The identification of diseases of alfalfa, their effect on production, and control

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Diseases of alfalfa may be caused by fungi (molds), bacteria, viruses, mycoplasma, nematodes, nutritional excesses and deficiencies, and by such physical factors as flooding at times when extremely high temperatures prevail. The determination of which disease is caused by which organism or factor is more than an academic exercise for the researcher - it is a necessity for the grower, the plant breeder or any one who wants to intelligently attempt to control the disease.

In the subsequent pages I shall discuss the use of resistant varieties to control diseases. Fortunately plant breeders, pathologists and entomologists have been able to find resistance to many diseases and insects. However the grower must bear in mind that no chain is stronger than the weakest link; thus although the plants may be resistant to one important disease, susceptibility to another disease will erase the positive effects of the resistance to the other diseases. The writer has seen fields near Riverside where Phytophthora root rot, southern anthracnose, crown rot, Stagonospora root rot, and bacterial wilt and root knot were all active. For this reason the search for resistant sources of germ plasm is a never ending one.

Unlike most insect-caused problems the causes of most diseases can not be readily seen except with the aid of a microscope. However, fortunately many of them can be identified by the symptoms that the various agents cause on the plant.

It seems important to indicate here that the type of commercial variety advertising which simply claims "disease resistance" is misleading. As you can see by this paper and those I will cite, there are many different diseases, each of which are important in different degrees and in different regions. I venture there is no variety which can be labeled as universally "disease resistant." Also important in evaluating varieties is the distinction as to how resistant they are. The percentage of the plants in a variety which are resistant, tolerant or susceptible to a disease could be and should be designated for any released variety.

I will attempt here to either explain or interpret the symptoms for each disease and to describe the control measures we know and the relationship of these to the causal agents.

For more detail and illustrations the reader is referred to the circular on diseases of alfalfa in California by Houston et al. (1960) and to the paper by Erwin on diseases of alfalfa in Southern California (1956). Bolton's (1962) chapter on diseases in Canada illustrates the bacterial wilt and the stem nematode diseases especially well and also treats many other diseases.

The diseases affecting alfalfa have been divided here into those affecting stand depletion and those which do not kill plants but repress growth. Since the stand depleting diseases seem to be the most important to us now in California these will receive the most attention.

Bacterial wilt.--The cause of this disease is *Corynebacterium insidiosum*, a bacterium which inhabits the xylem or water conducting tissues of the plant. It is a principle that all plant pathogenic bacteria penetrate plants passively and this bacterium is no exception. Alfalfa plants may be inoculated by the mower which carries bacteria from infected plants to healthy plants. The disease may start from an occasional infected plant that has persisted from a previous crop. The bacteria can also persist in dried hay stems for several months.

One of the latest findings about this disease is its relationship to the root knot nematode, *Meloidogyne hapla* as shown by Hunt et al. (1971) in Nevada. They showed that the disease was most severe and affected a larger percentage of plants when plants were inoculated with both organisms than when inoculated with *C. insidiosum* alone.

Plants affected with bacterial wilt are stunted and the leaves are smaller than usual and yellowed on the margins. The xylem tissue in the tap root is brown in color and often small pockets of bacterial infected tissue can be seen on the inside of the bark. These symptoms are very distinctive and are illustrated in UC Circular 485 (Houston, et al. 1960).

The spread of the disease in the field is rather slow the first year and most of the time the disease does not lower production until the end of the second or third year.

The bacteria do not persist for more than 2 years in field soils in absence of the alfalfa host. As far as it is known there is no other host so complete removal of alfalfa plants during the rotation should allow a farmer to plant alfalfa again on a three-year rotation.

Although theoretically the disease should be preventable by use of sanitary means resistance is the most efficacious control measure. Most universities have screened religiously for bacterial wilt resistance for many years and several varieties are notable for resistance to this disease. Some of these are Caliverde in California, Lahontan in Nevada, and Vernal in Wisconsin. Due to the heterozygosity of alfalfa it has not been possible to obtain varieties in which 100% of the plants are resistant. In most resistant varieties only about a quarter of the plant population is resistant. In Caliverde about 40% of the plants are resistant. In most cases since an excess of plants usually result from normal plantings in the first year, enough resistant plants survive until the third and fourth year to produce a successful crop.

Bacterial wilt does not seem as prevalent as in previous years but this probably reflects more the relatively shorter periods of time (2-3 year rotations) that an alfalfa planting is maintained compared to the 5-6 year plantings of previous times.

Phytophthora root rot.--This disease is probably the most important in California causing death of whole stands at the ends of irrigation runs or in wet fields. It is caused by a water mold - a fungus with a spore (zoospore) that swims in water (*Phytophthora megasperma*). This zoospore stops swimming and when it stops, it germinates and invades the alfalfa roots. Because the fungus has a swimming stage, soil water in excess of the field capacity is necessary for the fungus to attack alfalfa.

The fungus causes a brown to yellow discoloration of rotted tissue and after the lateral and tap roots are rotted off, the plant dies for lack of water and nutrients. Often the lower leaves of the affected plants become yellow and wilt. The lesion on the root is irregular in size and usually the rotted tissue is firm. This disease could be confused with *Rhizoctonia* root canker except that the latter disease is characterized by round to elliptical cankers around the emerging lateral root. In the Sacramento and San Joaquin, and Antelope Valleys and in the coastal areas, Phytophthora root rot is severe only in the spring, summer and winter but in the Imperial, Coachella, and Palo Verde Valleys it occurs in fall, winter and spring but not in the summer. This difference in activity is due to the fact that the fungus will not tolerate temperatures in the soil above 86°F.

The *Phytophthora* from alfalfa will not attack other agricultural crops since it is specific to alfalfa. It is distributed throughout California and is most severe in fields where long irrigation runs or low poorly drained areas exist in fields. Often the disease occurs on what appears to be sandy well drained soils, however examination of these soils with a soil sampling tube usually reveals a lens of soil with a different texture. Soil scientists have shown that these lenses act as a barrier to downward percolation of water which results in the soil above the lens approaching saturation.

The first type of control measure is to improve the drainage in soil by leveling, chiseling and reducing the length of irrigation runs as much as practicable. Theoretically if soil is well drained and irrigation is not excessive, there should be little trouble from this disease. However since achievement of these goals is not always practical, we and the plant breeders in California have been searching for resistance for several years. Some years ago we reported (Erwin 1966) that the variety Lahontan, which was introduced by Oliver Smith (1955) had a high level of tolerance to *Phytophthora*. This variety is probably the most unique of any released in that it also possesses resistance to bacterial wilt, stem and bulb nematode, and the spotted alfalfa aphid.

It's only disadvantage for much of California is its winter hardiness and corresponding suppressed growth in the winter season. We also reported that several experimental lines of the variety Arabia were resistant to Phytophthora (Erwin 1966)

Lehman et al. (1967) reported that the tolerance from Lahontan and from the nonwinter hardy variety, Arabia, was incorporated in the new experimental varieties Expt. 38 and Expt. 46. Prior to selecting for tolerance to Phytophthora, genes for resistance to the spotted alfalfa aphid, pea aphid and downy mildew had been incorporated Although these varieties were not immune or even highly resistant, about 19-23% of the plants were highly tolerant. At the present time a petition to release a new variety, Salton has been filed by W. F. Lehman, E. H. Stanford and D. C. Erwin. This variety carries advanced selections from Expt 38 and 46 and has shown improved tolerance when compared to the variety Moapa.

Rhizoctonia root canker and summer flooding injury (scald) in the southern California desert areas.--The causes of these diseases are different but since they occur together during the hot summer months and almost exclusively in the Southern California desert area, I will discuss both. *Rhizoctonia* root canker (Smith 1943) is caused by a strain of *Rhizoctonia solani*. The fungus is capable of growing at the high soil temperatures typical of soils in the desert valleys (up to 100°F in irrigated fields) and attacks the tap root in the region of the emerging lateral root or in the crown. Since the meristem tissue from which the new shoots emerge is in the crown, this area is the most vulnerable. However when two or three root cankers girdle the tap root all the phloem (sugar conducting tissue) is killed and the root below that point is nonfunctional and will not survive. During the summer months the lesions in which the fungus is active are brown in color. Usually a dark brown necrosis is also seen in the xylem tissue above and below the lesion. During the winter months, when the fungus is relatively inactive, the necrotic tissue becomes black. During this season the root may heal and resume active growth until the following season when the fungus again becomes active.

When viewed from the air the areas affected by Rhizoctonia are sharply delimited and roughly circular in contrast to the less delimited edges of areas affected by the perennial fungus *Phymatotrichum omnivorum*, the causal agent of "Texas" root rot.

To date all efforts to find a relatively high level of resistance that can be conclusively demonstrated in controlled greenhouse trials have failed; however Houston and Stanford selected surviving plants in the field and from these survivors produced seed from which the plants grew more vigorously in subsequent field trials.

The "scald" disease, occurring also in the hot summer months, was once thought to be due to the excessively high temperatures of irrigation water which occurred when the water absorbed from the hot soil. Measurements of temperature of irrigation waters by the writer (Erwin 1959) indicated that temperatures of the water were almost always less than that of air temperature and did not exceed it. When plants were subjected to flooding in the field, root damage occurred when soil temperatures at 2 inch depth reached 91-98°F and the soil remained saturated for 36 hours. In controlled greenhouse tests, roots were rotted only when the soil temperature was increased to 102-107°F for 8 hours. When heated but saturated soils were artificially aerated in greenhouse trials, no damage occurred. Thus the disease appeared to be due to lack of sufficient aeration. Experimental trials in the field indicated that newly mowed plants were much more sensitive to the summer flooding injury than those with one to three weeks of regrowth after mowing. Even running over alfalfa plants with a truck previous to irrigation caused death of plants in the wheel tracks in less than a week after flooding.

The symptoms by which the disease can be identified, are much less specific than those used to identify other root diseases. This is true of many diseases caused by a complex set of factors in the soil. In general the xylem of the affected plants becomes brown and necrotic and apparently nonfunctional for uptake of water or nutrients. The lower parts of affected roots often completely collapse with a soft root rot. The tops of affected plants wilt and usually the plants die within one week after irrigation.

There was a time in the southern desert areas when growers avoided irrigation throughout the hottest summer months mostly because of fear of losing a stand due to scald. Unless this practice was used in conjunction with seed production, the crop was relatively nonproductive during the summer season. However in the last 10-15 years almost all of the alfalfa in the desert has been irrigated throughout the summer season. The scald disease has been controlled only by carefully regulating the irrigation practices. Short frequent irrigations are much more effective than long irrigations since the degree of root rot is proportional not only to the temperature but also to the length of the period of time the soil is saturated.

Admittedly this type of cultural control has many difficulties and a misestimation of the length of an irrigation can result in nearly 100 per cent loss of plants during hot weather. Also short frequent irrigations often result in the accumulation of excessive concentrations of salts in the upper six inches of soil. Some of these problems were approached experimentally by Lehman et al (1968). Space does not permit more than a summary here. In general the frequent short irrigations (based on tensiometer readings) at different depths in the soil induced increased yield, stand persistence and hay quality in one experiment. In a second experiment on a different piece of land, little difference in actual yield was seen due to the relative frequency of irrigations; however when frequent long irrigations were used, the stand of alfalfa thinned resulting in an invasion of grass and consequently a poorer quality of forage.

Phymatotrichum root rot.--This disease is limited to certain areas in the southern California desert areas and damage from it occurs only during the summer months. The cause of the disease is *Phymatotrichum omnivorum*. The fungus produces characteristic strands or rhizomorphs (root-like strands) on the surface of the affected root. Details for identification of this disease are given by Streets (1937). Because the fungus produces resistant sclerotia even at great depths in the soil, there is little hope of eradicating the fungus. The fungus also attacks all other broad leafed plants during the summer season but during the winter these crops are not damaged. All grasses appear to be immune to the disease even in the summer.

The lesions on the roots of alfalfa plants are somewhat similar to those caused by *Rhizoctonia solani* except that they are more concave. Most characteristic is the presence of rhizomorphs which can be seen under low magnification. Diagnosis of Phymatotrichum root rot should be made with extreme care and by someone who knows the disease since an erroneous diagnosis could devaluate the land for sale purposes.

Dwarf disease.--This disease has been seen in the past in the Fresno area and near Riverside, California. The disease is recognized by dwarfing and the blue green color of the plants. When the tap root is cut open, the xylem tissue is brown in color. This symptom is similar to bacterial wilt except that there are no lesions on the inner bark with the latter disease.

Dwarf disease is caused by the same causal agent as that causing Pierce's disease of grape and is transmitted by the sharpshooter leaf hoppers. The recent work of Hopkins and Mortensen, who found that symptoms of Pierce's disease on grape were suppressed by tetracycline drenched on the soil, suggests that the disease may be caused by a mycoplasma and not a virus (1971) as previously supposed.

Dwarf appears to have diminished in importance during the past years, the cause of which is not well understood. Despite the reduction in prevalence the disease remains a serious threat to alfalfa production.

The tolerant variety California Common 49 was originally selected from surviving plants in a field and subsequently progeny tested by Stanford and Houston. This variety is not in use at the present time because of its susceptibility to the spotted alfalfa aphid.

Stem and bulb nematode disease.--This disease is a potentially serious problem in the coastal and Antelope valleys especially. It is frequently a problem in dairying regions where growers produce alfalfa more or less continuously with very short periods of time between crops of alfalfa.

The disease can be recognized readily by the swollen condition at the base of the stems and stunted growth. When the swollen stems are cut open in water, the nematodes causing the disease, *Ditylenchus dipsaci*, can be seen oozing out of the tissue. As the disease progresses the plant tissue becomes necrotic and when infection is severe enough, the plant dies. Very often the disease "runs" in the direction of the irrigation flow due to the spread of nematodes by the water. The nematodes can persist for many years in dried hay

The disease can be controlled by rotations of more than three years and by use of resistant varieties. The variety Lahontan and Nemestan are highly resistant (Smith 1955)

Other diseases of local importance.--I shall discuss several diseases together each of which by themselves can under certain circumstances be severely damaging.

The Fusarium wilt disease caused by the fungus Fusarium oxysporum f. medicaginis has not been of major importance to alfalfa production. Since this fungus is systemic, that is it can infect the root and pass upward in the xylem tissue to the stems, and also extremely long lived in dried plants on soil (up to 17 years), there would seem to be little reason to believe that this pathogen has not had sufficient opportunity to become well distributed.

Probably of greater importance is that there is a degree of natural resistance in most varieties of alfalfa. Stanford (unpublished data) tested 28 varieties and found that the percentage of resistant plants ranged from 20-70. The variety Africa, which has been a major source of germ plasm in nonwinter hardy alfalfa varieties, contained 50% resistant plants.

The disease can be readily identified by the brick red color in the xylem tissue of the tap roots. Often this discoloration runs in one-sided streaks in the root. Eventually the leaves become yellow and the plants die.

Stagonospora root rot becomes important in certain fields about two to three years after planting. The onset of disease is slow but once the plant becomes infected it does not recover. The disease can be readily recognized by the speckled red discoloration in the bark tissue of the tap root and in the lower stems. During moist weather the fungus may cause leaf spots and stem lesions in which small black bodies, called Pycnidia, appear. These are shaped like a round bottom flask and contain spores which ooze into water in a sticky matrix. In water these spores separate and can be splashed from plant to plant or flow with the irrigation water.

Since this fungus infects only alfalfa and sweet clover it can be controlled by rotating to a nonsusceptible crop for three or more years. Very little work has been done on a search for resistance to this disease.

Southern anthracnose is another local disease somewhat similar in nature to Stagnospora root rot but with quite a different symptomatology. The cause of this disease Colletotrichum trifolii, causes stem lesions and leaf spots on leaves in moist weather and due to the usually dry weather of California, these symptoms are seldom seen. However when the fungus invades the crown of the plant, the plant is killed by the fungus. The crown rot is usually V-shaped when viewed in cross section and blue to black in color. Quite often on the margin of the crown lesion there is a thin band of light reddish discolored tissue.

Resistance has been found in selections from several varieties by Ostazeski et al (1969) working in the USDA laboratory at Beltsville.

Non-lethal diseases with growth suppressive effects.--There are too many diseases in this category to discuss at length. Most of these are discussed by Houston et al (1960). Alfalfa mosaic is a disease which has in the past been considered to be of little importance to alfalfa but of major importance to growers of more susceptible crops. It has long been known that alfalfa, being a perennial crop, has served as a reservoir for this disease caused by the aphid borne alfalfa mosaic virus (AMV). Recent work by Crill et al. (1970) in Wisconsin and Froshiser in Minnesota (1969) has indicated that this virus caused considerable growth suppression of alfalfa plants. Furthermore a large number of different strains exist which vary from nonpathogenic to highly virulent on test alfalfa plants and varieties.

Since AMV is seed borne (1-4% (Froshiser 1964) it most likely exists in every field in the state. Also since AMV is spread by aphids the potential incidence of infected plants is high.

Recently Crill et al. (1971) showed that resistance in alfalfa to many strains of AMV was inherited as a single recessive gene.

Because of the potential importance and wide distribution of AMV, research studies on the effects of AMV on alfalfa in California have been started recently by University of California plant pathologists at Berkeley, Davis and at the San Joaquin Valley Research and Extension Center.

Discussion.--I have described the most important diseases of alfalfa in California and due to lack of space have omitted the leaf diseases caused by *Cercospora*, *Stemphyllium*, *Pseudopeziza*, *Ascochyta*, *Peronospora*, *Uromyces* and the nematodal root diseases caused by *Trichodorus* and *Meloidogyne*. This is not to say these are unimportant. At certain times, when environmental conditions favor them, each may have a suppressive effect on alfalfa quality and productivity. It is the aim of plant pathologists and plant breeders to attain the highest level of control for each disease and in a crop such as alfalfa the search for resistance in natural populations of existing varieties is often a productive area. Since there are so many diseases, an increase in research support will be required to systematically determine the relative resistance of a number of different clonal and synthetic lines of alfalfa. Such information would be valuable for commercial, University and USDA plant breeders.

Among the suppressive but nonlethal diseases, I have chosen to describe in more detail the alfalfa mosaic virus (AMV) disease in the greatest detail because there is perhaps less known of the damage potential of this disease than for most others listed above. One reason for this is the presence of so many strains of AMV with differing degrees of virulence. Also the virus is seed transmitted which almost guarantees there will be a source of inoculum in each new planting unless someone works out a method of producing virus-free seed as is done for lettuce mosaic virus. Even if that could be done, there are so many other natural hosts of AMV that it would be unlikely that a field would remain free of AMV for long. Breeding for resistance appears to show promise, however the great number of different strains of AMV complicates such a program Also important to such a program would be methods of assaying the degree of multiplication of AMV in different varieties. To identify as many strains as possible, serology will be helpful.

Of the existing lethal type diseases Phytophthora root rot is perhaps the most important. Fortunately some progress is being made on the search for resistance; however much more needs to be done to increase the level to a much higher degree than now exists.

It is important in breeding for resistance to understand that the disease problems vary immensely from area to area. Thus the Imperial Valley has a serious stand depletion problem in the summer caused by *Rhizoctonia solani* and by high temperature flooding injury during excessively long irrigations. These problems do not appear to be such a problem in the San Joaquin or Sacramento Valleys. Likewise in the coastal areas the stem and bulb nematode disease, downy mildew and other leaf spot diseases are more severe than in the drier inland areas.

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