ALFALFA GROWTH AND DEVELOPMENT

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ABSTRACT

The alfalfa (*Medicago sativa* L.) seedling develops into a mature plant by differentiation of several stems which form the primary crown. The initial four stems are the primary stem, two stems differentiating from the axils of the cotyledons and a stem from the axil of the unifoliolate leaf. Establishment of the primary crown is dependent on the development of these initial stems and the degree to which contractile growth occurs. All of these processes are influenced by soil temperature, and to a lesser extent, by photoperiod. We have determined optimum temperatures for alfalfa seedling development to be in the range of 68 to 72 degrees fahrenheit depending on the dormancy classification of the cultivar. Using this information and climatic information for a given area in California it may be possible to predict the most desirable time to plant alfalfa in that area.

INDEX WORDS

Medicago sativa L., Lucerne, seedling growth, crown development, planting date, environmental physiology.

INTRODUCTION

One of the most critical operations in the production of alfalfa is stand establishment. In the alfalfa research program at Davis we are committed to the application of fundamental biology to the improvement of both the alfalfa plant and the cultural methods used to grow the crop. In the present paper we will discuss the general pattern of alfalfa seedling growth, the influence of soil temperature and photoperiod (day length) on seedling development, and the use of this information to make farming decisions that take into account both biological and economic considerations.

SEEDLING DEVELOPMENT

Shortly after planting and watering, the seed begins to germinate. This is first detected by the penetration of the primary root into the soil to produce an unbranched tap root. Contained within the mature seed are seed leaves or cotyledons. As the area below the cotyledons (hypocotyl) straightens and elongates, the cotyledons are pushed above the soil surface (Figure 1). The first true foliage leaf to be produced is the unifoliolate (having a single leaflet) leaf. The seedling stem (primary shoot) continues to develop, producing spirally arranged trifoliolate (having three leaflets) leaves (Figure 2). Subsequently produced stems are referred to as secondary stems. The first secondary stem develops from an axillary bud at the unifoliolate node. This is followed by the second and third secondary stems which develop from axillary buds at the cotyledonary nodes (Figure 3,4). These four stems (primary plus 3 secondary) constitute the primary crown. Concurrent with the growth of the primary and secondary shoots, the hypocotyl shortens through a process known as contractile growth.

Specific internal cells (parenchyma) of the hypocotyl are responsible for contractile growth, since they simultaneously expand laterally and shorten longitudinally. This results in a lengthwise tension which shortens the hypocotyl overall. Outer tissues of the hypocotyl, which do not actively contract, are lifted in folds and wrinkles over the surface, producing the characteristic appearance of contracted roots and stems. Hypocotyl contraction in alfalfa seedlings begins at about the time the cambium (layer from which new cells are produced) becomes activated to produce woody stem and root tissues. As a consequence of this contractile growth both the cotyledonary nodes and the unifoliolate node may be pulled beneath the soil surface (Figure 3,5). The adaptive value of contractile growth is considered to be in protection of growing points from dessication, cold or mechanical damage. In order to insure that a new planting is established it is important to allow this growth to take place prior to introducing farming practices that are disruptive to this process.

INFLUENCE OF PHOTOPERIOD AND SOIL TEMPERATURE

Both photoperiod and soil temperature have an influence on alfalfa seedling development. These environmental conditions influence growth rate, stem initiation, and the allocation of photosynthetic products to the development of roots and stems. However, not all cultivars respond to the same degree to these environmental conditions. With multiple regression, the relative importance of photoperiod and soil temperature can be determined by comparison of their standardized partial regression coefficients (Table 1). Seedling development of dormant cultivars is influenced by both photoperiod and soil temperature, with photoperiod having about 75% as great an impact as soil temperature. In semidormant cultivars such as Lahontan, during the first month of growth soil temperature has the same importance as in dormant cultivars but photoperiod, while still significant, has about one-half the importance it does in dormant cultivars. In semidormant cultivars photoperiod has less effect after the first month of growth. Seedling development in nondormant cultivars like Moapa 69 is not influenced by photoperiod but is strongly influenced by soil temperature.

Table 1. Standardized partial regression coefficients for the relative importance of photoperiod and soil temperature on the growth of alfalfa seedlings from three cultivars.

Cultivar	Time from planting: 1st month			Time from planting: 2nd month		
	Photo-period	Temp-erature	Ratio#	Photo-period	Temp-erature	Ratio#
Norseman	0.41^{**}	-0.55^{**}	0.75	0.36	-0.50	0.72
Lahontan	0.27^{*}	-0.50^{**}	0.54	NS	-0.55	
Moapa 69	NS	-0.60		NS	-0.57^{**}	

(photoperiod) / (absolute value of soil temperature).
*, ** significant at $p < 0.05$ and $p < 0.01$, respectively.

The more important factor influencing seedling development is soil temperature. During the first 4 weeks following germination the optimum temperature for root growth is between 69 F and 76 F, depending on the cultivar. In general, dormant cultivars have lower optimum temperatures during this initial growth phase than nondormant cultivars. During the second 4 weeks of seedling development the optimum temperature for root development is about 72 F (Table 2). Optimum stem growth temperatures during this initial 8 week period of time are between 72 F and 76 F (Table 2). Under cooler soil temperatures (less than 68 F) a greater proportion of the total biomass produced is allocated to root development (Figure 6).

Table 2. Optimum soil temperature for root and stem development during the first two months of growth of three alfalfa cultivars.

Cultivar	Time from planting			
	1st month		2nd month	
	Root	Stem	Root	Stem
	-------- degrees Fahrenheit ------			
Norseman	69	76	72	72
Lahontan	72	76	73	73
Moapa 69	76	76	73	72

While the effect of photoperiod is less than that of temperature in cultivars grown throughout most of California, there are two major growth characteristics influenced by photoperiod that must be considered in understanding seedling development. Firstly, a photoperiod in the neighborhood of 12 hours stimulates the initiation of crown buds and stems. Secondly, under short photoperiods a higher proportion of the photosynthate (dry matter) produced is allocated to the development of roots. Therefore, seedlings developing under short photoperiods might be expected to develop more crown buds and large root systems than seedlings developing under long days.

IMPLICATIONS FOR ALFALFA ESTABLISHMENT

It follows that there is a greater chance of success in stand establishment if the alfalfa plant is given as near optimum conditions for development as possible. This can be accomplished by matching planting dates to prevailing climatic conditions. We have obtained long term mean monthly soil temperature and photoperiod information for three representative locations in California (Figure 7-9). By matching the optimum temperature and photoperiod for a cultivar with the corresponding seasonal conditions for a location, it may be possible to predict the most desirable time to plant. When this procedure is followed, the prediction is that alfalfa planting should be accomplished during either mid March to mid April or early to mid October in the low deserts, during either late April to mid May or mid September in Davis, and during mid June to the beginning of August in the Tulelake area.

Although specific field experiments to verify the above predictions have not been conducted, we have two types of information which suggest that these predictions are valid: 1) The prediction closely matches the recommended dates of planting in these areas, and 2) both Schoner et.al. and Marble and Peterson have conducted planting date experiments with results which support the fall planting date prediction. Results from these trials demonstrate that significantly higher yields are obtained from fall plantings than from spring plantings. This advantage of the fall planting over the spring planting is manifested beyond the first production season. A possible explanation for the apparent lack of agreement between the predicted time of planting in the spring and the results from the studies conducted by the workers cited above is that 1) fall planting is followed by a period of cool temperature and reduced photoperiod which promotes crown bud and root formation and 2) spring planting occurs under longer photoperiods than fall planting and is followed by much warmer soil temperatures which are not conducive to root and crown development.

Clearly the grower wants to receive maximum potential returns from a crop. The true benefit of precisely timing planting date to correspond with near optimum environmental conditions for seedling development is the improvement of farm productivity and income. If the cost of planting too early or too late is a significant loss in the potential yield of that crop over the life, of the stand, then economically it is to the growers advantage to plant an alternative crop. The development of such information on the relative potential yield from different planting dates would contribute significantly to making this type of farm management decision.

LIST OF FIGURES

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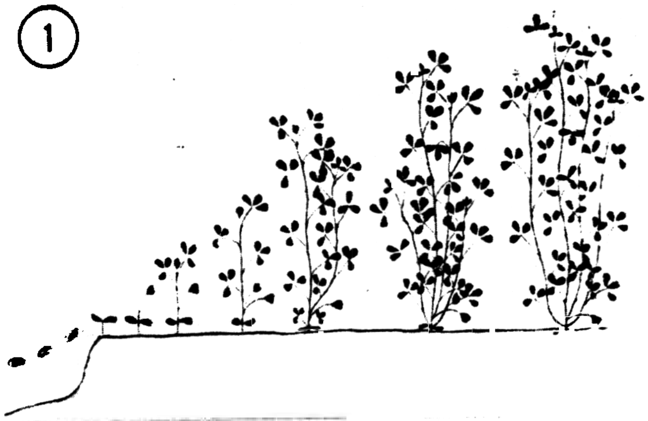
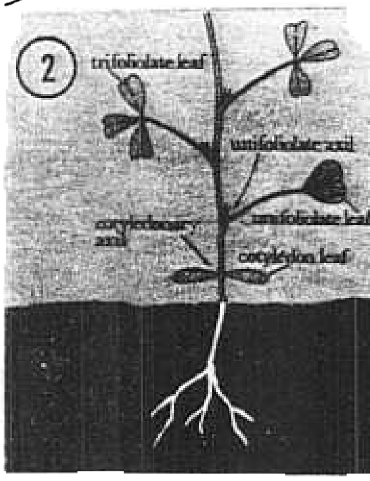
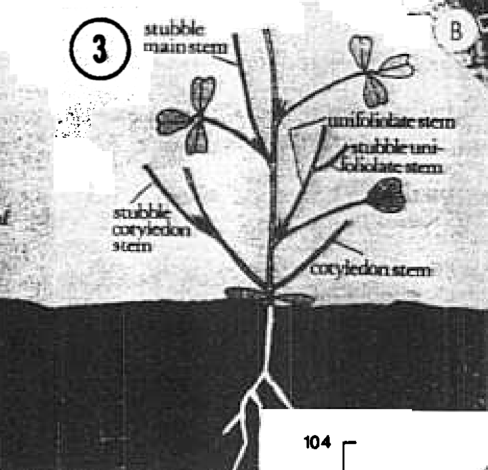
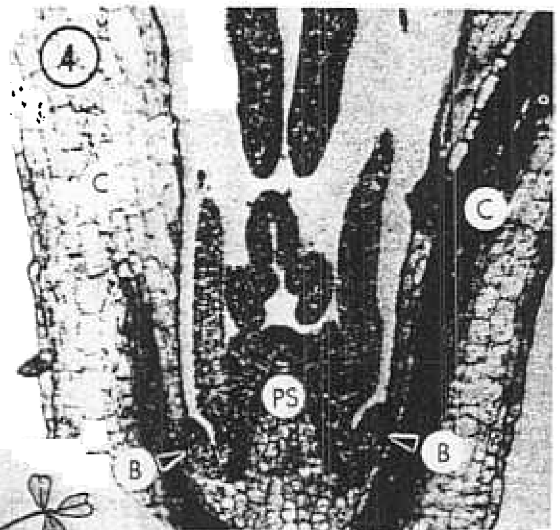




trifoliolate leaf
unifoliolate axil
cotyledonary axil
unifoliolate leaf
cotyledon leaf



stubble main stem
unifoliolate stem
stubble uni-foliolate stem
stubble cotyledon stem
cotyledon stem



C
PS
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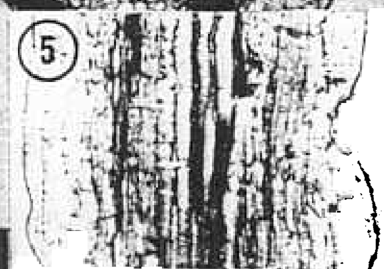
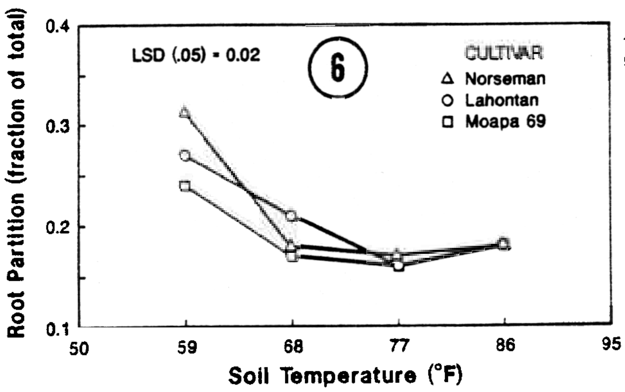
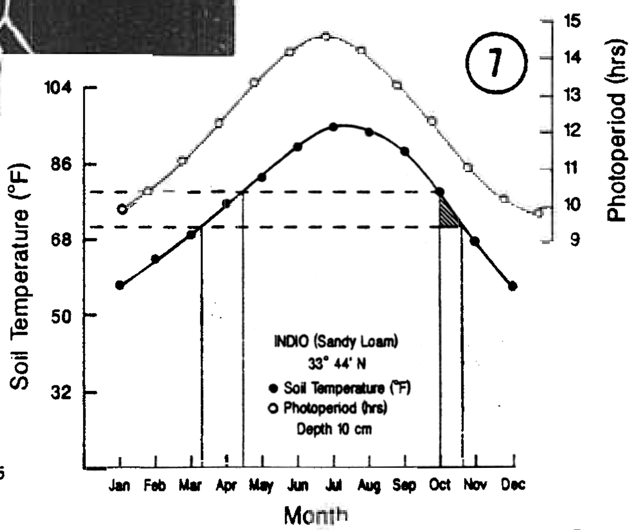
B
C

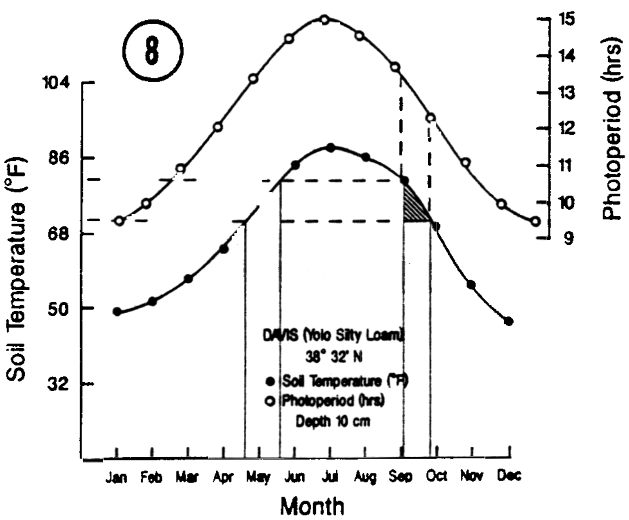




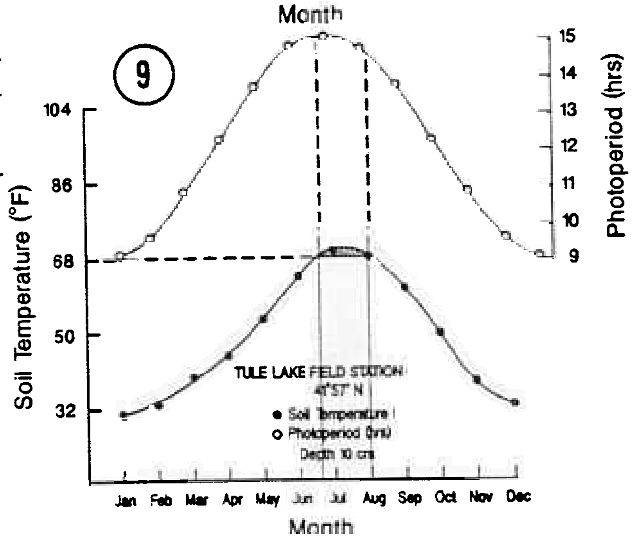
Root Partition (fraction of total)
0.1
0.2
0.3
0.4
LSD (.05) = 0.02
CULTIVAR
Norseman
Lahontan
Moapa 69
50
59
68
77
86
95
Soil Temperature (°F)



Soil Temperature (°F)
32
50
68
86
104
Photoperiod (hrs)
9
10
11
12
13
14
15
INDIO (Sandy Loam)
33° 44' N
● Soil Temperature (°F)
○ Photoperiod (hrs)
Depth 10 cm
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month



Soil Temperature (°F)
32
50
68
86
104
Photoperiod (hrs)
9
10
11
12
13
14
15
DAVIS (Yolo Silty Loam)
38° 32' N
● Soil Temperature (°F)
○ Photoperiod (hrs)
Depth 10 cm
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month



Soil Temperature (°F)
32
50
68
86
104
Photoperiod (hrs)
9
10
11
12
13
14
15
TULE LAKE FIELD STATION
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month

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