

OBSERVATIONS CONCERNING CLOVER DISEASES.¹

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Red clover has long occupied an important place in the world's agriculture. Of late years, the growing of clover has met increasing difficulties in some sections of the United States. While this is apparently due to a number of different causes,² disease is one of the important factors. The following observations concerning clover diseases were made in the vicinity of Lafayette, Indiana, during the period 1920-1927 while studying the rusts and mildew of clovers.

Anthracnose. This is probably one of the most important³ of the clover diseases in the United States. *Gleosporium caulivorum* and *Colletotrichum trifolii* both produce the condition known as anthracnose. Pieters and Monteith (*l.c.* 3) state that the *Colletotrichum* is the most prevalent in the southern part of the clover belt while *Gleosporium* is the most important northward. Monteith⁴ has found that the former is favored by high temperatures while the latter develops at lower temperatures, in keeping with their distribution. Both of these fungi have been found at Lafayette. In 1926, *Gleosporium* was the most prevalent, while this season (1927) *Colletotrichum* is very abundant.

The symptoms produced by both pathogens are very similar and consequently the two are not often distinguished. In the late spring and early summer, the disease is usually first noted as small dark lesions on the stems, petioles, peduncles, etc. The girdling of these causes a wilting and results in a bending of the petioles, etc., in a characteristic manner (Fig. 1). This may result in considerable defoliation even in the first cutting. When anthracnose is severe, especially during late summer and autumn, the tops are completely killed and the crown invaded and rotted. The root oftentimes remains in good condition for some time. Many plants which are not killed in the fall enter the winter in a weakened condition and die before spring so that good stands of clover may show only scattered plants in the spring.

In June, 1926, there was a moderate amount of anthracnose in the variety plots due to *Gleosporium*. French (38,631), Ital'an (2,424) and

¹ Contribution from the Department of Botany, Purdue University Agricultural Experiment Station.

² Pieters, A. J. Clover Failure. U. S. Dept. Agr. Farmer's Bul. 1365. 1924.

³ Pieters, A. J. and Monteith, J. Anthracnose as a Cause of Red Clover Failure in the Southern Part of the Red Clover Belt. U. S. Dept. Agr. Farmer's Bul. 1510. 1926.

⁴ Monteith, J. *Colletotrichum trifolii* and *Gleosporium caulivorum* on Clover (Abstract). Phytopath. 16:71. 1926.

Altaswede were moderately infected while Indiana, Oregon (2,474) several French, Hungarian, Roumanian and Polish strains showed slight infection. A Chilean strain and most of the North American strains showed only a trace of infection.

In the autumn of 1927 considerable infection from *Colletotrichum* developed in the variety plots and by November several of the strains showed considerable crown infection and dead plants. The most severely infected were both North American strains, Oregon (14,266) and Idaho (14,120). Several Idaho, a Michigan, Wisconsin, Utah, Indiana, German and Italian strain were moderately infected. A number of French, a German, Hungarian, Polish, Russian, Roumanian, Chilean, Idaho, Colorado, Indiana, Ohio, Michigan and Tennessee strain showed a slight



Fig. 1.—Anthracnose of red clover. The branch to the left showing characteristic bent leaflets and peduncle. The two plants to the right showing dead tops and rotted crown with the tap roots still in good condition.

amount of infection. Infection was not, however, uniformly distributed.

Monteith⁵ states that clover from seed raised in southern Europe is more susceptible to injury by anthracnose (*Colletotrichum trifolii* and *Gleosporium caulivorum*) than clover from North American seed. Pieters⁶ states that *Colletotrichum* was most severe at Washington, D. C., on plots from Italian and German seed. Bohemian, English, French, Polish, Oregon, Idaho and Minnesota strains were heavily infected. Chilean showed somewhat less injury. The Tennessee resistant strain and a strain from southwestern Ohio showed approximately no injury. Hesler,⁷ under conditions of moderate infection, found Roumanian, Chilean and Wisconsin strains moderately infected and Italian, French, Hungarian

⁵ Monteith, J. Relative Susceptibility of Red Clover to Anthracnose. (Abstract.) *Phytopath.* 14:62-63. 1921.

⁶ Pieters, A. J. Symposium—The Forage Problem. *Jour. Amer. Soc. Agron.* 16:153-238. 1924.

⁷ Hesler, L. R. Relative Susceptibility of Red Clover at Wooster, Ohio. *Plant Disease Reporter* 9:92-93. 1925.

and a number of North American strains slightly infected in Ohio. Adams⁸ states that a French strain showed abundant infection, while Italian, Minnesota and Oregon were moderately infected and English, Roumanian, Chilean, Ohio and Michigan showed slight infection by *Gleosporium* in Delaware.

That clover can be developed resistant to *Colletotrichum* has been demonstrated by Bain and Essary.⁹ It is not certain whether this strain will show sufficient resistance and adaptability in the northern part of the clover belt. However, their results indicate that resistant selections can be developed from adapted North American strains.

Powdery Mildew. *Erysiphe polygoni* first attracted attention in this country in 1922. Since that time it has been more or less prevalent in Indiana and is apparently established as one of the widespread diseases of red clover. The alarm with which its appearance was greeted has decreased since it has not resulted in marked damage. It covers the leaves with a dense white mat of mycelium and spores. Mildew probably greatly reduces the photosynthesis of the leaves and results in their premature death. This not only causes a loss of a valuable portion of the hay but tends to weaken the plant and may in the case of young seedlings reduce the chances of overwintering.

As has been previously noted¹⁰ resistant individuals are more or less prevalent in all strains of red clover. They occur in a greater proportion in those strains of European origin and oftentimes North American strains can be distinguished from European by their more generally mildewed appearance. The following notes illustrate this difference.

Relative Susceptibility in 1923

<i>Severe</i>	<i>Moderate</i>	<i>Slight</i>
Oregon 2148	Chilean 2055	Chilean 2217
Idaho 2220	Chilean 2203	Chilean 2142
N. Dakota 1809	Australian 2156	English 2253
S. Dakota 2019	English 43592	Polish 54905
Ohio 2020	N. German 2218	Bohemian 2121
Ohio 2135	French 55502	Hungarian 2219
Tenn. 2138	Italian 54492	Riga 55002
Canadian 2301		Hamburg 2214
		French 2213, 54456, 54493, 2202, 56182
		Italian 54779, 1819, 2212

⁸ Adams, J. T. Relative Susceptibility of Red Clover Strains to Disease as Observed in Delaware, 1925. *Plant Disease Reporter Supp.* 48:368. 1926.

⁹ Bain, S. M. and Essary, S. H. Selection for Disease Resistant Clover. *Bull. Tenn. Sta.* 75, 10 p. 1906.

¹⁰ Mains, E. B. Differences in Susceptibility of Clover to Powdery Mildew. *Proc. Ind. Acad. Sci.* 1922. 307-313. 1923.

Relative Susceptibility in 1924

<i>Severe</i>	<i>Moderate</i>	<i>Slight</i>
Oregon 2396	Chilean 2394	Altaswede
2397G	Hungarian 56441	Chilean 2403, 2217
2148	Bohemian 2307	N. Zealand 56795
Idaho 2407	Swiss 56896	English 2399E, 2399J
Minn. 2398	Italian 56880	German 2399L
Mich. 2399A		French 2399H, 2401
Tenn. 2138		Italian 2429, 2397
Canadian 2409		

Relative Susceptibility in 1927

<i>Severe</i>	<i>Moderate</i>	<i>Slight</i>
Wis. 14126	Oregon 14266	Italian 2688
Minn. 14116	Idaho (Several)	French 2509, 2584, 2683,
Colorado	Utah	2687, 66127
Mich. 14118	S. Ind.	German 2665, 2666
N. Indiana		Hungarian 2667
Ohio 14121		Roumanian 2661
Tenn. 14026		Russian 67990
		Polish 65965
		Chilean 2658

This difference in the relative susceptibility of North American and European strains has been noted by a number of different investigators in various parts of the country. Apparently all of the strains contain resistant plants so that it should be possible to breed a strain highly resistant to mildew. This would be more difficult than for anthracnose since the mildew susceptible plants are not eliminated by the disease.



Fig. 2—Powdery mildew of red clover. The leaves to the right from a plot dusted with sulphur and practically free from mildew. Those to the left from the undusted check and heavily mildewed.

Sulphur has long been known as a fungicide for powdery mildews. During the summer of 1927, heavily mildewed plots of red clover were given two dustings with finely ground sulphur. While mildew continued to develop on the undusted checks it was practically eliminated from the dusted plots (Fig. 2). If control of the disease can be shown to result in a great enough saving, methods of dusting with sulphur will probably be developed which will control the disease.



Fig. 3—Bacterial leaf spot. To the left branch showing infected leaves. To the right an infected leaflet enlarged.

Bacterial leaf spot. This disease is caused by *Bacterium trifoliorum*.¹¹ In the vicinity of Lafayette it was first noted causing heavy infection of red clover in the spring of 1925. It develops largely during the spring months. It first appears as small water soaked spots which darken as they increase in size. The bacterial exudate is oftentimes so abundant that it gives a dark varnished appearance to the infected portions (Fig. 3). As the disease progresses the infected areas dry

¹¹ Jones, L. R., Williamson, M. M., Wolf, F. A. and McCulloch, Lucia. Bacterial Leafspot of Clovers. Jour. Agr. Res. 25:471-490. 1923.

up and break away giving a ragged appearance to the leaves. In cases of heavy infection considerable defoliation may result. Its development is apparently favored by the low temperatures of the spring months and its principal damage in the vicinity of Lafayette has been confined to the first cutting.

In 1925 it was specially severe on Roumanian 2399, Swiss 56896 and Indiana strains. Moderate infection was noted on Italian, French, Hungarian, Bohemian, Latvian, German, English, Chilean, Idaho, Michigan, Indiana and Canadian strains. Certain Italian, New Zealand, Chilean, Oregon, Minnesota, Indiana and Canadian strains showed slight infection while only a trace was noted on Finnish (56870) and a strain of Canadian alsike was free from infection. The Indiana check plots showed a considerable variation in the amount of infection so it is questionable to what extent these notes represent differences in relative susceptibility.

In 1926 the bacterial leaf spot was again severe in the variety plots and the foreign strains as a group were more heavily infected than the North American; Italian (2424, 2429), French (2414, 58472), Hungarian (2413, 2415, 59300), Roumanian (2423), Polish (58857), Pomeranian (2447), English (61333, 61332) and Chilean being severely infected; French (58631, 58632, 59290), Central Europe (2426), Michigan (2501) and Indiana being moderately infected; Michigan (2477) and Canadian (2404, 2409) slightly infected and Oregon (2474), Idaho (2407), Minnesota (2476), Wisconsin (2410), Tennessee D. R. (2469) Ohio (2471) and Altaswede showing only a trace of infection.



Fig. 4—*Macrosporium* leaf spot of red clover. A moderately infected leaf at the left and a heavily infected leaf to the right.

Macrosporium leaf spot. The *Macrosporium* leaf spot of clover is due to *Macrosporium sarcinaeforme*. It causes brown spots on the leaf which are characterized by alternate concentric rings of light and dark color (Fig. 4). In cases of heavy infection, these spots coalesce and the entire leaf may be killed. At Lafayette it has been most abundant in late summer and fall. In August, 1923, certain strains of Italian, French, Chilean clovers showed moderate infection while other strains

from the same origin as well as North European and North American showed slight infection. In the fall of 1927 it was specially abundant. All plots were more or less infected. Italian (2688), Russian (67990), Polish (65965), Roumanian (2661), German (2666), Chilean (2658), Minnesota (14116) and Tennessee (14026) showing somewhat less infection than other French, German, Hungarian and North American strains. Adams (*l.c.* 8) noted but little difference between foreign and North American clovers in the amount of this leaf spot. Krakover¹² has noted uninfected plants of red clover in the midst of badly diseased plants and considers that the control of this disease will depend upon selection and breeding of resistant strains.

Rust. The rust of red clover, *Uromyces fallens* (*U. Trifolii* of some authors) is characterized by brown powdery pustules on the leaves (Fig. 5). When it is severe, it causes premature death of the leaves.



Fig. 5—Rust of red clover. The two leaves to the left from susceptible plants. The leaf to the right from a resistant plant.

This disease was severe at Lafayette in the autumn of 1920. Plots of Indiana, North Dakota (1809), South Dakota (2019) and Ohio strains were heavily rusted while the Italian strains (1819, 2006) showed only a slight amount of rust. In the autumn of 1921 several different strains of red clover were inoculated with the rust in the field. The plants were spaced and counts were made of the severely, moderately and slightly rusted plants as follows:

	Rusted		
	Severely	Moderately	Slightly
South Dakota 2019.....	20	10	14
North Dakota 1809.....	1	1	7
Ohio 2020.....	12	19	12
Chilean 2055.....		7	10
French		3	41
Italian 1819.....	1		9

A more extensive test was made in the greenhouse during the winter of 1922-1923. Out of 151 plants of three North American strains, 10

¹² Krakover, L. J. The Leaf-Spot Disease of Red Clover Caused by *Macrosporium sarcinaeforme*. Mich Acad. Sci. 19 Rept. 275-328. 1917.

were classed as resistant or 6.6 per cent. Of 125 plants of four Chilean strains, 25 were classed as resistant or 20.0 per cent. Of 314 plants of four eastern European strains, 59 were classed as resistant or 18.7 per cent. Out of 141 plants of four French strains, 38 were classed as resistant or 26.9 per cent. Of 208 plants of three Italian strains, 41 were classed as resistant or 19.7 per cent. All of the plants tested for rust reaction had previously been selected for resistance to powdery mildew (*l.c.* 10) so that the rust resistant selections were resistant to mildew as well. The foreign clover strains tested, therefore, contained a greater proportion of both mildew and rust resistant individuals than the North American strains.

Only a trace of rust was noted in the field in 1922 and 1923. Although a careful search was made for red clover rust in 1924, 1925, and 1926 no trace of the rust was found. In late October, 1927, it was again noted slightly infecting occasional plants which showed heavy infection by the middle of November. The rust of red clover apparently is usually of minor importance in the vicinity of Lafayette, Indiana, and this is probably true for the state as a whole although it may occasionally become severe locally.

The rust of alsike clover has been noted more frequently although it usually is found on scattered plants. In August, 1927, a number of plants of alsike were showing infection and by the first of October several plots of alsike were heavily rusted and considerably defoliated. This rust is apparently more prevalent than the red clover rust in Indiana. The rust of white clover has been occasionally received from different parts of the state but it has been noted in the vicinity of Lafayette only during the fall of 1927, when a few infected plants were found.

The rusts of red, alsike and white clovers are physiologically distinct and do not pass from one to the other. There are also some differences in morphology. Some investigators^{13, 14} therefore, consider these distinct species, that on white clover *Uromyces trifolii-repentis* and that on alsike, *U. trifolii-hybridii*; that on red clover, *U. fallens* or *U. trifolii*.

Mosaic. Attention was first attracted to this disease in connection with some plants of red clover which had been brought into the greenhouse from the field. Not only were plants of red clover, *Trifolium pratense*, severely infected but *T. arvense*, *T. subterraneanum*, *T. incarnatum* and *T. resupinatum* showed mosaic, the last two being severely infected. The diseased plants showed mottling and contortion of the leaflets typical of mosaic diseases. (Fig. 6.) Various degrees of chlorosis were produced. In some plants only a few leaves showed a slight effect, while in others all the leaves were infected, showing pronounced chlorosis and necrosis along the veins. In severe cases the leaves died rapidly, followed finally by the death of the entire plant.

In 1925 mosaic was noted as specially prevalent in plots of Indiana,

¹³ Kobel, T. Zur Biologie der Trifolien-bewohnenden Uromycesarten. Centralbl. Bakt. 52:215-235. 1920.

¹⁴ Davis, W. H. Summary of Investigations on Clover Rusts, Mycologia 16:203-219. 1924.

Idaho and Minnesota strains. In 1926 the disease was abundant in plots of Indiana, Wisconsin, Canadian, Central European, English and French strains. In the autumn of 1927, it was especially noticeable in an Oregon strain.

Under the usual field conditions, it is difficult to determine the prevalence of this disease on account of the intermingling of healthy and diseased plants. In the autumn of 1927, however, mosaic was noted in a plot of spaced red clover planted by Prof. G. H. Cutler of the Agronomy Department. An examination of these plants showed that



Fig. 6—Leaves of red clover infected with mosaic showing chlorotic streaking and contortion.

out of a total of 390 plants, 24 showed severe infection, 34 moderate and 65 slight infection. In this planting, therefore, 31.5 per cent of the plants were infected with mosaic. The severely infected plants were in very poor condition, evidently dying. Orton¹⁵ has reported a 50 per cent infection on crimson clover in Pennsylvania. Elliot¹⁶ states that 75 per cent of the plants of red clover on the campus of the University of Arkansas showed mosaic in 1919. It is probable that mosaic is a much more important disease of clover than has been assumed.

Elliot found that red clover mosaic could be transmitted to sweet clover, *Melilotus alba*, burr clover, *Medicago arabica*, and horse bean, *Vicia faba*. Dickson¹⁷ found that infection took place between *Trifolium pratense*, *T. hybridum*, *T. repens*, *T. incarnatum*, *Medicago lupulina*, and *M. sativa* but not to *M. alba*. He also found that mosaic was seed carried. Seed from fields having a large percentage of mosaic plants should, therefore, be avoided.

Nematodes. A number of plants of red clover transplanted into the greenhouse in the fall of 1923 showed stunting and an examination of the roots resulted in finding the characteristic knotlike swellings produced by nematodes. This trouble has, however, never been noted in

¹⁵ Orton, C. R. Plant Disease Survey Suppl. 15, p. 171. 1921.

¹⁶ Elliott, J. A. A Mosaic of Sweet and Red Clovers. *Phytopath.* 11:146-148. 1921.

¹⁷ Dickson, B. T. Studies concerning Mosaic Diseases. *Macdonald College Tech. Bul.* 2:125 p. 1922.

the field in Indiana. It apparently is serious under field conditions only in the northwest.

Cercospora Spot. A cercospora leaf spot was noted moderately infecting alsike clover in the vicinity of Lafayette in 1923.

Sooty Spot. The sooty spot of white clover, *Phyllachora trifolii* (*Polythrincium trifolii*) has been noted every year in the vicinity of Lafayette. It is occasionally severe in small areas, causing considerable defoliation.

Root and Crown Rots. Several different root and crown rots have been noted with various fungi associated, especially species of *Fusarium*. In many cases these are probably secondary following anthracnose, mosaic, etc. In the spring of 1926 a crown rot was especially prevalent in Italian and French plots apparently due to a *Fusarium*. According to the investigations of Fergus and Valleau¹⁸ a number of species of *Fusarium* are responsible for clover root rots especially when favored by low soil productivity.

The control of clover diseases in most cases presents difficult problems. Apparently selection and breeding for resistance offers the most promise. While foreign clover strains show much greater resistance to such diseases as mildew and rust they are apparently for the most part more susceptible to anthracnose and are not adapted to most sections of the United States. Resistance to both mildew and rust occurs in North American strains and from these it should be possible to develop lines combining resistance to a number of diseases.

¹⁸Fergus, E. N. and Valleau, W. D. A Study of Clover Failure in Kentucky. Agr. Exp. Sta. Bul. 269. 210 p. 1926.