Soil-Moisture Tension Effects on Root Development and Shoot Growth of Alfalfa

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INTRODUCTION

In alfalfa production, high yield from the shoot system is the main interest. Adequate root activity for high yield is possible with relatively shallow root systems if proper environmental conditions are maintained.

Maintenance of a proper soil environment is extremely difficult, however, when the volume available for root exploitation is restricted. As surface soil is reduced in water and nutrient contents, a plant like alfalfa, with an extensive root system, may continue to fill its nutrient and transpiration demands from greater depths.

Water is one of the primary growth requisites for the root. Thus, the rate and extent of root development is controlled by water stress. Low soil moisture potentials, and subsequently low plant water potentials resulting in reduced tissue hydration, may affect plant growth in several ways. The research work presented here is aimed at investigating the effect of soil water potential on the extent of root development and shoot growth of alfalfa. A number of investigators have published data on observed relationships between soil-moisture tension and root elongation (5, 7, 8, 9). Bierhuizen (1), reported that frequent and light irrigations, when water is inadequate below, will restrict root penetration. It is also expected that if root development is restricted at the surface by drying the soil, a comparable increase will result at deeper depths if water is available. The data of Peters (8) showed that elongation of corn roots decreased as soil-moisture tension increased. Taylor and Slater (13), stated that growth of both roots and shoots is retarded when soil-moisture tension increases in the soil portion occupied by the roots. Nakayama and Van Bavel (7), on the other hand, reported that water removed by Sorghum from 120 to 180 cms was not appreciably different from various irrigation treatments. In addition, they reported that 90 % of the water uptake occured from the upper 60 % of the root zone. Watson (14), and Kramer (6), concluded that good yield is maximum when soil moisture potential is kept high enough. Quality is also expected to be affected by

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soil-moisture stress. Brenzeau and Sommer (2), studied the nutritive value of alfalfa as influenced by three irrigation treatments where available moisture was depleted to three levels before recharging the root zone. The 50 % level of depletion yielded 19.5 % more protein and 32.8 % more digestible Cellulose than the wet level of 25 % and 8.3 % more than the dry level of 75 %. In view of these and other reports, Danielson (3), indicated the need for more field experiments to substantiate a general conclusion.

MATERIALS AND METHODS

Three field plots were selected for the experiment at the Benkhela farm of the Faculty of Agriculture, University of Libya, at Sidi El-Masri, Tripoli, Libya. The experiment was conducted to test the influence of three soil-moisture tension values (irrigation levels) on root and shoot growth of alfalfa. The three treatments were applied at random to the three plots. Each plot was then divided into three subplots for sampling. These levels were to deplete moisture content to predetermined values of 30, 50 and 70 % of available moisture before commencing the next irrigation to bring the moisture content to field capacity in the effective root depth. These were achieved by scheduling different frequency and irrigation periods for each plot. A controlled sprinkler irrigation system was used for irrigation.

Tensiometers were placed at 60 cm depth. The soil-moisture tension readings were recorded daily, before, after, and between irrigations and their values were plotted versus time in days for the three plots.

Three similar trenches, one in each plot, 100 × 250 cm were dug to a depth of 150 cm. By carefully removing soil from the sides of the trench, a vertical layer of roots was exposed. The depth and development of roots were then measured. The soil-core method was used to obtain soil samples from subsequent layers for moisture content determination directly before irrigation to show moisture depletion distribution against depth. The same core samples from successive layers were also used for evaluating root growth. The core samplings penetrated, however, to a maximum depth of 110 cm only. Root development was observed in the trench down to a depth of 130 cm. A plant sample from each subplot was taken to evaluate shoot growth.

RESULTS

The Physical properties of soil in the test site classifies the soil as sandy loam soil. It is uniform and homogeneous throughout the root depth. Shoot growth and root development are shown in Table 1. Average soil moisture content directly before irrigation is shown in Fig. 1. Soil moisture values at a depth of 60 cm from the soil surface are plotted in Fig. 2 for the three treatments. This level was considered by Taylor (12), to be the most favorable depth to place instruments for irrigation control for alfalfa. A similar conclusion could be reached by examing the soil moisture content distribution before irrigation shown on Fig. 1. Weights of dry shoot samples from each treatment are listed in Table 1. The data show a significant difference between soil-moisture maintained (l.s.d. = 5.60gm/100 gm). It shows that maximum shoot growth resulted from maintaining the soil moisture tension in the root zone (at 60 cm depth) below 600 m.b. This corresponds to a 50 % depletion (treatment II) in the root zone. Yet the maximum root elengation and development was obtained when soil-moisture tension was lowered below 70 c.b. by depleting up to 70 % of the available soil-moisture in the root zone. In such a case, 90 % of the moisture used was obtained from the upper 90 cm of the root depth.

Table 1 Shoot and root growth for different treatments.

Irrigation treatment	Shoot growth gm/100 sq. inch			mean	Root Elongation cm.	Root development
	1	2	3			
I	53.6	54.4	55.0	**54.3**	133	90 % of the roots in the upper 90 cm.
II	59.0	58.6	60.2	**59.0*+**	126	90 % of the roots in the upper 80 cm.
III	52.0	50.8	53.3	**52.0**	120	80 % of the roots in the upper 60 cm.

*L.S.D. = 5.60 gm/100 sq. inch
+T II compared with T III

The (relatively) least elongation, however, occured when only 30 % of the available moisture was depleted where 80 to 90 % of the water consumed was depleted from the the upper 60 cm of the root zone.

This is in contrast to the conclusion reported earlier (13), where growth both of shoot and root were retarded when soil moisture tension increased. It is evident that the elongation rate decreases as water tension rises and that, per unit of increase in tension, the effects are higher in the low tension range (7). The inverse relationship between water content and aeration, however, must be considered. A rising water content corresponding to a lower soil moisture tension will result in thicker water films that surround the root and retard the rate of oxygen supply as well as the efflux of carbon dioxide (5,11). Another factor could be contributing to the observed differences and those concluded earlier (10). It is clear from Fig. 1 that top soil layers lost more of their available water at higher percent of depletion corresponding to higher soil-moisture stress. As lower depths still have more available water, the plant is expected to compensate for this by sending more roots downwards into these layers. A similar conclusion was reported for onions (10).

Low soil water potential and consequently low plant water potential control plant growth. Plant water potential depends upon absorption through roots and water lost through transpiration. The rate of supply of moisture to roots depends upon the soil moisture content and soil water conductivity. Both factors are related to soil-water potential (12). This would explain the significant difference in shoot growth due to change of soil-moisture potential maintained and the consequent relative high yield around 600 c.b. of soil moisture stress reported and shown in Table 1.

SUMMARY

An experiment was conducted to determine the effect of soil-moisture stress maintained in the effective root depth on root and shoot development of alfalfa. These levels were maintained before depleted moisture was replaced to bring soil moisture in root depth to field capacity. Highest shoot growth resulted when 600 m.b. suction was maintained. Root development, however, was more for a drier level of more than 700 m.b.

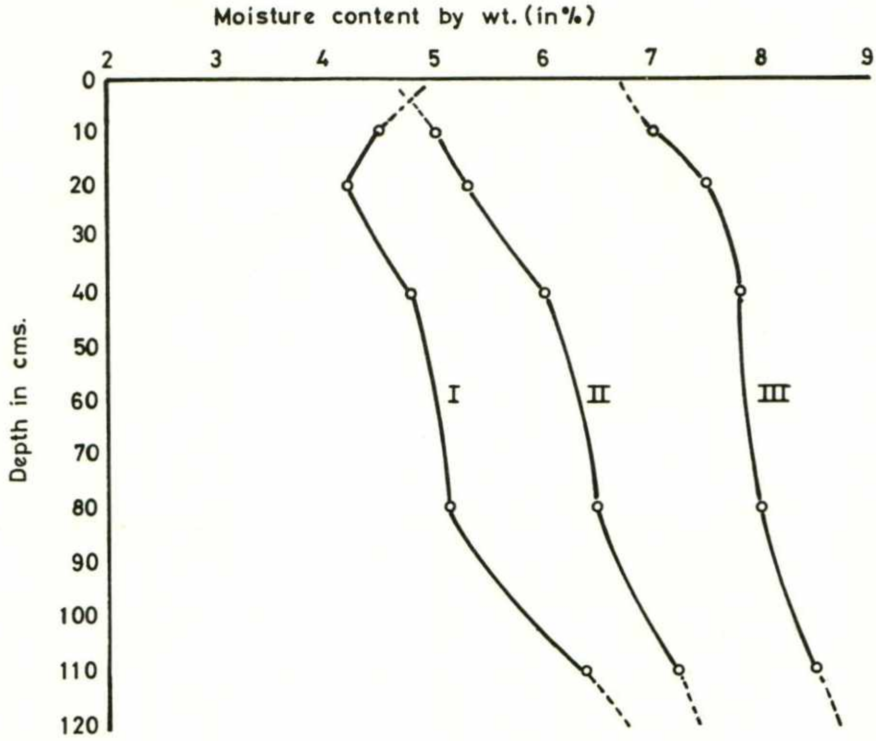

Fig. 1. Average soil moisture content at different depths of the three treatments taken directly before irrigation

The results indicate that under soil-moisture stress the shoot (aerial portion) of alfalfa is affected more than the root system. Consequently, in consideration of the plant system as a whole, growth was retarded at a faster rate in the aerial portion of alfalfa than in roots.

An explanation based upon the relation of both plant water potential, and rate of soil moisture conductivity to the roots, to soil-water potential was suggested. The soil aeration and oxygen rate of supply to roots was also suggested to explain the difference between the effect on the shoot and on the root. The results suggest an average amount of 3.18 inches of soil moisture to be replaced each 15 days to give the optimum results for irrigating alfalfa under conditions similar to those experimented.

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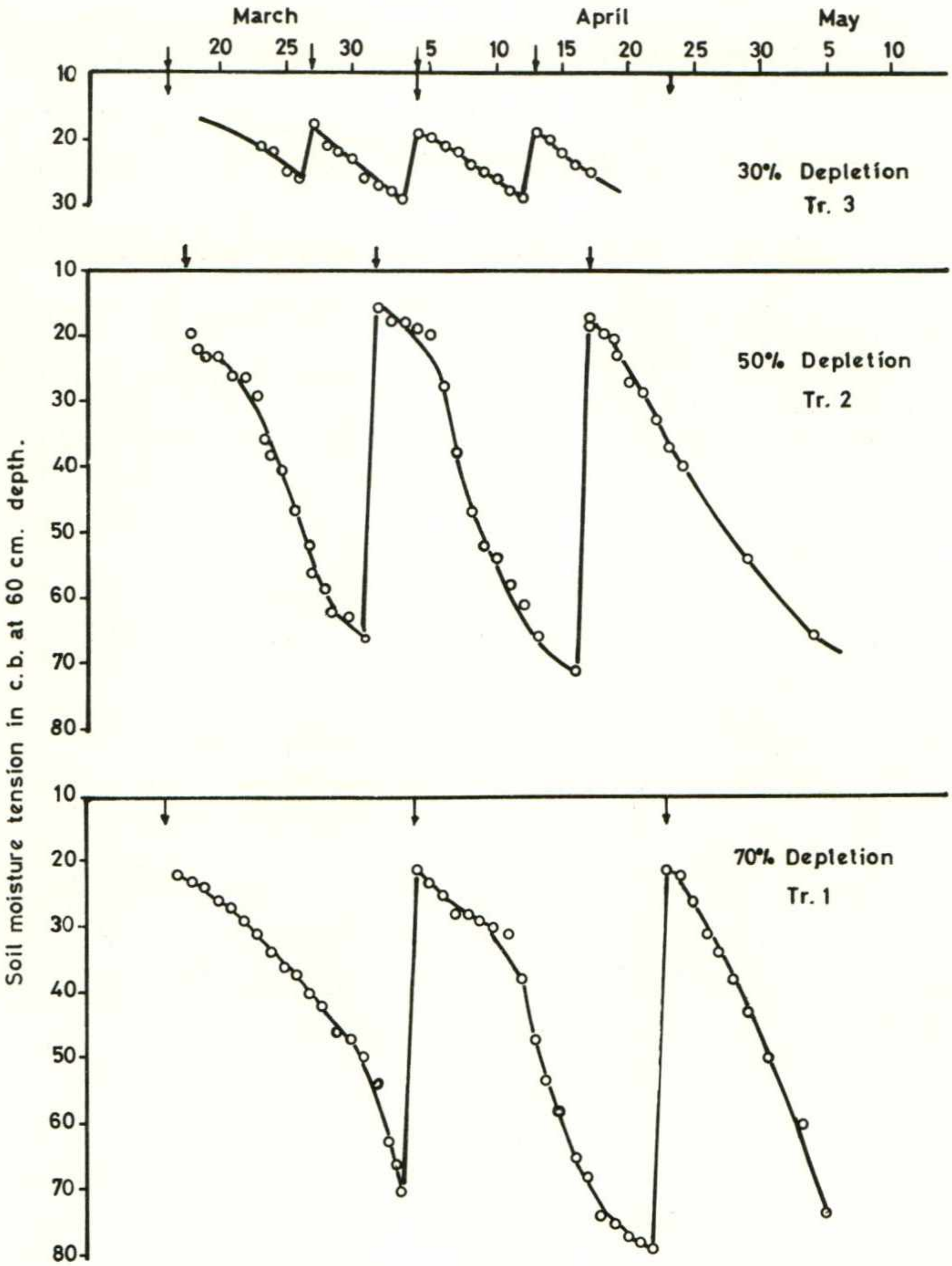

Fig. 2. Soil moisture tension in c.b. at 60 cm depth versus time for the three treatments.

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