at least 100 days. Fields planted to alfalfa, for the production of seed in dry land areas, should be free from shallow soils, hardpan layers, and excessive alkali. In other words, they should hold moisture sufficiently well to support a slow and even growth of alfalfa.

These conditions are usually found in valleys surrounded by hills in which moisture is retained from drifting snows, and where subsurface run-off in the spring and summer supplements the supply from precipitation. Although these valleys afford excellent conditions for the growing of alfalfa seed, level bench lands in many areas have produced successful seed crops with proper cultural treatment.

When irrigation is practiced, the soil should be deep and well drained. The land should be levelled with a slight grade to facilitate irrigation, since the distribution of water is quite often a determining factor in the production of a good seed crop. Prior to the use of DDT for insect control, it seemed necessary to hold in check an excessive vegetative growth of the alfalfa, so as to throw the plant into seed production. To this end, soils were used that had some distinctive defect; such as, drought, shallowness, high salinity, or low fertility. But with the introduction of new insecticides and effective control of lygus bugs, it has not been necessary to retard the growth of alfalfa in this manner. High seed yields are now being obtained from alfalfa growing under the most favorable agronomic conditions. It is apparent, therefore, that alfalfa seed may be grown under a wide range of conditions.

Under dry land conditions, the land should be left fallow during the year preceding planting. Seeding should be done without a companion crop early in the spring. Under irrigation, a cultivated row crop grown prior to planting leaves the soil in an excellent physical condition for the later seeding of alfalfa. Plowing is not necessary following these crops, but if done, it should be in the fall soon after the row crops

Fig. 2. Seed bed preparation. Firmness and uniformity are essential to obtaining good alfalfa stands

have been removed. A firm, well prepared seedbed is necessary to obtain a good stand of alfalfa (fig. 2).

Fertilizers

If phosphate deficiencies are suspected in the soil, laboratory tests should be made to determine fertilizer needs. Laboratory tests should be supported by strip tests in the field. Where a response in forage is obtained a related increase in seed yield can usually be expected.

On the Experiment Station farm, where the soil is fertile, no response in forage or seed was obtained from application of nitrogen, phosphorus, boron, zinc, copper, or manganese.

Inoculation

Benefits from alfalfa seed inoculation with legume bacteria have not been demonstrated in Utah. The soils generally appear to be well supplied with the proper *Rhizobia* bacteria.

Seeding

Rate and Method

Most alfalfa seed is produced from stands established for both hay and seed production. Where this dual purpose is desired, the rate of seeding should be determined by the requirements for hay production. For drilled or broadcast stands for both hay and seed production use 6 to 8 pounds per acre on dry land and 12 to 15 pounds per acre on irrigated land. Cut the rate in half if the stand is to be used primarily for seed production. When seeding in wide-spaced rows 1 to 3 pounds is sufficient.

Special methods are desirable to maintain the purity and identity of new varieties of alfalfa. This, however, is a task for the man who wishes to specialize in seed growing, particularly one who is willing to abide by the rules governing the production of foundation seed stocks. When grown in the usual way, stands frequently become contaminated with weed seeds and natural reseeding from other alfalfa that is carried into the fields with irrigation and run-off water. Thus, it becomes necessary to rogue the fields to prevent contamination of the stands with foreign alfalfas, dodder, weeds, and sweet clover.

Seed yields of alfalfa grown in hills, rows, and in drilled stands at the rate of 2, 4, and 9 pounds per acre are shown in table 3 and fig. 1. Seeding in rows can be done with the grass seeder attachments on an ordinary grain drill. Rows may be spaced at any convenient distance that will facilitate cultivation. Small acreages may be seeded with a garden drill. Furrows for irrigation are made with horse or tractor-operated equipment. Susbequent cultivation and weed control are essential.

Table 3. *Comparative seed yields from alfalfa grown in hills, rows, and in drilled stands sown at the rate of 2, 4, and 9 pounds per acre*

	Seed per acre*	Relative yield
	pounds	*percent*
Type of stand		
Hills	282	180
Rows	210	134
Drilled		
2 lbs. per acre	189	120
4 lbs. per acre	156	100 (check)
9 lbs. per acre	134	83

*Average of 3 years, 1928-1930, inclusive (Uinta Basin Alfalfa Seed Experimental Farm, Utah Agricultural Experiment Station, Fort Duchesne)

Depth

The seed should be covered approximately one-half inch on heavy soils. On light or dry soils a slightly heavier covering is better.

Time

Early spring seeding to take advantage of winter accumulation of moisture is recommended.

Companion Crops

Companion crops should not be used on dry land. On irrigated land barley or other small grains at about half the normal seeding rate can be used. With a thin stand of the companion crop the grain can be harvested without unduly exposing the tender seedlings to damage by the bright sun and the grain replaces a weed growth at a profit to the grower.

Irrigation

Present information is inadequate as a basis for formulation of rules governing irrigation practices. Local soil and moisture conditions are of paramount importance. Results obtained with lygus bug control lead to the belief that irrigation tests conducted before lygus bugs were considered a factor in seed production may have confused the issue. Likewise it is suspected that attractiveness of alfalfa to pollinators may be modified by irrigation when the plants are in bloom. It is generally advisable to maintain a vigorous growth without stimulating regrowth from the crowns. Wilting should never be permitted.

In a recent test at the Experiment Station on field plots (caged with bees) with a water table at six feet, yields with one irrigation when pollination was nearly completed were essentially the same as on non-irrigated plots (1024 and 1014 lbs. per acre, respectively).

It will be necessary to reevaluate irrigation practices before specific recommendations can be made.

Cropping Systems

Hay and pasture requirements of the farm unit often determine whether or not a farmer will cut the first crop for hay or leave it for seed. Many factors are modified by these cutting practices. Ordinarily insects and diseases are more difficult to control on the first crop (see page 35). The second crop should be timed to avoid frost in the fall. It should be kept in mind that about six weeks is required for the seed to mature after the flowers are tripped. Generally speaking the pods should be started by the 15th of August to avoid frost.

Many successful seed crops have been attributed to a plan of cutting or pasturing-off alfalfa prior to starting growth for seed. Under varying conditions of different regions, however, no consistently successful system has been developed. The experience of seed growers has been that in some years first growth will produce the most seed, while in other years the second has been found the best. It is doubtful,therefore, if any one plan for cutting or pasturing-off will be found suitable under all conditions. Many factors are involved, and further study will be required for a more specific answer to this question. However, the problem of insect control will be simplified where all growers in an area grow either all first or all second crop for seed.

An attempt was made to measure the effects of clipping and grazing of alfalfa prior to the growing of a seed crop in the Uinta Basin from 1927 to 1930, inclusive. The test was conducted on one-tenth acre plots replicated three times through four seasons. (A more limited test on one-eighth acre plots was conducted at Petersboro in 1946.)

In the early test no cutting and early grazing by sheep were about equal and superior to cutting at 5 different growth stages including full bloom. The lowest yields were obtained from plots cut in full bloom. Lygus bugs were not controlled in this test. However in the 1946 test, yields were in about the same order (favoring no cutting) whether the plots were dusted or not. Lygus were more abundant on the later cuttings. In view of the fact that there is a direct relation between the amount of forage and the amount of seed produced, it is believed that where insects, diseases, and spring frost are not factors that the highest yields will be obtained on the first crop. Data are briefly summarized in table 4.

Table 4. *Effects of cutting and grazing alfalfa prior to starting growth for a seed crop, Uinta Basin* 1927-1930

Treatment	Seed per acre	Relative yields
	pounds	*percent*
Not cut (1st crop)	204	100.0 (check)
Cut when 6" high	156	76.2
Cut in bud stage	148	71.9
Cut at intial bloom	170	82.6
Cut 1/10 bloom	90	43.9
Cut in full bloom	70	34.6
Grazed by sheep to May 25	217	106.2
Grazed by sheep to June 15	122	59.6
Petersboro 1946		
Not cut (1st crop)	112	100
Cut in the bud stage	70	62
Cut in early bloom	57	51
Cut in late bloom	23	20

Harvesting

The crop should be cut when two-thirds of the pods are black or brown, and during the early part of the day when the air is humid to reduce shattering. Choice of a method of harvesting is dependent upon such things as local weather, equipment available, and whether or not the chaff is to be fed. Threshing in the field has the disadvantage of scattering the chaff. Consideration should also be given to the fact that the chaff usually contains larvae of the alfalfa seed chalcid (page 38) and disease organisms. The manner of disposal of the chaff may affect infestations the following year. The chaff is the main source of chalcid infestation and it is difficult to reduce this source when the chaff is left in the field.

Three methods commonly employed in the harvesting and threshing of alfalfa seed are as follows: (1) cutting and piling with the "twister" attachments to the cutter-bar of a horse-drawn or tractor-operated mower, and threshing in a stationary thresher or combine; (2) windrowing and threshing with the pick-up combine when dry;

Fig. 3. Threshing alfalfa with a stationary machine. The seed growth has been cured in cocks and is being hauled to the thresher

and (3) combining direct. The first method has been commonly employed in the past (fig. 3), but is being replaced by labor-saving methods. The second method, which is relatively new, has much in its favor. Some risk is involved in its use in regions where strong winds may scatter the crop before it can be threshed. Its principal advantages, however, are reduction of hand labor, lower costs of operations, and reduction in seed losses under favorable conditions for harvesting. Direct combining is used where winds may be a hazard to windrowed crops, and when the crop has been permitted to stand uncut until after the foliage has been killed and partially dried out by the early fall frosts. This method is the lowest in cost and eliminates hand labor. It has been most successfully employed in irrigated regions with low annual precipitation. On certified seed fields the danger of contamination from volunteer seed may be an important consideration in combining.

PROTECTION FROM BIOLOGICAL FACTORS

Weeds

Pre-emergence Control

Annual weeds are often a problem in seedling alfalfa. The best control is to allow the weed seeds in the upper layer of soil to germinate and then kill them by cultivation before seeding. Companion crops also aid in control. Experiments with chemical control of weeds at the seedling stage are being conducted, but are not sufficiently advanced to be recommended at this time.

Post-emergence Control

Weeds are not usually a problem where a dense stand of alfalfa is maintained and the crop is cut for hay. The weed problem is aggravated by growing seed crops year after year on the same field. Early spring cultivation with a spring-tooth harrow limits development of weeds, diseases, and insects (see page 39). However, spots in the field known to have nests of alkali bee should not be cultivated deeper than 3 inches (page 69). Consistent use of first crop for seed encourages weed growth. Contact weed killers can be used on difficult cases. Consult the Experiment Station for details.

Dodder

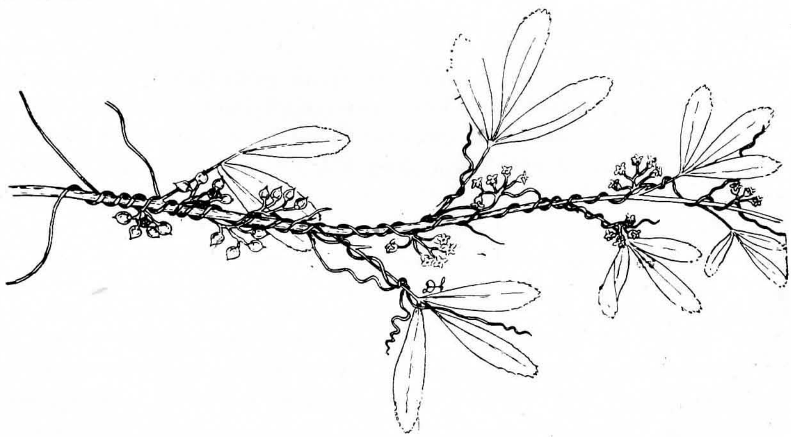


Fig. 4. Dodder growing on alfalfa stem

Dodders (*Cuscuta* spp.) are parasitic weeds in alfalfa (fig. 4). Dodder seed is difficult to remove from alfalfa seed and persists for a number of years in the soil. Where the weed occurs in small patches it should be cut and burned on the spot. For serious cases some growers have been able to control it by grazing with sheep or by growing hay crops and mowing before the dodder has had a chance to mature seed.

Diseases

Seedling Diseases

Treatment of alfalfa seed with a fungicide for the control of seedling diseases has not been studied sufficiently well in Utah to warrant a statement as to its value. It is doubtful if any increase in stand would be realized by seed treatment in an arid state such as Utah.

Bacterial Wilt, *Corynebacterium insidiosum* (McCull.) H. L. Jens.

Bacterial wilt causes a thinning of the stand (fig. 1) and reduction in yield starting about the third year. The only control is to plant resistant varieties such as Ranger or Buffalo.

Foliar Diseases

Numerous diseases of the leaves and stems of alfalfa have been observed, but little progress has been made in controlling them. Losses have resulted from outbreaks of the following two diseases in Utah:

Bacterial Stem Blight, *Pseudomonas medicaginis* Sackett

A disease of the first crop. The foliage is predisposed to infection by frost damage. Water soaked lesions that later turn dark occur on the stems and leaves and the growth is stunted. Mowing the first crop for hay will remove the damaged growth. The next cutting is not likely to be infected.

Yellow Leaf Blotch, *Pseudopeziza jonesii* Nannf.

Yellow leaf blotch is primarily a disease of the leaves causing necrotic lesions with marginal yellowing and later discoloration. A few fields have been observed with rather heavy infestations in the northern part of the state. Control methods have not been worked out.

The Stem Nematode *Ditylenchus dipsaei* (Kuhn) Filipjen

Nematodes are a problem in limited areas in the United States. The variety Nemastan is resistant, but is a low forage and seed producer and susceptible to foliar diseases. Promising new varieties that largely overcome these difficulties are being developed at state and federal experiment stations. Crop rotation also has value as a control measure. The fields should be kept free of alfalfa and clover plants for at least 2 or 3 years.

Rodents

Field mice and gophers are often problems in seed fields. Mice can be controlled with poisoned grain and gophers with poisoned carrots. Consult the county agent for details and precautions.

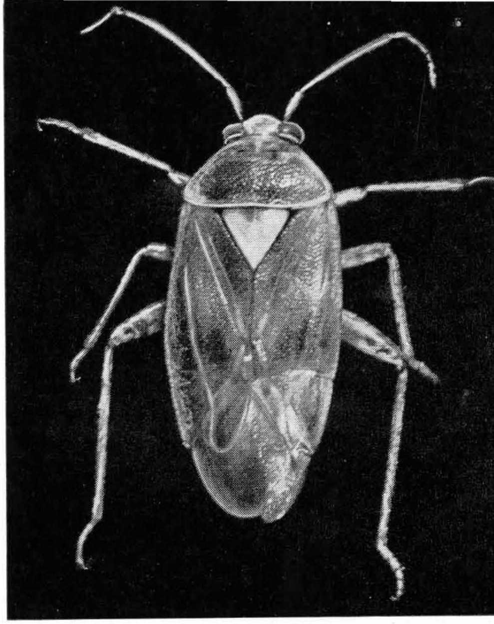


Fig. 5. Adult lygus bug (natural size about 3/16 inch long)

Injurious Insects and Their Control

Lygus Bugs (principally *Lygus elisus* Van D. and *L. hesperus* Knight)

Description and Injury

In the West lygus bugs are the most damaging pests of seed alfalfa. Both adults (fig. 5) and nymphs (fig. 6) feed upon the plants. The adults are about 3/16 inch long and one-half as wide. Their body color varies from pale green to reddish or dark brown. The newly-hatched nymphs are difficult to see with the naked eye, but fifth-stage nymphs, although wingless, become nearly as large as adults. Color of the nymphs varies from yellowish-green to bluish-green.

The mouth parts of these bugs are designed for piercing and sucking, and comprise a long "beak". The bugs use their beaks to draw out the plant juices for food. Besides the mechanical injuries to the plant tissues which thus result, a local injury also develops from the injection of saliva into the punctures. These bugs prefer to feed on the reproductive parts of plants, and the nymphs are much more destructive than the adults.

The greatest damage by lygus bugs to a crop of seed alfalfa generally occurs to the buds (fig 7). Two to five days after being fed upon, buds will die and bleach. If the infestation of lygus nymphs is heavy during the bud stage, total destruction of the buds may result and flowering will consequently be prevented. Bud damage is conspicuous, the field often assuming a greyish cast.

When flowering is not prevented, the bugs also feed upon the flowers and cause them to drop. However, not all flower fall is attributable to lygus bug injury. Like many other plants, alfalfa develops more flowers than can be retained by a healthy plant and a "normal" flower fall always occurs. Furthermore, when pollination is deficient, flower fall is correspondingly greater (see page 44).

Lygus bugs present in the field after pods form will feed upon the immature seeds. Injured seeds shrivel and turn brown (fig. 8). When lygus bugs are abundant in the seed field during this period, a high percentage of seed can be destroyed.

Vegetative growth of alfalfa is also affected by lygus bug feeding. Length of stems is reduced, generally in proportion to the in-

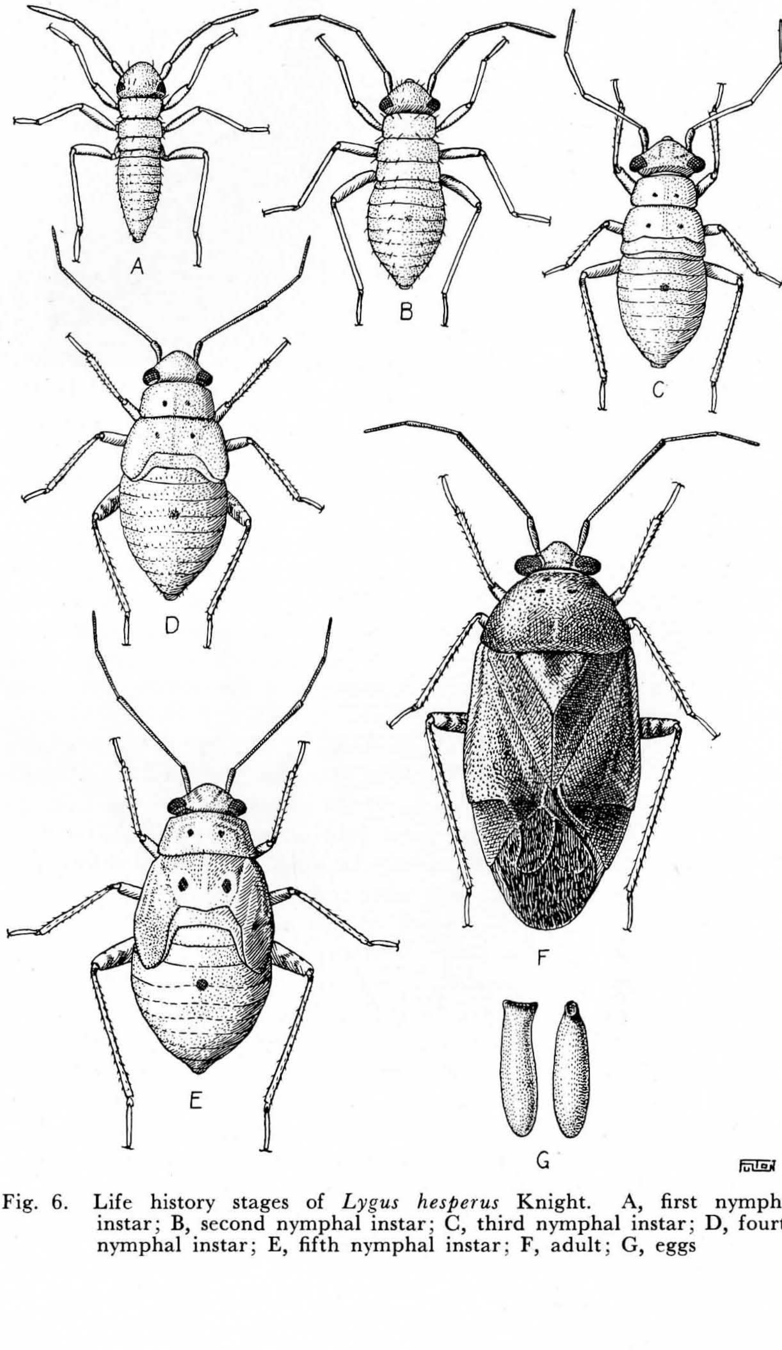


Fig. 6. Life history stages of *Lygus hesperus* Knight. A, first nymphal instar; B, second nymphal instar; C, third nymphal instar; D, fourth nymphal instar; E, fifth nymphal instar; F, adult; G, eggs

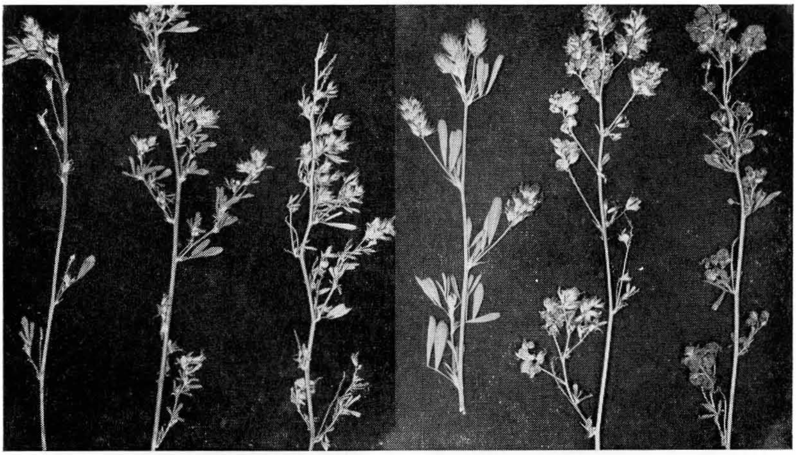


Fig. 7. Upper portions of three alfalfa stems showing lygus damage, left, and normal stems, right

tensity of the bug infestation. Stems become excessively branched with short internodes and frequently the leaves become more numerous, smaller, and distorted in shape. However, this type of damage is not important in hay production.

Effect of Damage on Seed Yield

The relative importance of the various types of damage to reproductive parts of alfalfa in a typical season can be appreciated by examination of table 5. In the Delta area in 1941, a few years before insecticides were used commercially on seed alfalfa, a detailed study of crop losses was made in 30 fields. This study showed an average of 36 percent of the potential seed crop was lost by death of buds, almost entirely attributable to lygus bug feeding. An additional 47

Table 5. *Relative importance of crop losses caused by lygus bugs,* 30 *alfalfa seed fields, Delta area, Utah,* 1949

Type of crop loss	Average amount occurring	Amount of potential seed crop thus lost	
		Total	Attributed to lygus damage*
	percent	*percent*	*percent*
Bud death	36	36	36
Flower fall	74	47	?
Seed damage	30	5	3

*Estimated

percent of the potential crop was lost by the dropping of 74 percent of the flowers that formed. A similar fall of flowers under natural conditions has been recorded in various investigations around the

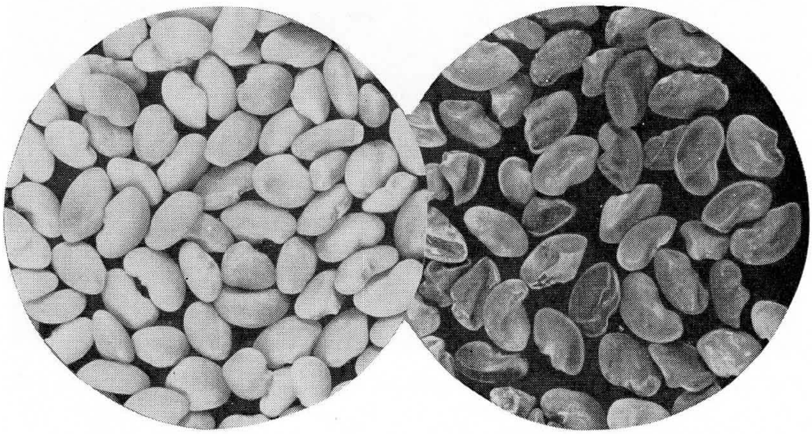


Fig. 8. Alfalfa seed. Left, normal. Right, damaged by lygus

world. Flower fall results from many factors such as deficient pollination, plant abnormality, weather effects, normal shedding of excess flowers, and insect damage. A considerable amount of the flower fall in lygus-infested fields is rightly attributed to lygus bug feeding, but it is impossible to measure this damage accurately. Finally, another 5 percent of the potential crop was lost as a result of insect damage to 30 percent of the seeds that formed. Lygus bug damage accounted for much of this loss.

When DDT was found to be effective for controlling lygus bugs numerous experiments were performed to compare seed setting and production in naturally infested plots with that in plots where the infestation was controlled. A summary of one of these comparisons is given in table 6. Effective control of lygus bugs provided a

Table 6. *Effect of lygus bug infestation upon seed setting and production, Petersboro, Cache Valley, Utah,* 1946

	Lygus bugs controlled	Lygus bugs not controlled
Lygus bugs (no. per net stroke)	1.0	5.7
Flowers (thousands per sq. yd.)	20.0	1.9
Bees (no. per sq. yd.)	3.2	0.4
Pods (no. per raceme)	8.5	2.9
Seed (lbs. per acre)	160	22

tremendous increase in flowering which in turn attracted many more bees. Nearly three times as many pods were formed and eight times as much seed was produced. This multiple-fold increase in seed production is a characteristic result of controlling lygus bugs. Reasons are apparent as follows: (1) flowers are abundant and not damaged, (2) more flowers develop seed pods, (3) pods formed contain more seeds, and (4) a higher fraction of the seed produced is of good quality.

Table 7. *Effect of lygus bug infestation on seed production under various levels of honey bee population, Newton, Cache Valley, Utah,* 1949

Supply of bees (controlled by use of cages)	Seed production per acre	
	Lygus bugs not controlled	Lygus bugs controlled
	pounds	*pounds*
Bees excluded	5	14
Natural (no cage)	18	198
Bees confined	31	321

The necessity for controlling lygus bugs if seed production is to be successful is further demonstrated in table 7. Irrespective of the quantity of honey bees supplied for pollination, the crop was a total failure when lygus bugs were allowed to thrive on the plants. It is equally clear, however, that adequate pollination is just as essential as effective lygus bug control measures.

Each year more and more growers are following the recommended practices for growing alfalfa seed. As a result Utah's average seed yield is being increased and may soon compare favorably with that of the early years of alfalfa seed production when high yields were obtained without special effort or formula. The trend in Utah's average yield during a 30-year period of available records is shown in table 8. In the first 9 years yields were remarkably high. However, they dropped sharply during the late twenties, and for an 18-year period the state average did not exceed 150 pounds of thresh-

Table 8. *Trend of alfalfa seed yields in Utah over a* 30-*year period of available records* (*U. S. Bureau of Agricultural Economics*)

Period	State yield of thresher-run seed	
	Range	Average
	pounds	*pounds*
1919-1927	222-336	281
1928-1945	72-150	103
1946-1948	120-173	148
1949	....	210*

*Subject to revision

er-run seed per acre. It was during this period of consistently low yields that many invesigations were made, and it was learned that lygus bug damage was a major factor in seed-crop failure. From 1946 to 1948 insecticides were applied, to an increasingly greater proportion of the acreage left for seed, and seed yields began an upward trend. By 1949 insecticide application had become an almost universal practice in growing seed and many growers had learned to appreciate the importance of such factors as pollination and plant size. The 1949 yield is estimated at 210 pounds, this being the first average state yield to exceed 200 pounds since 1927. Greater improvement seems inevitable and immediate if growers will follow recommended practices.

Life History and Habits

Three or four generations of lygus bugs are produced each year in Utah's seed areas, each generation requiring 6 to 7 weeks for its complete development. These bugs thrive on a wide range of both cultivated and uncultivated plants, and throughout the season the adults fly freely from host to host and from farm to farm. This wide-spread migration renders each successive generation of bugs less distinct. Nevertheless, lygus bug development, insofar as the growing of seed alfalfa is concerned, assumes a reasonably distinct and uniform pattern. Lygus bugs prefer to feed on the reproductive parts of a plant. Consequently, when the adults lay their eggs they select plants that will soon bud and flower. When the lygus adults exercise this preference in alfalfa, they synchronize the development of the lygus population with development of the seed crop and thus maintain an orderly sequence of events.

Lygus bugs spend the winter as adults in the shelter of debris, litter, and dormant plant cover on the ground. Their activity begins in the spring as soon as temperatures are favorable. They immediately seek the most attractive plants and begin to feed and breed. Usually the first plants infested in the spring are common early-flowering weeds. Examples are flixweed, whitetop, and pepper grass. These early weeds serve to expand the population of lygus bugs in a cultivated area, for on these plants nymphs often become full-grown and change to adults before alfalfa begins to bud.

Infestation of alfalfa in the early spring is negligible, but, as the first crop grows, it becomes more and more attractive. Lygus adults in the fields gradually increase in numbers as the growth approaches the bud stage. The normal population of adults that infests an alfalfa field at this time is numerically small, and from the practical viewpoint their damage to the plants is usually of minor consequence. Nevertheless, the adults lay many eggs, inserting them singly into the tissues of the plants and placing most of them in the top three inches of the growth.

Hatching of eggs, which on the average takes place in about 13 days, begins to occur in volume about the time the alfalfa develops buds. Lygus nymphs quickly become abundant on the plants. Because they occur in large numbers and feed constantly to provide their food requirements for growth, the nymphs cause most of the damage to seed alfalfa. The average time required for nymphs to complete their growth is three weeks during which time they can destroy the crop.

When full-grown, nymphs change to adults which ordinarily fly to fresh host plants and soon start another generation by laying eggs. These new adults that mature on first-crop alfalfa usually seek attractive second-crop alfalfa or such weeds as bassia, Russian-thistle, poverty weed, or saltbush, which flower in midsummer.

Development of the lygus bug population on second-crop alfalfa is similar but somewhat more rapid than that on the first crop. Adults lay their eggs in fresh stems, and, when the alfalfa reaches the bud stage, the eggs hatch in large numbers. Nymphs complete their growth in about three weeks, and again most of the adults fly away to more attractive host plants, which include third-crop alfalfa as well as bassia, rabbitbrush, and other wild plants that flower late in the season. As fall approaches egg laying gradually ceases and most of the late nymphs mature. The adults remain active as long as temperatures permit, gradually confining themselves to the protection of winter cover.

The use of insecticides to control lygus bugs on seed alfalfa alters the normal pattern of its attractiveness to the adults. Normally immigration by adults ceases after nymphs become abundant. When these nymphs are destroyed by an insecticide immigration of adults again occurs. This reinfestation is an important consideration in the recommendation of control measures.

Control

Any insect control program falls short of perfection, for it must meet practical limitations imposed by other factors. Control of lygus bugs on seed alfalfa must be accomplished without needlessly destroying domestic and wild bees that pollinate the flowers. Too drastic curtailment of populations of insect predators and parasites controlling some detrimental species must be avoided. And excessive contamination of the chaff is undesirable if it is to be utilized as feed. These considerations have influenced the designing of a recommended program, although the importance of adequate protection of the crop from lygus bug injuries has been the primary objective.

Whether seed is grown from the first or second crop of alfalfa, the hatching of lygus numphs in important numbers does not begin until the plants have started to develop buds. Applications of in-

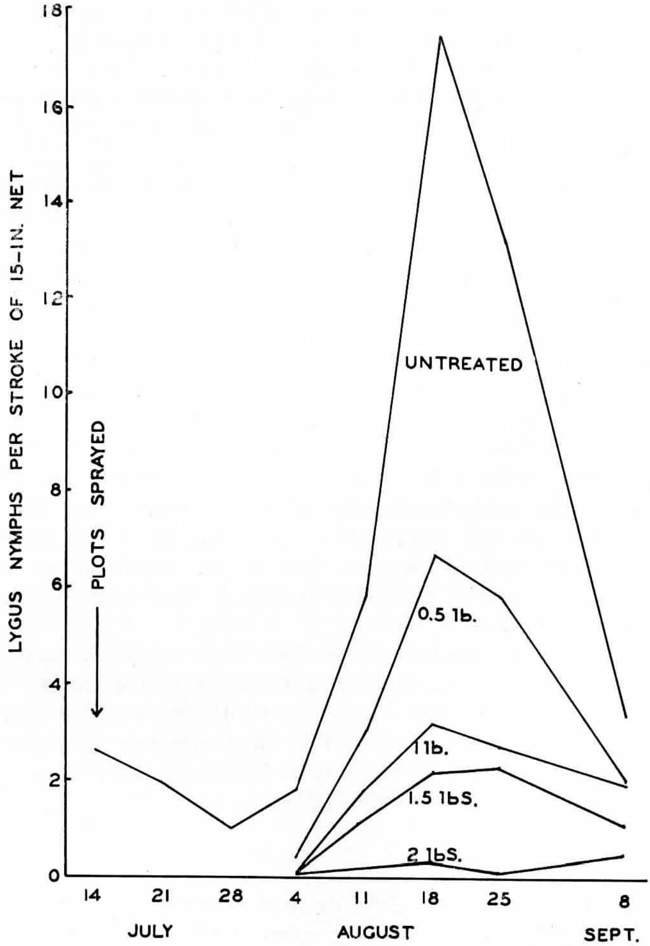


Fig. 9. Control of lygus nymphs by different dosages of DDT applied as water emulsion spray to plants in the bud stage of development

secticides for lygus bug control before this time are therefore usually considered unnecessary. Furthermore, since bees begin visiting the fields early in the flowering period, applications of insecticides after the plants pass the bud stage are not advisable. Consequently, a well-timed and adequate treatment while the plants are in the bud stage is recommended.

Of the insecticides on the market today, DDT gives the best control of lygus bugs. It can be applied either as dust or spray. When dust is employed, not less than 20 pounds of 10 percent DDT per acre should be applied. A water emulsion spray which delivers not less than 1.5 pounds of actual DDT per acre is equally satisfactory. Excellent results can be obtained with as little as 6 to 8 gallons of mixed spray per acre applied with low-pressure sprayers at 50 to 60 pounds of pressure.

It is important to use not less than the amount of DDT specified. The reason for recommending these amounts of dust or spray is illustrated in fig. 9 which shows the difference in control obtained by using 0.5, 1, 1.5, and 2 pounds of actual DDT per acre applied as a water emulsion spray to duplicated plots of alfalfa in bud in the same field. All four dosages of DDT eliminated lygus nymphs from the field for a period of 3 weeks. Reinfestation by adults occurred during this 3-week period. The greater the dosage of DDT applied, the quicker these adults were killed, the fewer eggs they laid, and the fewer nymphs later appeared on the plants. The number of nymphs hatching in the sprayed plots during the late bloom stage was greater with each decrease in the dosage. In plots sprayed with 2 pounds of DDT per acre, nymphs were virtually eliminated for the remainder of the crop period. Thus, necessity for another application of insecticide during the time the plants are blooming is usually avoided by using a relatively high dosage of DDT while the plants are budding. Dust is less effective than spray in keeping numbers of lygus nymphs down after the first three weeks following application. Therefore, a higher dosage of DDT is recommended when dust is applied.

The real need for a second application of insecticide is associated with abnormal reinfestation by migrating lygus adults. First-crop seed alfalfa generally has a longer flowering period, giving a longer time for reinfestation to occur. Likewise, the more deficient pollination is, the longer alfalfa tends to remain in bloom and the greater the chance of important reinfestation. Excessive reinfestation is therefore most common on such alfalfa, particularly in areas where both first and second-crop seed are grown in the same vicinity and adults are forced to migrate when first-crop hay is cut. After full bloom the more mature the plants become, the less attractive they are to lygus bugs. Troublesome reinfestation therefore generally takes place before the plants pass the peak of bloom. Usual reinfestation during this interval, while generally greater than the adult infestation prior to bud-stage treatment, does not result in much egg laying. Only excessive numbers of adults produce an economic population of nymphs during the bloom period. In such cases, a second application of insecticide is advisable, and the time to apply it is between 3 and 4 weeks after the bud-stage application of DDT.

Natural reinfestation varies considerably and in proportion to the sources from which adult migration takes place. It is difficult to give a general rule for determining the need for a bloom-period application of insecticide, particularly because any application of insecticide during the flowering period will kill bees. Where a service entomologist is available, it is best to request a field examination and let him decide if a treatment is warranted. If not, the grower must rely on his best judgement of his situation and help from his county agricultural agent or other extension workers.

If a second treatment is needed, the grower must be careful not to apply the wrong insecticide. *Only toxaphene is recommended for use on seed alfalfa in bloom.* Toxaphene may be applied as either dust or spray, but it must be applied between 7 p.m. and 7 a.m. to avoid killing too many bees. Applied between these hours, toxaphene kills only small percentages of bees, and is considered reasonably safe for bloom-period treatments. A satisfactory control of lygus nymphs during the bloom period is provided by 20 pounds of 10 percent dust or 1.5 pounds of actual toxaphene as a water-emulsion spray.

DDT should not be used in the bloom periods; toxaphene should not be used for lygus control in the bud-stage period. Chaff from seed crops treated with DDT or toxaphene should not be fed to dairy animals or meat animals being fattened for slaughter, or used in poultry feeds. The bud-stage application of DDT recommended for control of lygus bugs also gives satisfactory control of alfalfa weevil, aphids, thrips, and leafhoppers. The bloom-stage application of toxaphene recommended when necessary for lygus control also gives satisfactory control of grasshoppers and yellow-striped armyworms that may be present in the field.

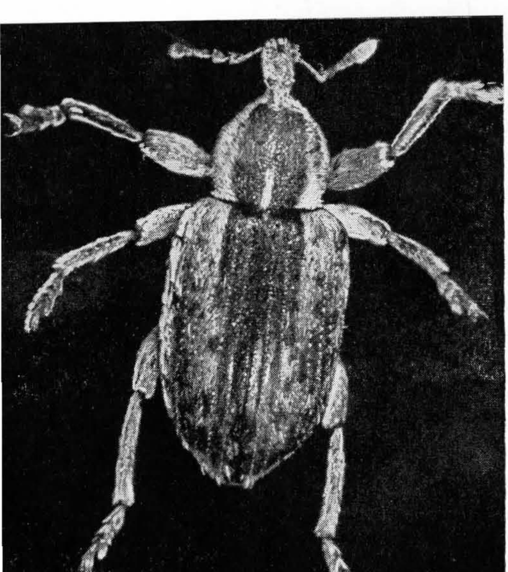


Fig. 10. Adult alfalfa weevil (natural length 3/16 inch)

Alfalfa Weevil (*Hypera postica* Gyll.)

Description and Injury

The adult alfalfa weevil (fig. 10) is a snout beetle about three-sixteeths of an inch long, varying in general color with age from brown to black. The beetles themselves cause little injury. Usually growers are unaware of their presence, except on warm spring days when they can be seen sunning themselves on the tops of the alfalfa plants or during harvest when large numbers accumulate on the hay slips.

The weevil egg (fig. 11), is tiny, oval, and lemon yellow, becoming darkened as hatching approaches. Most growers know that eggs are laid inside the growing stems, (fig. 12) but few realize that usually more than half the eggs are laid in small fragments of dead grass and alfalfa stems lying on the ground.

The larva is the stage most familar to growers. Newly-hatched larvae are yellow with shining black head and are one-twentieth inch long. When full-grown these worms are three-eighths inch in length and green with a brown head (fig. 11), and they have a conspicuous white stripe down the middle of the back. Newly-hatched larvae feed within the growing plant tips. As the worms grow larger, they molt 3 times and feed more and more upon opened leaves which soon become skeletonized (fig. 13), dry, and take on a grayish to whitish cast which is characteristic of economic damage.

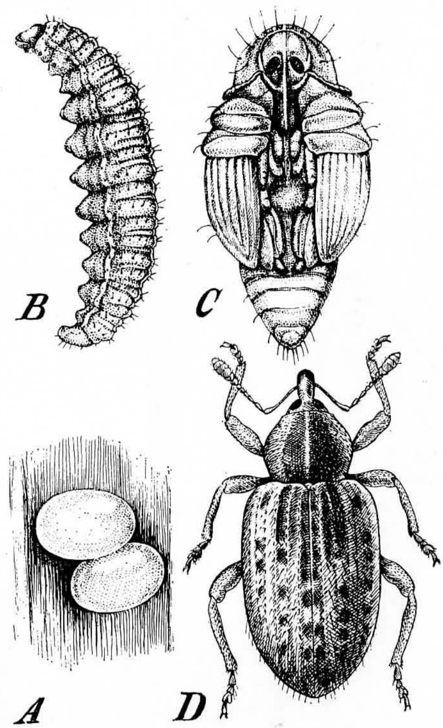


Fig. 11. Stages of the alfalfa weevil. A. eggs, B. larva, C. pupa, D. adult

(Courtesy U.S. Department of Agriculture)

When full-grown the weevil larva drops to the ground and spins a white, oval, netlike cocoon among fallen leaves or other debris.

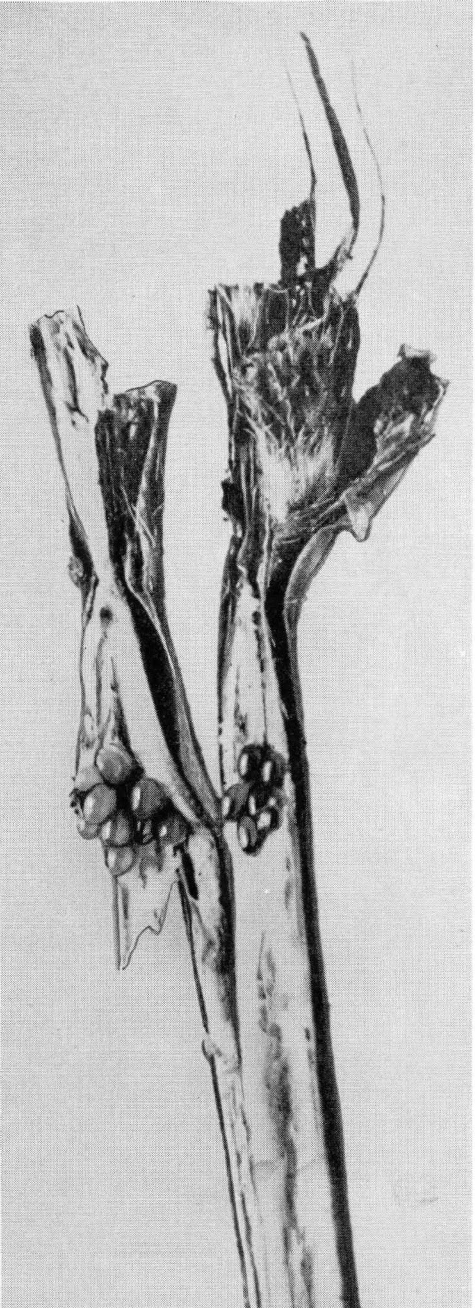


Fig. 12. Alfalfa stem split to show a cluster of eggs of the alfalfa weevil

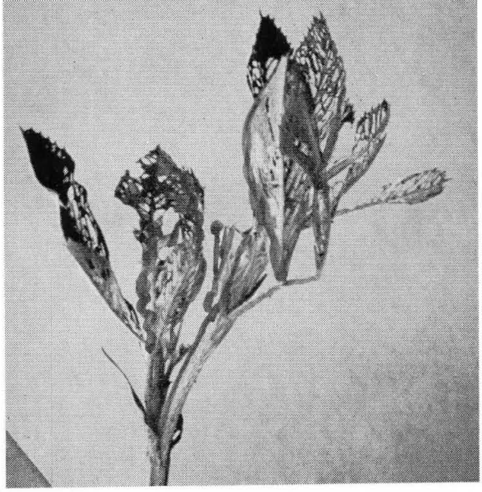


Fig. 13. Terminal leaves skeletonized by larvae of the alfalfa weevil

(Illustrations courtesy U.S. Department of Agriculture)

Fig. 14. Cocoons of the alfalfa weevil. Cocoons of the weevil parasite are visable inside two weevil cocoons

Inside this cocoon (fig. 14) the larva, when not parasitized, transforms to a pupa (fig. 12) from which an adult of the new generation later emerges.

Life History and Parasitism

The alfalfa weevil spends the winter chiefly in the adult stage. Some female beetles become sexually mature before cold weather

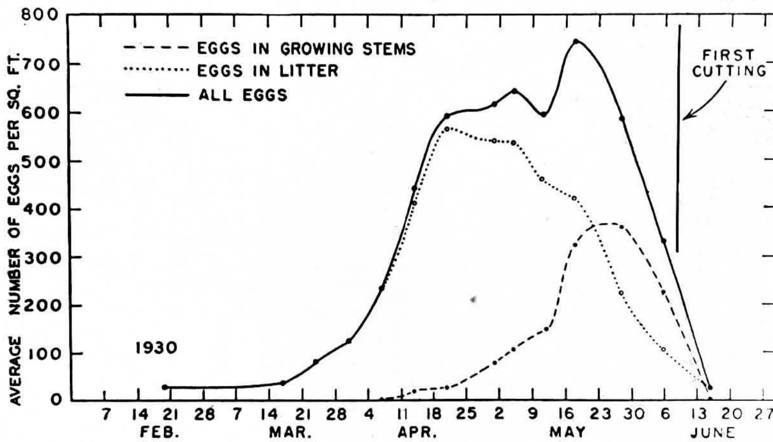


Fig. 15. Sequence and relative importance of egg laying by alfalfa weevil in dead stems and growing stems in a typical field, Salt Lake Valley, 1930

begins, and a few may lay small numbers of eggs which also overwinter. Soon after the snow covering has melted in the spring, all females become mature and begin laying eggs. At first eggs are laid only in dead stems on the ground. After the spring growth of alfalfa is about 6 inches tall and beetles gradually shift their egg laying from dead stems to growing stems (fig. 15). They will lay an average of from 200 to 800 eggs under field conditions, depending on the season.

Hatching of eggs in large numbers does not begin until about May 1, or later in the colder valleys. Thereafter larvae on the plants increase rapidly, feeding ravenously on the buds and leaves and causing economic crop damage as they become abundant in late May or early June. About May 15 the first few larvae become fullgrown and spin their cocoons. Thereafter, steadily increasing numbers of larvae complete their growth and spin-up.

Cutting of the first crop for hay will interrupt weevil development and destroy most of the eggs, larvae, and pupae before they mature. If the crop is not cut, weevil development will continue, and crop damage will increase until the insect population has run its course.

During the period that weevil larvae are feeding on the first-crop growth of alfalfa, the only important weevil parasite (fig. 16)

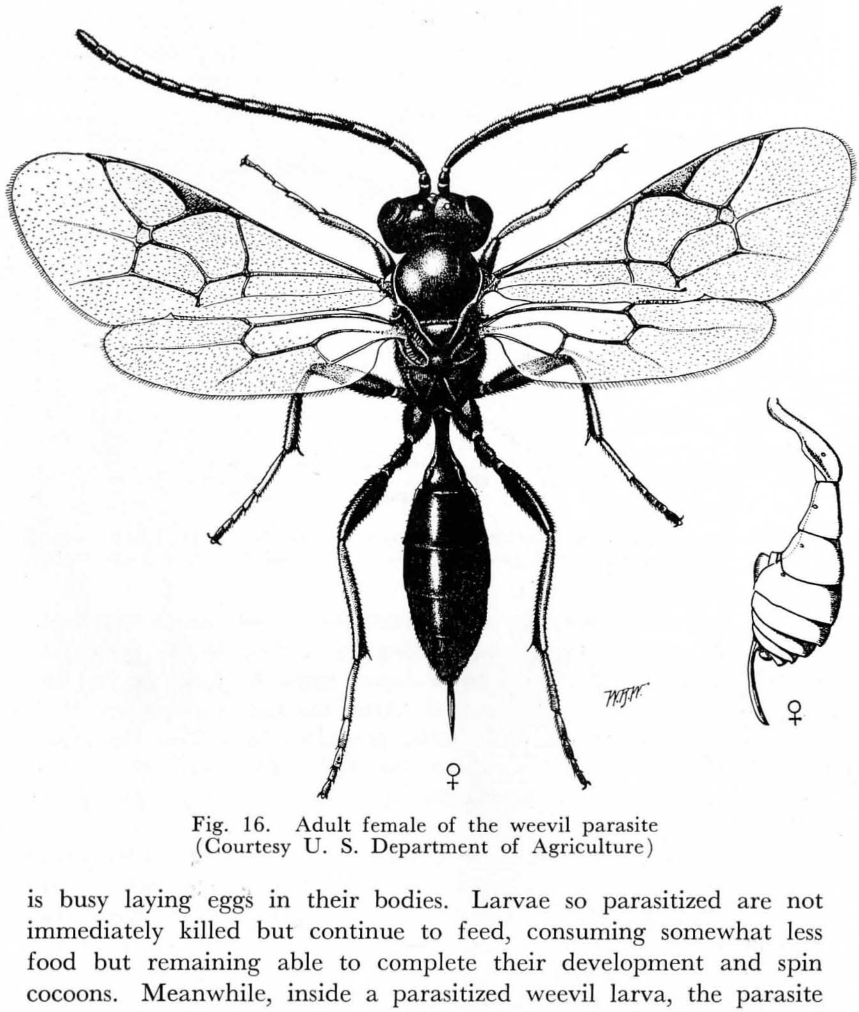


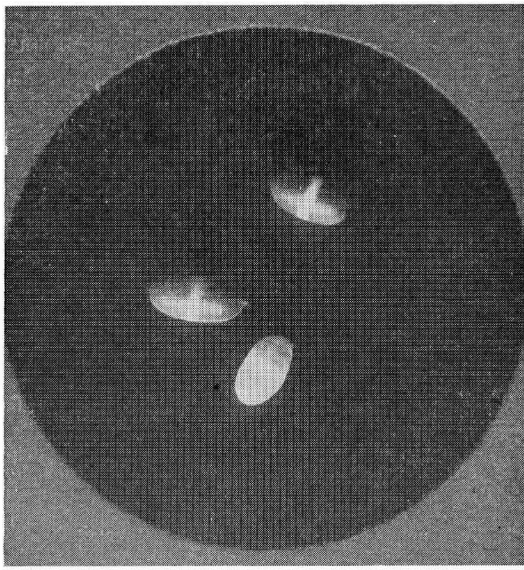
Fig. 16. Adult female of the weevil parasite
(Courtesy U. S. Department of Agriculture)

is busy laying eggs in their bodies. Larvae so parasitized are not immediately killed but continue to feed, consuming somewhat less food but remaining able to complete their development and spin cocoons. Meanwhile, inside a parasitized weevil larva, the parasite egg soon hatches into a larva which completes its development and kills its host after the weevil larva has spun its cocoon. The larva of the parasite emerges from the skin of its host and immediately spins a cocoon (fig. 17) of its own inside the netlike weevil cocoon.

This new parasite usually remains in its cocoon until spring of the following season.

The parasite is effective in preventing weevil larvae from developing into adults, but only during the early part of the first-

Fig. 17. Cocoons of the weevil parasite (Courtesy, U.S. Department of Agriculture)



crop period. The earliest weevil larvae are almost all parasitized and parasitism of larvae becoming full-grown and spinning cocoons remains high (80 to 90 percent or more) until the first crop reaches the bud stage of development. After this time parasitism usually declines rapidly.

Except that parasitism of weevil larvae becomes negligible, a similar sequence of events occurs on a small scale during the second-crop period. The few old weevils still alive lay a few eggs which produce a small larval population incapable of producing damage to the second crop or attracting attention. These few larvae begin cocooning about mid-July shortly before the second crop begins to bud. Most of them, being unparasitized, can become pupae and, later, adults.

Control

The adult weevils populating a particular alfalfa field are predominantly produced within that field as a result of the cropping and harvesting practices used. Weevil control is therefore an individual field problem. In a field devoted entirely to hay production, weevil

Fig. 18. Dusting alfalfa

can be controlled and economic damage prevented by maintaining a dense, vigorously growing stand and cutting the first and second growths as soon as most of the alfalfa plants are in the bud stage of development. Growing a seed crop from either the first or second growth prevents control by this early-cutting method. The seed grower must resort to use of insecticides.

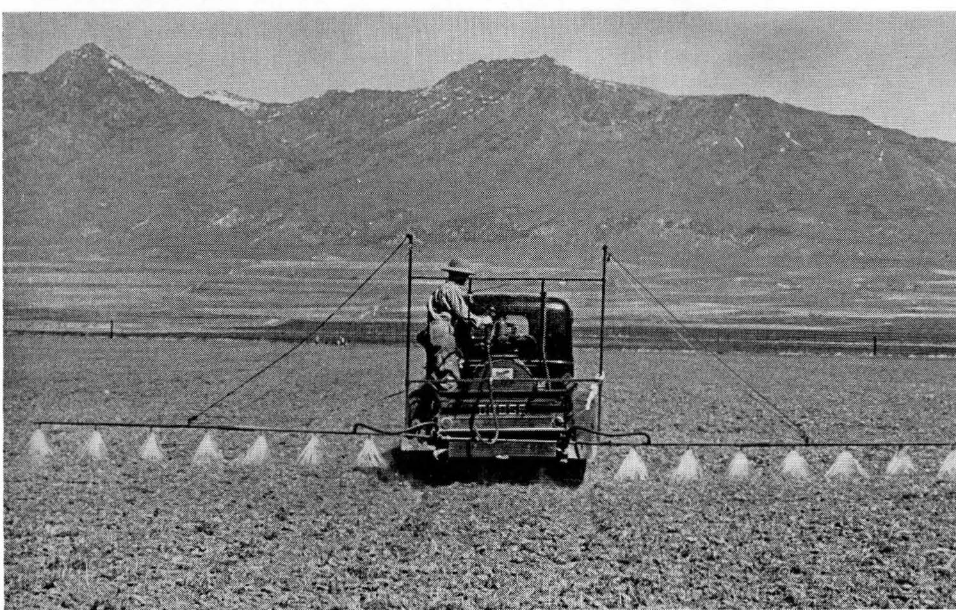
When the first crop is left for seed production the grower is concerned with direct damage by weevil larvae in late May or early June, usually just as the plants reach the bud stage of development. The number of larvae on the plants at this time must be immediately reduced to a low figure, or important damage will occur. Since at this time lygus bugs must also be controlled (see page 25), it is recommended that DDT be applied as soon as the leaves become noticeably ragged from the feeding of weevil larvae. Satisfactory weevil control usually can be obtained with an application of 20 pounds of 10 percent DDT dust per acre (fig. 18) or with a water emulsion spray delivering at least 1.5 pounds of actual DDT per acre.

Care must be taken not to apply the DDT too soon or too late, for most of the larvae should be on the plants, but their damage must not be allowed to cause the plants to show the grey cast typical of economic injury. The difficulty of timing this treatment accurately enough on a seed crop is a good reason for growing seed from the second growth when practical.

Recent experiments have shown that most of the weevil adults can be killed in the early spring before they lay many eggs. An application of chlordane as a water emulsion spray is recommended. A dosage of at least 1.5 pounds of actual chlordane per acre should be applied when the alfalfa is about 1 to 2 inches high (fig. 19). This treatment greatly reduces the number of larvae which occurs on the plants in May and June and thus overcomes the difficulty encountered in timing the bud stage application of DDT to prevent economic injury to seed growth by weevil larvae. Growers currently having difficulty controlling alfalfa weevil larvae on first-crop seed growth are urged to try this supplemental treatment. Any substantial reduction in the larval population will ease the timing problem, even though the grower does not succeed in applying the spring treatment so that maximum benefit is obtained.

When the spring growth of alfalfa is cut for hay and the second crop is left for seed production, the seed grower is usually not troubled with weevil injury. Except in rare cases, the trouble he does have is confined to delay in the starting of the second growth. If weevil larvae have been numerous on the first growth, there is always

Fig. 19. Spraying in the early spring to kill adults of the alfalfa weevil



a slight delay (7 to 10 days) in start of the second growth. This is of little importance unless the season is short, and the danger of frost damage is thereby substantially increased. Excessive retardation of the second crop commonly prevents ripening of a seed crop.

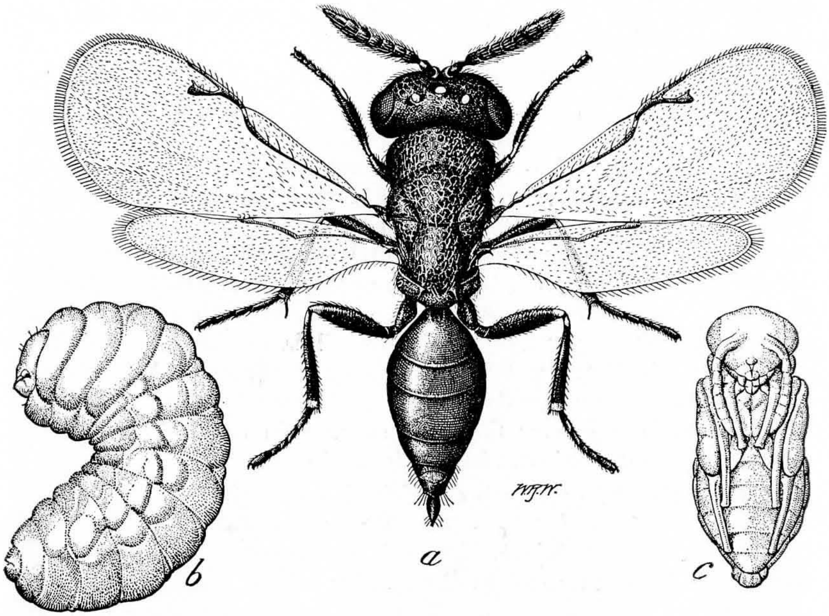


Fig. 20. The seed chalcid. A. adult, B. larva, C. pupa (Courtesy, U.S. Department of Agriculture)

This delay is occasioned by failure to cut the first crop for hay as soon as most plants reach the bud stage at which time the second-crop shoots have not yet appeared. When the first crop is cut at this stage of development, the larvae, in good harvest weather, are deprived of a suitable food supply and readily die of starvation and exposure. Retardation of the second-crop may also be prevented by proper control of weevil larvae with insecticides on the first crop. Since the latter is a hay crop, calcium arsenate at the rate of 2 pounds per acre, as either dust or spray, should be applied when the leaves become noticeably ragged from feeding of the larvae. The suggested use of chlordane emulsion in the spring to kill adult weevils will also prevent retardation of the second growth. Application of insecticides to the stubble field after removal of the first crop is not recommended, for the damage that retards the second growth is largely inflicted before the cut hay can be cured and removed from the field.

The Seed Chalcid (*Bruchophagus gibbus* Boh.)

Description, Life History, and Injury

The seed chalcid is a small, jet-black wasp about 1/12 inch long (fig. 20). The female lays eggs in newly-formed seeds by inserting her ovipositor through both pod and seedcoat. The pods are small and green when eggs are laid.

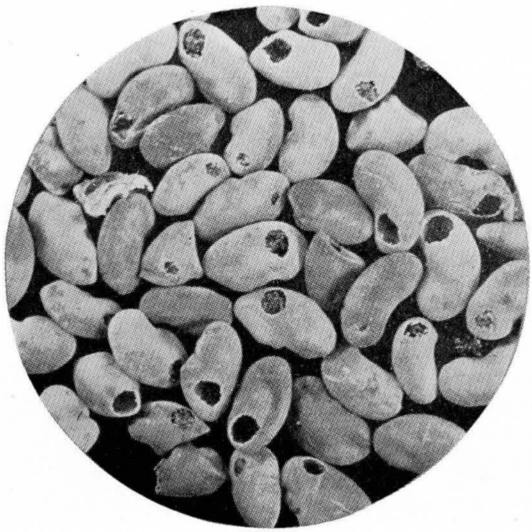


Fig. 21. Alfalfa seed damaged by the chalcid

Only one egg is deposited in each seed selected, for the kernel supplies just enough food for the complete growth of one seed chalcid. Eggs hatch in about 4 days, and the larvae become full-grown in 10 to 15 days. The larvae then pupate within the seedcoat, emerging as adults about 12 days later by chewing a conspicuous hole through the seedcoat (fig. 21) and, when necessary, through the ripened pod (fig. 22). Two to three generations are produced each season. Larvae of the last generation remain in the seedcoat for the winter, pupating and emerging as adults in the spring about the time the first alfalfa or clover flowers appear.

Destruction of the seeds it infests is the only damage of the seed chalcid, but loss from this damage can render seed production unprofitable. In Utah as much as 60 percent of the seed crop has been destroyed. Usually, damage varies greatly from place to place and from field to field in accordance with sources of infestation at the time the crop begins to set. The majority of Utah seed fields lose 10 to 20 percent of the seed formed every year. All this loss can-

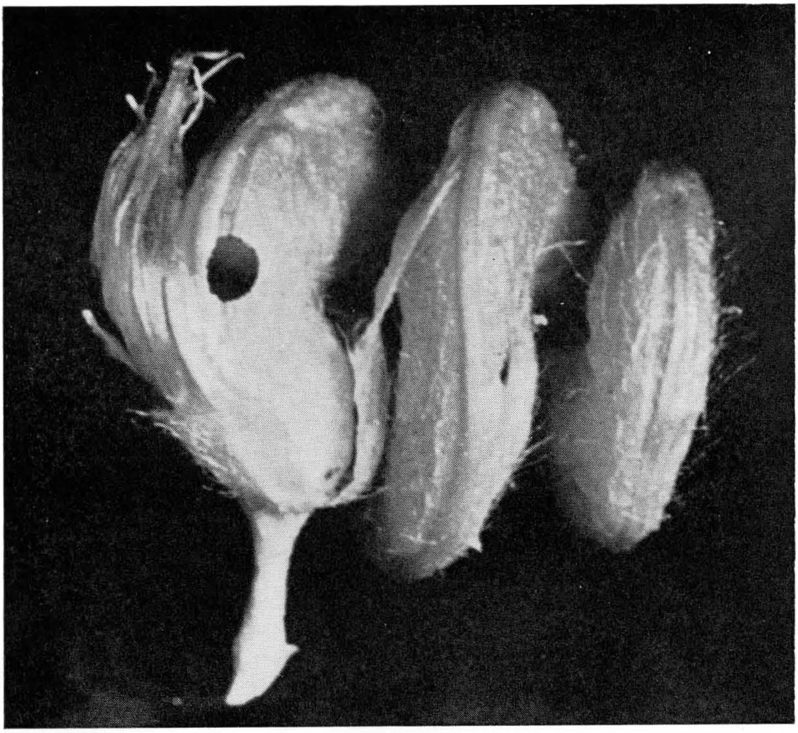


Fig. 22. An alfalfa pod showing a chalcid emergence hole

not be prevented, but damage can be substantially reduced by proper control measures. Control is a community problem, and every grower must cooperate if infestations are to be successfully curtailed.

Control

In any year the chalcid larvae living through the winter inside the seedcoats of seeds they have destroyed are the source of infestation. These infested seeds occur (1) on the field surface as a result of shattering of ripe pods, (2) in the chaff stacks where most of the infested seeds are blown during threshing, (3) under and on plants of volunteer or other unharvested alfalfa, bur clovers, red clover, and crimson clover, and (4) in uncleaned seed or the screenings of cleaned seed. Naturally, when the seed crop is harvested with a combine the infested seeds which would otherwise occur in the chaff stack are deposited in the field. Furthermore, shattering of pods increases when the crop ripens unevenly or harvest is delayed.

Practices recommended for control of chalcids are:

1. *All farmers in a seed district should grow seed from the same crop, preferably the second.* When first- and second-crop seed are grown in the same vicinity, the first crop serves as a source of infestation for the second, increasing losses. When no first-crop seed is grown, most of the overwintered chalcids emerge at a time when only volunteer growth bears pods. They are thus deprived of an abundance of host plants on which to expand their numbers. The second crop also develops and matures faster than the first crop.

2. *The seed crop should be managed to ripen the seed as uniformly as possible.* Variations in stand and growth cause plants to vary in time of blooming which results in uneven ripening of seed and increased shattering of overripe pods during harvesting. Irregular irrigation contributes greatly to such variations.

3. *The crop should be harvested carefully and promptly.* In harvesting, use methods which will minimize the loss of seed in the field (see harvesting, page 15).

4. *Prevent all volunteer alfalfa and bur, red, and crimson clovers from forming pods.* This is best accomplished by cutting or pasturing. Burning is sometimes used.

5. *Eliminate chaff stacks before chalcids emerge in the spring.* Feed, compost, or burn the entire stack, leaving no remnants, before May 1.

6. *Reclean all seed and destroy or feed all screenings.* Do not plant infested seed, and do not hold seed uncleaned. Cleaning is worth the cost.

7. *Cultivation.* Harrowing with spring-tooth or disk will bury many chalcid-infested seeds. Burial often results in death of the chalcid, particularly when the soil is moist. Either fall or spring cultivation is beneficial.

The success of a chalcid control program depends on how completely all growers follow all recommended practices. The various control measures are interrelated, and neglect of one may offset the value of carrying out another. Insecticides have not been used successfully in chalcid control.

Others

Grasshoppers (*Locustidae*)

Damage by grasshoppers may range from light leaf stripping to complete destruction of the crop. Grasshoppers may be controlled in alfalfa by cultural methods, by the use of poison bait, by application of insecticides, or by a combination of these methods.

Cultural control. Grasshoppers deposit large numbers of eggs in the soil of ditch banks, field margins, and weed patches. Cultivation of these areas to a depth of 2 inches in late fall or early spring with a spring-tooth harrow or other cultivation equipment will destroy the majority of the egg pods. The migratory grasshopper deposits many eggs in small-grain stubblefields. Infested stubblefields should be plowed before May 15. Do not plow or deep cultivate areas known to contain nests of wild bees.

Control with poison bait. Under a cooperative federal, state, and county program poison bait composed of millrun bran, sawdust, sodium fluosilicate, and water is furnished to farmers either free of charge or at a nominal cost. Systematic baiting of hatching areas will often reduce the infestation to a point where further control is unnecessary. Bait should be applied to infested areas in the spring as soon as the majority of young grasshoppers have hatched. Hatching of grasshoppers varies from year to year. Baiting should begin when the majority of the eggs have hatched or not until an economic population appears. Several baitings should be made at weekly intervals, applying 20 pounds of wet bait per acre. Good kills may be obtained consistently on dry stubble lands but baiting is not satisfactory when green, succulent food is available. For this reason, alfalfa fields that become infested must be baited during the stubble period between cuttings.

Control with insecticides. Chlordane and toxaphene, both as sprays and dusts, are effective in the control of grasshoppers. Sprays give higher initial kills, and continue to kill over a longer period, than equal dosages of dusts. When using sprays apply 1 pound of technical chlordane or 1½ pounds of technical toxaphene per acre. When using dusts apply 30 pounds of 5 percent chlordane or 20 pounds of 10 percent toxaphene per acre. These dosages give high initial kills and have residual action lasting one to three weeks. Slightly lower dosages are effective against newly hatched grasshoppers, but if long-continued killing action is desired, the dosages recommended above should be followed. A slight increase in the dosage of both sprays and dusts may be necessary late in the season, when most of the grasshoppers are adults and vegetation is maturing.

Spray or dust infested areas around the fields as soon as most of the grasshoppers have hatched. This will destroy the grasshoppers before they move into the fields. When the fields become infested, either from hatching within the field or from migration, the alfalfa growth itself may be treated. First-crop seed alfalfa is usually in bloom by this time, and only toxaphene should be applied. Apply between 7 p.m. and 7 a.m. to avoid killing too many bees. Second-crop alfalfa can usually be most effectively treated when the growth is 6 to 10 inches high. When alfalfa is not in bloom, either chlordane or toxaphene may be used at any suitable time of day.

Community Action. Grasshopper control on a community-wide basis will accomplish much more than individual action by farmers. In case of large scale outbreaks, community or county organizations should be effected to insure control over large areas. Cleaning up an entire community will not only save existing crops but should eliminate or greatly reduce the need for control the following year.

Spider Mites

Mites are not insects but are generally grouped with them because of similarity of their damage and in methods of controlling them. These tiny creatures usually go unobserved until they have become abundant and have caused considerable damage to plants. During the past 2 seasons (1948 and 1949) some alfalfa has been economically damaged by them and interest in their control has been aroused among seed growers. Unfortunately, since the introduction of DDT as an insecticide, outbreaks of mites have been repeatedly associated with its use. DDT does not control mites, but readily kills other insects that feed upon them and keep them to non-injurious numbers most of the time. Mites are not likely to become troublesome to the alfalfa seed grower, however, if the recommended general program of insect control is followed and application of DDT several times in any one season is avoided.

Mites generally occurring on alfalfa are the common red spiders including the two-spotted mites and the brown mites. They are about 1/50 inch long, usually yellow or orange in color with two indefinite black spots on the body. Their eggs are white and spherical. These mites confine their activities to the underside of the leaves where they feed, lay eggs, and spin delicate webs. They occur first on the bottom leaves of a plant, and, as infestation and damage increases, the population gradually moves upward until the tips are reached. Damage by the mites consists of piercing cells of the leaves through the lower surface and sucking out the juices. The damaged leaves assume a mottled appearance as individual or groups of cells die and gradually turn completely brown and drop (fig 23). When conditions are favorable for the mites they become abundant, destroy almost all the leaves on the plants, swarm to the tops, and spin great amounts of webbing over the tips of the stems. Most are entrapped in the accumulation of webbing and die there. Others

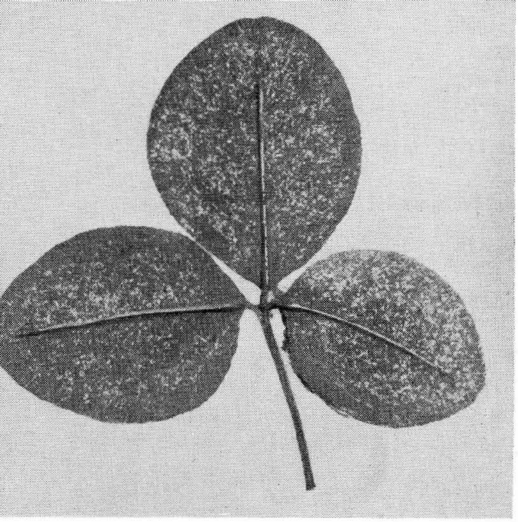


Fig. 23. Mite damage on clover. Damage to alfalfa is similar (Courtesy L. R. Cagle, Virginia Agricultural Experiment Station)

migrate through the air on strands of webbing or by crawling on the ground and seek out fresh plants on which to feed and multiply. When the season is over they winter as eggs on debris in and around the field.

Mites should be controlled before they become abundant. Cultural practices such as cultivation in the fall or spring and between crops will reduce likelihood of a menacing mite population. Mites usually cannot free themselves from soil when buried at least one inch deep. Loose soil helps make migration difficult. Dusting sulfur kills mites and appears to be the material most practical to apply to plants for this purpose. In fields where mites are considered a threat to seed production, sulfur should be applied before the plants bloom. In hot weather sulfur sometimes burns flowers and causes them to drop. Ordinarily two applications of dusting sulfur at the rate of 10 to 25 pounds per acre applied 10 days apart are recommended. However, a single application may often be adequate to keep mites from causing economic loss. The addition of sulfur to the bud stage application of DDT is therefore suggested. Ten percent DDT dusts containing 50 percent sulfur would provide the minimum dosage of sulfur (10 pounds per acre); 10 percent DDT dusts containing as high as 85 percent sulfur have been offered by insecticide companies. Other materials known to be toxic to mites have not been evaluated for mite control on alfalfa in Utah. These new materials often involve killing of bees, toxicity to the operator, and destruction of predators that keep mites in check.

Thrips, Leafhoppers, and Aphids

Damage by these insects to seed alfalfa in Utah is considered to be of minor importance, except when infestations are unusually high. The recommended program for control of lygus bugs appears to be adequate for control of these insects.

Yellow-Striped Armyworms (*Prodenia ornithogalli* Guen.)

Outbreaks of this insect (fig. 24) occasionally occur in Utah, and the worms cause considerable damage to seed alfalfa by devouring the flowers. Toxaphene is most effective against the yellow-striped

Fig. 24. Yellow-striped armyworm

armyworm, and DDT will also control it. Growers following the control program recommended for lygus bugs will ordinarily not be troubled. When specific control is required apply toxaphene at the rates and under the conditions recommended for control of lygus bugs.

Effect of Insecticides on Bees

Many of the insecticides recommended for use in controlling pests today are highly toxic to both honey bees and wild bees. Their use on alfalfa in bloom will frequently result in a high mortality of bees visiting the alfalfa flowers. Because the pollinating activity of these bees is essential to seed production, growers must avoid killing too many bees while controlling injurious insects. Control measures recommended in this circular are designed to minimize losses of bees as well as kill pests.

No insecticide can be applied to flowering alfalfa without killing some bees. However, when applied during the period bees are not visiting the field (7 p.m. to 7 a.m.), toxaphene has been shown by numerous tests consistently to cause only slight mortality. Fortunately, toxaphene is effective against most of the alfalfa pests that may need to be controlled while the plants are in bloom. It is therefore recommended for use, when necessary, on flowering alfalfa for control of lygus bugs, grasshoppers, and armyworms.

Generally speaking, dusts are more destructive to bees than are sprays, and they have a greater tendency to drift.

Based on results of experimental field applications to date the following insecticides are too toxic to bees to be used on flowering alfalfa during day or night: DDT, chlordane, lindane, benzene hexachloride, parathion, aldrin, and dieldrin.

Residues of Insecticides in Alfalfa Chaff

Alfalfa chaff has long been utilized as livestock feed; sold as such, it has consistently brought from 1/3 to 1/2 the current price of alfalfa hay. Widespread use of DDT, toxaphene, or chlordane on seed crops during the past few years, and consequent better crop returns, has not appreciably altered this practice. Therefore, the problem of insecticide residues in the chaff is real.

When these insecticides are applied to seed alfalfa after the crop has made appreciable growth, small amounts generally remain at harvest. These insecticide residues persist in the chaff after threshing and until utilized. For example, chaff from seed crops dusted with 20 pounds of 10 percent DDT when the plants are in the bud stage usually contains from 2 to 28 parts per million of DDT.

DDT, toxaphene, and chlordane are recommended for control of insects in this circular. When they are used as recommended, the residues occurring in the chaff do not appear to be harmful to animals fed. However, when animals consume feed containing these residues, they store the insecticides in their tissues and eliminate them in their milk. Also, poultry eliminate them in the yolk of their eggs. When feed containing these insecticides is discontinued, the amounts in tissues, milk, and eggs gradually decline.

Little is known about how these insecticide residues in meat, milk, and eggs will affect man when he consumes these products. Therefore, it is recommended that contaminated chaff not be fed to dairy animals, to meat animals being fattened for slaughter, or to poultry.

POLLINATION

THE problem of alfalfa pollination has been subject to misconceptions for many decades. At first alfalfa was believed to be wholly self-fertile and to pollinate itself automatically in the manner of peas and beans. Later it was recognized that "tripping" is essential for commercial seed production. The relative importance of the agencies capable of tripping the flowers cannot be understood until the peculiar mechanism of the flower has been studied in some detail.

The Flower and How It Is Tripped

The male and female parts of the alfalfa flower, although enclosed in a sheath (keel) and in intimate contact, are non-functional until released. This process of releasing the sexual parts from the keel is known as tripping (see fig. 25). Tripping is essential for pod development. About one percent of the non-tripped flowers form pods compared to 50 percent or more of the tripped flowers under field conditions. When tripping does not occur the flowers usually drop. Pollination and fertilization follow tripping. In popular usage

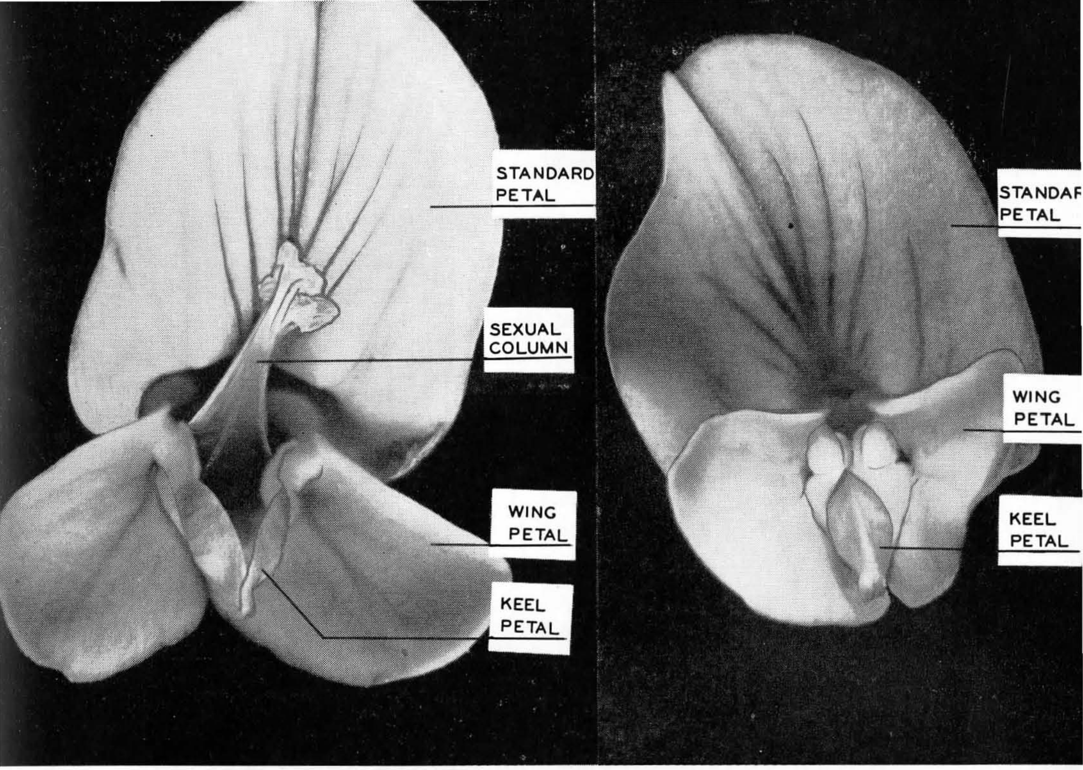


Fig. 25. Alfalfa flowers, left, tripped, right, untripped

both terms convey the same meaning. Pollination is actually the transfer of pollen from the anthers (male part) to the stigma (female part). This defines the part bees play in alfalfa seed production including tripping. Fertilization (subsequent to pollination) is a plant function which defines the part the alfalfa plant plays in the so-called pollination.

Once on the tripped stigma the pollen grain germinates and sends a germ tube down the core tissue of the sexual column (style) to the ovule (potential seed). Actual fertilization is accomplished by the union of the male part from the germ tube with the female part). The defines the part bees play in alfalfa seed production including tripping. Fertilization (subsequent to pollination) is a plant function which defines the part the alfalfa plant plays in the so-called pollination."

Self and Cross-Pollination

The story gets more complicated. If pollen from another alfalfa plant (known as "foreign" pollen) comes in contact with the stigma, both the flower's own pollen and the foreign pollen will germinate, but the germ tubes from the foreign pollen usually get to the ovule first, producing cross-fertilized seed. If no foreign pollen is present,

Table 9. *Efficiency of pollination, percent of flowers forming pods, in alfalfa in various parts of the world*

Location	Type of pollination: Natural (includes untripped)	Type of pollination: Crossed by hand	Flowers enclosed (selfed): Not tripped	Flowers enclosed (selfed): Hand tripped
	percent flowers forming pods			
Piper et al. 1908-12, Montana	......	......	5.5	30.6
Frandsen 1911-12, Denmark	......	......	9.3	35.6
Southworth, Canada	26.4	46.8	12.8	46.5
Hadfield-Calder, New Zealand	26.5	50.6	16.0	41.0
Tysdal, Nebraska	22.6	78.3	3.0	27.0
Carlson, Utah	32.2	64.7	11.3	28.9
Means	26.9	60.1	9.6	36.6

self-fertilization (fertilization with the flower's own pollen) will result to a limited extent. Let us compare the consequences of self- and cross-fertilization as shown in table 9. Only 36.6 percent of the self-pollinated (or "selfed") flowers on the average formed pods compared to 60.1 percent of the "crossed" flowers. Cross-pollination also increases the number of seeds per pod.

It is conceivable that under certain circumstances a reasonable amount of self-pollinated seed could be produced. If so, would it be the thing to do? As shown in fig. 26 after one generation of selfing, seed production was reduced 62 percent and continued to be reduced at a slower rate for 8 more generations after which the plant breeder must have been satisfied that "selfing" and seed production didn't mix. The reduction in forage production was similar, but not so spectacular.

The percent of flowers forming seed pods when they are all tripped and crossed (47 to 78 percent) may be considered the upper limit of the plant's ability to profit from pollination, or, in other words, its potential for pod production. Under natural conditions in the tests included in table 9, an average of only 27 percent of the flowers formed seed pods. Since most of the flowers tripped under natural conditions are cross-pollinated, this low percentage appears to result from failure of many of the flowers to be tripped. It is obvious that alfalfa must be tripped and cross-pollinated in order to set an appreciable amount of seed. The next problem is to determine under what conditions and with the help of what outside agencies these objectives may be obtained.

Methods of Obtaining Pollination

Wind

Growers in windy areas have often ascribed some tripping to wind. However, investigators have concluded that wind plays a minor role

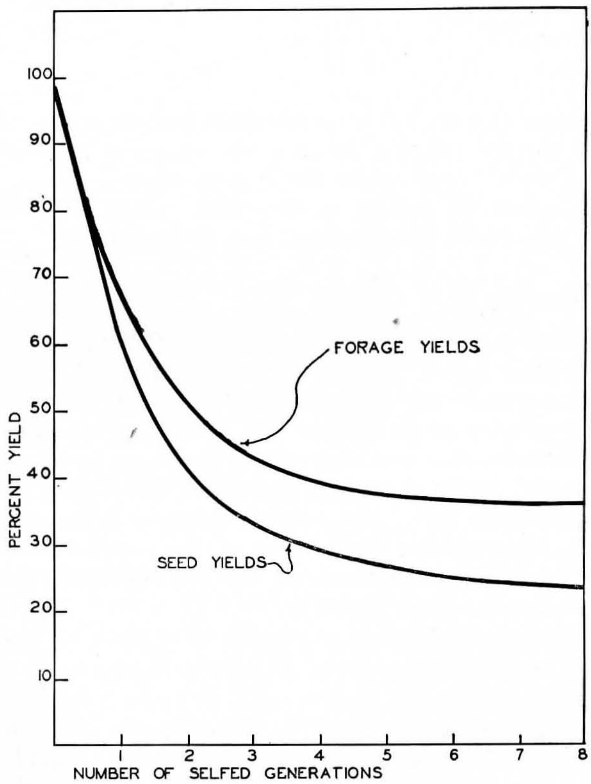


Fig. 26. Theoretical reduction in alfalfa seed and forage yields caused by self-fertilization. From Tysdal 1942

in tripping. Limited tripping will occur if the plants are whipped against each other or on the ground. The drying effect of the wind may also contribute to conditions favorable for automatic tripping. However, since alfalfa pollen is not adapted to air transportation and the flowers are not adapted to receive pollen from the air, it is inconceivable that tripping caused by wind could result in much cross pollination.

Table 10. *Comparative effect of rain, simulated rain, and cross-pollination by hand on tripping and pod set*

	Tripped	Setting pods
	percent	*percent*
Cross pollination	100.0	86.0
Stimulated rain	100.0	12.0
Natural rain	8.3	0.5

Adapted from Tysdal 1946

Rain

Rain trips some flowers but the subsequent pod set is low. An average of 8.3 percent tripping by rain was observed at Scotts Bluff, Nebraska. Only 0.5 percent of the flowers tripped by rain formed pods compared to 86 percent in the check (table 10). Obviously, tripping by rain is not beneficial and may be harmful.

Heat and Humidity

Under laboratory conditions automatic tripping can be induced by excessive heat and is favored by low humidity. Of what value is such information to the seed producer? To what extent does tripping occur spontaneously in nature? The latter question cannot be accurately answered. However, it is certain that some spontaneous tripping does occur. A few plants in a population will trip automatically; some are difficult to trip. The population varies between these two limits. It is believed that the percent of the population exhibiting self-tripping will be proportional to the environmental conditions, especially temperature and humidity.

Unfortunately, spontaneous tripping is subject to the limitations of self-pollination and so is actually a detriment to the crop. Furthermore, temperatures high enough to cause appreciable spontaneous tripping would probably be injurious to the plant under field conditions. Even slight wilting causes many flowers to drop. Nevertheless, these weather conditions are important in their effect on insect activity and its benefits. In the first place, bees fly best when the weather is dry and warm (see page 53). In the second

Table 11. *Average July rainfall and temperature* (40 *year record*) *at Columbus, Ohio, and Logan, Utah*

	Ohio	Utah
Rainfall	3.5	0.65
Temperature	75.4	73.1

U.S. Dept. Agr. Yearbook. 1941

place, since the percentage of flowers tripped by nectar-collecting honey bees is variable, it would seem logical to suppose that their efficiency would be greater under the warm, dry conditions which favor automatic tripping.

Table 12. *The effect of mechanical tripping of seed setting in alfalfa* 1939 *and* 1940

	Seed in percent of check	Flowers tripped in percent of check
Harrow	43	354
Page wire	101*	960*
Float	66	732
Stone boat	53*	1338*
Post	98	216
Logging chain	63*	439*
Rotary tripper	73	164
Tramping	80*	70*
Float with 175 pounds on it	42†	191†
Wire single strand	78*†	80*†
Rotary tripper with pegs in drum	88*†	95*†
Check	100*†	100*†
Average	71	422

From Silversides and Olson 1941
*1939
†1940 (checks for each treatment)

Weather conditions of the West are generally more favorable for alfalfa seed production than are those of the Midwest, East, or South. The average July rainfall figures for Logan, Utah, and Columbus, Ohio (table 11) illustrate the contrast in conditions. July temperatures are similar in the two towns, but rainfall during the same month is 3.50 inches in Columbus compared to 0.65 inches in Logan. Relative humidities tend to fall in line with the rainfall figures. Conditions associated with the lower rainfall and humidity of the West are: (1) More days of good flying weather for bees, (2) increased nectar flow during clear weather, (3) theoretically greater likelihood of tripping by nectar-collecting bees.

Mechanical Tripping

No method of tripping flowers mechanically with resulting increase of seed has been devised and experimentally tested (table 12). Eleven methods, such as harrowing and pulling a wire over the plants, were tested by Silversides and Olson. On the average, tripping was increased 422 percent, but seed produced was only 71 percent of that on the check field where no artificial methods were tried. This type of tripping not only damages the plants, but is also subject to the limitations of selfing. To be satisfactory a machine used for mechanical tripping would have to cover the field several times during flowering without excessive damage to the plants and at the same time trip and cross-pollinate a high percentage of the flowers. This appears to be an engineering impossibility.

Hormones

The objective in applying hormones would be to prevent blossoms from dropping until pollination could take place. Where this has been tried on alfalfa no benefits have been observed.

Lodging

As heavily producing plants are often observed to be prostrate, one may wonder whether the plants are prostrate from the weight of the seed or whether they seed better if prostrate. An experiment designed to study this question showed that upright plants produced from two to five times more seed than comparable lodged ones.

Breeding for Self-Tripping

A number of plants closely related to alfalfa do not require insects for pollination and are self-fertile. Individual plants of alfalfa can be found that possess these same characteristics to a degree. For a time this appeared to be a promising lead, and breeders tried for years to develop a plant that would not depend upon insects for pollination. Two lines, as suggested by the situation, have been followed. One method has been to select from a large population of alfalfa plants, individuals that set a reasonable amount of seed independently of insects. The other method has been to cross other species with alfalfa and select in the offspring, plants combining the desirable qualities of alfalfa with the self-tripping, self-fertile characters of the other parent. Although breeding an alfalfa that does not require insect pollination has been largely discouraging, it has not been entirely discarded.

Tripping and Cross-Pollination by Insects

At present, the methods of pollination previously discussed are of no practical significance in setting a commercial crop of seed. Repeated experiments in which insects have been excluded confirm their importance as agents in the transfer of alfalfa pollen. Repli-

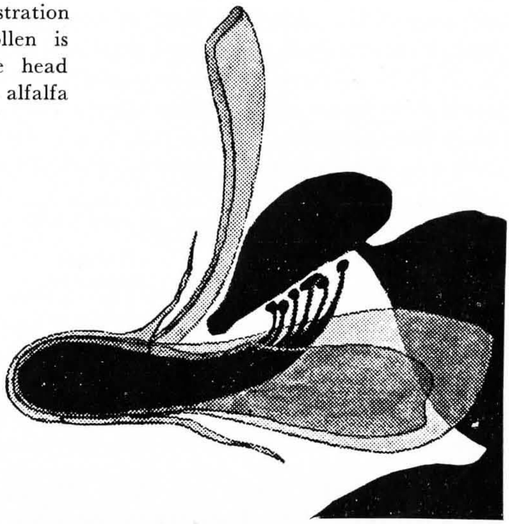


Fig. 27. Diagramatic illustration showing how pollen is deposited on the head of a bee when an alfalfa flower is tripped

cated plots of alfalfa from which insects were excluded produced 14 pounds of seed per acre in contrast to 198 pounds an acre under nautral conditions (see page 23).

The alfalfa flower is adapted for cross-pollination by insects. When an insect thrusts its head into a flower it releases the sexual column and is thereby struck on the head by a mass of sticky pollen and by the receptive area (stigma) of the female organs. By entering a flower of another plant it receives another load of pollen on the same part of the head and at the same time contributes pollen from its previous load to the stigma (fig. 27).

From the foregoing we can see that the seed grower must depend upon the activities of insects for the tripping and cross-pollination needed for successful seed production.

This dependency upon insect pollination complicates alfalfa seed production. We might logically inquire next, What are the factors affecting pollination by insects? Pollination of alfalfa by insects is affected both by differences in the insects and differences in the plants.

Plant characters possibly significant in influencing insect visitation include odor, color, nectar, pollen, shape and size of flower, mechanical features, and competition. The bee locates the food and conveys this information to its fellow workers. However, unless the plant is a worthwhile source of food, the bees disregard it. The available food (nectar and pollen) varies from plant to plant within a group of alfalfa plants and on a broader scale is modified by competition among insect visitors. A large population of one kind of insect may use all or most of the food, thereby limiting the amount available for another insect which may be a more efficient pollinator

(see page 62). Another kind of competition is related to populations of surrounding plants and their attractiveness compared to alfalfa. A field of sweet clover may draw some of the nectar-collecting honey bees from alfalfa. Likewise, a field of corn may draw away the pollen-collectors.

Table 13. *Seed yields of 3 varieties of alfalfa with natural pollination and with bees confined*

Variety	Natural pollination	Honey bees enclosed	Percent gain
	Varietal response in seed yields to pollination		
	lbs./acre	*lbs./acre*	
No. 1370	834	1164	40
Ranger	606	984	62
Nemastan	561	909	62
Mean	667	1019	54.6

Some alfalfa plants are more attractive than others to pollen-collecting bees. The character in the plant responsible for this variation in attractiveness is not known. The possibility of improving varieties for seed production by improving their attractiveness to bees is suggested by data in table 13. It would appear that the poor seed production of Nemastan may be caused by its unattractiveness to bees. When pollination was forced by enclosing honey bees with the plants, Nemastan was nearly equal to Ranger in seed production. Both Ranger and Nemastan gained about 50 percent more than No. 1370. This suggests that attractiveness to pollinators is at least partly responsible for the inherent high seed production of No. 1370. It is possible that breeding alfalfa plants for increased nectar production and attractiveness would be more productive than breeding aimed at eliminating the need for bees.

Pollinators of Alfalfa

With few exceptions bees are the only insects of value as pollinators of alfalfa.[1]

Seed produced when alfalfa was first grown in the West was pollinated almost entirely by various kinds of wild bees existing in the area before honey bees were introduced. Now, however, wild bees have become scarce in most seed fields and honey bees, introduced and maintained for honey production, have to a large extent replaced them as pollinators of alfalfa.

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[1]A species of soldier beetle (*Chauliognathus pennsylvanicus*) in some midwestern states and a genus of scoliid wasps (*Campsomeris*) in the arid southwest trip alfalfa and have occasionally been seen in useful numbers.

Comparisons of the tripping efficiency of native bees with honey bees have led many investigators to conclude that honey bees are of only minor importance in alfalfa seed production. This view is still held in many areas of the Midwest and Canada where, perhaps, the differences in efficiences are particularly great. However, intensive studies in the past few years have shown that in Utah and California honey bees, in spite of their rather low efficiency as individuals, are performing most of the pollination of the commercial seed acreage.

An ample supply of either wild bees or honey bees, or both, is valuable to the seed grower not only to cross-pollinate a high percentage of the blossoms on his field but also to do it rapidly. Rapid pollination shortens the period of flowering and hastens maturity, thus reducing the time during which damage from insects is likely to occur and, in the case of second-crop seed, minimizing danger of frost damage. Generally speaking, when an alfalfa field holds a profuse "flower garden" bloom, it is a sign that tripping is inadequate. Conversely, a field in which the flowers are rapidly tripped develops a brownish cast imparted by the wilted flowers and developing pods.

Conditions known to be generally favorable for activity of bees on alfalfa are (1) warm, sunny, and relatively quiet weather, (2) an abundance of healthy flowers, and (3) relative scarcity of competing sources of pollen and nectar.

Pollination By Honey Bees

Most honey bees visiting alfalfa seed fields in Utah belong to hives owned by beekeepers and, thus, their distribution on a broad scale is controlled by the judgment of the beekeeper. This judgment is influenced by many factors but the primary consideration is usually the possibility of an economic honey crop from the blossoms in the area. Other considerations such as remuneration for pollination services may become more important in the future.

The 20,000 to 25,000 bees in the field force of an average colony seldom range more than one and one-half miles unless pressed by lack of food. Their distribution within this range is governed primarily by the most attractive areas of bloom and secondarily by distance from the hives. Alfalfa bloom is attractive to honey bees, but the number of bees actually visiting it is governed by the number and proximity of hives and competition from other attractive sources of pollen and nectar in the area.

Pollinating Activities

Honey bees visit flowers to collect both pollen and nectar.[2] On many plants, including alfalfa, the visiting bees or "field force" become divided into nectar collectors and pollen collectors (fig. 28). Alfalfa under most conditions is an attractive source of nectar and suffers little from competition with other plants for visits from nectar collectors. It is not an attractive source of pollen, however, and pollen collectors are apt to neglect it in favor of better sources. Consequently, in alfalfa fields nectar collectors nearly always outnumber pollen collectors, in some areas by more than 100 to 1. Relative numbers of pollen and nectar collectors undoubtedly vary according to availability of other pollen sources but they also have been seen to vary from field to field where competition was playing no apparent role. In addition there are broad regional trends which may relate more to climate than to competition. For example, an almost total absence of pollen collectors has been reported from Canadian seed areas. In Utah pollen collectors are quite scarce in Cache and Box Elder Counties but in Millard County they frequently make up from 5 to 35 percent of the population on the field.

Pollen Collectors and Nectar Collectors

When collecting pollen from alfalfa, honey bees trip the majority of the flowers they visit and compare favorably in efficiency with many wild bees. Nectar collectors, on the other hand, usually are able to procure nectar without tripping the flowers. This they do by inserting their tongues at the side of the flower between the overlapping parts of the standard and wing petals. However, there is some evidence that bees making their first visits to alfalfa for nectar enter flowers directly and trip them, often getting their face or tongue pinched by the sexual column of the flower in the process. Tripping by nectar collectors usually varies from 0.5 to 2.0 percent, but may exceed that figure. The tripping rate is believed to be affected by environmental conditions (see page 49).

Honey bees were largely discounted as pollinators because of the slow tripping rate of nectar collectors and their preponderance on most fields. The collection of alfalfa pollen in considerable quantities

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[2]Nectar and pollen are almost the sole foods of all species of bees, both in the adult and larval stages. Adult bees, needing a ready source of energy, consume mostly nectar, which is a carbohydrate. Pollen is the principal food of larvae, being rich in protein. Since adult bees visit flowers for their own food as well as to collect it for their young, they are all pollinators of plants. With the exception of the honey bee, both sexes visit flowers, but males are less efficient and diligent since they need only satisfy their own energy requirements.

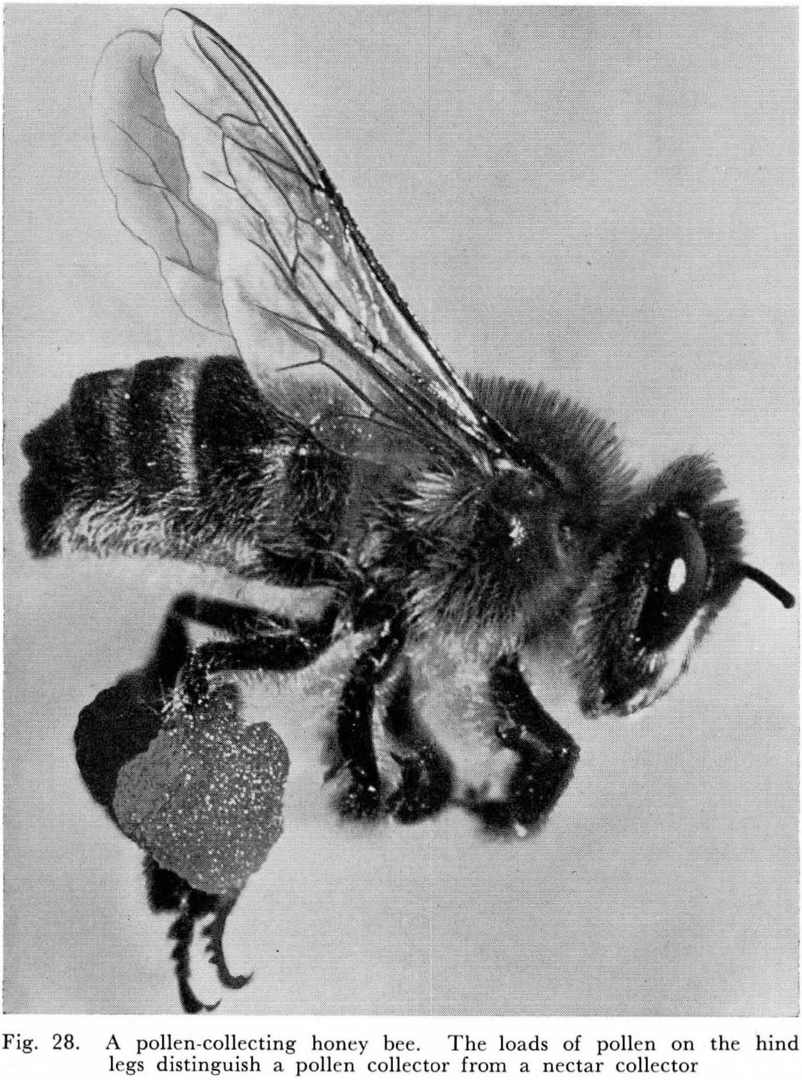


Fig. 28. A pollen-collecting honey bee. The loads of pollen on the hind legs distinguish a pollen collector from a nectar collector

in pollen traps in certain areas was conclusive evidence of the value of pollen collectors. However, tripping by nectar collectors, even if at a slow rate, is important. Bees tripping 1.5 percent of the flowers they visit will trip about one flower every ten minutes. An average of two nectar-collecting bees per square yard tripping at this rate over a three-weeks' period would set about 70 pounds of seed per

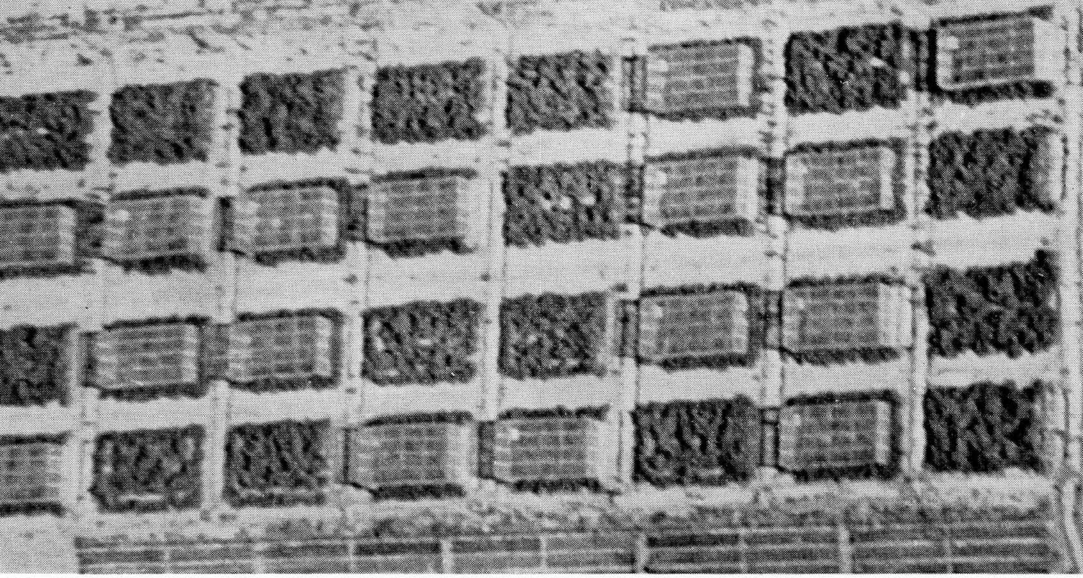


Fig. 29. Air view of experimental plots of alfalfa showing cages used to confine or exclude bees

acre. As many as four or five bees per square yard have been found on alfalfa with abundant bloom. An increase in the tripping rate or in the number of bees on the field would result in better setting.

Benefit of Honey Bees to Seed Yields

Two experiments recently conducted in Utah have made it possible to evaluate the honey bee as an alfalfa pollinator and to predict that increased yields are likely to result from increasing their numbers. In 1948 on replicated plots at Newton, populations of bees were regulated by the use of large cages in the field. Some plots were open and on others cages were used to exclude bees or to confine them in large numbers (figs. 29 and 30). In 1949 near Logan open plots were compared with ones on which bees were confined. The seed yields obtained in both experiments are shown in table 14. Only 14 pounds of seed per acre were produced when bees were excluded. Increasing the supply of pollinators over the number present in the vicinity on plots in which lygus bugs were controlled, resulted in seed increases of 62 percent in 1948 and 53 percent in 1949. The higher yields of 1949 seemed to be associated with the higher bee popula-

Table 14. *Seed yields* as affected by various levels of bees, Newton* (1948) *and Logan* (1949)

	Bees per sq. yd.		Seed yields	
Levels of bees	1948	1949	1948	1949
No bees	0	......	14	......
Natural	2.2	4.3	198	666
Bees confined	4.9	13.6	321	1,018

*Lygus bugs controlled

tions although other factors probably also played a part. These experiments show clearly that although moderate yields of seed may result where no special provision is made for pollination, the naturally occurring supply of pollinators is usually inadequate for high production and more seed should result from increasing the number of honey bees.

The benefit from honey bees in seed fields of Utah has been shown in another way. For many years there has been an annual movement of migratory colonies of bees from California to the seed areas of Utah. These colonies definitely augment the number of pollinators in the seed areas, but their numbers have varied widely during the past 23 years, ranging from 1,500 to 15,000 annually. When comparing this traffic with the state seed yields per acre, it is apparent that the yields have tended to vary up and down with the number of incoming colonies (fig. 31). High yields have tended to occur in years of high migratory traffic and low yields when there was less of such traffic. It is surprising that this relationship should be evident through the years in the presence of such other powerful factors affecting seed yields as injurious insects and weather conditions. Since the advent of lygus control on a large scale in 1946 this trend has continued but with yields at a generally higher level than in preceding years.

Fig. 30. A close up of one of the experimental cages

This influence of migratory bees on alfalfa seed yields indicates that Utah can use many more bees. In fact, the data in fig. 31 suggest that for each additional 1,000 colonies the state may expect an increase of about five pounds per acre, or about 250,000 pounds on the basis of the 53,000 acres planted to seed in 1949.

THE REGRESSION OF UTAH ALFALFA SEED YIELDS ON THE NUMBER OF MIGRATORY HONEY BEE COLONIES ENTERING STATE DURING PAST 21 YEARS. UTAH 1928-48.

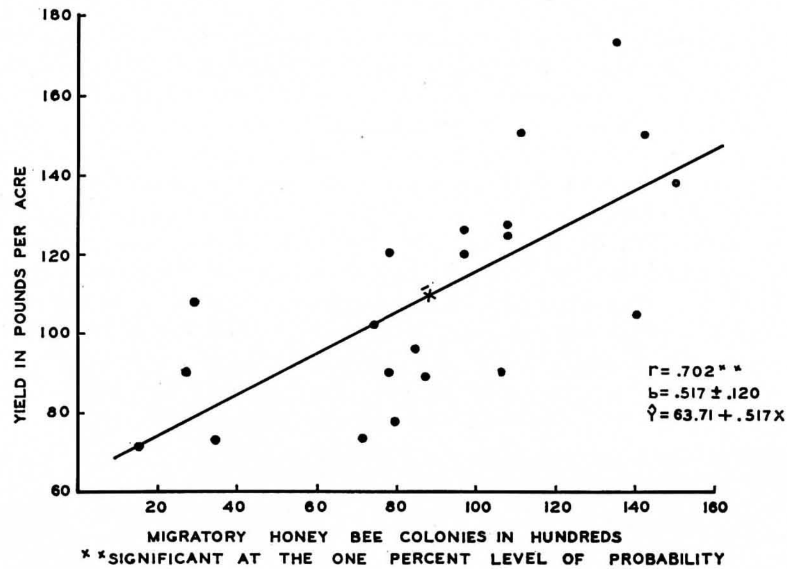


Fig. 31. Chart showing the relationship between alfalfa seed yields and colonies of honey bees moved into Utah, 1928-1948

Utilization of Honey Bees for Pollination

For adequate pollination seed fields should have at least four or five honey bees per square yard during the flowering season. Depending upon the abundance of other attractive plants within range, this may require from one to five or more colonies per acre of alfalfa. Concentrations greater than the honey crop will support can be provided by beekeepers if the seed grower is willing to pay for pollination service.

Obviously no hard and fast number of colonies per acre can be recommended. The number of native bees normally on the field and the relative numbers of pollen- and nectar-collecting honey bees influence the number of colonies needed. So, too, does the amount of competing bloom. If wild bees are scarce and pollen collecting by honey bees is low in a district, the field will probably need as many honey bees as its bloom can possibly attract. If there is much competing bloom in the area, as many as five colonies per acre could doubtless be used to advantage. There is some evidence from studies in California that increasing the number of colonies from two or three to five or six per acre does not always increase the total number of bees on the field but is likely to increase the number of young adult bees, which are the more frequent trippers when collecting nectar.

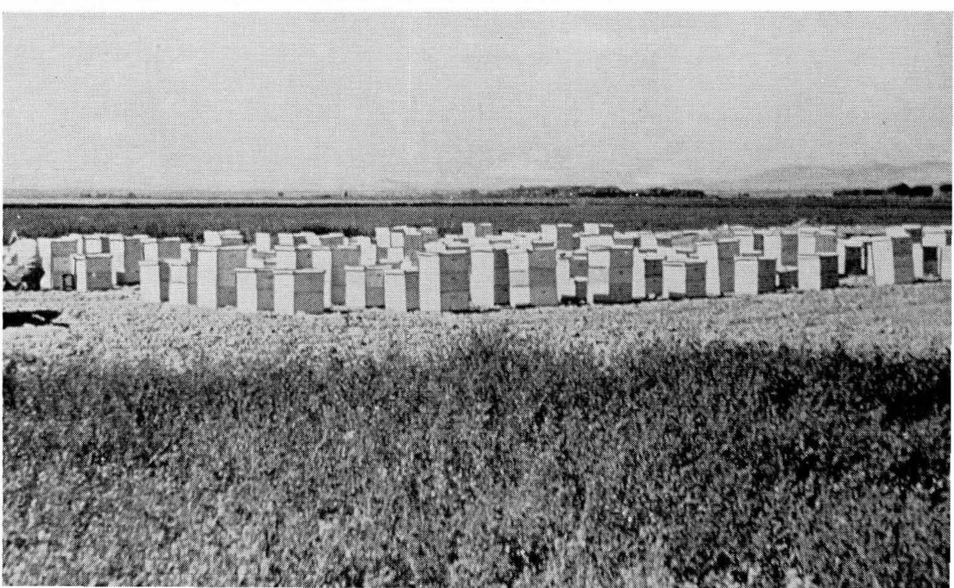
Research workers in California recommend a minimum of two colonies per acre for production of 250 to 500 pound seed crops and an additional colony for each additional 100 pounds. The upper limits were not determined but, using six colonies, they report yields of 1,000 pounds or more. In such cases, the colonies were placed in groups in the field. This placement in the field presumably takes full advantage of the higher tripping rate of the young bees which do not fly far from the hive.

Bees should be placed in or close to the field (fig. 32) *as soon* as it begins to show purple. Placement before bloom might cause the bees to become oriented to other areas. Under intermountain conditions flowers tripped after August 15 are not likely to form mature seeds by harvest so, from the standpoint of pollination, hives may as well be moved out by that time.

Seed Grower - Beekeeper Cooperation

Pollination is to a considerable extent a community problem. Bees cannot be "fenced in" so an enlightened grower providing for the

Fig. 32. Honey bees placed close to seed alfalfa for better pollination



pollination of his seed crop may be sharing the benefits with his neighbors. At the same time both he and the beekeeper may suffer from careless application of insecticides by these same neighbors.

Most seed growers in Utah are largely dependent on the beekeeping industry for their supply of pollinators. In order to increase the supply, which is generally short, steps should be taken to encourage more beekeeping in the state.

Some of the economics of beekeeping are not well understood by the seed grower. The beekeeper's income is derived from the sale of honey and the expenses involved in its productions are much greater than is generally realized. It is estimated that production of at least 80 pounds of surplus honey per colony is necessary for a full-time beekeeper to pay expenses and make the equivalent of wages for skilled labor. Many factors influence this production. The application of insecticides may either kill a colony outright or so reduce the field force that little or no honey will be stored. Production is also decreased by overstocking. The "carrying capacity" of alfalfa for honey production is variously estimated at from one to two colonies per acre. Adverse conditions for bee flight and poor nectar production by the flowers may reduce this capacity drastically.

Three basic steps can be taken by the seed growers to encourage beekeeping in this area and thus increase the supply of pollinators. (1) They can provide good apiary locations close to or in their fields. (2) They can follow the recommendations for control of injurious insects which are also designed to minimize damage to bees. (3) They can pay the beekeeper for pollination services whenever more colonies are required for satisfactory seed production than is practicable for honey production. Payment for pollination has not been practiced in alfalfa areas of Utah and many factors enter into an equitable remuneration for such service.

It is obvious that provision for a strong, steady supply of honey bees well distributed over the seed-producing fields could best be accomplished by community action. Potentially, seed growers and beekeepers are partners in an enterprise; but, because of the wide-ranging habits of bees, this partnership can only be entirely satisfactory on a community-wide basis.

Pollination By Wild Bees

This discussion of wild bees refers to the various species native to this country and does not include honey bees, whether they come from apiaries or wild colonies. "Wild" honey bees perform on alfalfa in the same manner as "domestic" ones but they should actually be discouraged since their hives serve as reservoirs of apiary diseases.

In Utah over 60 species of wild bees have been found visiting alfalfa fields. For reasons of either scarcity on alfalfa or inefficiency as pollinators about two thirds of the total number of alfalfa-visiting species can be practically disregarded. Consequently in Utah and southern Idaho, where most of our studies have been made, about 20 species appear to be of real or potential importance as pollinators in one or more areas.

That wild bees are efficient pollinators of alfalfa has been recognized for many years by scientific investigators and seed growers alike. In fact until recently, they have been considered as the only important pollinators.

With few exceptions wild bees visit alfalfa for pollen as well as for nectar. Many species seem to have a special knack for tripping the blossoms to get at the pollen whereas others have much difficulty and a number of small species content themselves with blossoms that have already been tripped. In general, bees more than three-eighths inch long are more efficient trippers than smaller species and bees less than one-fourth inch long do not trip at all. Some of the observations made on tripping rates for various kinds of bees are summarized in table 15. Since such extreme variation exists

Table 15. *Number of alfalfa flowers tripped per minute by various kinds of bees (California, Utah, Kansas, Saskatchewan)**

Genus of bee	No. species observed	Flowers tripped per minute: Average for all species	Flowers tripped per minute: Range between species
Megachile			
(leaf-cutter bees)	7	17	15-20
Bombus			
(bumble bees)	7	17	13-21
Nomia			
(alkali bees)	2	13	10-17
Xylocopa			
(carpenter bees)	1	23	....
Osmia			
(Osmia bees)	1	18	....
Melissodes			
(long-horned bees)	4	9	8-10
Apis (honey bees)			
pollen-collectors	1	7	....
nectar-collectors	1	0.1 (approx.)	....

*Observations by Linsley, MacSwain (California); Peck, Bolton (Saskatchewan); Franklin (Kansas); Bohart (Utah) between species, it is obviously futile to make statements concerning the pollinating efficiency of wild bees in general. However, it is easy to see how honey bees, most individuals of which collect nectar and trip only a small percentage of the flowers they visit, came to be lightly regarded in comparison.

Number of Bees Needed

By relating tripping rates and working hours of bees with the number of flowers in a stand and the percentage of tripped flowers forming pods, it is possible to make a rough estimate of the concentration of various kinds of bees required to set a particular seed crop. On this basis it has been estimated that about one pollen-collecting bee per ten square yards over a 3-week period would be required to set a seed crop of 400 pounds per acre. The more efficient bees such as bumble bees and leaf cutters need not be quite so abundant and the less efficient ones such as alkali bees and pollen-collecting honey bees should be somewhat more abundant.

Number Available

Unfortunately, wild bees are not present in most seed fields in sufficient numbers to set a satisfactory crop. Their distribution is uneven, but even if they could be spread more evenly over the acreage to be pollinated, their numbers would not be adequate for the task. It must be admitted that we have not yet learned how to increase wild bees at will and move them to places where they are needed, as we can so readily do with honey bees. Not only are wild pollinators scarcer than is desirable, but they seem to be in a state of progressive decline, if one may judge from past trends. It has been common experience for areas newly opened up to crop production to produce excellent seed yields and then for yields to decline within a few years. Increase of injurious insects may be responsible in part, but farmers and investigators have both observed that wild bee populations decline drastically within a few years after an area has gone under cultivation. It is probable that this decline results from several causes including destruction of nesting sites, increase of acreage to be pollinated, and killing of bees by insecticides. Destruction of food sources during certain periods probably also plays an important part.

Life History, Protection, and Utilization

A basic knowledge concerning the value, distribution, life history, and living requirements of the more important types of wild bees must precede any attempt to outline definite measures the seed grower might take to improve pollination on his fields by wild bees. The three most commonly encountered wild pollinators in Utah and southern Idaho are bumble bees, alkali bees, and leaf cutter bees.

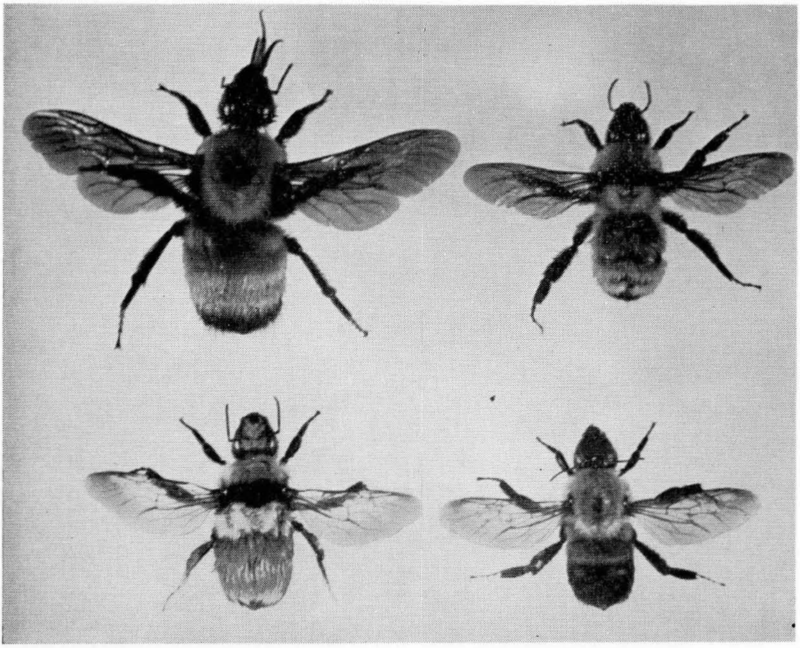


FIG. 33. Four species of bumble bees which pollinate alfalfa in the west

Bumble bees (*Bombus* spp.). Bumble bees (fig. 33) are the large furry creatures familiar to everyone. In the West they tend to be most abundant in small mountain valleys and along foothill benches. However, a few species may be found in lesser abundance in the larger valleys. In only a few small fields have they been seen in the numbers necessary to set a good seed crop. In Utah and southern Idaho six kinds have been seen in various fields in important numbers. Most of these have a wide host range but they usually limit their visits to rather conspicuous flowers. Many of the legumes and composites in particular are attractive to them and offer competition to alfalfa for their visitation. Adequate bloom early in the season when the colonies must build up is important for their survival.

Like honey bees, bumble bees form colonies and possess queen and worker castes. The principal differences is that bumble bee colonies die out in the fall and only the fertilized queens persist through the winter. In the spring these queens must establish a new colony and provide for a brood of workers before they can retire to a life of egg laying. Another striking difference is in the small size

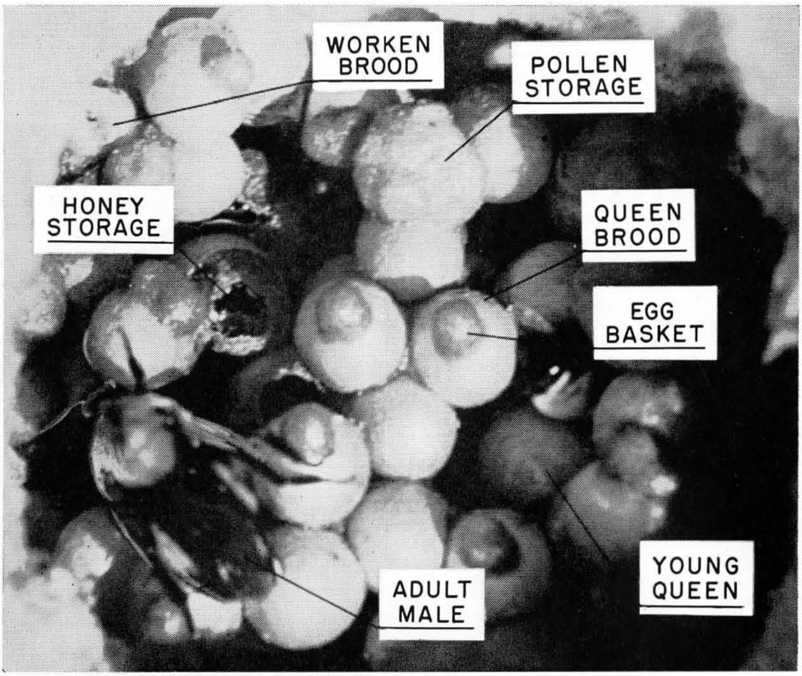


Fig. 34. A bumble bee nest containing mature brood

of the colonies (fig. 34). These generally attain a maximum size of from 50 to 500 individuals in the late summer as compared with an average honey bee colony of 40,000 individuals. At the time of maximum colony development many drones and new queens are produced. Soon after mating with drones the new queens leave the colony and seek sheltered places in which to hibernate. The colony, having accomplished its mission of producing fertile queens for the following year, gradually dies out. By September brood-rearing has generally ceased and bees still seen on flowers are feeding on nectar to extend their span of life. In the spring in Utah it often takes the queen until June to produce her first brood of six or eight workers and thus set the stage for more rapid increase. By early August, when second crop alfalfa is in full bloom the colony has usually reached maximum size and vigor. Basic features in the bumble bee life history are summarized in table 16.

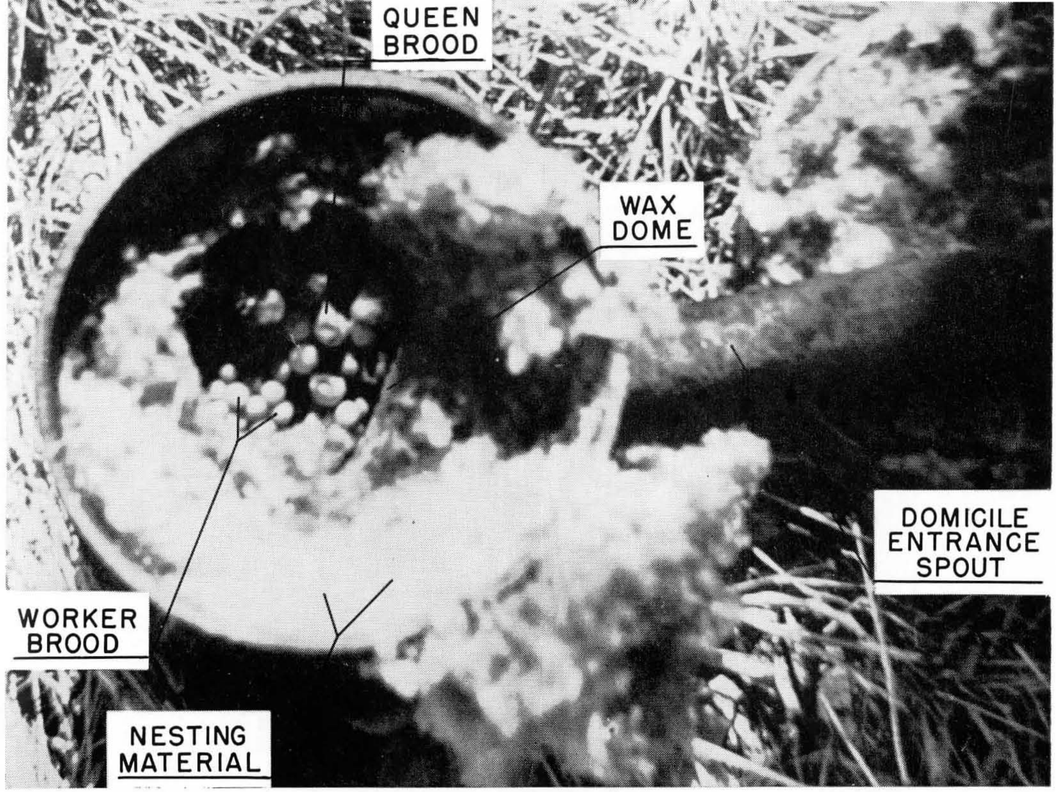


Fig. 35. An artificial domicile accepted by a bumble bee. Domicile has been dug up and lid and top of nest have been removed

In our area two of the six species of bumble bees valuable to alfalfa extend their ranges into the large valleys. They usually nest above ground and in the spring searching queens may accept as domiciles gallon cans containing a handful of mattress stuffing or similar material (fig. 35). These cans may be hung up in sheltered places in barns, granaries, and other outbuilding. The other species

Table 16. *Typical course of events in bumble bee colonies in Cache Valley, Utah*

October-March	Mated queen hibernates
April-Early May	Queen emerges, seeks nesting place
May-Early June	Queen starts colony, stores nectar and pollen, lays eggs
June	First workers produced. Queen retires to nest
July-August	Workers available in large numbers for pollination. New queens, drones produced
September	New queens mate, seek shelter. Colony dies out
October-March	Mated queens hibernate

of bumble bees partial to alfalfa are more apt to nest underground. Cans with lids and entrance spouts placed underground have been successful in attracting two species. Such cans should be placed in well drained places, protected from rain.

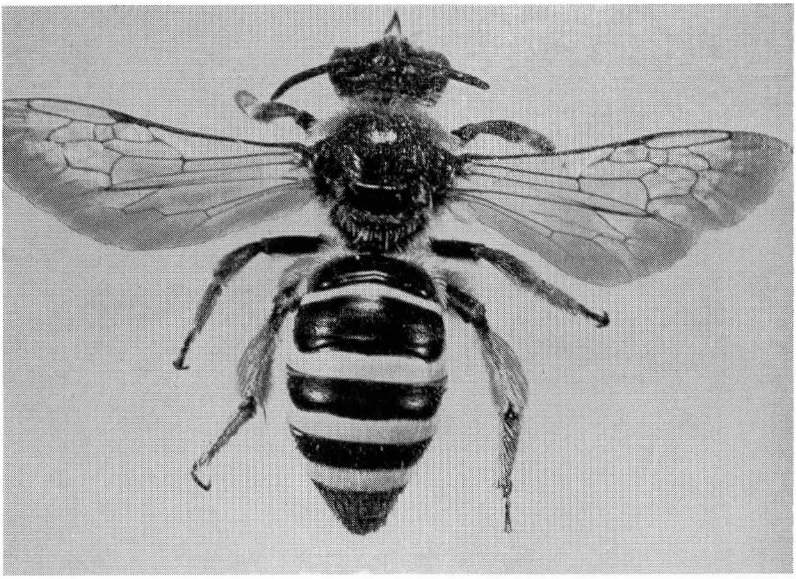


Fig. 36. Female alkali bee

Mice are detrimental to bumble bees during the nest establishment phase of the colony. Control of house and field mice should encourage increase of bumble bees. Insecticides can also be hazardous. In foothill areas insecticides applied to fruit bloom can kill the foraging queens and thus destroy entire colonies.

Alkali bees (*Nomia melanderi* Ckll.). Alkali bees are about two thirds as large as honey bees and can be readily recognized by the pale green or greenish bronze, highly polished bands across the rear portion of their bodies (fig. 36). In Utah they are found principally in the larger valleys where poorly drained, alkaline areas are prevalent. They are abundant in some fields or areas and totally absent in others. It is also common experience for them to appear in numbers in one season and to disappear almost as quickly several years later.

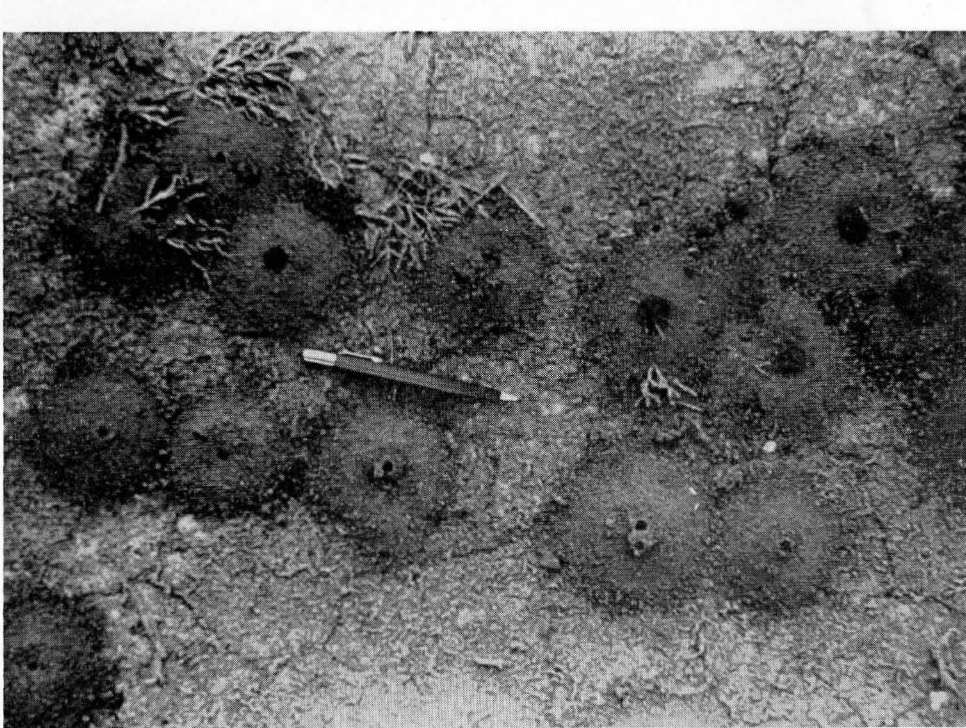
The host range of alkali bees is rather limited. In the Delta area only sweetclover and Russian-thistle offer serious competition to alfalfa, although a few other less abundant plants such as salt cedar *(Tamarix),* morning-glory, and various clovers are attractive. Common competitors in the area for honey bees such as greasewood, poverty weed, gumweed, sunflower, and rabbitbrush present no attraction for alkali bees.

Alkali bees are gregarious in that they construct their nests close together to form nesting aggregations (sometimes loosely spoken of as colonies or communities). However, each female is solitary because she functions as both queen and worker and constructs and provisions an individual nest burrow in the soil. Aggregations may cover an acre or more with burrows which are in many cases not more than an inch or two apart. Populations in such nesting sites compare favorably with populations of honey bees in an average apiary.

Nesting takes place in fine textured, somewhat cohesive soils of either a sandy or clayey nature. The prime essential seems to be a high year-around moisture content, although the area should not be flooded for extensive periods. Nesting sites may be on bare ground but are usually associated with a sparse growth of salt grass or bassia that allows direct light to reach the ground (fig. 37).

An individual nest consists of a spoils mound at the ground surface and a vertical underground burrow branching into two groups of brood cells, one about four and the other about seven inches deep. Each story is composed of five to ten separate oval cells placed

Fig. 37. Entrances to nests of alkali bees



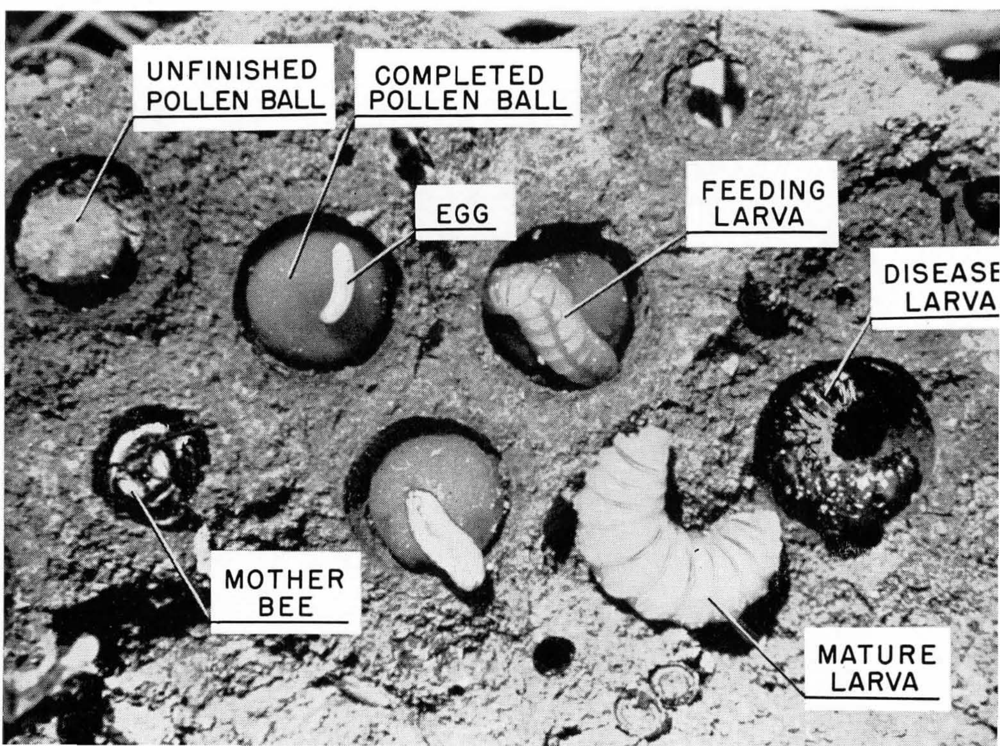
side by side rather close together (fig. 38). After constructing a story the bee provides each cell with a ball of pollen, places an egg on the ball and seals the cell. The young larva, after hatching from the egg, must complete its development without further assistance.

In Utah adult male alkali bees usually appear in the fields near the first of July. Females often do not appear in numbers until the middle or even the end of July. Males in the field are "flighty" and stop only occasionally to feed on nectar from flowers. However, they do trip a high percentage of the flowers visited and we have observed fields in which they have been the major pollinating agents.

Table 17. *Typical course of events in nesting sites of alkali bees in Utah and southern Idaho*

Mid-September-June	Full grown larvae in cells in ground
Early July	Males emerge, visit some flowers
Mid-July-early August	Females emerge, visit flowers and produce larvae
Early-late August	Second generation females become active
Late August-early September	Second generation adults complete nesting activities, perish
Mid-September-June	Progeny of second-generation carry through as larvae

Fig. 38. Nest of an alkali bee exposed from the top to show cells and their contents



Females work much more efficiently than males, and the grower, in order to take full advantage of alkali bees should time his bloom for late July or early August. At least two generations of adults

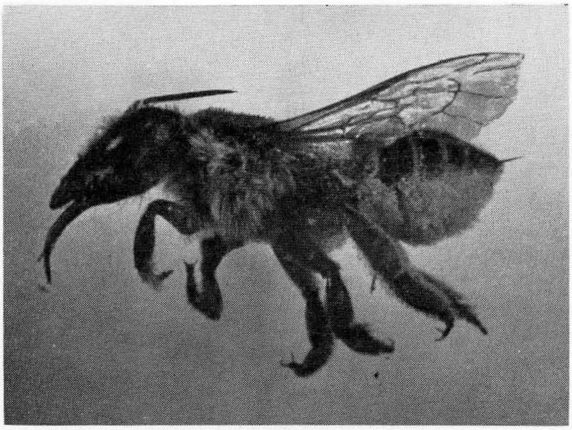


Fig. 39. Female leaf-cutter bee showing pollen load on the underside of its abdomen

appear during the season. By early September, when most of the host flowers have gone to seed, the adults all perish, but their offspring persist in the soil as mature larvae until the following summer. Basic features in the seasonal life history of an aggregation of alkali bees are summarized in table 17.

Since alkali bees are gregarious and are also rather exacting in their nesting requirements, it is important that their nesting sites be protected from disturbance. During the active season any disturbance such as harrowing, flooding, and trampling can be disastrous. During the fall, winter, and spring months pasturing, light watering, and shallow harrowing should not be harmful unless the surface is left in a "fluffy" condition. Nesting areas should not be drained. Application of insecticides during bloom is quite hazardous to alkali bees and should be done only according to recommendations (see page 4).

It has been observed that under certain conditions aggregations will take over a new area in a single season. This indicates that the grower could prepare and maintain favorable sites near his alfalfa and wait for natural occupancy to take place. Research is under way on methods for obtaining these conditions and for further helping nature by moving brood into favorable areas to get new aggregations started.

Leaf-cutter bees (*Megachile* spp.). Leaf-cutter bees range in size from slightly smaller to slightly larger than honey bees. Females can be readily recognized by their dark grey color and the fact that

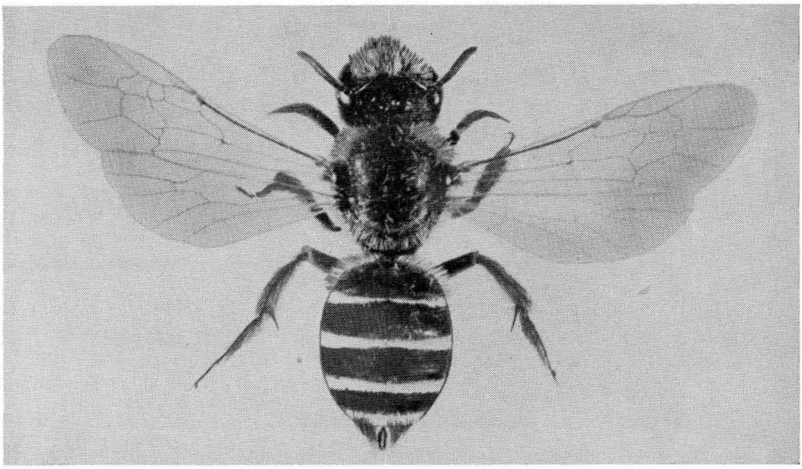


Fig. 40. A sweat bee, one of the many species occasionaly observed pollinating alfalfa in Utah.

they pack pollen on the underside of their bodies rather than on their legs (fig. 39). Circular and oval holes about one half inch wide in leaves of shrubs betray their presence in the area but do not prove their presence on alfalfa.

Although they may be seen in nearly all alfalfa fields, they are rarely abundant. An average of more than one leaf-cutter bee per 50 square yards is unusual although one per 5 square yards has been observed. Considering their efficiency, even such small numbers as one per 50 square yards can aid materially in pollinating the seed crop.

The largest populations are most likely to be found on small fields near uncultivated areas. Although alfalfa-pollinating leaf-cutters in some seed areas, such as Saskatchewan, nest in beetle holes in timber and must have access to wooded country, our best pollinators nest in small cavities or burrows in the ground and are usually encountered in nearly treeless areas.

The host plant range for the commoner species of leaf-cutter bees is wider than that for alkali bees but narrower than that for bumble bees. Legumes and composites are favored but many other common flowers such as rose and mallow are also visited. Although these host plants can be looked upon as competitors for the attentions of leaf-cutters during the blooming season of alfalfa, some of them are necessary to maintain the bees during other periods.

In Utah leaf-cutter bees generally appear in May and reach their greatest abundance in August. During this period it is probable that there are at least two and probably three generations. The adult female utilizes various kinds of roughly tubular cavities in which to place a linear series of cells lined with leaf pieces. Each cell is provided with a mass of honey-moistened pollen in which an egg is imbedded. During the summer the young develop into adults within about one month. The last generation in the fall develops into adults which remain in their leaf cells until May or June.

Since leaf-cutter bees are largely solitary and specific nesting preferences for species important in this region are not known, no practical suggestions can be offered at this time for preserving or increasing their nesting sites. Any preservation of uncultivated land should help them to survive.

Other wild bees (fig. 40). It is impossible in this circular to discuss separately the various other kinds of wild bees that pollinate alfalfa. However, if a seed grower is benefiting from other kinds, he would do well to have them identified on the chance that he could get information on how to protect them.

Principals for Utilization and Protection of Wild Bees

From the foregoing discussion certain general conclusions can be drawn concerning measures that might be taken to better utilize wild bees.

1. If useful wild bees are known to be present, time alfalfa bloom with the period of greatest abundance.
2. Take advantage of areas where alfalfa-pollinating species are known to be abundant.
3. If wild bees in isolated seed areas are setting most of the crop, don't expand your seed acreage beyond the capacity of the bees to take care of it.
4. Reduce competing sources of pollen and nectar in the area during the period your seed crop is in bloom.
5. Search for nesting sites of alkali bees and keep them in an unaltered condition.
6. Control mice in order to encourage bumble bees.
7. Apply insecticides to blossoming plants only in accordance with recommendations in this circular.

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