SUMMER STAND DEPLETION OF ALFALFA IN THE LOW DESERT VALLEYS OF SOUTHERN CALIFORNIA

Donald C. Erwin
Department of Plant Pathology
University of California, Riverside 92502

William F. Lehman
Department of Agronomy
University of California
Imperial Valley Field Station
El Centro, California 92243

In the southern deserts of California, Coachella, Imperial, and Palo Verde valleys and in the Yuma region of Arizona, the extreme summer temperatures are considerably higher than in the high desert such as the Antelope Valley or in the San Joaquin or Sacramento valleys farther north. For instance in August 1950-52 at Brawley, California, there was an average of 28 days with a maximum above 100°F but at Fresno there were only 10; at Brawley there were 7 days above 110°F but at Fresno there were none above 110° (from U.S. Dept. of Commerce Climatological Data, California Vol. 54, 55 and 56) (Erwin et al. 1959b). Growth and development of alfalfa in the southern desert valleys are depressed during the months of July and August. This in part is probably due to the lack of physiologic adaptation of the crop to relatively high soil temperatures.

Information on the effect of soil temperature on growth of alfalfa was obtained from an experiment conducted in the greenhouse at Riverside (air temperatures varied from 70°F at night to 85°F in the day). Alfalfa plants (var. Africa) were grown in a steamed sandy silt soil in stainless steel water tight cans about 10 inches in diameter and 14 inches in depth (air dry weight of soil was 20 lbs). Soil moisture was maintained between 5 and 12% by irrigating with deionized water as indicated by readings on a tensiometer. The cans were maintained in large tanks of water in which each temperature was thermostatically controlled (± 2°F). The foliage from plants in each can (2 plants/can) was clipped when blooms began to appear and the dry weights were recorded. The data (Table 1) indicated that a soil temperature of 99°F was less favorable for growth than at the lower temperatures. When plants became well established optimum growth occurred at 72 and 81°F (Fig. 1).

Table 1. The effect of controlled soil temperatures on growth of Africa alfalfa in a greenhouse. Plants were started on August 2.

Temp (°F)	Yield (grams) of alfalfa forage at three dates of harvest[a/]		
	Sept. 24	Oct. 10	Dec. 4
63	1.2	1.3	2.8
72	1.8	1.7	4.6
81	1.0	1.0	3.4
90	1.0	1.4	1.8
99	0.4	0.4	0.8

[a/] Yield data were also recorded November 6 but due to an experimental error could not be used.

In addition to the depressing effect of high temperature on alfalfa growth, certain diseases are also favored by high soil temperatures (Erwin 1956, 1971; Houston et al. 1960). For this reason, the summer season in the Imperial Valley was once looked upon as the dormant season during which little growth or development of alfalfa was expected. Many growers did not irrigate during July and August and allowed the land and plants to become dry. Some plants survived this enforced dryness and when reirrigated revived and produced forage during the fall, winter, and spring. To replace the plants lost during the summer the practice of replanting alfalfa in the fall evolved as a practice unique to the Imperial Valley. These practices were aimed at avoiding the disease that is popularly called scald (Fig. 2). This and other diseases of alfalfa have been described (Erwin 1971), Houston et al. 1960).

Indeed it was a popular belief that soil temperatures increased as the irrigation water flowed over the land and that plants were killed by the heat, hence the term "scald." Experimental work has indicated that this is not true. Although soil temperatures in excess of 120-130°F have been recorded in the Imperial Valley, the soil temperatures recorded in alfalfa fields between 1953 to 1959 indicated that irrigated soil at 4 inches depth was always cooler than the irrigation water and that the irrigation water was always cooler than air temperature. Additional data has been reported (Erwin et al. 1959a, 1959b).

The symptoms of summer flooding injury (scald) are quite distinctive. Following irrigation by flooding during periods of high temperature (105-112°F), it is common for nearly all the plants in the flooded area to quickly wilt and subsequently die within 7-10 days. Plants on the raised borders are not affected. If one examines the roots of plants in the initial stages of the disease, the xylem (woody water conducting tissue) becomes brown in color (Fig. 3). Later the root may collapse due to a soft rot presumably due to the action of bacteria in the soil. Often the affected root in this stage have an unpleasant odor.

In research designed to find the cause of scald, it was found in greenhouse work that flooding Holtville clay loam soil at high temperatures (104°F) for periods of 10-12 hours caused a severe root rot of alfalfa plants and a darkening of the xylem tissues of the root, whereas plants flooded at lower temperatures (90°F) were not injured. Plants which were grown at 104°F or at higher temperatures in moist but nonflooded soil were not damaged. In other experiments sterilization of soil before flooding at high temperatures prevented damage, indicating that microorganisms were involved in the disease. After obtaining these different types of information, we concluded that the cause of damage was due to the interaction of high soil temperature, length of the flooding period, and the effect of soil microorganisms (Erwin et al. 1959b). In another experiment when air was bubbled through the flooded field soil in pots held at 104°F, injury was prevented (Fig. 3). We surmise that the competition for oxygen by soil microorganisms at high soil temperatures might result in rapid deterioration of the roots of affected alfalfa plants. Thus the term scald does not adequately describe the complex cause of this disease. Summer flooding injury probably describes the disease more accurately; however, the term scald will probably persist because of prior usage.

In field plots at the Imperial Valley Field Station we found that short flooding periods of 12 to 24 hours at high temperatures did not cause any visible loss in stand but when the flooding period was extended to a 36-60 hour period severe flooding injury occurred with loss of nearly all the plants in the plots. It may seem that the requirement of a 36-60 hour flooding period for root damage to occur in the field was unrealistic since few if any farmers would allow an irrigation to continue for that length of time. However field observations soon indicated that our relatively short 300 feet long plots were much more efficiently drained than most commercial fields because of their short length and precise slope. In commercial fields where the irrigation runs are often as much 1/2 mile in length irrigation for periods of only 12 hours often resulted in complete saturation of the soil for 24-60 hours depending on the degree of drainage.

In addition to the flooding period we found that mowing plants just before irrigation increased their susceptibility greatly. This was proved conclusively in greenhouse pot tests and in the field (Table 2). We think the increased susceptibility of clipped plants may be due to the fact that foliage could supply at least some oxygen to the roots during the flooding period.

Research on isolation of associative microorganisms from roots affected by flooding injury during the late 1950s did not reveal any particular associative microorganisms that would reproduce the flooding injury symptoms when tested on alfalfa plants in the greenhouse (Erwin et al.1959). However in recent years we have frequently isolated a Phytophthora sp. from rotted roots that grows actively at 110°F. Since this Phytophthora is pathogenic to tap roots and is different than the P. megasperma isolates that cause root rot in the fall, winter, and spring (Erwin 1954b, 1956, 1965, 1966), it is possible that in addition to poor aeration this fungus is also involved in this complex root disease.

Table 2. Effect of clipping alfalfa foliage prior to flooding on plant loss due to flooding injury on field plots flooded for 36 and 60-hour periods of time.

Treatments	Plants living per square foot 10 days after flooding began	
	Flooded 36 hrs (day, night, day)	Flooded 60 hrs (day, night, day, night, day)
	%	%
Mowed 1 day before flooding	26	0
Mowed 5 days before flooding	44	0
Mowed 20 days before flooding	88	25

Rhizoctonia root canker, caused by Rhizoctonia solani, also occurs only during the hot summer months (Smith 1943, 1945, 1946; Erwin 1956, Houston et al.). The disease is characterized in the summer by light brown to tan elliptical cankers at the point of emergence of lateral roots on the main taproot (Fig. 4). During the winter these lesions become black and the causal fungus becomes inactive. The disease is lethal when many lesions occur on the taproot. Rhizoctonia root canker is unique in that it has been recorded only from Southwestern United States and in Queensland, Australia, following heat waves (Purss 1965).

In an effort to determine whether a time period for irrigation could be established that would promote the highest yield of forage and the least amount of stand loss, two field experiments were conducted in different years (Lehman et al. 1968). In these experiments each of which were observed over a 2-year period, the effects of irrigation management by use of tensiometers to measure the dryness of the soil on the yield, persistence of the stand, and on the levels of soil salinity in the root zone were tested A frequent short irrigation (flooding for 3 hours when soil tensiometers indicated a soil suction of 30 centibars (cb) increased the yield, stand persistence and quality of forage when compared to a normal short (flooding for 3 hours when tensiometers indicated a soil suction of 70-80 cb), and a frequent long (flooding for 6 hours when tensiometers indicated a soil suction of 30 cb) (See Fig. 1, Lehman et al. 1968).

In a subsequent experiment on another field the yield was approximately the same for all treatments except that in the frequent long irrigation treatment there was a depletion in stand resulting in replacement of alfalfa by grass which reduced the quality of the forage.

In these studies (Table 2, Lehman et al. 1968) the stand count (plants/sq. ft.) decreased gradually in all treatments to only a few plants/sq. ft. over the two years indicating that soil borne diseases were important. In the first experiment there were 42 to 50 plants/sq. ft. plot, when the experiment started, but after 2 years the numbers were reduced to an average of 0.3 to 5/plot. Likewise in the second experiment the numbers were reduced from 15 to about 3 per sq. ft. plot. In the second experiment when a detailed examination of plants for disease symptoms were made in the normal short treatment there were only 4.6% plants with Rhizoctonia root canker compared to 14.2% and 19.7% for the frequent short and frequent long treatments respectively. Incidence of xylem necrosis characteristic of flooding injury was 6.3% for the normal short compared to 20.1% and 23.8% for the frequent short and frequent long treatments respectively. There was no Phytophthora root rot (Erwin 1954, 1965) on May 15 in the normal short irrigation but in the other treatments the disease was recorded in several areas. We concluded that there was a lower incidence of the summer diseases, Rhizoctonia root canker and summer flooding injury, and a lower incidence of the winter disease, Phytophthora root rot, under conditions in which the plants were stressed for moisture. However observation for these diseases do not entirely explain why the stand was reduced so drastically by the end of the second year especially in the normal short treatment in which there was the least amount of the known diseases.

Admittedly we need more research to determine whether there may be other soil-borne diseases for which the cause is as yet not understood. In 1954 (Erwin 1954a) a detailed study of crown rot was made but of the frequently isolated Fusaria, Phoma and other fungi,

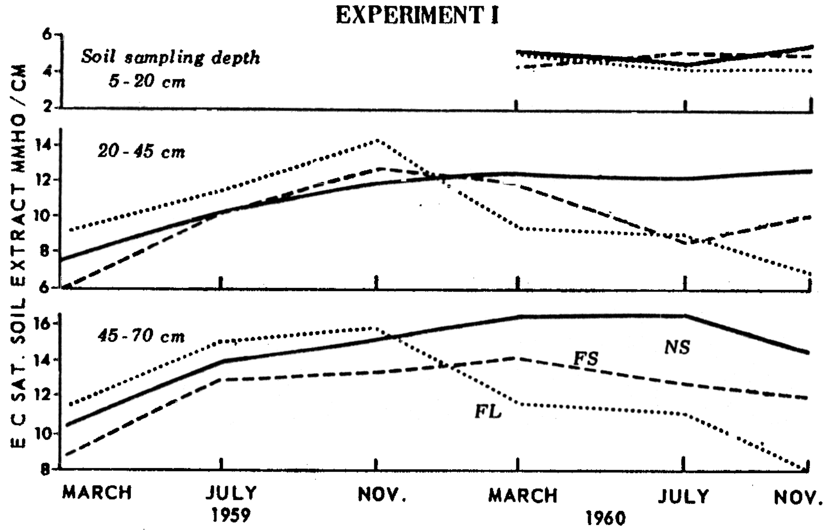


Fig. 7. Soil salinity trends during Experiment I as measured by the electrical conductivity at 25° C of the saturate extracts of soil samples taken from the three depths of the indicated dates during the experiment. Each plotted point is an average of two sampling locations per plot and three replicated plots. See text for the irrigation treatments specified by NS, FS, and FL, respectively.

Table 6 shows the averages for individual plots. The surface samples, 0 to 5 cm, were replicated three times; the Of considerable interest is the fact that the 13 irrigations with 24-hour durations resulted in no greater reductions

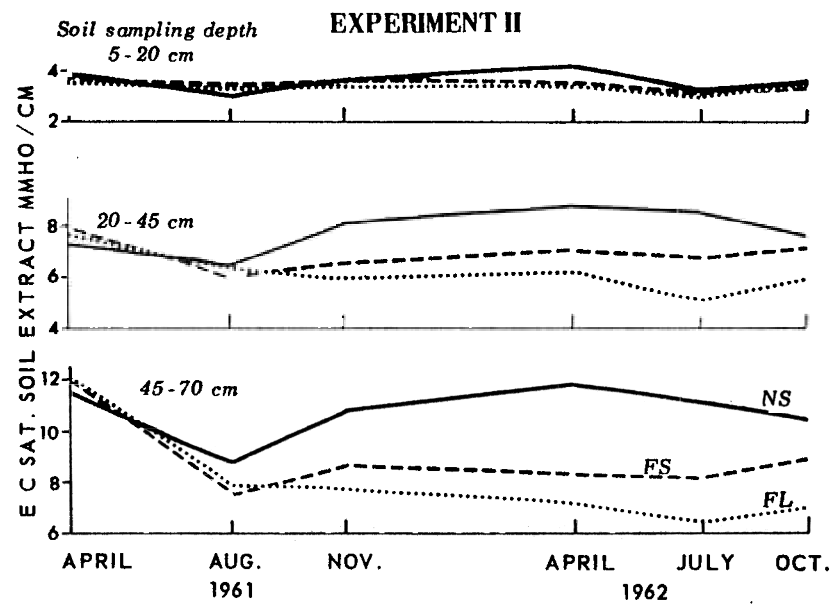


Fig. 8. Soil salinity trends during Experiment II as measured by the electrical conductivity at 25° C of the saturate extracts of soil samples taken from the three depths of the indicated dates

none could be proved to be pathogenic. Some Rhizoctonia isolates caused cankers on stems but none reproduced the severecrown rot so commonly seen in the field (Fig. 5). This disease may be one of the most important and is perhaps the most puzzling of all alfalfa diseases. Although the associative fungi could not be shown to be cause of typical crown rot on rapidly growing plants in the greenhouse, we perhaps need to reconsider whether or not frequent clipping, excess salinity or mechanical injury are predisposing factors that could favor the pathogenesis of slow-growing plant pathogens.

In the two experiments by Lehman (1968) the salinity was lowest in the frequent long irrigation plots followed by the frequent short and normal short (see Fig. 7, Lehman et al 1968). For instance in July 1960 with the 45-70 cm depth in soil the values (E.C. X 10^3 of the saturated soil extract in mmho/cm) the normal short readings were over 16, frequent short about 13 and frequent long about 11. In general in the frequent long treatments the salinity decreased most during the winter months when plant demand for water was least.

Thus in irrigation management, reduction in the frequency and length of irrigation has a decided effect on reduction of certain diseases such as Phytophthora root rot, Rhizoctonia root canker, and summer flooding injury (scald), but shorter irrigations result in an increase in soil salinity. Since the soil type and salinity conditions vary from field to field, it is difficult to make precise recommendations but it is well founded to say that careful avoidance of unusually long periods of irrigation especially at high temperatures reduces the severity of these three diseases.

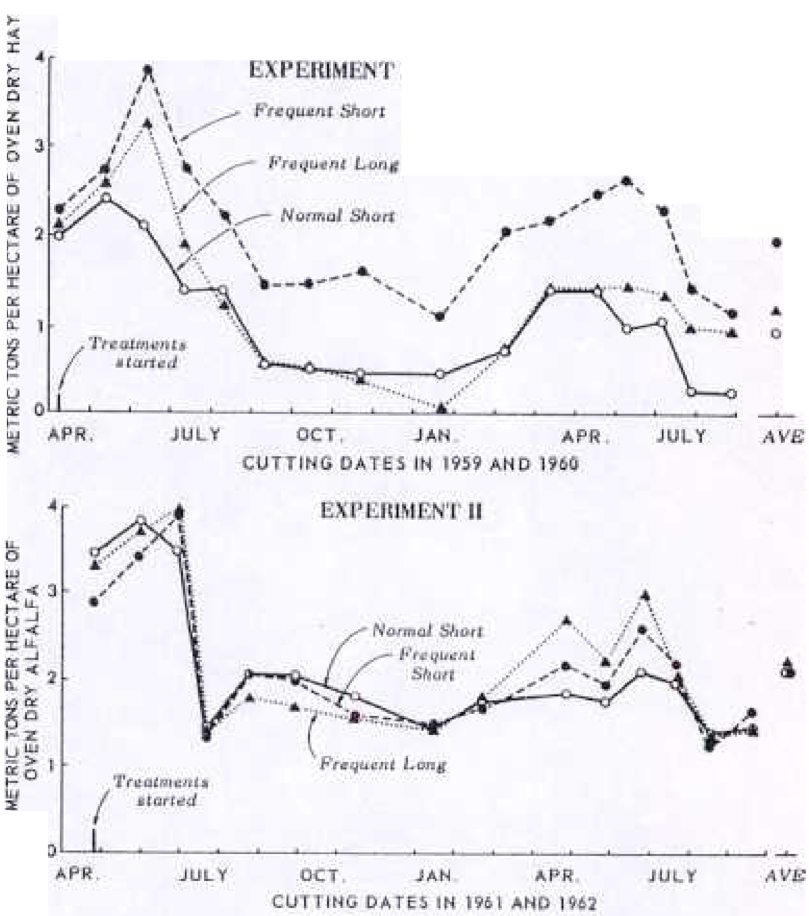
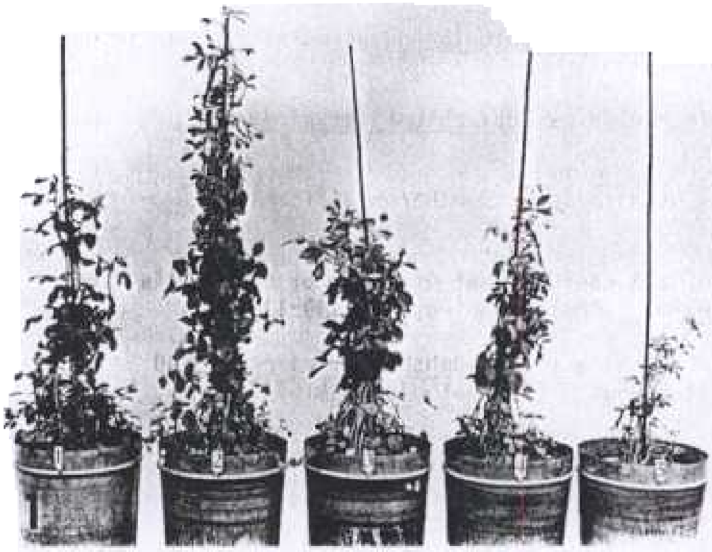
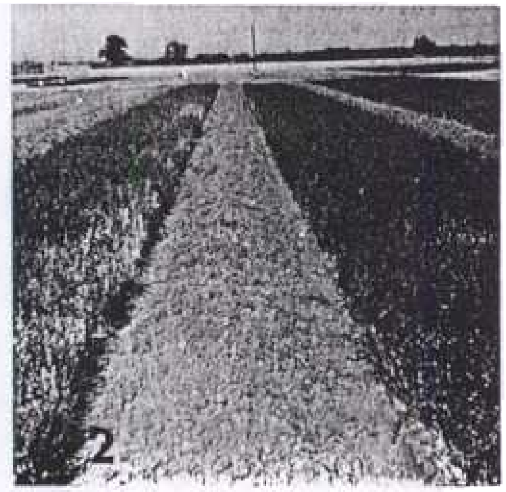
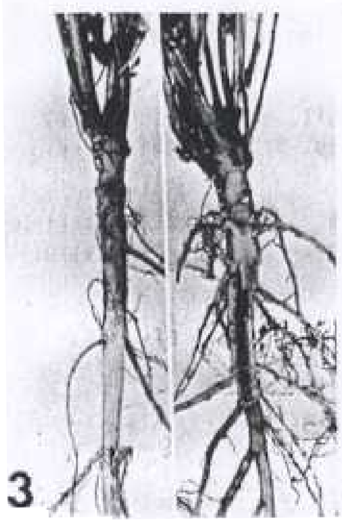


Fig. 1. Alfalfa hay yield by cutting date for two experiments with three irrigation treatments each.

(Reprinted from Lehman et al, 1968)







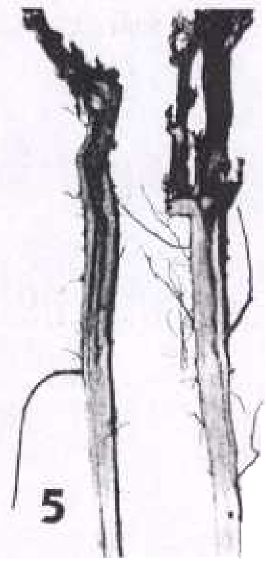


Fig. 1. The effect of soil temperature on the growth of alfalfa in the greenhouse (air temperature 70-85°F). Pot 1: 63°F; pot 2: 72°F; pot 3: 81°F; pot 4: 90°F; and pot 5: 99°F.

Fig. 2. Plot on the left was flooded for 39 hrs and the one on the right for only 29 hrs on July 21, 1958. Plants on the 39-hr flooded plot are dying because of high temperature flooding injury (scald).

Fig. 3. The effect of artificially aerating flooded Holtville clay loam soil at high temperatures (104°F) on root damage in a greenhouse experiment. The healthy plant on the left was grown in aerated soil and the plant on the right with xylem necrosis was grown in nonaerated soil. The roots of both plants were cut longitudinally to show the necrosis of the water conducting tissue.

Fig. 4. Rhizoctonia root cankers on the taproots of alfalfa plants collected in the Imperial Valley in October. The lesions at this time are inactive.

Fig. 5. Crown rot of alfalfa on a plant collected in the Imperial Valley in July. Cause of this disease is complex and has not been proved to be due to any particular fungus.

LITERATURE CITED

Erwin, D. C. 1954a. Relation of *Stagonospora*, *Rhizoctonia* and associated fungi to crown rot of alfalfa. Phytopathology 44:137-144.

Erwin, D. C. 1954b. Root rot of alfalfa caused by *Phytophthora cryptogea*. Phytopathology 44:700-704.

Erwin, D. C. 1956. Important diseases of alfalfa in southern California Plant Dis. Rptr. 40:380-383.

Erwin, D. C. 1965. Reclassification of the causal agent of root rot of alfalfa from *Phytophthora cryptogea* to *P. megasperma*. Phytopathology 55:1139-1143.

Erwin, D. C. 1966. Varietal reaction of alfalfa to *Phytophthora megasperma* and variation in virulence of the causal fungus. Phytopathology 56:653-657.

Erwin, D. C. 1971. The identification of diseases of alfalfa, their effect on production and control. Proc. Calif. Alfalfa Prod. Symposium Dec. 7-8, 1971. Fresno, Calif.

Erwin, D. C., B. W. Kennedy, and W. F. Lehman. 1959b. Xylem necrosis and root rot of alfalfa associated with excessive irrigation and high temperatures. Phytopathology 49:572-578.

Erwin, D. C., W. F. Lehman, B. W. Kennedy, and G. F. Worker, Jr. 1959a. Summer flooding of alfalfa. Calif. Agr. 13(10): pp 7 and 12.

Houston, B. R., D. C. Erwin, E. H. Stanford, M. W. Allen, D. H. Hall, and A. O. Paulus. 1960. Diseases of alfalfa in California. Calif. Agr. Exp. Sta. Ext. Serv. Circ. 485: 20 pp.

Lehman, W. F., S. J. Richards, D. C, Erwin, and A. W. Marsh. 1968. Effect of irrigation treatments on alfalfa (*Medicago sativa* L.) production, persistence, and soil salinity in southern California. Hilgardia 39:277-295.

Purrs, G. S. 1965. Diseases of Lucerne. Queensland Dept. of Primary Ind. Div. of Plant Industry Advisory Leaflet 812: 12 pp.

Smith, O. F. 1943. Rhizoctonia root canker of alfalfa (*Medicago sativa*) Phytopathology 33:1081-1085.

Smith, O. F. 1945. Parasitism of *Rhizoctonia solani* from alfalfa. Phytopathology 35: 832-837

Smith, O. F. 1946. Effect of soil temperature on the development of Rhizoctonia root canker of alfalfa. Phytopathology 36:638-642.