

DIFFERENCES IN THE SUSCEPTIBILITY OF CLOVER
TO POWDERY MILDEW.¹

E. B. MAINS, Purdue Agricultural Experiment Station.

The powdery mildew of clover has aroused considerable interest this year (1922), because it has been widespread and abundant. This disease has heretofore been rare in America and in consequence the general whitening of clover by mycelium and spores of this fungus has caused more or less alarm among the farmers, from whom numerous inquiries have been received. The disease made its first noticeable appearance in the fall of 1921, and during the spring and summer of 1922 spread rapidly. According to the Plant Disease Survey², the mildew first made its appearance upon the first crop of clover in the South, and was first reported from Louisiana, April 10. With the advance of the season, it spread northward and by June 28 was reported in Maine and Minnesota. The writer saw the disease more or less prevalent practically everywhere on his trips through South Carolina, Virginia, Tennessee, Kentucky, Indiana, Wisconsin, and Michigan during May, June, and July. According to the Plant Disease Survey³, the first record of this disease in the United States was from Prof. Sheldon who reported its inconspicuous occurrence in the vicinity of Morgantown, W. Va., in 1908. In 1915, reports were received from Idaho, Washington, and Oregon, and in 1916 and 1917 from Utah.

There is some question as to the identity of this mildew, since, as far as the writer is aware, no perithecia have been found accompanying the disease, at least in the eastern United States. Miss V. K. Charles (*l.c.* 3) found perithecia on collections from Oregon, Washington, Montana, Colorado, and Idaho, but not from any of the eastern states. Since all clover mildew has been considered as belonging to the species, *Erysiphe Polygoni* D.C., it is very likely that the mildew so prevalent in the eastern United States is this species and that the proper conditions for perithecia formation have not occurred in this region.

Although it is generally agreed that clover mildew has been very severe, there seems to be considerable difference of opinion among pathologists as to the damage caused (*l.c.* 2, 3), some believing very little damage is caused while others believe considerable loss is suffered. The reasons given for attributing loss to this disease, are the death of the lower leaves (Fromme) causing hay to be slightly off color and of poorer quality, the reduction in tonnage by death of lower leaves and also the proportionally higher percentage of stems (Edgerton), and the greater shattering and powdering of the leaves in hay from diseased fields (Elliot). This is one of the diseases of plants for which it is hard to obtain any accurate estimate since it does not kill the plants attacked nor reduce the yield to such a marked extent but that the loss

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

² U. S. Dept. Agr. Plant Disease Survey Bull. Vol. 6, No. 1, pp. 8-14. 1922.

³ U. S. Dept. Agr. Plant Disease Survey Bull. Vol. 6, No. 3, pp. 53-55. 1922.

can be attributed to weather conditions. However, it hardly seems possible that fields can be so thoroughly infected with a disease that they "look as if they had been heavily dusted with flour" (Edgerton) and "when the mower goes through the field a white cloud arises on all sides" (Anderson) without the fungus interfering considerably with development and yield of its host. Not only must considerable food be withdrawn from the host by the parasite but also the mat of mycelium on the surface of the leaves and the haustoria within the cells must interfere considerably with photosynthetic activities of the plant and thus prevent, to a more or less extent, the manufacture of the plant's food. The withdrawal of food and the weakening of the plant undoubtedly brings about the premature death of parts of the plant such as the older, longest-infected leaves but not so rapidly but what new leaves take their place, which in turn gradually are infected. However, the plant as a whole is probably very seldom if ever weakened so much as to succumb entirely except after prolonged attack. In the absence of destruction or serious weakening of all or part of the crop, there is no good basis for measuring loss since the widespread occurrence of the disease precludes the opportunity of comparing diseased and disease-free fields of like fertility, and otherwise comparable. As indicated above, the enormous mycelial and spore production must reduce to some extent the stored food of the clover plant and correspondingly its feeding value. The premature death of the older leaves and possible increased shattering of the diseased younger leaves is another source of loss. If the second crop of clover is saved for seed, possibly the loss may be more easily measurable since with the lowered food content of the clover plant there is likely to be a reduction in the number or quality of seed matured.

A matter of considerable concern to the farmers is whether mildewed clover is fit for feed. From the evidence furnished by the Plant Disease Survey (*l.c.* 2) no harm is liable to result from feeding such clover. Hesler reports that tests conducted by the Tennessee Experiment Station indicate that stock (horses, cattle, sheep, swine) is not injured after being fed or grazed 14 days on mildewed clover. Edgerton reports that no poison or injurious substance is formed. Dungan quotes C. M. McWilliams, Farm Adviser of Randolph County, Illinois, who observed no ill effects from feeding the mildewed clover to cattle, horses, and mules. There is a possible slight danger in feeding the hay to horses on account of the presence of the spore-dust. Tehon reports a trouble in cattle similar to 'heaves' attributed to mildewed clover in southern Illinois.

Control of a disease of the nature of mildew under the cultural conditions necessary for clover is extremely difficult, and apparently the only feasible method is in the discovery or development of disease-resistant strains. The biology of the mildew of clover, however, has not been extensively studied. Salmon⁴, upon a morphological basis, considers the mildew of clovers as *Erysiphe Polygoui* DC. for which he gives 359

⁴ Salmon, Ernst S. A Monograph of the Erysiphaceae. Mem. Torrey Bot. Club. 9:1-292. 1900.

species belonging to 154 genera as hosts. He gives the following species of clover as hosts: *Trifolium agrarium*, *T. alpestre*, *T. urvense*, *T. filiforme*, *T. hybridum*, *T. incarnatum*, *T. involueratum*, *T. longipes*, *T. lupinaster*, *T. medium*, *T. minus*, *T. monanthum*, *T. montanum*, *T. moranthum*, *T. pauciflorum*, *T. pratense*, *T. procumbens*, *T. repens*, and *T. rubens*. That *E. Polygoni* must consist of a large number of specialized races is indicated by the researches of Neger and Salmon⁵, the former being unable to infect *Trifolium repens*, *Vicia sepium* or *Hypericum montanum* with conidia from *T. incarnatum*, and the latter finding that the mildew from *T. pratense* would not infect *T. agrarium*, *T. repens*, *T. medium*, *T. montanum*, *T. incarnatum*, *T. filiforme*, *Lotus corniculatus*, *Melilotus arvensis*, *Medicago sativa*, *Lupinus luteus* or *Pisum sativum*, but infected *T. pratense* heavily. According to this, the mildew on *T. pratense* is a race restricted to that species of clover. Likewise the mildew on *T. incarnatum* represents another closely restricted race. Observations by various pathologists during the past year as reported in the Plant Disease Survey agree with these results.

There are evidently few or no observations upon varietal or individual differences in the reaction of *T. pratense* to the specialized race of mildew which exists on it. Dr. A. J. Pieters (*l.c.* 2) has observed at Arlington, Virginia, that many of the American varieties of red clover were affected while most of the European strains were free or nearly so. In the fall of 1921, the writer noticed that considerable differences existed between the species of *Trifolium* as to susceptibility to mildew, and also that similar differences were to be found between varieties of *T. pratense*. The plants upon which these observations were made were started in pots of sterilized soil in the greenhouse and were transplanted to the field in late summer. The plants were set about ten inches apart in rows two feet apart, so that there was no difficulty in observing individual differences. By October 13, when notes were taken, the plants were well established and in good condition. The notes given in the following table represent the reaction of individuals and varieties under field conditions to natural infection of the powdery mildew.

⁵ Salmon, Ernst S. On Specialization of Parasitism in the Erysiphaceae. Beihefte Bot. Centralbl. 14:261-315. 1903.

TABLE I. Susceptibility of Clovers to Powdery Mildew in the Field, Lafayette, Ind., October 13, 1921.

Species and Variety	Original Source of Seed	No. of Plants Examined	Degree of Susceptibility—No. Plants			
			Heavy	Moderate	Slight	None
<i>Trifolium pratense</i> 2019*	South Dakota	44	13	22	9	
<i>Trifolium pratense</i> 2020	Ohio	44	9	15	19	1
<i>Trifolium pratense</i> 1809	North Dakota	9	2		7	
<i>Trifolium pratense</i> 2055	Chile	17		1	16	
<i>Trifolium pratense</i> 1819	Italy	10			8	2
<i>Trifolium pratense</i>	France	44			15	29
<i>Trifolium pratense</i> 43592	England	10				10
<i>Trifolium incarnatum</i> 2054		10				10
<i>Trifolium hybridum</i> 2047		12				12
<i>Trifolium repens</i> 48625	Holland	8				8
<i>Trifolium repens</i> 1928	Wisconsin	10				10
<i>Trifolium repens</i> 1912	Idaho	25				25
<i>Trifolium repens</i> 48019	England	12				12
<i>Trifolium subterraneanum</i> 51212		10				10
<i>Trifolium fragiferum</i> 29012		12				12
<i>Trifolium reflexum</i> 03308		12				12

*Numbers following names are those used by the Office of Forage Crop Investigations, U. S. Dept. Agriculture.

Encouraged by these results, further work was started this past summer (1922). Seed of 17 varieties of clover grown on the Experiment Station farm at Lafayette, Indiana, were sown in individual flats of sterilized soil in the greenhouse. About midsummer the mildew showed up and spread fairly rapidly. In order that all the flats might be uniformly inoculated, they were dusted with the mildew the latter part of November, atomized and kept covered with moist cloths for several days. The mildew developed rapidly and by the first of December the older leaves of a number of the varieties were white with the mycelium and spores. The plants were then taken from the flats, sorted according to susceptibility, counted and the immune and highly resistant plants were transplanted. The varieties tested and the results obtained are given in table II.

TABLE II. Susceptibility of Varieties of Red Clover, *Trifolium pratense* to Mildew, in Greenhouse Tests, December 1, 1922.

Varietal No.	Original Source of Seed	No. of Plants Examined	Degree of Susceptibility, No. Plants		
			Heavy	Moderate—Slight	None
2135	Ohio	206	151	39	16
2138	Tennessee	133	90	30	13
2148	Oregon	117	45	55	17
2203	Chile	113	12	88	13
2217	Chile	129	43	68	18
2142	Chile	130	25	73	32
2055	Chile	138	28	67	43
2218	North Germany	230	34	129	67
2214	Hamburg	128	7	55	66
2121	Bohemia	221	1	109	111
2219	Hungary	215	7	147	61
2202	France	127	6	87	34
51456	France	140	15	73	52
51493	France	127	10	76	41
51492	Italy	153	9	95	49
54779	Italy	139		68	71
2212	Italy	168	3	95	70

An examination of table I shows that, among the various species of *Trifolium* represented, only *T. pratense* was mildewed. *T. incarnatum*, *T. hybridum*, and *A. repens*, all of which are given as hosts for *Erysiphe*

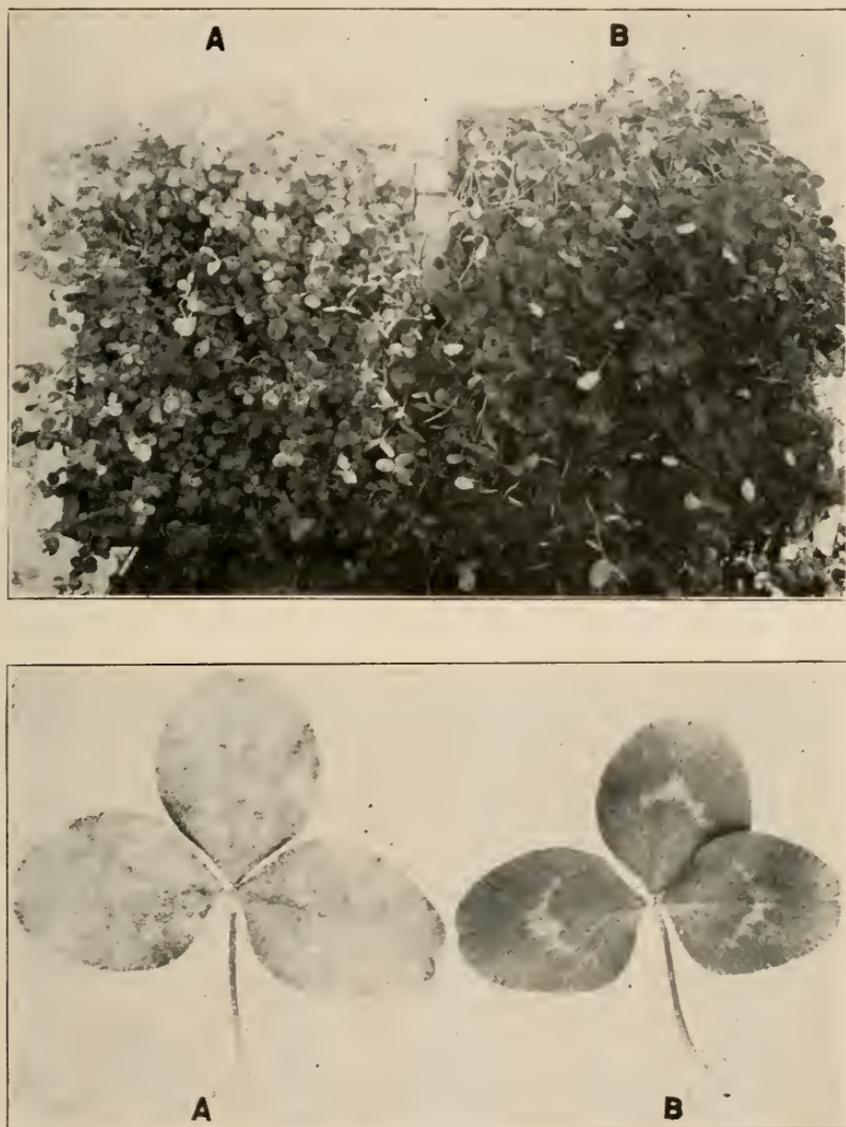


Fig. I. Difference in Susceptibility to Mildew. (A and B.) Difference in Two Clover Varieties. A. Flat of Tennessee 2138 clover susceptible to mildew. B. Flat of Italian 54779 clover resistant to mildew. (A' and B'.) Difference in Two Plants of Variety Ohio 2135. A'. Leaf of susceptible plant. B'. Leaf of immune plant.

Polygoni, were absolutely free from mildew. This, therefore, would agree with the results of Salmon as well as the observations of a number of pathologists in this country in 1922 that the mildew of red clover

is restricted to that species. However, not all of the varieties of *T. pratense* were found to be susceptible. An examination of tables I and II shows an interesting situation, the North American varieties being generally quite susceptible, while the European show in general rather high resistance. The Chilean seemed intermediate between the two. Figure I (A and B) shows the difference in susceptibility shown by a flat of the variety Tennessee 2138 and a flat of the variety Italian 54779.

What the significance of this situation may be, is hard to say. It is possible that the long presence of mildew in Europe may have had a selective effect, possibly preventing the formation of seed in susceptible plants. This would necessitate a very marked effect of the mildew on seed production. On the other hand, the absence of mildew in this country would preclude any such selection. However, as far as the writer has been able to determine, no one has noted red clover resistant or immune to mildew in Europe. On the other hand, judging from the lack of comment on the disease, it may not be serious at the present time, possibly indicating resistance but not complete immunity. It is useless, however, to theorize until we have a better knowledge concerning the biology of this disease and the relation of the race on *T. pratense* to a greater number of other species of *Trifolium*, especially native wild species, and until we know whether differences exist between the mildew in North America and Europe in its ability to attack varieties, whether the mildew in this country has been recently introduced or whether climatic conditions of the past year have been responsible for the development and conspicuous appearance of the disease, and what the effect is on the clover plant, especially upon seed production.

Another thing noticeable in tables I and II is the presence of resistant individuals in all except three of the varieties tested. It is likely that if a larger number of plants of these three had been tested, resistant plants would also have been found among them. Figure I (A' and B') shows a leaf from a susceptible and a leaf from a resistant plant of Ohio 2135.

As we have already noted the discovery or development of resistant varieties suggests the most likely control. Unfortunately in most cases the presence of one or more undesirable qualities in resistant varieties complicates the situation. Thus several of the resistant European varieties apparently are not especially adapted to our climate, since those in the field during the comparatively mild winter of 1921-1922 winter killed badly. Prof. A. T. Wiancko⁶ has stated that in his field tests of clover varieties, the Italian killed out entirely during the winter of 1920-1921. In consequence it appears very doubtful if these varieties would be of much value except for hybridizing work. Unless other European varieties prove to be hardy, the most promising method of obtaining mildew-resistant strains appears to be by the selection of resistant individuals in American varieties.

⁶ Wiancko, A. T. Report of the Director, Purdue University Agricultural Experiment Station. 1921:37.

TABLE III. Source of Seed and Its Bearing on Winter Injury.
Condition of Varieties of *Trifolium pratense*, Spring, 1922

Varietal No.	Original Source of Seed	Condition—No. of Plants		
		Good	Poor	Dead
2019	South Dakota	30	6	8
2020	Ohio	33	4	7
1809	North Dakota	7	1	1
2055	Chile	3	7	7
1819	Italy		1	9
	France	3	11	30
43592	England		1	9

SUMMARY.

1. The mildew of red clover, *Trifolium pratense*, is apparently specialized on that host, crimson, *T. incarnatum*, Alsike, *T. hybridum*, and white, *T. repens* not being infected.
2. Considerable differences exist between varieties of red clover as to susceptibility to the mildew, American varieties being much more susceptible than European.
3. Resistant individuals are probably to be found in all varieties, the number varying with the variety.
4. Selection and breeding for resistance offers the best means for controlling the disease.

The writer wishes to acknowledge his indebtedness to Dr. A. J. Pieters, Office of Forage Crop Investigations, U.S. Dept. of Agriculture, and Mr. R. R. Mulvey, Soils and Crops Dept., Purdue Agricultural Experiment Station, for furnishing the seed of clover varieties upon which this work was done.

