The TREFOILS—

Adaptation and Culture

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CONTENTS

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THE TREFOILS—ADAPTATION AND CULTURE

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The perennial trefoils, *Lotus* species, are important legumes on various soil areas of the United States for permanent pasture and hay. For many years prior to 1935 many imported seed lots of trefoil, chiefly birdsfoot, were tested by the U.S. Department of Agriculture in cooperation with several State agricultural experiment stations. The advantages of using trefoil were not readily apparent in those early tests, because most of the trials were made in comparison with alfalfa and on alfalfa soils under hay management. The discovery in the 1930's of productive, naturally occurring stands of trefoil in permanent pastures in various areas of the United States awakened agricultural workers to the realization of the potential forage value of one or more of these species.

Since 1938 many continuing research programs have been initiated to determine adaptation, culture, management, and improvement of the trefoil species.

ORIGIN AND DISTRIBUTION

The cultivated forms of the trefoil species are native to Europe in the region from the Mediterranean Sea northward to the Scandinavian Peninsula. Robinson (*34*)[1] reports that the trefoils have been used to a limited extent in the British Isles and in various parts of France, Italy, Denmark, and elsewhere in Europe for a great many years. These legumes have recognized forage value over much of Europe. They are used for forage and seed production in the southern countries, chiefly France and Italy. In more northern areas, birdsfoot trefoil is used for pasturage and it is an important species in many Alpine meadows.

Birdsfoot trefoil and big trefoil are well adapted to limited areas in Austrialia (*11*) and New Zealand. In South America birdsfoot is adapted to various areas of Argentina and Uruguay. In tropical environments the species are reported by Hosaka (*17*) and Quiros (*33*) to be well adapted at the higher elevations in the Hawaiian Islands and Costa Rica.

When and how trefoils were introduced into the United States is not known. It is quite probable that the seed entered as impurities in ballast deposits and in shipments of other seeds from Europe, and became established on the east and west coasts.

The trefoils first became naturalized in eastern New York; western Oregon, northwestern California, and in the tidewater areas of Virginia. The success with birdsfoot trefoil in these areas stimulated interest in them in other areas. More detailed reports on the origin and distribution of the trefoil species may be found in reports by MacDonald (*24*) and McKee and Schoth (*27*).

DESCRIPTION OF TREFOIL SPECIES

Three species of trefoil are presently grown in various areas of the United States: Birdsfoot trefoil (*Lotus corniculatus* L.) (~~fig. 1~~), narrowleaf trefoil (*L. tenuis* Wald et Kit.) (~~fig. 2~~), and big trefoil (*L. uliginosus* Schkuhr) (~~fig. 3~~).

Birdsfoot trefoil is a broad-leaved, long-lived herbaceous perennial with a well-developed, branching taproot and few to many ascending stems developing from each crown. It is a tetraploid with a somatic chromosome number of 24. It is similar to alfalfa in growth habit. The plants, for the most part, are erect or ascending and reach a height of 12 to 30 inches. The stems are comparatively slender, sparingly branched, and moderately leafy. The leaves are borne alternately on opposite sides of the stem and are composed of five leaflets, of which one is terminal, two are apical, and two are at the base of each petiole. The last two resemble stipules and are often mis-

[1] Italic numbers in parentheses refer to Literature Cited, p. 15.

FIGURE 1.—Flowering branches and plants of birdsfoot trefoil.

FIGURE 2.—Flowering branches and plants of narrowleaf trefoil.

taken for them. The flowers, generally numbering two to six, are borne in umbels at the extremity of a long peduncle arising from the leaf axil. The flowers, resembling the flowers of peas, are yellow with faint red or orange stripes usually present in young flowers. Pods form at right angles at the end of the peduncle in the shape of a bird's foot; hence the common name of the species, birdsfoot. The seeds are oval to spherical and number from about 324,000 to 550,000 seeds per pound. They vary from light to dark brown and are usually speckled with dark spots.

Narrowleaf trefoil, as the name implies, has narrow, linear-lanceolate leaflets on slender, weak stems with comparatively long internodes. MacDonald (*24*) found that this species has a more shallow root system than the broad-leaved species. Flowers are slightly smaller and fewer in number, and usually change from yellow to orange red at maturity. Narrowleaf trefoil

is a diploid species with a somatic chromosome number of 12. Otherwise, narrowleaf is similar to the birdsfoot species.

Big trefoil is similar to birdsfoot trefoil in appearance but differs in having rhizomes and more flowers per umbel than either birdsfoot or narrowleaf trefoil. It is shallow rooted, lacks drought resistance, and grows best in continuously moist soils. The seeds of big trefoil are almost spherical and vary from yellowish to olive green, without any speckling. Like narrowleaf, big trefoil is a diploid species with a somatic chromosome number of 12. Big trefoil seeds are much smaller than the seeds of the other two species and number from about 800,000 to 1,075,000 seeds per pound.

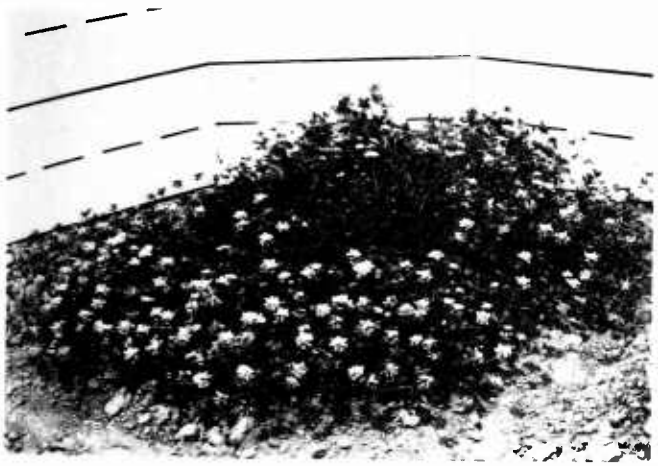

FIGURE 3.—Flowering branches and plants of big trefoil.

GENETICS AND CYTOLOGY OF TREFOIL

Knowledge of the phylogeny of the tetraploid *Lotus* species is basic to the development of any sound breeding program.

As indicated earlier, broad-leaved birdsfoot trefoil is a tetraploid having a somatic chromosome number of 24. Cytological studies by Dawson (*6*), Tome and Johnson (*39*), and Donovan (*8*) show quadrivalents to be rare at meiosis. However, genetic studies of the inheritance of cyanogenesis by Dawson (*6*), flower and keel tip color by Bubar (*5*), keel tip color by Hart and Wilsie (*15*), and leaf size by Donovan (*8*), show that tetrasomic inheritance is involved. On the basis of these studies, the species is believed to be autoploid in origin. Dawson (*6*) and Guinochet (*14*) proposed the narrow-leaved diploid species, *Lotus tenuis*, as the progenitor of *L. corniculatus*. Tome and Johnson (*39*) were unable to successfully cross an artificially induced tetraploid plant of *L. tenuis* and *L. corniculatus*; however, Erbe, Keim, Mears,[2] and Gershoy (*12*) successfully made this cross. The diploid form of *L. corniculatus* var. *alpinus* Ser., according to Larsen (*22*), closely resembles and could have been the ancestor of the tetraploid form. The existence of a great many forms of the tetraploid *L. corniculatus* has been noted by taxonomists and geneticists alike. MacDonald (*24*), McKee (*26*), and McKee and Schoth (*27*) have

[2] Erbe, L. W. A study of the fertility relationships of Lotus corniculatus, tetraploid L. tenuis and their F1 hybrid progeny. 1955. (Thesis, M.S. Grad. Col., Univ. Vermont, Burlington.)

Keim, W. F. Interspecific hybridization studies in Trifolium and Lotus, using embryo culture technique. 1952. (Thesis, Ph. D. Cornell Univ., Ithaca, N.Y.)

Mears, K. A. Studies in specific hybridization in the genus Lotus. 1955. (Thesis, M.S. Grad. Col., Univ. Vermont, Burlington.)

discussed the morphological differences of many of these forms or varieties. There is evidence that some of the different tetraploid forms could have arisen by ploidy from different diploids.

Exploratory studies were made during the period 1956–60 at Beltsville, Md., on the content of tanninlike substances in various *Lotus* species. The tannin content on individual plants was estimated in accordance with the method used by Bates and Henson (*3*) for *Lespedeza cuneata* (Dum.-Cours.) G. Don. When green leaves of many *Lotus* species were pressed into filter paper containing ferric ammonian citrate, the color and intensity of the spot formed was reasonably uniform within the species, but varied from a tan to greenish brown in some species to a blue black in others. Chemical analyses of tannin content showed the latter group to be generally higher in total tannins. It is suggested that at least some of the phenolic substances making up the tannin complex differ with different species, depending in part on their origin.

Differences in the tannin complex were first noted between field-grown plants of tetraploid forms of *Lotus corniculatus*. Leaves of Empire, the variety or ecotype indigenous to New York State, produced tan to brown spots on the treated paper. In contrast to this, leaves from the erect-growing European form consistently produced darker, blue-black colored spots. Differences were less distinct within greenhouse-grown plants, due possibly to lower light intensity.

Among the diploid species (2n=12), the tannin reaction of *Lotus tenuis* and *L. filicaulis* Dur. in Duch. was similar to that of Empire. *L. divaricatus* Soland. ex Buch, *L. uliginosus*, and *L. parviflorus* Desf. were high in tannin content comparable to that of the erect form of *L. corniculatus* from Europe. These observations indicate that the Empire ecotype may well have arisen from *L. tenuis* through ploidy, since both are relatively low in tannin and both contain cyanogenetic plants. However, the low tannin content of *L. tenuis* is not entirely compatible with the suggestion that this species is the sole progenitor of the European type. Plants of the two tetraploid types, Empire and the European form, cross readily, indicating a close phylogenetic relationship.

Bent,[3] in recent studies, successfully crossed both 2n and 4n *Lotus uliginosus* with *L. corniculatus*. He was also successful in crossing *L. uliginosus* with *L. tenuis*.

The present evidence suggests that although the Empire ecotype appears to be an autoploid, the possibility that the erect European ecotype is of different origin but closely related, should not be overlooked.

The self-fertility of a number of *Lotus* species has been reported. Within the tetraploid species, *L. corniculatus* var. *arvensis* (Schkuhr) Ser. and var. *vulgaris* W.D.J. Koch are relatively self-sterile. Studies have shown that 70 to 80 percent of the plants are self-sterile (*26*, *38*).[4, 5] The most self-fertile plants, however, produce 50 to 80 percent more seeds when outcrossed, as compared to selfing. *L. corniculatus* var. *hirsutus* W.D.J. Koch is highly self-fertile. The annual tetraploid *L. hispidus* Desf. is apparently autogamous.

Of the diploid species, *Lotus tenuis* is self-sterile. *L. uliginosus*, as reported by Silow (*38*), Bent,[6] and McKee (*26*), and *L. corniculatus* var. *japonicus* Regel, by Bent,[6] are moderately self-fertile. McKee (*26*) found *L. filicaulis* to be highly self-fertile while *L. divaricatus* and *L. ornithopodoides* L. were autogamous.

The inheritance of self-fertility in *Lotus* is complex. Results of studies by Brandenburg [7] on *L. corniculatus* and by Elliott [8] on *L. tenuis* did not support the hypothesis that the inheritance of self-sterility is due solely to oppositional factors. Additional studies are needed to clarify the fertility relationships in the genus.

[3] BENT, F. C. INVESTIGATIONS IN INTERSPECIFIC HYBRIDIZATION AND FERTILITY OF CERTAIN LOTUS SPP. 1958. (Thesis, Ph. D., Cornell Univ., Ithaca, N.Y.)

[4] ERBE, L. W. See footnote 2, p. 3.

[5] GILES, W. L. THE MORPHOLOGICAL ASPECTS OF SELF-STERILITY IN LOTUS CORNICULATUS L. 1949. (Thesis, Ph. D. Univ. Missouri, Columbia.)

[6] BENT, F. C. See footnote 3.

[7] BRANDENBURG, N. G. SELF- AND CROSS-FERTILITY IN BIRDSFOOT TREFOIL, LOTUS CORNICULATUS L. 1959. (Thesis, Ph. D. Univ. Maryland, College Park.)

[8] ELLIOTT, F. C. THE INHERITANCE OF SELF-INCOMPATIBILITY IN LOTUS TENUIS WALD. ET PIT. 1945. (Thesis, M.S. Iowa State College, Ames.)

ADAPTATION

The birdsfoot and narrowleaf trefoils are adapted to the temperate climate of the northern part of the United States. Within this region birdsfoot trefoil is particularly well suited to the less fertile soils and is productive on soils having relatively poor internal drainage. On such soils it has become an important long-lived perennial legume for pasture and hay (*1*, *7*, *9*, *31*, *40*).

Trefoil also has a place on fertile soils in permanent pastures (*37*) that are left down for long periods of time or in pastures that are difficult to plow or cultivate. On well-drained fertile soils the present varieties of trefoil are generally less productive for hay than is alfalfa.

Birdsfoot trefoil is not well adapted in the regions below an approximate line drawn from the eastern end of the Nebraska–Kansas border to the east coast, except at higher elevations in the Appalachian Mountains. Farther south, stands of this species are short lived due, in part, to its susceptibility to various crown- and root-rotting diseases.

Narrowleaf trefoil is well suited to heavy, poorly drained clay soils. This species is an important constituent in pastures in the Hudson River Valley of New York State. In California, Peterson and others (*30*) reported that narrowleaf trefoil is an important pasture plant, especially on the poorly drained, heavy-textured clay soils. This species grows well in soils containing large quantities of soluble salts and is the most common legume on saline and alkali soils in regions having relatively mild winters, as in the Rogue River Valley of southern Oregon. In general, narrowleaf trefoil, particularly the strain from the West, is not so hardy as birdsfoot.

Big trefoil, according to Howell (*18*), is well adapted to the acid coastal soils of the Pacific Northwest. In this region of mild winters, big trefoil grows well on the low-lying soils that are frequently flooded during the winter months. It also grows well in relatively moist uplands. In contrast to birdsfoot trefoil, which requires lime on very acid soils for maximum production, big trefoil grows well on soils of pH from 4.5 to 5.5. Lime application to such soils has not increased the productivity of this species.

Big trefoil appears promising as a pasture legume in the acid flatwood soils of the southeastern coastal regions when adequately fertilized with phosphate and potassium (*41*). The productivity of this species in this southern climate may be reduced during periods of warm, dry weather. Maximum and continued growth of big trefoil occurs in regions of frequent summer rains. During the long warm summers of the Southeastern States, diseases such as Rhizoctonia, anthracnose, and black patch may seriously reduce the productivity of the species.

VARIETIES

Birdsfoot Trefoil

The present varieties of birdsfoot trefoil are derived from either seed stocks from old established stands in New York State or from imported lots from Europe, chiefly Denmark, France, and Italy. Descriptions of the named varieties of birdsfoot trefoil follow:

Empire.—An increase of an ecotype of naturalized birdsfoot trefoil occurring on selected farms in the vicinity of Preston Hollow, in Albany County, N.Y. Empire is a semierect, hardy, late-maturing type with leafy, much-branched stems. It flowers from 10 days to 2 weeks later than the common European forms. Flowering is indeterminate, occurring from late in June to mid or late July in New York State. Young seedlings of Empire generally lack seedling vigor but once established, the variety is an exceptionally long-lived, productive legume for pasture and hay. Empire was developed and released by the Cornell University Agricultural Experiment Station, Ithaca, N.Y.

Cascade.—An erect-growing, productive, early-maturing variety developed from an importation from France, F.C. 20153.[9] In the development of this variety a large number of superior plants were selected out of F.C. 20153 and allowed to intercross. The resulting seed was bulked, tested, and later released as the Cascade variety. Cascade birdsfoot trefoil has good seedling vigor and is relatively easy to establish. It is not so hardy as Empire and is not grown in regions having extremely cold weather. Cascade was developed cooperatively by the Washington Agricultural Experiment Station at Pullman and the U.S. Soil Conservation Service.

Granger.—Originated from seed lot F.C. 22557,[9] imported from France. It is similar to Cascade in that it is an erect, broad-leaved, early-maturing, productive variety. Granger also has good seedling vigor and establishes with ease, but is not so hardy as Empire. Granger was developed cooperatively by the Oregon Agricultural Experiment Station at Corvallis, and the U.S. Agricultural Research Service.

Viking.—Developed by selecting desirable plants from a Danish importation and from two erect-growing, early-maturing New York State local strains. Selected plants were allowed to cross and their progenies tested. Superior plants on the basis of progeny tests were combined for seed production. The bulked seed was extensively tested and the resultant variety re-

[9] Forage Crops accession number.

leased as Viking. This is an erect, broad-leaved, rapid-growing, productive type with good seedling vigor. It is more winter hardy than imported stocks from France and Italy and is superior to Granger and Cascade in this regard. Viking was developed and released by the Cornell University Agricultural Experiment Station, Ithaca, N.Y. (*25*).

Mansfield.—This variety is similar in many respects to Viking. In the development of Mansfield, vigorous, erect-growing, productive plants were selected from the following seed sources: (1) An imported seed lot that had been grown at Shelburne, Vt., (2) a seed stock from Columbia County, and (3) a seed stock of Danish origin. The selected plants were isolated, allowed to intercross, and the resultant progeny tested. Several hundred superior plants were combined to produce seed of the new variety. Results of tests across the Northern States show that Mansfield is well adapted to the same general areas as Viking. Mansfield was developed and released by the Vermont Agricultural Experiment Station (*12*) at Burlington.

Tana.—A vigorous, erect-growing, broad-leaved variety developed from a high-yielding lot from Europe. Tana has good seedling vigor and is very similar to Cascade and Granger. This variety was developed and released by the Montana Agricultural Experiment Station at Huntley.

Douglas.—Originated in Douglas County, Oregon. Out of several European lots of birdsfoot trefoil under test by the county agent, this one gave the best results. It is an erect-growing, vigorous European type.

In addition to the above varieties, a number of strains have been developed. Varieties of birdsfoot are quite variable and when brought into a new area and grown and harvested for seed over several generations, the resulting strain may be quite different from the original variety.

Narrowleaf Trefoil

Los Banos.—A new variety, Los Banos, is the only named variety of narrowleaf trefoil. It was developed and released cooperatively by the California Agricultural Experiment Station at Pleasanton, and the U.S. Soil Conservation Service. Other seed stocks of narrowleaf trefoil usually carry the State of origin, as New York narrowleaf, or Oregon or California narrowleaf. All have fine stems, narrow leaves, and are decumbent to semierect in habit of growth. Tests at various locations have shown that New York narrowleaf is somewhat more winter hardy than those of west coast origin.

Big Trefoil

Seed of two varieties of big trefoil is available. Both were developed by the Oregon Agricultural Experiment Station at Astoria, and the U.S. Agricultural Research Service.

Beaver.—The variety Beaver is quite hairy, with stems and leaves well covered with fine hairs, giving the plant a gray-green appearance.

Columbia.—The variety Columbia, in contrast to Beaver, is smooth with relatively few hairs. Its dark-green foliage resembles that of birdsfoot in general appearance. Both varieties are well suited to the wet winters and cool summers of the Pacific coastal areas of the Northwestern States.

OBJECTIVES OF IMPROVEMENT

The objective of any trefoil improvement program may vary with the region and to some extent within the region. General objectives are (1) greater longevity for pasture, hay and silage; (2) improved yields; (3) increased seedling vigor; (4) improved seed habits; and (5) rapid recovery after cutting. Greater winter hardiness is desirable in the more Northern States, whereas resistance to crown and root rots is extremely important in Southern States.

Widely adapted, more productive, longer-lived varieties of birdsfoot trefoil must be developed if the full potential value of this forage legume is to be realized. The present varieties are readily separated into two groups, according to origin and plant type. In one group are the spreading to semierect varieties Empire and strains of Empire origin derived from old naturalized stands. The second group is made up of varieties derived largely from more recently introduced European seed stocks. These are Cascade, Granger, Douglas, Mansfield, Tana, and Viking and are essentially erect-growing with somewhat coarse stems, and are similar in many respects to alfalfa.

Stands of the Empire type persist for many years even under continuous, close grazing when once well established in the more northern areas. Some seed is produced each year and reseeding is a factor in maintaining stands. Seedling plants generally lack vigor. Thin, unproductive stands frequently result from new

seedlings, due in part to the loss of seedlings through severe competition with weeds and other species. Recovery is slow after cutting for seed or hay, with resultant low aftermath production.

The erect-growing varieties are best suited for hay or rotational pastures. Because of their growth habit, plants may be completely defoliated by the grazing animal. Repeated defoliation under continuous grazing weakens the plants, making them susceptible to prevailing crown and root rots, winter injury, and adverse environmental conditions. Good results have been obtained under systems of rotational or deferred grazing. It is possible that as further studies are made, some of these erect varieties may prove to be more persistent and productive than others under grazing.

The erect varieties are superior to the Empire types in seedling vigor and can be established with greater ease. However, even these varieties are lacking in seedling vigor as compared with alfalfa, red clover, and many other forage plants.

A high percentage of the trefoil seed produced may be lost in the harvesting operation. At relatively low humidity, seed pods may dehisce as they mature, making it very difficult to harvest satisfactory quantities of seed. All the seed does not mature at the same time; flowers, green and purple pods, and dehisced pods can usually be found on the same plant as the pods begin to mature. These characteristics are largely responsible for generally unprofitable seed yields and usually high seed prices. Peacock and Wilsie (*29*) reported a 17-percent reduction in pod dehiscence through one cycle of selection. The possibility of developing varieties having relatively indehiscent pods appears promising. Also, the development of varieties with essentially indehiscent pods through interspecific hybridization is a possibility since some other *Lotus* species possess this character.

A complex of crown- and root-rotting organisms attack, and under some conditions seriously reduce trefoil stands. Plant losses from these diseases are most noticeable at the more southern locations of the trefoil region. A summary of plant losses within many introductions and varieties at Beltsville, Md., from 1952 to 1958, reveals that two-thirds of the plants are lost by the end of the second year after seeding. Slight to serious plant losses partially caused by root rots have been reported from various areas in the Central and North Central States. Plant losses in the Pacific Coast areas from diseases have been low.

To date foliar diseases have not been particularly severe on birdsfoot trefoil. Graham (*13*) reported that a species of *Stemphylium* on birdsfoot trefoil in the Northeast has been causing significant leaf and stem losses. Foliar diseases may become severe as the acreage of the crop expands.

Winter hardiness is important in the northern tier of States. In Minnesota, Schmidt and Thomas (*35*) reported severe winterkilling of Cascade, Granger, Oregon narrowleaf, and imported seed lots from France and Italy. Stand losses due to winter injury in Empire and Viking were not severe.

ESTABLISHMENT

The occurrence from time to time of unsatisfactory stands of trefoil in seedings has been one of the factors responsible for slow acceptance of the species. Seedling plants of trefoil are less vigorous than those of alfalfa or red clover. Competition with nurse crops, grasses, and weeds often causes poor stands and unproductive seedlings that later succumb to winterkilling or disease. Good stands depend upon seed quality, fertilization, seedbed preparation, inoculation, choosing the proper time, depth, and rate of seeding, and weed control.

Seed Quality

Varying amounts of large to small and plump to shriveled seed are found in most trefoil seed stocks. Good quality seed should be plump, relatively free from badly shriveled seed, and test high in germination. In the trefoil program at Beltsville, Md., many seed stocks have been tested for seedling vigor. Results of these tests consistently show that, with few exceptions, the large plump seeds produce the most vigorous seedlings. Highly significant positive correlations exist between weight of seed and height and weight of young seedling plants.

Fertilization

Birdsfoot is similar to red clover in its lime and fertilizer requirements. Lime is needed on acid soils. Phosphate is generally needed on less fertile soils, whereas potash is needed in many areas. When little is known of the fertilizer needs of a trefoil field, soil samples should be taken and analyzed for lime, phosphate, and potassium needs. Apply lime and fertilizer as recommended from soils tests.

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Seedbed Preparation

Trefoil seedings generally fail when made on grass sod without any seedbed preparation. A fine, firm seedbed is necessary. Where land is plowed, it should be done well in advance of seeding to permit rains or irrigation to settle the seedbed. In the final preparation the field may be disked, harrowed, and rolled or cultipacked before seeding. The preparation required varies with the kind of soil, its moisture content, and the season of the year. Delay seeding until a satisfactory seedbed can be prepared.

Inoculation of Seed

Since the trefoils are new to many areas, the seed should be inoculated. Poor or no inoculation has resulted in stand failures in some areas. The bacteria that inoculate common legumes such as alfalfa and red clover, will not inoculate the trefoil species. Specific trefoil inoculum is required. Strains of bacteria that inoculate birdsfoot and narrowleaf trefoil may not be effective for big trefoil (*10*). In seeding any of the trefoil species, be sure to purchase the proper inoculum. Follow the instructions printed on the inoculum container.

Seeding

After a fine, firm seedbed has been prepared any of several different methods may be used in seeding trefoil. Band seeding or drilling has given satisfactory stands in many areas. In band seeding, fertilizer is drilled in bands 1½ to 2 inches deep and the seed dropped above the fertilizer. The seed is covered with a packer wheel attached to the drill or by rolling the field with a corrugated roller. Seeding with a cultipacker seeder also gives good stands. Another method is to broadcast the seed with a cyclone seeder and cover with a corrugated roller. More uniform stands usually result from drilling.

Cover the seed to a depth of ⅛ to ¼ inch only. Do not cover too deeply.

Early spring seedings are generally most successful in the central and northern parts of the United States. The actual date of seeding varies from late March in the southern part of this region to mid-June in the North. Fall or February seedings are recommended in California (*30*). In Oregon (*18*), big trefoil is seeded in March, whereas fall seedings are preferred in Florida (*41*).

Four to six pounds of good quality birdsfoot and narrowleaf trefoil seed per acre should give good results. Two or three pounds of big trefoil seed per acre is enough for good stands. Seed stocks containing a high percentage of hard seed should be scarified before seeding.

Weed Control[10]

New Seedings

Trefoil seedlings grow slowly and furnish little competition to rapidly growing weeds. Too often weeds soon overtop the trefoil seedlings. Seeding oats as a nurse crop to aid in controlling weeds is a questionable practice (*4, 21, 36*). A nurse crop, like weeds, will compete with seedling plants for light, moisture, and nutrients. Where there is a nurse crop or where weedy grasses are allowed to grow unchecked, many of the young trefoil plants may be killed or will be weak going into the winter season. Winter injury of weak plants is likely to be heavy, resulting in thin, unproductive stands. If a nurse crop of oats is used, it should be seeded at not more than 1½ bushels per acre and either grazed off or cut early for hay.

Where upright, broad-leaved weeds, such as pigweed and ragweed, present a problem, they may be partially controlled by mowing them close to the ground after they have reached a height of 10 to 15 inches. When mowing is delayed to this stage of growth, considerable effects of competition have already occurred, but earlier mowing causes excessive lateral branching of the weeds and gives poor control. Repeated mowings are necessary to prevent weeds from forming a canopy over trefoil. Mowing sets back the trefoil plants but the benefits of reduced competition partially offset this injury. The second and subsequent mowings should be at a height of 3 or 4 inches to reduce injury to the trefoil plants.

Grasses are more injurious to new seedings of birdsfoot trefoil than are the usual broad-leaved weeds. Where weed grasses such as foxtail, crabgrass, and fall panicum are present, they often provide severe competition to the young plants. Mowing is not effective for control of most grasses.

Where practical, weeds can be partially controlled by light grazing with cattle, which should be followed by mowing to remove ungrazed weeds. New seedings should not be grazed when soils are wet. Heavy grazing injures the stand on either wet or dry soils.

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[10] Prepared by D. L. Klingman, Crops Research Division, Agricultural Research Service.

Herbicides for Broad-leaved Weed Control

Use the amine salt of 4-(2,4-dichlorophenoxy)butyric acid (4-(2,4-DB))[11] at the rate of 1 to 2 pounds per acre for selective control of such weeds as ragweed, lambsquarters, pigweed, and mustard when they are still small. There will be slight stunting and curvature of the birdsfoot trefoil seedlings but they recover. Lespedeza, a serious competitor in new trefoil seedings in some areas, is not well controlled with 4-(2,4-DB) nor are the weed grasses. Other herbicides are required for their control. Ethyl *N*, *N*, di–*n*–propylthiolcarbamate (EPTC),[12] applied at the rate of 2 pounds per acre to the seedbed just before planting and incorporated in the surface 1 or 2 inches of soil by disking or harrowing, controls many of the broad-leaved weeds and all the annual grasses without injury to birdsfoot trefoil.

Dalapon Controls Grasses and Some Other Plants

The sodium salt of 2,2-dichloropropionic acid (dalapon) applied at the rate of 2 to 5 pounds per acre will kill the annual weed grasses and lespedeza and severely injure volunteer red clover, alsike clover, and Ladino clover, which are sometimes problems in trefoil seedings. A single treatment in the spring before weed grasses are over 3 inches high may give season-long control in the Northern States. Where crabgrass and other grasses continue to germinate during the summer, two or more treatments are required. In this case a spring treatment of dalapon followed with another about a month later, if more grasses have germinated, will usually control grasses for the full growing season.

At the recommended rates of treatment, dalapon will not injure trefoil significantly at any stage of growth. Trefoil is slightly stunted at the time of treatment but quickly recovers and benefits from the weed control.

[11] 4-(2,4-DB) and dalapon cannot be recommended (as of July 25, 1960) for use on legume seedlings to be grazed by livestock, since evidence has not been developed to prove that they will leave no residue and/or tolerances have not been set under Public Law 518. They can be used on seed production fields.

[12] Trefoil should not be grazed within 60 days after treatment.

Combination Treatments Are Usually More Successful

Usually broad-leaved weeds and weed grasses occur together as problems in new seedings of trefoil. Combinations of treatments are needed for their control. Applications of 4-(2,4-DB) at the rate of 1 to 2 pounds per acre plus 2 to 5 pounds of dalapon per acre should be made when the broad-leaved weeds still are small. Later in the season if weeds again become a problem, these herbicides can be applied singly or together, depending on the weed infestation. Dalapon combined with mowing is also effective for control of grasses and broad-leaved weeds when it is used as suggested in the section entitled "Dalapon Controls Grasses and Some Other Plants."

Weed Control for Seed Production

Weed grasses should be controlled in trefoil seed-production fields. Dalapon is effective when 2 to 5 pounds per acre is applied before the trefoil exceeds 6 inches in height. Later treatments may reduce seed production.

Where bedstraw is a problem in seed fields, spot spraying with 2-(2,4,5-trichlorophenoxy) propionic acid (silvex) in the early spring at the rate of 2 to 3 pounds per acre is effective, but the trefoil seed production will be greatly reduced for a season in the sprayed spots.

Other legumes in trefoil may be controlled with applications of one-half pound of silvex per acre. Treatments in the spring cause little injury to the trefoil.

Where broad-leaved weeds such as ragweed, pigweed, and lambsquarters are a problem in seed fields, apply sprays containing 1 pound per acre of an amine salt formulation of 4-(2,4-DB) early in the spring while weeds are small.

On old established stands in the humid Pacific Coast region, the application of 1½ to 2½ pounds of 3-(3,4-dichlorophenyl)-1,1-dimethylurea (diuron) per acre in the fall gives excellent winter-annual weed control and often controls those germinating in the following spring.

TREFOIL IN MIXTURES

More uniform all-season production may be expected from mixtures of trefoil and a single grass specie. Including a grass results in the formation of a sod that permits grazing during wet conditions with little injury from trampling. In pure stands trefoil tends to lodge, reducing hay and seed yields. The presence of a grass reduces lodging. Simple mixtures of a grass with 4 to 6 pounds of trefoil seed per acre

are generally successful. Attempts to establish trefoil in mixtures with other legumes and with more than one kind of grass usually results in poor stands of trefoil.

Timothy is less competitive to trefoil in establishment than most of the other grasses. Seeding a mixture of 3 to 4 pounds of timothy and 4 to 6 pounds of trefoil per acre is a common practice in the Northeastern and North Central States for hay and pasture.

In the more northern part of the Bluegrass region, a mixture of Kentucky bluegrass and trefoil is successfully used for permanent pasture. In establishing pastures on land which has been in row crops, 4 to 5 pounds of Kentucky bluegrass seed and 4 to 6 pounds of birdsfoot trefoil seed is sufficient for good stands.

In areas where orchardgrass, bromegrass, and tall fescue are well adapted they provide severe competition to seedling plants of trefoil. Productive pastures of mixtures of trefoil with these grasses have been secured. Seeding rates of the grasses are reduced to 4 to 5 pounds per acre in a mixture with 6 pounds of Viking, Granger, Mansfield, and other varieties of birdsfoot trefoil having good seedling vigor.

In the Pacific Northwest good results have been obtained by seeding trefoil in alternate rows with a grass.

Meadow foxtail in association with narrowleaf or big trefoil has been successfully used in the Northwest.

Trefoil is frequently seeded on old pasture sods which have been renovated either by shallow plowing or by disking several times. It is usually not necessary to reseed the grass. This is particularly true with Kentucky bluegrass and on sods where timothy predominates.

COMPOSITION AND NUTRITIVE VALUE

Many analyses have been made on birdsfoot trefoil hay. Its composition is similar to that of alfalfa. At Beltsville, Md., protein analyses were made on a large number of plots of birdsfoot trefoil and of alfalfa cut at comparable stages of growth. The average protein content for two cuttings of all plots was 16.7 percent for birdsfoot and 17.4 percent for alfalfa hay. MacDonald (*24*) reported a decreasing protein content with maturity, ranging from 28 percent for young immature growth to 9 percent in plants having mature seed pods. He reported a somewhat higher percentage of lignin in an erect-growing European type than in New York common (Empire type).

Loosli and others (*23*) found that milk from cows fed birdsfoot trefoil hay had excellent keeping qualities and contained more carotene, vitamin A, and tocopherol than milk from cows receiving Ladino clover and timothy hay.

In studies at the Indiana Agricultural Experiment Station at Lafayette [13] on the carotene content of a number of legume-grass associations, the carotene content of birdsfoot trefoil was higher than that of alfalfa and Ladino clover whether grown alone or in mixture with grass, and remained so throughout the season. Plummer (*32*) found that carotene losses in rapid drying of green forage of comparable cuttings of birdsfoot trefoil, alfalfa, and Ladino clover were 11, 22, and 48 percent, respectively. Studies by the Animal Husbandry Division, at Beltsville, Md.,[14] indicate that the average percentage loss of carotene in drying at 60° F. was only 1.3 percent for birdsfoot trefoil. Under the same conditions, two samples of Ladino clover and one sample of alfalfa hay lost 38.2 and 19.1 percent of carotene, respectively.

Various reports indicate that the trefoils are somewhat less palatable than other commonly used legumes. In general, when animals become accustomed to trefoil forage they consume it readily. Sericea lespedeza is a legume of low palatability, partly because of the high tannin content of the leaves. In preliminary tannin analyses of leaves of various trefoil species, varying but relatively small amounts of tannin were found. The highest—5.5 percent—was found in big trefoil and European broadleaf. The leaves of Empire and the narrowleaf species contained less tannin.

Indications are that the composition of trefoil is different from that of many other legumes. Much work is needed on the composition of the trefoil species as related to nutritional values. Trefoil herbage seems to be nonbloating, and this also needs more study.

[13] BURGER, O. J. INFLUENCE OF SPECIES AND VARIETY INTERACTION UPON THE CAROTENE CONTENT OF THE COMPONENTS OF GRASS-LEGUME MIXTURES. 1947. (Thesis, M.S., Purdue Univ., Lafayette, Ind.)

BURGER, O. J., HAUGE, S. M., and MOTT, G. O. EFFECT OF GRASS-LEGUME ASSOCIATIONS UPON THE CAROTENE CONTENT OF VARIOUS LEGUME-GRASS COMPONENTS. 1947. (Paper presented at Agronomy Society Meeting, Cincinnati, Ohio, Nov. 1947.)

[14] Agricultural Research Service, 1953–54. (Unpublished.)

UTILIZATION

Where birdsfoot trefoil is well adapted it is a very desirable long-lived perennial legume for permanent pastures. It can also be harvested for hay and silage and is valuable as a seed crop. Because of the nonbloating character of this crop, there is no need for growing a grass with it solely for bloat control.

Grazing Management

The varieties of birdsfoot trefoil vary in their ability to persist under different systems of grazing.

The erect-growing varieties, Cascade, Granger, Viking, Mansfield, Douglas, and imported stock from Europe, can be completely defoliated by the grazing animal. These varieties are similar to alfalfa in their response to grazing. Continued close grazing or overgrazing greatly reduces the vigor of the plants and if carried on too long the weakened plants die, leaving thin, unproductive stands. Continuously grazed pastures should be so managed as to leave a minimum of 4 inches of growth on the plants at all times.

Rotational grazing or a system of supplemental grazing is preferable for these erect-growing varieties. Fields may be divided into three or more pastures and grazed in rotation. In grazing each of the pastures, 2 to 4 inches of growth should be left on the plants at the end of each grazing period. During periods when birdsfoot is growing rapidly one or more pastures may be cut for hay.

Empire and locally adapted strains originating from Empire are less affected by close grazing due to their low or more prostrate type of growth. Cattle rarely graze off all top growth from these varieties; the leafy stems close to the ground remain ungrazed. These stems provide nutrients for continued plant growth. In addition, they produce seed, which is important in maintaining stands through natural reseeding.

Many stands of Empire birdsfoot trefoil are continuously grazed, particularly by beef animals. However, rotational grazing may be desirable, depending upon the kind and class of livestock utilizing the pastures. Sheep are more selective in their grazing habits and may overgraze birdsfoot trefoil under continuous grazing. Grazing three or more fields in rotation or using some form of deferred grazing when other pasturage is available seems to be the most desirable program for sheep. High-producing dairy cows benefit from the more nutritive forage provided by rotational grazing.

Both narrowleaf and big trefoil are spreading, low-growing plants. In the West the grazing management for these species is very similar to that for Empire and strains derived from Empire.

Hay and Silage

Birdsfoot, narrowleaf, and big trefoil are not usually grown for hay alone. However, in the utilization of the trefoils for pasture it is frequently desirable to take a cutting for hay or silage. Where rotational grazing is practiced, the first growth on the last pasture grazed in the first grazing round may become quite heavy and tall. In grazing, a large part of this tall growth is lost by trampling and fouling with manure. Cutting a part of the acreage for hay or silage gives more profitable utilization of the crop.

The trefoils make good quality hay. In general, they can be cut as they come into bloom. Cutting should be done after the dew dries from the plants. High-quality hay is leafy hay. All raking, stacking, or baling operations should be so handled as to preserve maximum percentages of leaves. Under good drying conditions, the crop should be windrowed or raked 4 to 6 hours after cutting. The leaves will become brittle and a high percentage of them will be lost if raking is delayed. Windrow-cured hay may be baled from the windrow or stacked, if the proper equipment is available.

Preliminary tests have shown that the trefoils make good silage. For specific information on making trefoil silage consult your county agent or write to your State agricultural experiment station.

SEED PRODUCTION

Seed yields of birdsfoot trefoil are usually low compared with other legumes. Satisfactory yields of trefoil seed are difficult to secure. Various reports show yields of 40 to 100 pounds per acre as common in the North Central and Northern States. Top yields of 300 pounds per acre have been reported. Peterson and others (*30*) report California seed yields as ranging from less than 100 to 425 pounds per acre. The low seed yields make seeding costs high and have limited the use of this legume. Low yields are due primarily to the tendency of pods to dehisce as they mature. Seed harvesting is further complicated by

the fact that mature and green pods are found on most plants throughout the seed-production cycle since the plants flower over a long period of time. Considerable experience is required to determine when to harvest the seed crop.

Statistics on total seed production of trefoil in the United States are not available. Important seed-producing areas are indicated in the report by Hill (*16*) on amounts of certified seed produced in 1958. A total of slightly less than 1 million pounds of seed of all classes—foundation, registered, and certified—was produced in 1958. New York and Vermont produced 63 percent, Minnesota and North Dakota 16 percent, and California and Oregon 21 percent of the total certified seed crop in 1958. Many of the adjoining States produce some seed. Wiggans and others (*42*) reported a production of 40,000 pounds in Iowa in 1955.

Considerable birdsfoot trefoil seed is imported from Europe, primarily from France and Italy. According to Agricultural Statistics of the U.S. Department of Agriculture, 893,000 pounds of trefoil seed was imported annually during the 10-year period 1948–57.

Pollinators

Practically all trefoil seed is produced from cross fertilization of the flowers by various insect pollinators. Good seed yields are produced only when adequate numbers of pollinating insects are present. Honey bees and various species of wild bees, including bumblebees, are effective pollinators of trefoil flowers. Honey bees are generally relied upon, since the numbers necessary for effective pollination can be supplied. Studies by Morse (*28*) in New York showed that an average of one bee per square yard is adequate to pollinate all flowers. On this basis one average-sized colony of bees could be relied upon to pollinate the flowers of an acre of trefoil.

Pure Stands versus Grass Mixtures

Studies have been conducted in various areas showing the effect on seed production of seeding various grasses in mixture with trefoil. MacDonald (*24*) concluded that severe lodging greatly reduced seed yields and among the grasses tested, trefoil, in association with timothy, appeared to have some value in increasing seed yields. In central Iowa, Anderson and Metcalfe (*2*) reported significantly greater seed yields of trefoil when grown in association with Kentucky bluegrass, orchardgrass, or timothy, than when grown in pure stands. In their tests the highest yields were obtained fro[redacted]ture. Birdsfoot trefoil in pure stands was rated as 69 percent lodged for the 2 years of the test. The average lodging of trefoil when grown with Kentucky bluegrass, orchardgrass, and timothy was 6.5, 21.0, and 17.8 percent, respectively.

After a 2-year study, Schoth and Rampton [15] found that grasses were of little value in increasing trefoil seed yields. In California, Peterson and others (*30*) recommended only pure stands of birdsfoot trefoil for seed production under irrigation. Additional studies on this point are needed, but present evidence indicates that severe lodging in birdsfoot trefoil reduces seed yields in the North Central and Eastern States. When lodging is a problem it may be reduced by planting birdsfoot trefoil in mixture with Kentucky bluegrass or timothy, thereby increasing seed yields. Where no lodging occurs there is no advantage in mixtures. For information on weed control for seed production, see page 9.

Harvesting the Seed Crop

The first crop of trefoil is usually harvested for seed. Two seed crops may be possible under irrigation in some areas of the West. Much lower seed yields were secured from the second crop in Iowa (*2*) and New York (*23*) when the first crop was taken for hay.

Time of Harvest

Seed fields should be observed frequently to determine when to harvest the crop. From flowering to pod maturity requires approximately 30 days. Warm, dry weather during this period hastens maturity from 2 to 4 days, whereas cool, moist weather delays maturity of the seed. The crop should be harvested when a high percentage of the pods are light brown to brown and before appreciable shattering occurs. The crop should be mowed before the dew is off to reduce shattering as much as possible. The use of a mower with swather attachment to the cutter bar is a widely accepted practice. The crop should be combined as soon as it is dry enough to thresh. If it is dry and warm with correspondingly low humidity, 8 hours in the swath may be all that can be allowed before combining. Under more humid conditions a drying time of 24 to 48 hours may be necessary before combining the crop.

[15] Schoth, H. A., and Rampton, H. H., Crops Research Division, Agricultural Research Service, in cooperation with the Oregon Agricultural Experiment Station, Corvallis. 1949–50. (Unpublished data.)

Direct Combining

Direct combining of birdsfoot trefoil without defoliants is practicable to a limited extent in some areas. Where the crop is not lodged, most of the seed pods will be in the upper parts of the plants and fair to good seed yields can be obtained. Under these conditions the speed of the combine must necessarily be slow, thus limiting the acreage that can be harvested per combine. Under most conditions the rank, leafy growth of the crop makes direct combining a slow and difficult process.

Direct Combining With Defoliants

Chemical defoliants can be successfully used (*20, 29, 41*) to defoliate or partially defoliate the green trefoil plants. When sprayed on the green plants, the defoliant will cause some of the leaves to drop and others to wilt, thereby reducing the moisture content of the plant to the point where it may be combined before seed shattering becomes severe. The time between defoliation and combining will depend on the kind and concentration of defoliant used and on the weather. Growers interested in defoliants should consult their State agricultural experiment stations for specific information.

Freshly combined seed contains various amounts of green stems, pods, leaves, and other foreign matter, all relatively high in moisture. The seed also may contain green and partially dried seed. The combined seed should be screened immediately to remove wet trash and then spread out to dry.

After harvesting, trefoil seed should be watched carefully to prevent heating, molding, and loss of germination, as the moisture content may be high in the seed itself and, under some circumstances, in the inert material mixed with it. It is usually advisable to scalp off most of the inert material before storing. Store the seed in small lots until it is dry enough to prevent heating.

The separation of trefoil seed from those of other small seeded legumes such as white and alsike clover is rather difficult. On the Pacific Coast the removal of hop clover seed is very difficult.

Hard Seed

Seed of birdsfoot trefoil normally contains a high percentage of hard seed. The seed coat of hard seed is impermeable to water and the germination of such seed is greatly retarded. Hard seeds may eventually germinate but they are of little value in securing good stands. Seed lots containing over 15 percent of hard seed should be scarified before seeding. The amount of scarification necessary to reduce the hard seed content should be carefully determined. Hughes and MacDonald (*19*), reporting on studies in Iowa, showed that excessive scarification injures the seed, causing lower germination and seedling emergence. Seed viability is generally reduced when it is mechanically scarified and then stored. Wood (*43*) suggested the use of infrared heat treatment for scarification to reduce the number of hard seeds without loss of viability in storage.

DISEASES[16]

The most destructive disease of big and birdsfoot trefoil is caused by the soil-inhabiting fungus *Rhizoctonia solani* Kuehn, which incites not only foliar blight but crown and root rots as well. It is most destructive in dense stands during hot, humid weather from May to September. The disease is less prevalent at higher elevations, possibly because of cooler nights. Damage occurs in patches and the fungus sometimes kills up to 90 percent of the plants in an affected area.

Rhizoctonia solani usually attacks the lower leaves first and mycelium of the fungus rapidly overruns foliage and stems. The fungus sometimes attacks so rapidly that plants are killed within a few days. Affected leaves wilt, turn gray, and become matted to stems and petioles. New shoots are killed and large gray- to straw-colored lesions with irregular reddish-brown margins are formed on stems. The lesions often girdle the stems, causing death of the foliage. All varieties of big and birdsfoot trefoils are susceptible. The disease can be controlled to some extent by harvesting the crop at the earliest sign of infection.

Next to the blight caused by *Rhizoctonia solani*, the crown- and root-rot fungi are most destructive. Fungi associated with root rots include *Fusarium* spp., *Verticillium* spp., *Leptodiscus terrestris* Gerdemann, and *Sclerotinia trifoliorum* Eriks. Limited observations indicate that birdsfoot trefoil is more heavily damaged by root-rot fungi than is big trefoil. These fungi frequently occur in localized areas and may be serious in some fields. They are most prevalent in heavier, wetter soils but sometimes occur in any soil

[16] Prepared by K. W. Kreitlow, Crops Research Division, Agricultural Research Service.

in a wet season. Root-rot fungi attack plants at any stage of growth, but they appear to be most destructive on plants one or more years old. With the exception of *S. trifoliorum*, the above fungi are mostly associated with summer dying.

Sclerotinia trifoliorum attacks plants mainly during late winter and early spring. The fungus causes a watery soft rot of the crown and upper taproot. The entire plant is usually killed and tufts of white, cottony mycelium can sometimes be seen at or near the crown. Later the fungus forms gray to black round, or oblong, sclerotia from $\frac{1}{16}$- to $\frac{1}{4}$-inch in size. These are usually found attached to the outside of the crown or taproot or embedded in diseased tissue.

Leptodiscus terrestris is sometimes associated with root rot of birdsfoot trefoil. It is characterized by decay of the crown and taproot. The advancing margin of decay is black or sometimes reddish brown and many tiny sclerotia are present in decayed tissue. Root tissues affected by *L. terrestris* are usually dry and shredded. The disease is sometimes difficult to distinguish from root and crown rot caused by *Rhizoctonia solani*. Also, the disease is frequently associated with other root-rotting organisms.

There are no specific symptoms associated with infections by species of *Fusarium* and *Verticillium*. In most cases these fungi are found in association with *R. solani* and *L. terrestris*. Undoubtedly, the several organisms acting in association attack crowns and roots under different environmental conditions and possibly do more damage collectively than they do individually.

The southern blight fungus, *Sclerotium rolfsii* Sacc., sometimes attacks plants of big and birdsfoot trefoil during warm, wet weather. This fungus infects plants singly or in groups at or near the soil line, producing grayish-tan lesions that enlarge and girdle the stems. Infected plants usually wilt in 3 or 4 days. Leaves of diseased plants often turn grayish green and then cinnamon brown and resemble foliage of plants that are mechanically girdled. The foliar blight and stem girdling from *S. rolfsii* sometimes resembles symptoms resulting from infection by *Rhizoctonia solani*. Generally no reddish-brown margin borders the lesions incited by *S. rolfsii*. Creamy-white to reddish-brown, round sclerotia 1 to 2 mm. in diameter form on dead stems and further characterize the disease. Since the disease occurs sporadically, no effort has been made to develop resistant varieties.

In the Southeast big and birdsfoot trefoil are susceptible to attack by four species of root-knot nematodes. Nematode infection induces formation of swellings or galls on the roots. These sometimes resemble the swellings of root-knot nematode infected plants become stunted and yield poorly. No varieties presently grown are resistant.

Aside from foliar blight caused by *Rhizoctonia solani*, the most prevalent foliar disease of birdsfoot trefoil (leaf spot and stem canker) is caused by *Stemphylium loti* Graham. This disease generally occurs throughout the growing season wherever birdsfoot trefoil is cultivated. Principal damage is from defoliation. Formation of one lesion may cause a leaflet to drop prematurely. *S. loti* produces reddish-brown circular spots on leaflets and copper-colored cankers on stems of birdsfoot trefoil. Spots range from pinpoint to 5 mm. in diameter and often are concentrically zoned. The centers of mature lesions are usually lighter than the surrounding borders. The fungus survives on host tissue and in association with seed. When seedborne, the fungus kills young seedlings. No resistant varieties are known at present.

A foliar blight of stems and leaves of birdsfoot trefoil caused by *Fusarium roseum* Lk. has been reported from New York. Infection induces bleaching and wilting of the shoot tips which often involves the entire plant. Symptoms often start as apical yellowing followed by bleaching of blighted shoots. In some plants the blight progresses from the tips of the shoots to the crown of the plant. In others it becomes arrested and only stem tips wither and die. Affected plants have been observed in seedling stands and in those 2 to 5 years old. Blighted plants are conspicuous among the normal dark green, vigorously growing plants. The disease occurs sporadically and seldom involves many plants. When first seen, the symptoms somewhat resemble those of blight caused by *Rhizoctonia solani*. No resistant varieties are known.

In the Southeast big trefoil is sometimes attacked by the blackpatch fungus *Rhizoctonia leguminicola* Gough & Elliott. The fungus is most prevalent during warm weather, causing the leaflets to blight and the stems to turn dusty green, darkening to brown. The coarse, black fungus mycelium can nearly always be seen on leaves and stems without the aid of a hand lens.

A leaf spot caused by the fungus *Cercospora loti* Hollós has been found defoliating plants of big trefoil in Maryland, Georgia, and Florida. The disease occurs mostly in the spring but can be found on older plants throughout the growing season. Lesions produced on leaves are usually circular, 3 to 5 mm. in diameter, and olive gray to reddish brown when mature. Diseased leaflets shrivel and drop off at the slightest touch. No resistant varieties are available.

This leaf-spot fungus has not been found on birdsfoot trefoil in the field. However, artificial infection in the greenhouse has shown that birdsfoot trefoil is mildly susceptible to it.

INSECTS INJURIOUS TO TREFOIL[17]

Several species of insects attack and injure birdsfoot trefoil. The meadow spittlebug (*Philaenus spumarius* (L.)) is probably the most important pest in the Midwest and East. Nymphs of this species, protected by a mass of spittle, suck the sap from stems and leaves, causing a rosetting of the foliage and stunting of the plants. Nymphs and adults of the potato leafhopper (*Empoasca fabae* (Harris)) also suck the plant juices and cause the foliage to turn red or yellow, beginning at the tips of the leaflets. The alfalfa plant bug (*Adelphocoris lineolatus* (Goeze)) and the rapid plant bug (*A. rapidus* (Say)) also suck plant sap. Lygus bugs (*Lygus* spp.) may cause a blasting of buds, floret blight, and loss of seed. Stink bugs, grasshoppers, cutworms, and seed chalcids are pests at times.

For information regarding control of insects on trefoil, consult your county agent, State agricultural experiment station, or write to the U.S. Department of Agriculture, Washington 25, D.C.

[17] Contributed by the Entomology Research Division, Agricultural Research Service.

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