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Effects of Photoperiods and Temperatures Upon Early Growth of Tall Fescue & Ladino Clover at Various Lengths of Growing Period

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EFFECTS OF PHOTOPERIODS AND TEMPERATURES UPON EARLY GROWTH OF TALL FESCUE & LADINO CLOVER AT VARIOUS LENGTHS OF GROWING PERIOD

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser   Date

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INTRODUCTION

Tall fescue (Festuca arundinacea) is widely grown in the Pacific coast and in the southern states of the United States. In the south, its greatest value is to provide winter grazing. During summer months, it either goes dormant, dies out or cannot compete with adapted warm season species. However, tall fescue is considered to have wide adaptation. One variety of tall fescue with a large acreage is Kentucky 31, which comes into prominence because of its ability to make considerable growth and provide pasturage during the winter and early spring.

Ladino clover (Trifolium repens var. Ladino) is one of the most important pasture legumes in the United States. It is a highly palatable and nutritious forage for livestock and poultry. When grown in association with pasture grasses, ladino supplies nitrogen to the grasses. This usually results in increased yield and improved quality of forage. In the lower part of the southern states, it is generally looked upon as a winter annual, though a few plants may live through the summer without making much growth. The reason for the disappearance of stands is not clearly known.

The bloat hazard from grazing ladino clover alone has brought about the more general use of grass-ladino pastures. Tall fescue is widely used with ladino clover because in fescue-clover pastures, quality of forage is much higher than fescue alone. Therefore, maintaining the clover is an important management practice but has proved to be difficult for most farmers.

The main weakness of ladino clover as a forage is the short life of stands in pastures. Failure of stands may be the result of several environmental factors associated with weather. The effects of weather are most critical during the period of germination and in the early seedling stage. Perhaps the greatest losses, in effort and substance, are sustained through a failure "to get a stand" of the seeded grass or legume than through any subsequent steps in a forage crop program (1, 14, 19).

Thus, it seems advisable to determine what environmental conditions are necessary to obtain a satisfactory stand. The environmental conditions investigated were temperatures and photoperiods. The purpose of this preliminary study, therefore, was to try to determine the effects of photoperiods and temperatures upon early growth of tall fescue and ladino clover seedlings at various lengths of growing period.

REVIEW OF LITERATURE

Studies on the effect of photoperiods and temperatures on tall fescue and ladino clover are limited. However, investigations have been done with other crops and the results are comparable.

Light intensity

Blackman et al. (3, 4) investigated light intensity effects on growth in clover-grass associations and concluded that the legume-grass balance within a sward depended largely on competition for light.

Black (5) dealt with the influence of light intensity on the growth of herbage plants and stated that pasture legumes were intolerant of even moderate shade. He concluded, as did Brown and Munsell, (6) that competition for light was a major factor in the disappearance of white clover from field stands.

Low light intensities and high temperatures, causing high rates of respiration, limited the rate of dry matter gain of a plant community. Therefore, the net photosynthesis of a forage community decreased when foliage density became too high (6). Beinhart (2) concluded that both temperature and light intensity influenced growth rate of white clover plants by affecting leaf area production.

Went (21) reported that the light intensity was at its highest for only a few hours each day. In the morning and in the evening, intensities were approximately 1,000 ft-c. On cloudy days the light intensities may remain well below 1,000 ft-c. even at noon. Thus, plants are usually subjected to light of lower intensity than full sunlight (about 8,000 ft-c).

Light intensity of 1200 ft-c. was used for this study.

Photoperiods

Daubenmire (8) concluded that light was an important factor in the local distribution of plants on account of the wide variation of intensity in different microenvironments, but the quantity and quality of light vary so little from one region to another that these aspects of light were not important factors in plant geography. The photoperiod, however, was of considerable goegraphic significance.

Waxman (20) showed that when cuttings were taken from Cornus florida plants growing under long days and under various photoperiodic treatments, the number of roots produced for cutting was lower under short day than under long day treatments. He also reported that summer cutting of Cornus florida produced twice as many roots in an 18 hour photoperiod as those in a 9 hour photoperiod. Similar responses have been demonstrated with other species. He also found that certain species did not respond to variation in photoperiods.

Snyder (17) working with Taxus cuspidata cuttings taken in December, found little difference in the rooting response between an 18 and an 8 hour photoperiod. He reported that top growth of the cutting was stimulated in an 18 hour day length while no bud activity took place in the 8 hour daylength.

Gardner and Allard (9) stated that preliminary observations of Biloxi soybeans indicated that the duration of the daily illumination period might exert a marked effect on the relative development of the root and the top of the plant.

Lubimenko and Szeglova (10) found that the weight of the roots of tomato increased in proportion to the weight of the whole plant as the length of the day became progressively longer.

Crist and Stout (7) found that lettuce and radish plants, grown under the longest period of illumination, had the lowest top-root ratios while the short day plants had the lowest actual weight of both tops and roots.

In general, long-day plants have higher top-root ratios under long photoperiods, and short-day plants have higher top-root ratios under short photoperiods. These generalizations are in agreement with the observation that plants blossoming or with young fruits have higher top-root ratios than vegetative plants. The explanation probably lies in the monopolization of food materials by flowers and developing fruits. It is also possible that the decreased formation of phloem tissues associated with flowering plays a role in restricting the flow of foods into the root system. Inadequate soil aeration results in a reduction in root growth in most species and commonly leads to increased shoot-root ratios (12).

Temperature

Numerous examples of morphologic effects of temperature upon vegetative development can be cited. Some such effects are clearly related to the differential influences of temperature upon the processes of photosynthesis and respiration (12). Temperature, therefore, is characteristically one of the cyclic factors of the environment. Both rates of growth and the morphogenic development of plants are markedly influenced by the pattern of the temperature cycle to which they are subjected (8, 13, 22).

Mitchell et al. (13) studied temperature effect on the growth of pasture species. He found that white clover grew best at 24°C, but grew nearly as well at 18° or 30°C. Stolon growth and the rate of appearance of new stolons were the most useful indicators of responses to be expected under field conditions; these characteristics varied greatly with temperature.

Nuttonson (16) pointed out that a combination of daylength and temperature summation was better than temperatures alone for expressing the influence of climate on plant development.

Sprague (18) concluded that the largest net increase in dry matter of Sudan grass, brome grass and ladino clover occurred at temperatures of 70°F to 85°F; that of orchard grass, meadow fescue, colonial bentgrass, Kentucky bluegrass and timothy at 55° to 70°F. In every instance the dry matter produced, the number of leaves, and the height of the tallest leaf on each plant was lower under the

9-hour than under the 16-hour daylength. The amount of roots produced decreased under the shorter daylength. Root-top ratios were reduced by temperatures of 70°F to 85°F and in general were increased by temperatures below those at which optimum dry matter was produced.

MATERIALS AND METHODS

Species Used

Two forage crops were used; a grass and a legume. The grass was tall fescue (Festuca arundinacea var. Kentucky 31) and the legume was ladino clover (Trifolium repens var. Ladino)[1]

Growth Chamber

In order to reduce to a minimum the natural fluctuations inherent in greenhouse and field studies, a growth chamber was utilized with controlled temperatures and photoperiods. Since only one growth chamber was available, a subchamber consisting of three compartments was built. It was made from 2 cm. thick plywood painted white. Size of each compartment was 40 cm. x 117 cm. Two air intakes were made in each compartment. They were 3 cm. in diameter, and located 2 cm. above the bottom. One intake was located in the end of each compartment. Air intakes in each compartment were covered with a metal light trap. The air outlet at the other end had a fan motor (Model Dayton 2C782-3160 RPM) to provide enough air circulation to minimize heat built up within the compartment. Each compartment was covered with a removable 0.5 cm. thick plastic sheet. The plastic sheets were covered with aluminum foil so that no light could enter when covers were in place.

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[1] Certified seeds. Pennington Grain & Seed, Inc., Columbia, S.C.

Inside of each compartment were four wires, each wire was 115 cm. long and extended from end to end in the compartment. Twenty eight plastic growth pouches were hung on these wires (4 out of 28 pouches as spares). Wires were 11 cm. apart. Three aluminum cans containing water were put in each compartment to bolster relative humidity to 78 per cent.

Growth Pouch

DisPo growth pouches,[1/] size 16 x 20 cm., were used. Root development could be observed through the transparent plastic. A wick was inserted in each pouch. It consisted of paper germination toweling folded along the top edge in a trough that was perforated to permit root penetration from seedling area.

Nutrient Solutions

Hoagland's complete nutrient solution[2/] (complete-$FeCl_3$) at one fourth strength, pH 6.8, was employed throughout the study.

Light Intensity

Artificial illumination was provided by fluorescent lamps

[1/] S/P Seed-Pak Growth Pouch. Cat #B1220, Scientific Products, Evanston, Ill.

[2/] Machlis, L., and J. G. Torrey. 1966. Plants in Action. A Laboratory Manual of Plant Physiology. W. H. Freeman and Co. San Francisco, p. 282.

which produced an intensity at plant level of approximately 1,200 ft-c.

Photoperiods and Temperatures

Photoperiods of 10, 11, 12, 13, 14, and 15 hours were used at constant temperatures of 65°F and at 75°F.

Experimental Procedures

Five seeds of each forage crop were planted in a trough in each side of a pouch. Tall fescue was seeded on the right, and ladino clover on the left. To induce germination, 50 ml. distilled water was added. Seven days after planting, the same amount of one-fourth strength nutrient solution was added instead of water. All pouches were placed in an upright position and attached to wires at 1,200 ft-c. level. Desired photoperiods and temperatures were established at the beginning, however, paper clips were used to cover each trough for 7 days after planting.

Seedlings were thinned to 2 strongest plants per pouch at the age of 7 days. The eighth day was considered as the first day of the experiment.

During weekdays, nutrient solution was added to maintain 50 ml. per pouch at all times. Each week a fresh solution was provided plants in each pouch. Four pouches were removed at random and data recorded every week. All pouches were rotated in position every week to expose each pouch to similar conditions.

Since each compartment required different photoperiodic treatments, daylengths were controlled by using mechanical methods. The top of each compartment was removed to permit entry of artificial light at the top of the compartment at the exact time required to give the desired daylengths.

Collection and Analysis of Data

Data were collected on the following: length of tallest leaf, number of leaves, length of roots, dry weight of tops and roots, and root-top ratios. In order to determine the dry weight of tops and roots, samples were kept in an oven at 170°F for 3 days. The root weight was divided by the top weight to obtain root-top ratios. However, all data were based on one plant basis. There were 4 replications of each treatment.

The plan lay-out was a Factorial design which included the following aspects:

2 forage crops - tall fescue and ladino clover

6 photoperiods - 10, 11, 12, 13, 14, and 15 hours

2 temperatures - 65°F and 75°F

6 growing periods - 1, 2, 3, 4, 5, and 6 weeks

4 replications

RESULTS AND DISCUSSION

I. Effect of photoperiods and temperatures on top weights

Tall fescue

With tall fescue there were highly significant differences for all sources of variation including main effects and interactions (Table 2). There were differences in top weights due to different temperatures, photoperiods and lengths of growing period (Table 1). Responses to temperature were modified by the length of day under which the plants were grown. The greatest top weights occurred at the highest temperature and next to the longest photoperiod. This relationship suggests that the metabolic processes in the plant were approaching optimum at 75°F when photoperiod was held at 14 hours. Regardless of photoperiods and lengths of growing period, top weights were greater at 75°F than at 65°F. However, growth continued to a limited extent at shorter daylengths at both temperatures. Photoperiod and temperature variations increased top growth of the fescue more in the 5th and 6th week which would indicate that the roots and leaves were becoming more functional.

Because all top weight differences due to main effects, i.e., temperatures, photoperiods and different growing periods were highly significant, interactions among them would be expected to show significant differences. The interactions would be expected to change with environmental conditions like the main effects.

Table 1. The effect of photoperiods, temperatures and length of growing period on top weight per plant of tall fescue.*

Weeks after thinning**	Photoperiods (hr.) at 65°F						Photoperiods (hr.) at 75°F					
	10	11	12	13	14	15	10	11	12	13	14	15
1	1.40	.95	1.25	.70	1.62	.52	1.70	2.02	2.10	2.30	2.12	1.85
2	1.42	2.75	3.15	3.37	2.57	3.82	5.15	7.00	9.70	7.12	8.40	8.02
3	3.15	3.25	4.50	5.45	4.65	9.25	13.85	15.50	21.02	14.87	24.47	24.87
4	19.82	11.07	10.27	13.50	31.82	32.50	31.82	31.15	55.22	38.60	69.45	61.47
5	20.67	22.15	50.85	49.87	66.72	77.90	79.55	53.00	89.35	58.82	147.90	110.22
6	65.25	68.00	90.75	80.97	90.70	178.45	148.32	70.47	157.17	90.20	353.10	292.20
Mean	18.62	18.03	26.79	25.64	33.01	50.41	46.73	29.86	55.76	35.32	100.91	83.10

*Each figure is the average in milligram of 4 replicates.

**Each pouch was thinned to 2 strongest seedlings 7 days after planting.

Table 2. Analysis of variance of top weight per plant of tall fescue.

Source of variation	df	SS	MS	F
Total	287	55684.64	--	--
Temperatures (T)	1	432.92	432.92	50.22**
Photoperiods (P)	5	10182.29	2036.46	370.94**
T x P	5	650.67	130.13	37.61**
Weeks (W)	5	18287.62	3657.52	367.22**
T x W	5	1084.74	216.95	28.62**
P x W	25	20350.04	814.00	114.16**
T x P x W	25	3301.66	132.07	24.23**
Replicates (R)	3	28.20	9.40	NS
T x R	3	25.85	8.62	
P x R	15	82.28	5.49	
T x P x R	15	51.91	3.46	
W x R	15	149.39	9.96	
T x W x R	15	113.67	7.58	
P x W x R	75	534.95	7.13	
Residual	75	408.45	5.45	

NS--No significant difference

**Significant at 1% level

Table 3. The effect of photoperiods, temperatures and length of growing period on top weight per plant of ladino clover.*

Weeks after thinning**	Photoperiods (hr.) at 65°F						Photoperiods (hr.) at 75°F					
	10	11	12	13	14	15	10	11	12	13	14	15
1	1.00	.67	.60	.55	.90	.60	.92	.57	.62	.72	1.02	.90
2	1.12	.90	1.05	.95	1.57	1.52	1.47	1.65	1.67	1.47	2.65	2.00
3	1.72	1.25	1.60	1.22	3.42	4.60	2.27	2.15	3.15	2.60	6.70	5.55
4	3.00	2.00	1.72	2.22	9.95	9.50	2.57	2.82	3.72	3.40	9.55	6.50
5	4.47	2.95	3.80	2.80	18.67	16.87	4.02	4.20	5.05	5.32	20.00	20.02
6	6.57	6.80	14.27	5.00	49.25	28.65	6.15	5.67	5.75	9.42	83.87	65.87
Mean	2.98	2.43	3.84	2.12	13.96	10.29	2.90	2.84	3.33	3.82	20.63	16.81

*Each figure is the average in milligram of 4 replicates.

**Each pouch was thinned to 2 strongest seedlings 7 days after planting.

Table 4. Analysis of variance of top weight per plant of ladino clover.

Source of variation	df	SS	MS	F
Total	287	1202331.23	--	--
Temperatures (T)	1	64207.36	64207.36	279.72**
Photoperiods (P)	5	84728.83	16945.77	38.48**
T x P	5	26290.45	5258.09	33.11**
Weeks (W)	5	689036.19	137807.24	379.97**
T x W	5	65125.58	13025.12	65.63**
P x W	25	151927.28	6077.09	21.85**
T x P x W	25	71728.13	2869.13	21.05**
Replicates (R)	3	110.93	36.98	NS
T x R	3	688.63	229.54	
P x R	15	6604.60	440.31	
T x P x R	15	2382.07	158.80	
W x R	15	5440.21	362.68	
T x W x R	15	2977.11	198.47	
P x W x R	75	20861.59	278.15	
Residual	75	10222.27	136.30	

NS--No significant difference

**Significant at 1% level

Ladino clover

Results with ladino clover (Table 4) were similar to those with tall fescue, even though the clover was considerably smaller in top weights (Table 3). This is due to the difference in the inherited growth characters of the species. Changes in photoperiods, temperatures and length of growing period caused highly significant differences in top weights of ladino clover. Interactions were also highly significant (Table 4). The figures for different top weights of ladino clover are presented in Table 7. The treatment of 75°F and 14-hour photoperiods was most favorable for dry matter production.

In general, the manner in which photoperiods and temperatures regulate growth is complex. Experiments have shown that the removal of leaves will produce an increased growth. This suggests that some inhibitory mechanism is involved in the process. The experiments presented under "Receptor organ" pointed toward the inhibitor hypothesis (12). In the case of Weigela, the removal of leaves promoted growth under the short days (20). The simplest explanation would be that under short days, leaves manufacture an inhibitory substance which caused vegetative growth to stop. In contrast a growth promoting substance was formed under long days (2, 22). Tall fescue and ladino clover may perform in a similar manner. However, no attempt was made to find out what kinds of inhibitory substance and growth promoting substance were formed under environmental conditions of this experiment.

II. Effects of photoperiods and temperatures on root weights

Tall fescue

As shown in analysis of variance (Table 6), photoperiods, temperatures, and lengths of growing period all had a highly significant effect on root weight per plant of tall fescue. Highly significant interactions were temperatures x photoperiods, photoperiods x weeks, and temperatures x photoperiods x weeks. The interaction of temperatures x weeks was significant at the 5% confidence level. Table 5 shows that as photoperiods were increased and temperature held at 65°F, root weight increased. At 75°F, root weight under 10, 11, 12, 13-hour daylengths fluctuated, however, the highest root weight was at 75°F and 14-hour photoperiods. When photoperiod was increased to 15-hour at 75°F, root weights decreased slightly when fescue was 6 weeks old (Figure 2). Results of root weights should be of special interest because of their relationship to plant growth development, especially top weights. According to Lubimenko (10) weight of roots increased in proportion to weight of tops. As shown in Table 5 and Figure 2, the responses of root weights to photoperiods, temperatures, and length of growing period were similar to responses of top growth.

Ladino clover

Table 5. The effect of photoperiods, temperatures and length of growing period on root weight per plant of tall fescue.*

Weeks after thinning**	Photoperiods (hr.) at 65°F						Photoperiods (hr.) at 75°F					
	10	11	12	13	14	15	10	11	12	13	14	15
1	.47	.45	.50	.42	.97	.35	.47	.62	.57	.70	.70	.55
2	.55	.85	.77	.90	.85	1.02	1.17	2.37	3.47	2.57	2.30	1.87
3	.90	.87	1.07	1.42	1.52	3.12	2.80	4.72	8.40	4.87	7.40	8.00
4	4.77	1.72	2.22	2.50	11.25	10.90	7.55	11.57	20.67	13.42	24.32	25.30
5	5.32	6.10	13.17	21.62	23.22	29.62	21.20	22.02	37.97	22.45	57.62	47.80
6	22.72	19.50	29.37	24.25	55.22	68.45	46.20	22.27	48.30	32.25	147.57	111.35
Mean	5.79	4.91	7.85	8.52	15.50	18.91	13.23	10.59	19.90	12.71	39.98	32.48

*Each figure is the average in milligram of 4 replicates.

**Each pouch was thinned to 2 strongest seedlings 7 days after planting.

Table 6. Analysis of variance of root weight per plant of tall fescue.

Source of variation	df	SS	MS	F
Total	287	12959.05	--	--
Temperatures (T)	1	14.05	14.05	21.95**
Photoperiods (P)	5	2331.92	466.38	107.46**
T x P	5	16.12	3.22	5.11**
Weeks (W)	5	4099.08	819.82	151.54**
T x W	5	22.53	4.51	3.47**
P x W	25	5797.81	231.91	64.24**
T x P x W	25	149.43	6.78	12.55**
Replicates (R)	3	19.74	6.58	NS
T x R	3	1.92	0.64	
P x R	15	65.06	4.34	
T x P x R	15	9.41	0.63	
W x R	15	81.11	5.41	
T x W x R	15	19.48	1.30	
P x W x R	75	270.66	3.61	
Residual	75	40.73	0.54	

NS--No significant difference

**Significant at 1% level

Table 7. The effect of photoperiods, temperatures and length of growing period on root weight per plant of ladino clover.*

Weeks after thinning**	Photoperiods (hr.) at 65°F						Photoperiods (hr.) at 75°F					
	10	11	12	13	14	15	10	11	12	13	14	15
1	.30	.35	.30	.22	.55	.32	.40	.35	.25	.27	.40	.37
2	.40	.35	.35	.32	.72	.57	.52	1.05	1.32	1.12	.85	.50
3	.67	.45	.52	.57	1.42	1.57	.62	1.50	1.42	1.67	2.32	1.62
4	.92	.60	.67	.67	3.87	4.32	.70	1.70	1.95	2.10	4.00	2.27
5	1.47	1.12	1.42	.97	6.30	8.15	1.12	1.92	2.27	2.57	7.02	6.25
6	2.32	3.17	5.67	1.72	32.85	17.35	1.65	2.07	2.52	4.52	38.72	22.67
Mean	1.01	1.01	1.49	.74	7.62	5.38	.83	1.43	1.62	2.04	8.88	5.61

*Each figure is the average in milligram of 4 replicates.

**Each pouch was thinned to 2 strongest seedlings 7 days after planting.

Table 8. Analysis of variance of root weight per plant of ladino clover.

Source of variation	df	SS	MS	F
Total	287	189709.90	--	--
Temperatures (T)	1	8975.77	8975.77	237.26**
Photoperiods (P)	5	17859.61	3571.92	94.42**
T x P	5	3373.10	674.62	17.83**
Weeks (W)	5	98103.72	19620.74	518.65**
T x W	5	8463.19	1692.64	44.74**
P x W	25	35418.05	1416.72	37.45**
T x P x W	25	9344.35	373.77	9.88**
Replicates (R)	3	46.84	15.61	NS
T x R	3	45.76	15.25	
P x R	15	653.74	43.58	
T x P x R	15	799.01	53.27	
W x R	15	434.58	28.97	
T x W x R	15	224.90	14.99	
P x W x R	75	2343.78	31.25	
T x P x W x R	75	3623.50	48.31	
Pooled error	216	8172.11	37.83	

NS--No significant difference

**Significant at 1% level

In Table 8, the analysis of variance indicated similar results with ladino clover to those with fescue in root weights except the interaction between temperatures and weeks was also highly significant. The highest root weights of clover occurred with 75°F and 14-hour photoperiods. Nevertheless, the growth of roots was slow under shorter days of both temperatures (Table 7). As shown in Figures 7 and 8, responses of root development were similar to those of top growth development with the longer growing periods at 75°F, length of daily illumination period produced a marked progressive increase in the relative development of roots and tops of ladino clover except at the photoperiod beyond 14 hours.

The environmental conditions to which roots are exposed are usually very different from those which the aerial organs of plants encounter. Because of reciprocal influences between the roots and tops of a plant, effects of any environmental factor upon the development or physiological process of the roots almost invariably affect the behavior of the aerial organ and vice versa (7, 12, 15). However, top weights of the plants were greater than root weights (Tables 3 and 7). When the supply of nitrates from the nutrient solution are abundant, a small proportion of the total quantity absorbed is utilized in the roots. A larger proportion of the nitrogen, as a constituent of one kind of compound or another, is translocated into the aerial portion of the plants, where much or all of it is used in the synthesis of protoplasmic proteins. The enhanced vegetative development of the aerial organs of the plants which is favored by such metabolic conditions results in the utilization of more carbohydrates as well as more proteinaceous foods by the aerial meristems. Because of the vigorous vegetative development of the shoot system, the proportion of the carbohydrate foods which is translocated to the roots may be relatively small.

III. Effect of photoperiods and temperatures on top height

Tall fescue

Fescue made the highest increase in top height at 75°F especially under 14-hour photoperiods (Table 9). Regardless of photoperiodic treatments, the temperature of 75°F brought about a greater increase in top height than that of 65°F. Long daylengths were more favorable than short daylengths. Top height was affected more in the 5th and 6th week by photoperiods and temperatures than other growing periods of this experiment (Table 10). Figure 3 also shows that at every photoperiod, the height of seedling at 75°F was higher than at 65°F. These results pointed out that 65°F was not within the optimum range. Because top height measurement was made of the tallest leaf, this would affect the photosynthetic area. Thus, as height of tall fescue increased, the photosynthetic area would likely be increased. However, the area also depended upon number of leaves produced, and their size (2, 11). Further discussion about number of leaves will be given in Part V.

Table 9. The effect of photoperiods, temperatures and length of growing period on top height per plant of tall fescue.*

Weeks after thinning**	Photoperiods (hr.) at 65°F						Photoperiods (hr.) at 75°F					
	10	11	12	13	14	15	10	11	12	13	14	15
1	2.97	5.55	7.07	6.72	5.57	4.82	10.25	10.95	8.47	10.80	10.32	10.42
2	6.45	10.70	11.02	10.95	8.92	10.57	14.45	16.50	17.57	16.40	17.15	19.62
3	10.35	9.60	12.32	15.02	9.87	15.90	20.42	19.75	23.45	20.85	22.42	23.65
4	18.45	16.07	15.95	17.12	20.60	23.22	25.97	23.92	28.52	23.12	25.52	27.20
5	18.47	18.80	24.05	22.40	21.60	24.45	32.20	25.82	26.70	27.40	29.80	26.17
6	22.12	23.12	26.70	24.05	22.25	24.82	32.67	26.37	29.52	26.52	36.40	35.07
Mean	13.13	13.97	16.18	16.04	14.80	17.30	22.66	20.55	22.37	20.85	23.60	23.69

*Each figure is the average in centimeter of 4 replicates.

**Each pouch was thinned to 2 strongest seedlings 7 days after planting.

Table 10. Analysis of variance of top height per plant of tall fescue.

Source of variation	df	SS	MS	F
Total	287	1652.69	--	--
Temperatures (T)	1	14.09	14.09	17.61**
Photoperiods (P)	5	379.68	75.94	94.92**
T x P	5	66.75	13.35	16.69**
Weeks (W)	5	690.82	138.16	172.70**
T x W	5	13.51	2.70	3.37**
P x W	25	258.58	10.34	12.92**
T x P x W	25	57.19	2.29	2.86**
Replicates (R)	3	2.15	0.72	NS
T x R	3	0.41	0.14	
P x R	15	7.19	0.48	
T x P x R	15	13.32	0.89	
W x R	15	11.80	0.79	
T x W x R	15	12.53	0.84	
P x W x R	75	64.10	0.85	
T x P x W x R	75	60.57	0.81	
Pooled error	216	172.07	0.80	

NS--No significant difference
**Significant at 1% level

Table 11. The effect of photoperiods, temperatures and length of growing period on top height per plant of ladino clover.*

Weeks after thinning**	Photoperiods (hr.) at 65°F						Photoperiods (hr.)at 75°F					
	10	11	12	13	14	15	10	11	12	13	14	15
1	2.10	2.77	2.22	2.32	1.95	2.02	3.10	2.25	2.17	2.62	3.30	3.07
2	3.30	3.95	3.80	3.87	3.90	3.62	4.27	3.25	3.17	3.52	4.77	4.47
3	4.05	4.40	4.37	4.00	4.47	5.10	4.75	3.50	3.30	3.85	6.87	5.97
4	4.52	4.62	4.55	4.12	6.20	7.10	4.87	3.72	3.77	4.50	7.52	6.52
5	4.75	4.95	4.67	4.35	8.30	7.92	5.02	4.92	4.05	4.90	8.77	9.40
6	5.00	5.42	6.85	4.95	9.90	8.02	5.40	5.25	4.67	5.60	13.22	14.00
Mean	3.95	4.35	4.41	3.93	5.79	5.63	4.57	3.81	3.52	4.16	7.41	7.24

*Each figure is the average in centimeter of 4 replicates.

**Each pouch was thinned to 2 strongest seedlings 7 days after planting.

Table 12. Analysis of variance of top height per plant of ladino clover.

Source of variation	df	SS	MS	F
Total	287	19633.33	--	--
Temperatures (T)	1	3576.47	3576.47	570.41**
Photoperiods (P)	5	314.65	62.93	10.04**
T x P	5	187.56	37.51	5.98**
Weeks (W)	5	13244.17	2648.83	422.46**
T x W	5	146.29	29.26	4.67**
P x W	25	343.92	13.76	2.19**
T x P x W	25	465.31	18.61	2.97**
Replicates (R)	3	20.30	6.77	NS
T x R	3	8.91	2.97	
P x R	15	142.07	9.47	
T x P x R	15	71.04	4.74	
W x R	15	142.56	9.50	
T x W x R	15	115.22	7.68	
P x W x R	75	383.94	5.12	
T x P x W x R	75	470.92	6.27	
Pooled error	216	1354.96	6.27	

NS--No significant difference

**Significant at 1% level

Ladino clover

The analysis of variance showed highly significant differences in top height of plants due to temperatures, photoperiods, and length of growing period. In breaking this down to interactions all main effects were highly significant (Table 12). Top heights per plant of clover were presented in Table 11 and Figure 10. The greatest increase in height was also at 75°F and under 14-hour photoperiods. Results with clover (Table 12) were similar to those with fescue (Table 10), but height of the clover was shorter than that of the fescue under the same environmental conditions. The height of ladino clover in relation to tall fescue could be one of the major reasons for its disappearance from fescue-clover stands. Proper clipping of the fescue should help to solve this problem.

IV. Effect of photoperiods and temperatures on root growth

Tall fescue

There were no significant differences in root length of fescue due to different temperatures (Table 14). Highly significant differences were found due to photoperiods, lengths of growing period, temperatures x photoperiods, and photoperiods x weeks. In addition, temperatures x weeks was significant at 5% level but the interaction of temperatures x photoperiods x length of growing period was not

Table 13. The effect of photoperiods, temperatures and length of growing period on root length per plant of tall fescue.*

Weeks after thinning**	Photoperiods (hr.) at 65°F						Photoperiods (hr.) at 75°F					
	10	11	12	13	14	15	10	11	12	13	14	15
1	4.77	6.07	6.77	6.20	5.87	5.25	9.02	7.60	6.77	10.00	11.05	9.47
2	6.52	10.62	10.42	10.65	8.90	10.55	12.82	15.37	13.50	13.65	15.35	14.17
3	7.60	8.95	10.57	11.32	8.20	12.25	14.82	19.85	22.07	16.77	18.52	19.22
4	15.65	12.27	15.32	14.45	16.80	14.92	15.12	20.77	22.85	20.80	21.52	20.77
5	12.65	12.32	16.82	15.97	17.05	17.52	17.02	21.65	22.90	22.62	23.17	22.02
6	19.92	16.62	19.10	16.85	17.92	20.52	18.72	23.97	22.95	23.55	25.40	22.15
Mean	11.18	11.12	13.17	12.57	12.46	13.50	14.59	18.20	18.51	17.90	19.17	17.97

*Each figure is the average in centimeters of 4 replicates.

**Each pouch was thinned to 2 strongest seedlings 7 days after planting.

Table 14. Analysis of variance of root length per plant of tall fescue.

Source of variation	df	SS	MS	F
Total	287	3755.08	--	--
Temperatures (T)	1	0.61	0.61	.26NS
Photoperiods (P)	5	1095.38	219.08	93.62**
T x P	5	145.46	29.09	12.43**
Weeks (W)	5	1675.65	335.13	143.22**
T x W	5	29.96	5.99	2.56**
P x W	25	227.33	9.09	3.88**
T x P x W	25	74.62	2.98	1.27NS
Replicates (R)	3	0.56	0.19	
T x R	3	9.80	3.27	
P x R	15	52.69	3.51	
T x P x R	15	27.83	1.86	
W x R	15	34.41	2.29	
T x W x R	15	17.68	1.18	
P x W x R	75	185.52	2.47	
T x P x W x R	75	177.58	2.37	
Pooled error	216	506.07	2.34	

NS--No significant difference

**Significant at 1% level

Table 15. The effect of photoperiods, temperature and length of growing period on root length per plant of ladino clover.*

Weeks after thinning**	Photoperiods (hr.) at 65°F						Photoperiods (hr.) at 75°F					
	10	11	12	13	14	15	10	11	12	13	14	15
1	3.42	4.15	4.07	4.12	4.12	4.52	6.00	3.20	2.37	4.07	6.65	7.50
2	6.52	5.05	6.07	5.45	7.12	7.60	7.40	4.35	4.25	4.62	7.90	7.57
3	7.60	6.70	6.65	5.57	7.40	9.67	8.62	5.75	6.25	5.70	11.02	9.42
4	9.45	6.75	7.20	5.72	11.92	12.67	9.25	5.75	6.32	6.77	13.67	11.55
5	10.57	9.60	7.72	9.45	13.55	13.20	9.62	6.35	6.40	7.02	15.60	15.35
6	11.90	10.60	12.42	9.92	14.27	13.42	10.90	6.57	8.57	8.52	16.55	15.45
Mean	8.24	7.14	7.35	6.70	9.73	10.18	8.63	5.33	5.69	6.12	11.90	11.14

*Each figure is the average in centimeters of 4 replicates.

**Each pouch was thinned to 2 strongest seedlings 7 days after planting.

Table 16. Analysis of variance of root length per plant of ladino clover.

Source of variation	df	SS	MS	F
Total	287	9976.87	--	--
Temperatures (T)	1	2089.27	2089.27	417.85**
Photoperiods (P)	5	313.34	62.67	12.53**
T x P	5	112.70	22.54	4.51**
Weeks (W)	5	5697.64	1139.53	227.91**
T x W	5	223.37	44.67	8.93**
P x W	25	187.27	7.49	1.49NS
T x P x W	25	273.28	10.93	2.19*
Replicates (R)	3	12.49	4.16	NS
T x R	3	15.86	5.29	
P x R	15	81.97	5.46	
T x P x R	15	46.82	3.12	
W x R	15	77.80	5.19	
T x W x R	15	98.42	6.56	
P x W x R	75	341.33	4.55	
T x P x W x R	75	405.31	5.40	
Pooled error	216	1080.00	5.00	

NS--No significant difference

* Significant at 5% level

** Significant at 1% level

significant. In Table 13, means of root lengths under different photoperiods differed slightly at 65°F. By the 6th week of age (Figure 4) these apparent differences were not as great as with top weight and root weight per plant (Figures 1 and 2).

Ladino clover

Table 16 shows highly significant variations in root length of ladino clover due to photoperiods, temperatures and length of growing period. The interaction of photoperiods and length of growing period was not significant, however, temperatures x photoperiods x weeks was significant at 5% level. The means of root lengths under 10, 11, 12, 13, 14, and 15-hour photoperiods regardless of age were about the same (Table 15). At 6 weeks of age under 10, 11, 12, and 13-hour photoperiods, roots were shorter under 75°F than in corresponding treatments at 65°F. Nevertheless, the longest root length occurred with 14-hour daylengths at 75°F (Figure 10). When harvesting the seedlings, this treatment seemed to show the best results of all treatments and this observation was verified by root length measurements.

Previous experiments (7, 15, 22) showed that both temperature and photoperiod brought about differences in rates of cell elongation and differentiation. The roots of pea seedlings increased in length consistently with rise in temperature in the range of -2° to 29°C. In case of oats, light was found to increase the rate of elongation of the leaf of oats, but had little or no effect on the duration of the elongation period in this organ.

Judging from the statistical analysis, the photoperiods and temperatures affected top heights and root lengths of tall fescue and ladino clover. However, differences in root lengths of both species were less visible under all treatments (Figures 4 and 10). The great differences in root weights (Figures 2 and 8) appeared to be due to the number and length of lateral branches. Although the depth to which roots penetrate is in part a species characteristic, this can be modified by various soil conditions when tall fescue and ladino clover are grown in the field. In order to obtain a good stand, plants must have good root development, the extensive branching of roots is an important index of its effectiveness in absorbing water and mineral salts from the soil.

V. Effect of photoperiods and temperatures on number of leaves

Tall fescue

The effect of temperatures on number of fescue leaves was not significant at 5% level (Table 18). Highly significant differences were found due to photoperiods, length of growing period, temperatures x photoperiods, temperatures x weeks, and photoperiods x weeks. An obvious increase in number of leaves occurred during the 6th week of seedling growth (Table 17). Since there was no significant difference in number of leaves due to temperatures, leaf

Table 17. The effect of photoperiods, temperatures and length of growing period on number of leaves per plant of tall fescue.*

Weeks after thinning**	Photoperiods (hr.) at 65°F						Photoperiods (hr.) at 75°F					
	10	11	12	13	14	15	10	11	12	13	14	15
1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	1.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.50	2.00	2.00	2.00
3	2.00	2.00	2.00	2.00	2.25	2.50	3.00	3.00	3.00	3.00	3.25	3.00
4	3.00	3.00	3.00	3.00	3.50	3.25	3.75	3.00	3.75	3.00	4.75	5.00
5	3.00	3.50	5.20	4.75	4.50	5.50	4.75	3.25	3.75	3.25	8.00	6.75
6	5.75	5.00	6.00	5.50	6.00	6.75	6.00	4.25	5.75	3.75	9.25	8.50
Mean	2.62	2.75	3.21	3.04	3.21	3.50	3.42	2.75	3.29	2.67	4.71	4.37

*Each figure is the average of 4 replicates.

**Each pouch was thinned to 2 strongest seedlings 7 days after planting.

Table 18. Analysis of variance of number of leaves per plant of tall fescue.

Source of variation	df	SS	MS	F
Total	287	4.63	--	--
Temperatures (T)	1	0.00	0.000	.00NS
Photoperiods (P)	5	0.30	0.060	30.00**
T x P	5	0.10	0.020	10.00**
Weeks (W)	5	3.60	0.720	720.00**
T x W	5	0.07	0.014	14.00**
P x W	25	0.20	0.008	4.00**
T x P x W	25	0.07	0.003	3.00**
Replicates (R)	3	0.01	0.003	NS
T x R	3	0.00	0.000	
P x R	15	0.03	0.002	
T x P x R	15	0.03	0.002	
W x R	15	0.02	0.001	
T x W x R	15	0.01	0.001	
P x W x R	75	0.12	0.002	
Residual	75	0.07	0.001	

NS--No significant difference

**Significant at 1% level

Table 19. The effect of photoperiods, temperatures and length of growing period on number of leaves per plant of ladino clover.*

Weeks after thinning**	Photoperiods (hr.) at 65°F						Photoperiods (hr.) at 75°F					
	10	11	12	13	14	15	10	11	12	13	14	15
1	--1/	--	--	--	--	--	--	--	--	--	--	--
2	--	--	--	--	--	--	--	--	--	--	.50	1.00
3	1.00	.50	.75	.50	1.25	1.00	1.00	.25	.75	--	2.00	1.75
4	2.00	2.00	2.00	2.00	2.00	2.00	1.25	1.00	1.00	1.00	2.00	2.00
5	2.00	2.00	2.25	2.00	2.50	2.25	2.25	2.00	2.00	2.00	3.50	3.00
6	2.25	3.00	3.75	2.25	4.00	3.50	2.25	2.00	2.25	2.75	4.50	4.25
Mean	2.08	2.33	2.67	2.08	2.83	2.58	1.92	1.67	1.75	1.92	3.33	3.08

1/Because ladino clover is a trifoliated plant, leaflets are not counted as a leaf.

*Each figure is the average of number of leaves of 4 replicates.

**Each pouch was thinned to 2 strongest seedlings 7 days after planting.

Each figure of the mean is the average of the 4th - 6th week.

Table 20. Analysis of variance of number of leaves per plant of ladino clover.

Source of variation	df	SS	MS	F
Total	287	11.70	---	---
Temperatures (T)	1	0.17	0.17	34.00**
Photoperiods (P)	5	0.68	0.14	28.00**
T x P	5	0.29	0.06	12.00**
Weeks (W)	5	8.20	1.64	328.00**
T x W	5	0.06	0.01	2.00NS
P x W	25	0.78	0.03	6.00**
T x P x W	25	0.50	0.02	4.00**
Replicates (R)	3	0.02	0.01	NS
T x R	3	0.02	0.01	
P x R	15	0.08	0.01	
T x P x R	15	0.09	0.01	
W x R	15	0.08	0.01	
T x W x R	15	0.12	0.01	
P x W x R	75	0.27	0.00	
T x P x W x R	75	0.34	0.00	
Pooled error	216	1.02	0.005	

NS--No significant difference

**Significant at 1% level

development could be attributed solely to a photoperiodic response. At 6 weeks of age, seedlings had greatest number of leaves under 14-hour daylengths and 75°F temperature as shown in Figure 5.

Ladino clover

All sources of variation of main effects and their interactions with ladino clover were highly significant (Table 20). Both at 65°F and 75°F under all photoperiods, trifoliated leaves began to form at the age of 3 weeks (Table 19). Prior to 3 weeks they had only leaflets, which were not counted at harvest time. The earliest seedlings to have leaves, were those under 14- and 15-hour photoperiods at 75°F. Leaves appeared in the 2nd week. However, number of leaves were dependent on temperatures and photoperiods as shown in Figure 11.

Generally speaking, leaf production is positively correlated with yield of many crops, nevertheless, in some cases it may be negatively correlated with yield or quantity (12). Whatever the relationship, the close agreement between computed and actual leaf development reading indicated the utility of quantitative morphologic methods for detecting the influence of environmental factors on plant growth. The photosynthetic area depends upon the number of leaves produced, their size and length. Therefore, measuring these parameters on plants grown under controlled condition should prove useful for further studies. This is especially evident for leaf area index [1] (LAI concept) because net assimilation rates (i. e., dry matter gain per unit of photosynthetic surface) and crop growth rates vary with LAI, and different species show different responses (2, 11, 12).

VI. Effect of photoperiods and temperatures on root-top ratios

Tall fescue

In Table 22, analysis of variance showed that root-top ratios were significantly affected by photoperiods, temperatures x photoperiods, temperatures x weeks, photoperiods x weeks, and temperatures x photoperiods x weeks. Temperatures and length of growing period did not significantly affect root-top ratios. In Table 21 as maturity advanced, there appeared to be a difference in root-top ratios but this was not statistically significant. At 6 weeks of age, seedlings at 65°F temperature had the greatest root-top ratios under 14-hour photoperiods. This would be due largely to photoperiods rather than the temperatures (Figure 6) .

Ladino clover

Very similar responses of root-top ratios were found with clover (Table 24) as with fescue (Table 22). At 6 weeks of age, clover seedlings had the greatest root-top ratios under 14-hour

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[1] The LAI of a plant community is defined as the ratio of leaf area to soil surface area.

Table 21. The effect of photoperiods, temperatures and length of growing period on root-top ratios per plant of tall fescue.*

Weeks after thinning**	Photoperiods (hr.) at 65°F						Photoperiods (hr.) at 75°F					
	10	11	12	13	14	15	10	11	12	13	14	15
1	.34	.48	.40	.60	.60	.68	.29	.31	.27	.30	.33	.29
2	.39	.30	.25	.26	.33	.27	.23	.34	.36	.36	.28	.23
3	.29	.27	.24	.26	.38	.37	.20	.31	.40	.33	.30	.32
4	.23	.15	.21	.17	.35	.32	.23	.36	.37	.35	.36	.41
5	.26	.28	.26	.43	.34	.38	.26	.42	.42	.39	.41	.43
6	.35	.32	.32	.40	.61	.38	.31	.32	.30	.35	.42	.39
Mean	.31	.30	.28	.35	.43	.40	.25	.34	.35	.35	.35	.34

*Each figure is the average of 4 replicates obtained by divided root weight by top weight.

**Each pouch was thinned to 2 strongest seedlings 7 days after planting.

Table 22. Analysis of variance of the root-top ratios per plant of tall fescue.

Source of variation	df	SS	MS	F
Total	287	6.2977	--	--
Temperatures (T)	1	.0654	0.0654	4.25NS
Photoperiods (P)	5	.8510	0.1702	16.21**
T x P	5	1.3606	0.2721	36.77**
Weeks (W)	5	.1383	0.0277	1.88NS
T x W	5	.5038	0.1008	5.06**
P x W	25	.8583	0.0343	5.04**
T x P x W	25	.5824	0.0233	2.99**
Replicates (R)	3	.0071	0.0024	NS
T x R	3	.0426	0.0154	
P x R	15	.1571	0.0105	
T x P x R	15	.1109	0.0074	
W x R	15	.2210	0.0147	
T x W x R	15	.2992	0.0199	
P x W x R	75	.5090	0.0068	
Residual	75	.5874	0.0078	

NS--No significant difference

**Significant at 1% level

Table 23. The effect of photoperiods, temperatures and length of growing period on root-top ratios per plant of ladino clover.*

Weeks after thinning**	Photoperiods (hr.) at 65°F						Photoperiods (hr.) at 75°F					
	10	11	12	13	14	15	10	11	12	13	14	15
1	.30	.52	.49	.41	.62	.59	.43	.62	.43	.38	.39	.42
2	.35	.41	.33	.34	.47	.39	.35	.63	.79	.77	.32	.25
3	.39	.36	.33	.47	.41	.35	.28	.70	.48	.68	.34	.30
4	.31	.30	.40	.30	.38	.46	.28	.61	.53	.62	.41	.38
5	.32	.40	.38	.39	.50	.48	.28	.46	.45	.48	.35	.30
6	.35	.47	.40	.34	.67	.61	.26	.37	.45	.48	.45	.34
Mean	.34	.41	.39	.37	.51	.48	.31	.56	.52	.57	.38	.33

*Each figure is the average in centimeter of 4 replicates.

**Each pouch was thinned to 2 strongest seedlings 7 days after planting.

Table 24. Analysis of variance of the root-top ratios of ladino clover.

Source of variation	df	SS	MS	F
Total	287	3.7922	---	---
Temperatures (T)	1	.0156	0.0156	2.84NS
Photoperiods (P)	5	.3925	0.0785	14.27**
T x P	5	.2427	0.0485	8.82**
Weeks (W)	5	.5157	0.1031	18.74**
T x W	5	.7649	0.1530	27.82**
P x W	25	.3605	0.0144	2.62**
T x P x W	25	.3043	0.0122	2.21**
Replicates (R)	3	.0025	0.0008	NS
T x R	3	.0208	0.0069	
P x R	15	.1072	0.0071	
T x P x R	15	.0720	0.0048	
W x R	15	.0687	0.0046	
T x W x R	15	.0614	0.0041	
P x W x R	75	.4532	0.0060	
T x P x W x R	75	.4102	0.0055	
Pooled error	216	1.1960	0.0055	

NS--No significant difference

**Significant at 1% level

photoperiods at 65°F. Means in Table 23 show their fluctuations because the rate of top growth was more rapid than the rate of increase in root growth so that the root-top ratios were not constant as with the fescue. The different results in figures of root-top ratios between the fescue and the clover may be due to differences in hereditary characters.

Sprague (18) found similar results from several pasture species. He indicated that root-top ratios of the seedlings were highest at or below the temperatures giving the greatest net increase in total dry matter. This statement was particularly true in case of tall fescue and ladino clover as shown in Figures 6 and 12 respectively.

The explanation in this study probably lies in the monopolization of food materials by top growth and developing aerial parts of the fescue and clover, especially their leaves. It is also possible that the decreased formation of phloem tissues associated with budding plays a role in restricting the flow of food into the root system. Inadequate aeration resulted in a reduction in root growth in both the fescue and clover.

Effect of environmental factors on tall fescue.

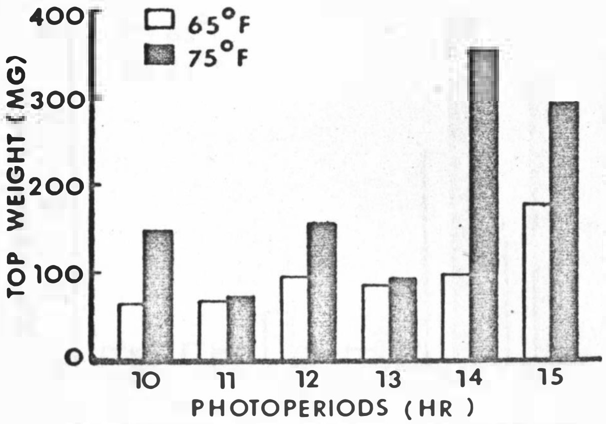

Figure 1. Effect of photoperiods and temperatures on top weight per plant at 6th week.

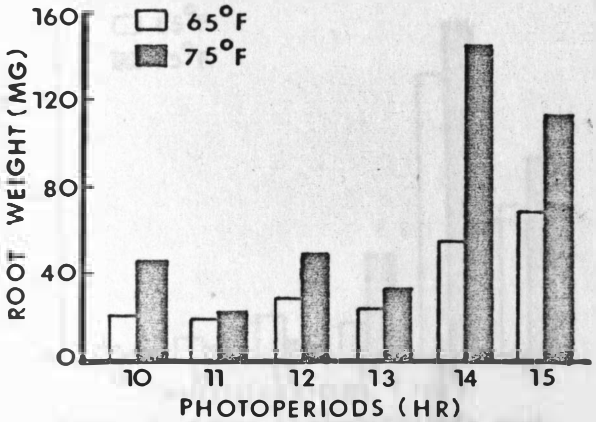

Figure 2. Effect of photoperiods and temperatures on root weight per plant at 6th week.

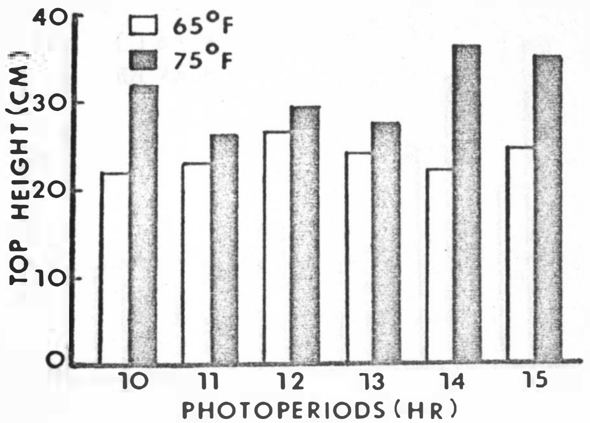

Figure 3. Effect of photoperiods and temperatures on top height per plant at 6th week.

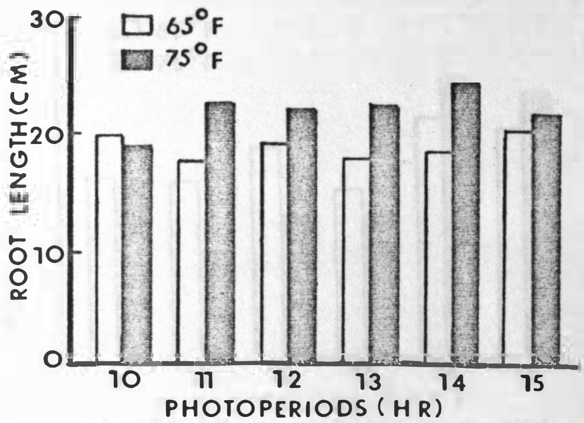

Figure 4. Effect of photoperiods and temperatures on root length per plant at 6th week.

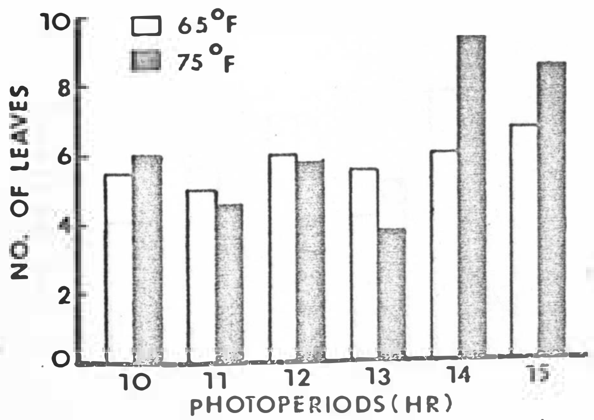

Figure 5. Effect of photoperiods and temperatures on number of leaves at 6th week.

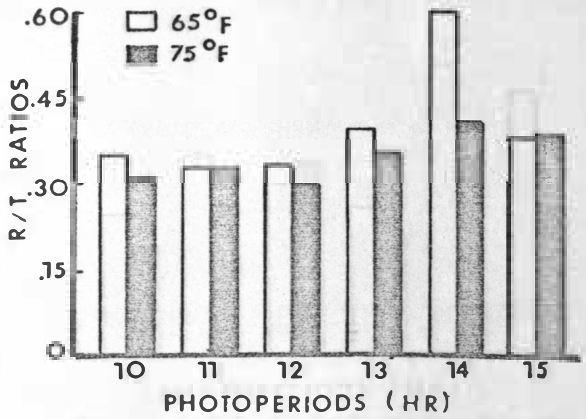

Figure 6. Effect of photoperiods and temperatures on root-top ratios per plant at 6th week.

Effect of environmental factors on ladino clover.

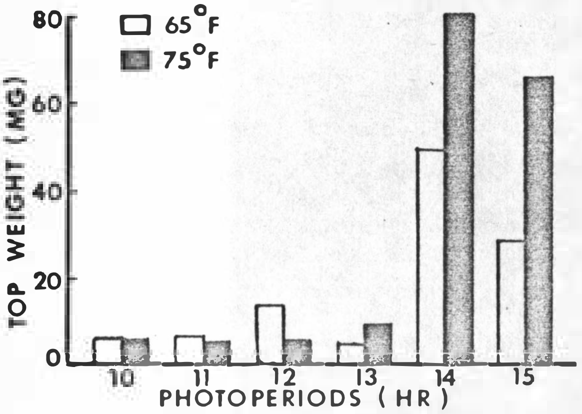

Figure 7. Effect of photoperiods and temperatures on top weight per plant at 6th week.

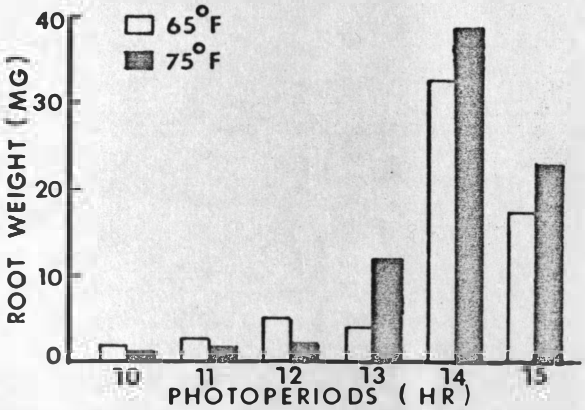

Figure 8. Effect of photoperiods and temperatures on root weight per plant at 6th week.

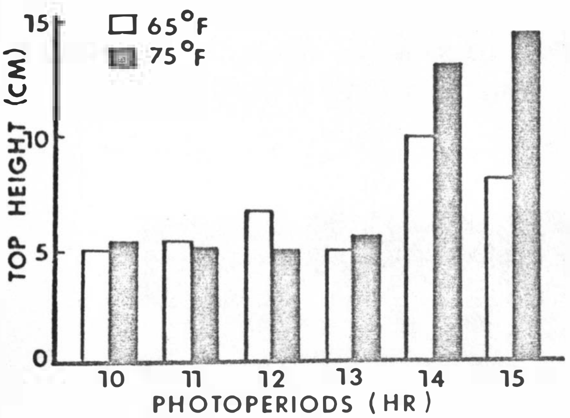

Figure 9. Effect of photoperiods and temperatures on top height per plant at 6th week.

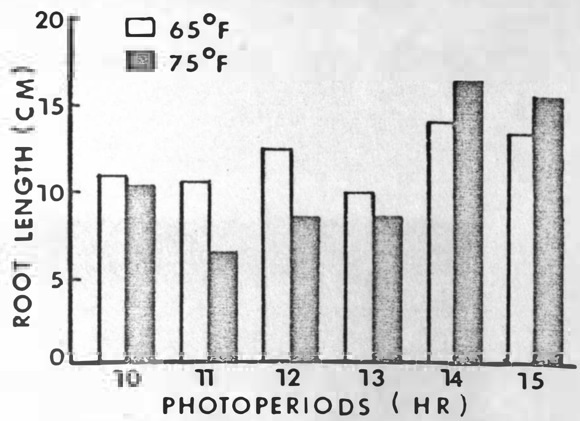

Figure 10. Effect of photoperiods and temperatures on root length per plant at 6th week.

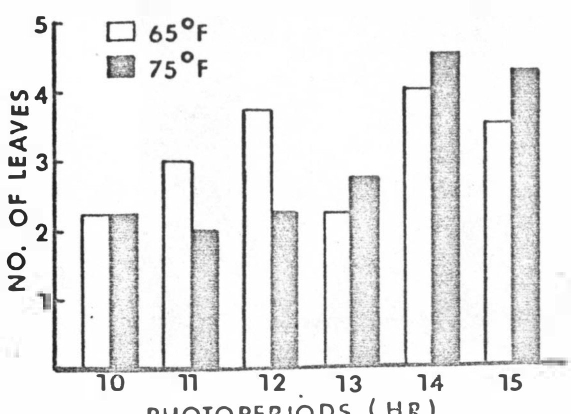

Figure 11. Effect of photoperiods and temperatures on number of leaves per plant at 6th week.

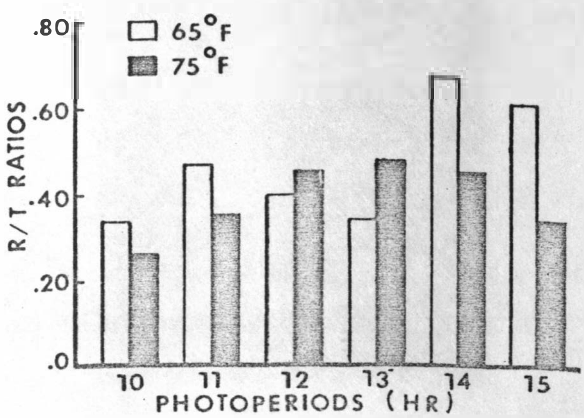

Figure 12. Effect of photoperiods and temperatures on root-top ratios per plant at 6th week.

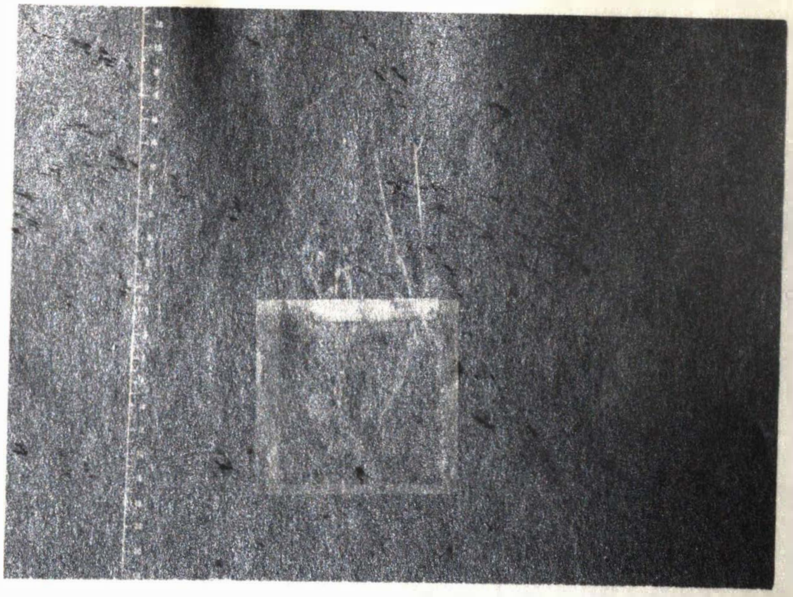

Figure 13. Growth pouch with ladino clover on the left and tall fescue on the right.

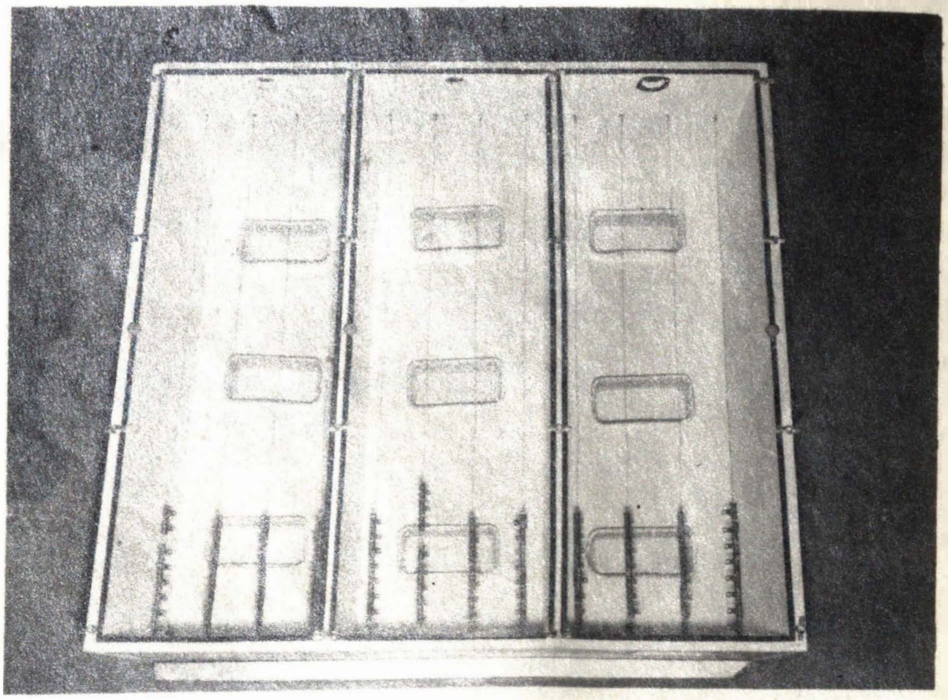

Figure 14. Top view of a subchamber showing fan motors, wires, aluminum cans and metal light trap.

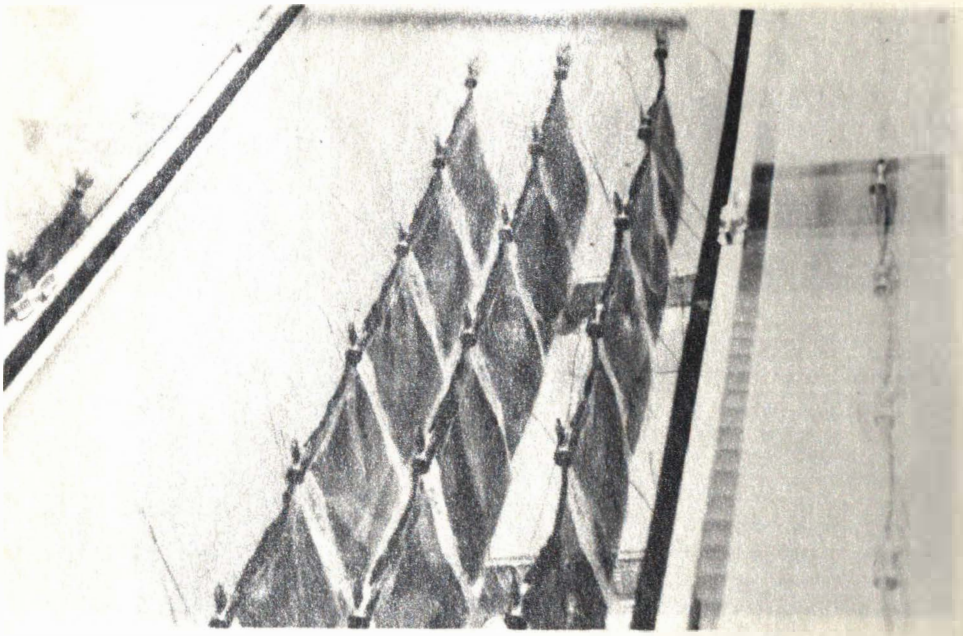

Figure 15. Growth pouches on wires in upright position in a compartment.

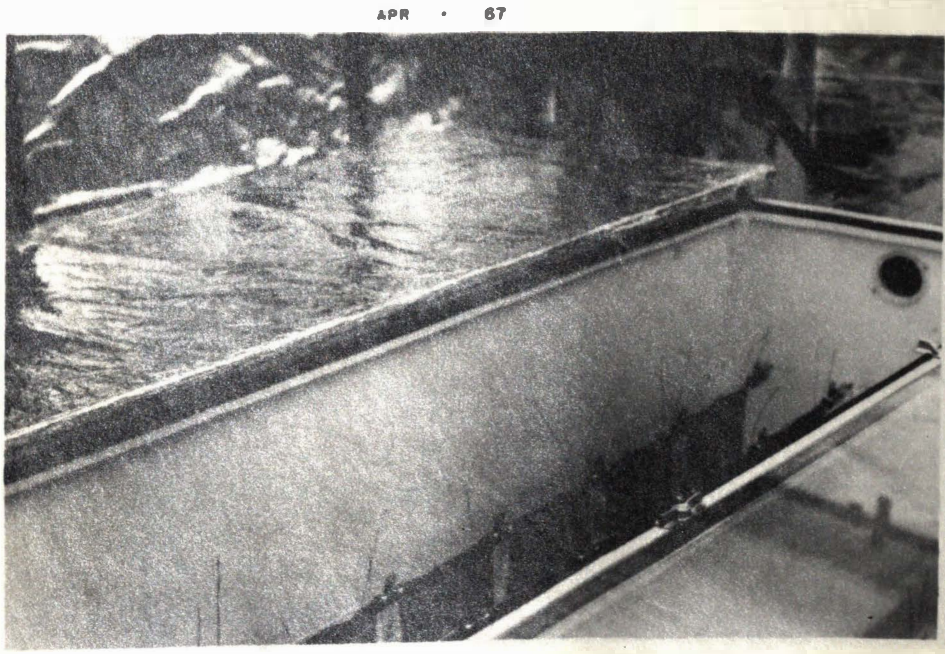

Figure 16. Subchamber showing method of controlling photoperiods by removing top covers.

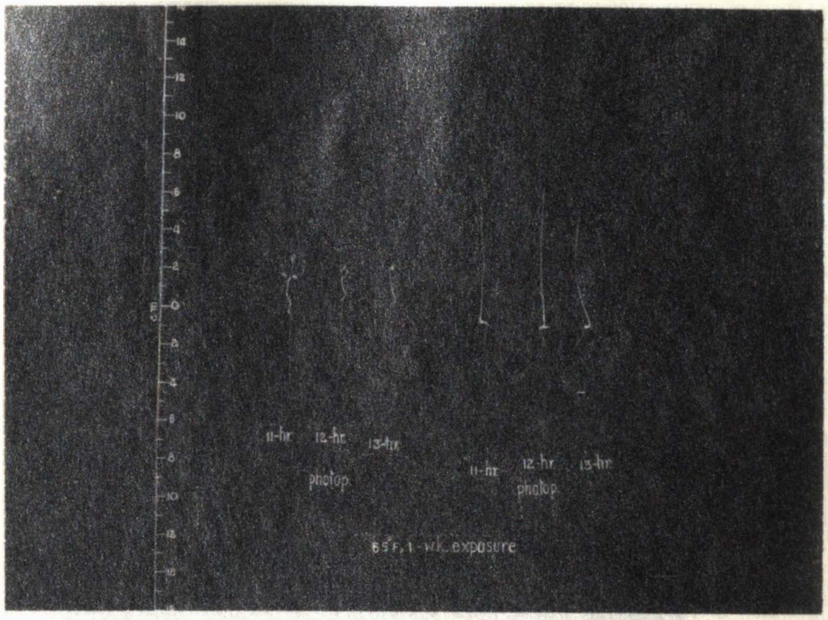

Figure 17. Seedlings at 65°F, 1-week exposure, 11, 12, and 13-hour photoperiods.

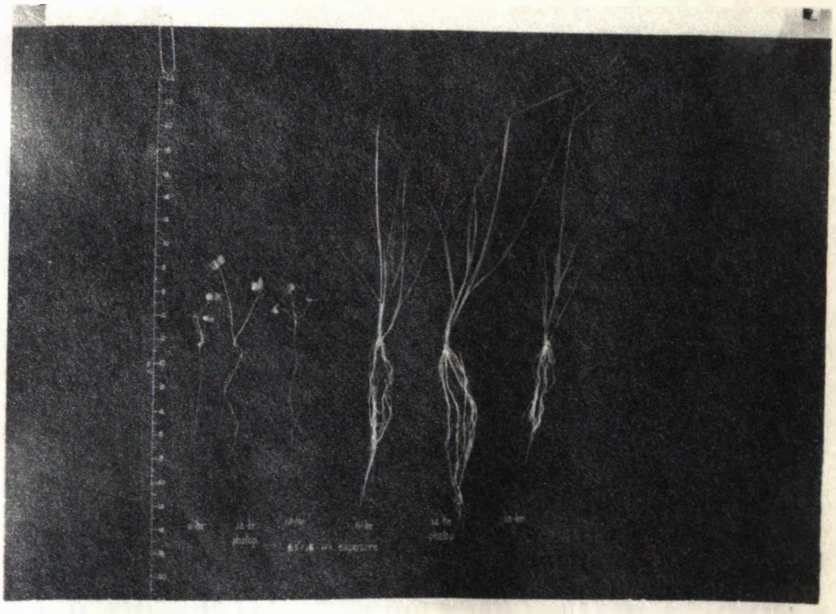

Figure 18. Seedlings at 65°F, 6-week exposure, 11, 12, and 13-hour photoperiods.

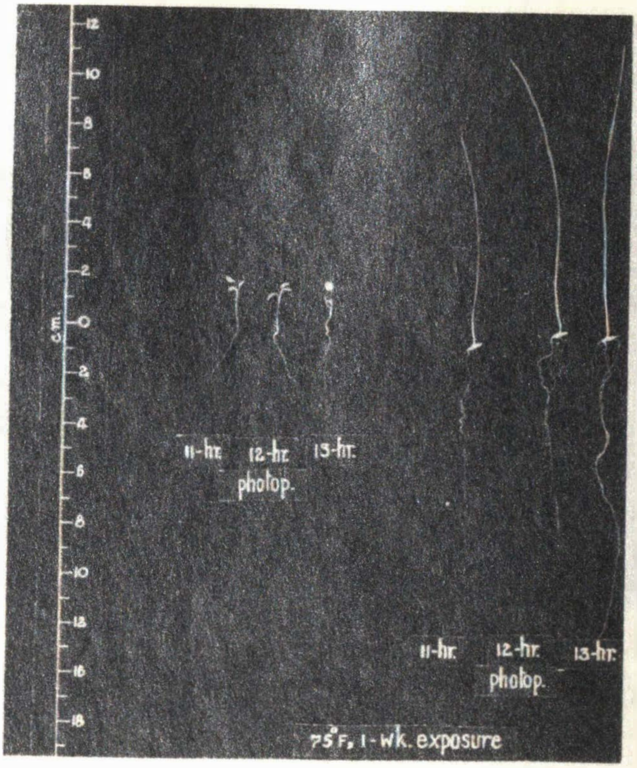

Figure 19. Seedlings at 75°F, 1-week exposure, 11, 12, and 13-hour photoperiods.

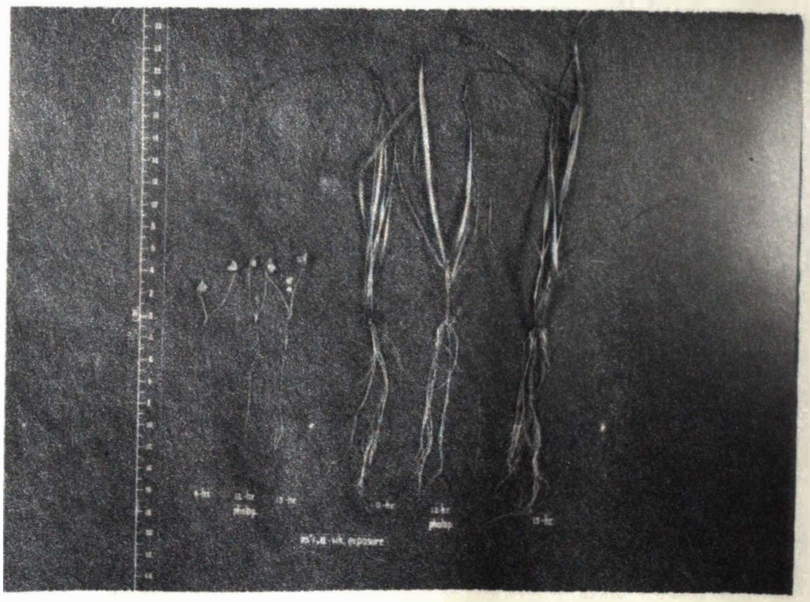

Figure 20. Seedlings at 75°F, 6-week exposure, 11, 12, and 13-hour photoperiods.

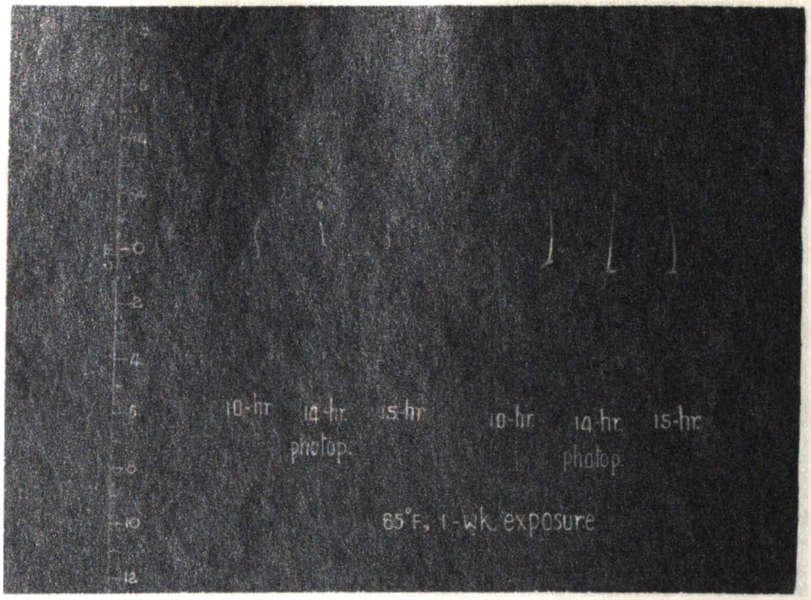

Figure 21. Seedlings at 65°F, 1-week exposure, 10, 14, and 15-hour photoperiods.

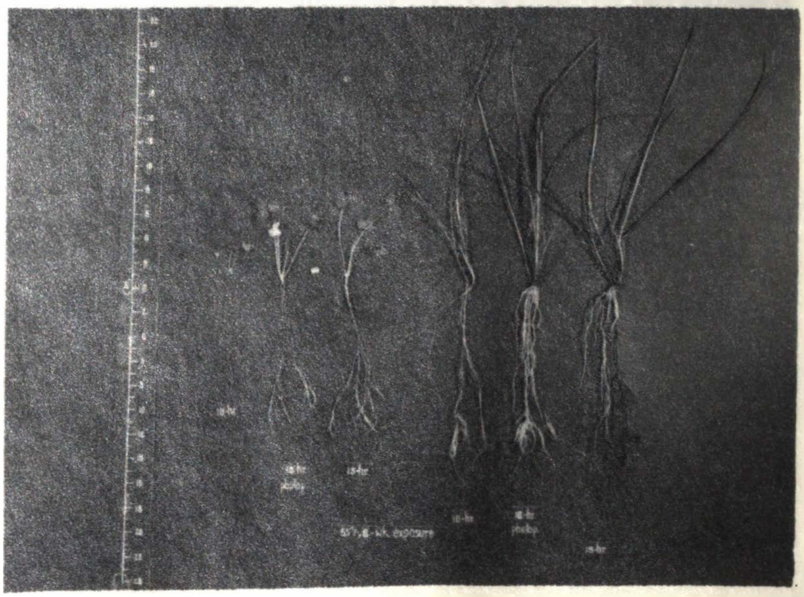

Figure 22. Seedlings at 65°F, 6-week exposure, 10, 14, and 15-hour photoperiods.

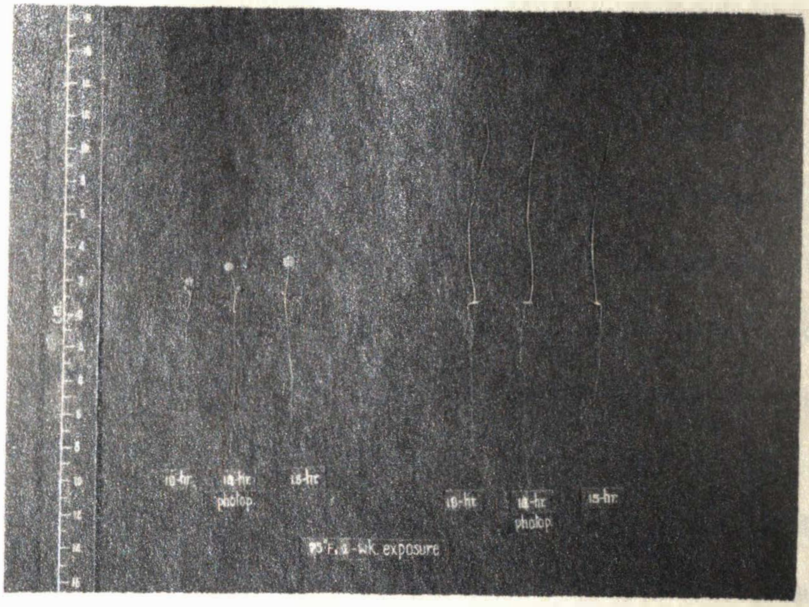

Figure 23. Seedlings at 75°F, 1-week exposure, 10, 14, and 15-hour photoperiods.

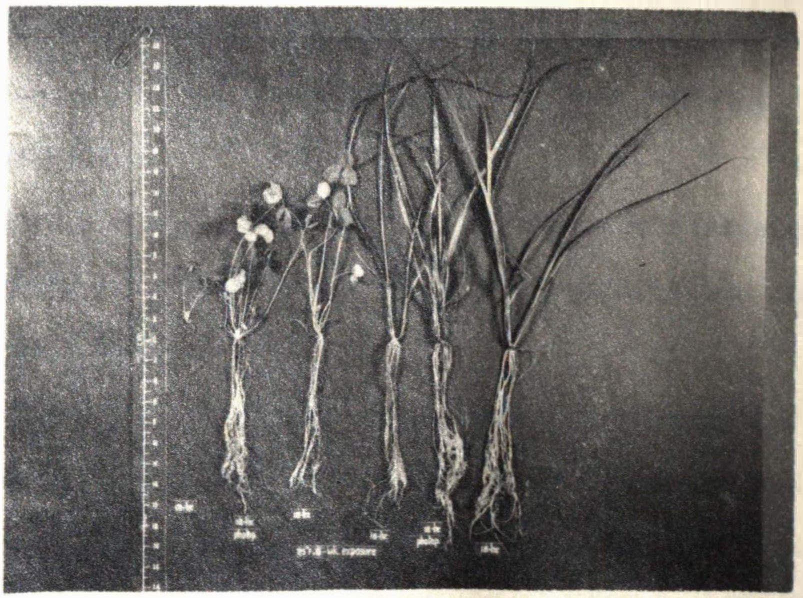

Figure 24. Seedlings at 75°F, 6-week exposure, 10, 14, and 15-hour photoperiods.

SUMMARY

A preliminary study of effects of photoperiods and temperatures upon early growth of tall fescue and ladino clover was carried out at weekly intervals for 6 weeks after thinning. The purpose of this study was to determine effects of photoperiods and temperatures on the 2 forage crops grown under control conditions at various growing periods.

The two species were grown in a growth chamber under photoperiods of 10, 11, 12, 13, 14, and 15 hours at two constant temperatures of 65°F and 75°F. Seedlings were grown in growth pouches under all combinations of the above environmental conditions. One-fourth strength of Hoagland's nutrient solution was applied. Seedlings were harvested at 1, 2, 3, 4, 5 and 6 weeks of age after thinning. The number and height of leaves, length of roots, dry weight of roots and tops, and root-top ratios were determined.

The emergence of the clover was faster than the fescue by about 2 days. However, tall fescue grew faster and taller than ladino clover in later periods.

Both species of forage crops were affected by the photoperiods and temperatures used in this experiment. Tall fescue and ladino clover responded similarly to photoperiods and temperatures in almost every aspect. Within the physiological range for plants, the fescue and the clover grew better at 75°F than at

at 65°F. It was found that seedlings under long photoperiods developed more favorably than under short photoperiods. Of the different combinations of photoperiods and temperatures used in this experiment, the two crops made the largest net increase in growth development under 14-hour photoperiods at 75°F. Seedlings responded considerably to the different environments after the 4th week of age.

The results found in this study relating to environmental factors would indicate that they should be considered when planting tall fescue and ladino clover for establishment of good stands. This could be attained by selection of planting dates that would compare favorably with the temperatures and daylengths which gave maximum growth in the growth chamber.

How well the plants will continue to grow and have a good balance in the fields depends on many other factors. Several investigators agree that the problem of disappearance of the clover in the fescue-clover field is mainly due to competition for light. Although this study did not include the shade effect of tall fescue on ladino clover in early stages of growth, it does suggest the following: fescue should be clipped back when it starts to head out to keep it from shading the clover. This suggestion would help materially in maintaining good stands that are already established.

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Appendix Table A. Tall fescue summary table showing effects of photoperiods, temperatures, and lengths of growing period on plant development.

Photop.	Wk.	Top weight (mg)		Root weight (mg)		R/T ratios		Top height (cm)		Root length (cm)		Number of leaves	
		65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F
10-hr.	1	1.40	1.70	.47	.47	.34	.29	2.97	10.25	4.77	9.02	1.00	1.00
	2	1.42	5.15	.55	1.17	.39	.23	6.45	14.45	6.52	12.82	1.00	2.00
	3	3.15	13.85	.90	2.80	.29	.20	10.35	20.42	7.60	14.82	2.00	3.00
	4	19.82	31.82	4.77	7.55	.23	.23	18.45	25.97	15.65	15.12	3.00	3.75
	5	20.67	79.55	5.32	21.20	.26	.26	18.47	32.20	12.65	17.02	3.00	4.75
	6	65.25	148.32	22.72	46.20	.35	.31	22.12	32.67	19.92	18.72	5.75	6.00
	Total	111.71	280.39	34.73	79.39	1.86	1.52	78.81	135.96	67.11	87.52	15.75	20.50
	Mean	18.62	46.73	5.79	13.23	.31	.25	13.13	22.66	11.18	14.59	2.62	3.42
11-hr.	1	.95	2.02	.45	.62	.48	.31	5.55	10.95	6.07	7.60	1.00	1.00
	2	2.75	7.00	.85	2.37	.30	.34	10.70	16.50	10.62	15.37	2.00	2.00
	3	3.25	15.50	.87	4.72	.27	.31	9.60	19.75	8.95	19.85	2.00	3.00
	4	11.07	31.15	1.72	11.57	.15	.36	16.07	23.92	12.27	20.77	3.00	3.00
	5	22.15	53.00	6.10	22.02	.28	.42	18.80	25.82	12.32	21.65	3.50	3.25
	6	68.00	70.47	19.50	22.27	.32	.32	23.12	26.37	16.52	23.97	5.00	4.25
	Total	108.17	179.14	29.49	63.57	1.80	2.06	83.84	123.31	66.75	109.21	16.50	16.50
	Mean	18.03	29.86	4.91	10.59	.30	.34	13.97	20.55	11.12	18.20	2.75	2.75

Appendix Table A. Tall fescue (cont.)

Photop.	Wk.	Top weight (mg)		Root weight (mg)		R/T ratios		Top height (cm)		Root length (cm)		Number of leaves	
		65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F
12-hr.	1	1.25	2.10	.50	.57	.40	.27	7.07	8.47	6.77	6.77	1.00	1.00
	2	3.15	9.70	.77	3.47	.25	.36	11.02	17.57	10.42	13.50	2.00	2.50
	3	4.50	21.02	1.07	8.40	.24	.40	12.32	23.45	10.57	22.07	2.00	3.00
	4	10.27	55.22	2.22	20.67	.21	.37	15.95	28.52	15.32	22.85	3.00	3.75
	5	50.85	89.35	13.17	37.97	.26	.42	24.05	26.70	16.82	22.90	5.25	3.75
	6	90.75	157.17	29.37	48.30	.32	.30	26.70	29.52	19.10	22.95	6.00	5.75
	Total	160.77	334.56	47.10	119.38	1.68	2.12	97.11	134.23	79.00	111.04	19.25	19.75
	Mean	26.79	55.76	7.85	19.90	.28	.35	16.18	22.37	13.17	18.51	3.21	3.29
13-hr.	1	.70	2.30	.42	.70	.60	.30	6.72	10.80	6.20	10.00	1.00	1.00
	2	3.37	7.12	.90	2.57	.26	.36	10.95	16.40	10.65	13.65	2.00	2.00
	3	5.45	14.87	1.42	4.87	.26	.33	15.02	20.85	11.32	16.77	2.00	3.00
	4	13.50	38.60	2.50	13.42	.17	.35	17.12	23.12	14.45	20.80	3.00	3.00
	5	49.87	58.82	21.62	22.45	.43	.39	22.40	27.40	15.97	22.62	4.75	3.25
	6	80.97	90.20	24.25	32.25	.40	.35	24.05	26.52	16.85	23.55	5.50	3.75
	Total	153.86	211.91	51.11	76.26	2.12	2.08	96.26	125.09	75.44	107.39	18.25	16.00
	Mean	25.64	35.32	8.52	12.71	.35	.35	16.04	20.85	12.57	17.90	3.04	2.67

Appendix Table A. Tall fescue (cont.)

Photop.	Wk.	Top weight (mg)		Root weight (mg)		R/T ratios		Top height (cm)		Root length (cm)		Number of leaves	
		65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F
14-hr.	1	1.62	2.12	.97	.70	.60	.33	5.57	10.32	5.87	11.05	1.00	1.00
	2	2.57	8.40	.85	2.30	.33	.28	8.92	17.15	8.90	15.35	2.00	2.00
	3	4.65	24.47	1.52	7.40	.38	.30	9.87	22.42	8.20	18.52	2.25	3.25
	4	31.82	69.45	11.25	24.32	.35	.36	20.60	25.52	16.80	21.52	3.50	4.75
	5	66.72	147.90	23.22	57.62	.34	.41	21.60	29.80	17.05	23.17	4.50	8.00
	6	90.70	353.10	55.22	147.57	.61	.42	22.25	36.40	17.92	25.40	6.00	9.25
	Total	198.08	605.44	93.03	239.91	2.61	2.10	88.81	141.61	74.74	115.01	19.25	28.25
	Mean	33.01	100.91	15.50	39.98	.43	.35	14.80	23.60	12.46	19.17	3.21	4.71
15-hr.	1	.52	1.85	.35	.55	.68	.29	4.82	10.42	5.25	9.47	1.00	1.00
	2	3.82	8.02	1.02	1.87	.27	.23	10.57	19.62	10.55	14.17	2.00	2.00
	3	9.25	24.87	3.12	8.00	.37	.32	15.90	23.65	12.25	19.22	2.50	3.00
	4	32.50	61.47	10.90	25.30	.32	.41	23.22	27.20	14.92	20.77	3.25	5.00
	5	77.90	110.22	29.62	47.80	.38	.43	24.45	26.17	17.52	22.02	5.50	6.75
	6	178.45	292.20	68.45	111.35	.38	.39	24.82	35.07	20.52	22.15	6.75	8.50
	Total	302.44	498.63	113.46	194.87	2.40	2.07	103.78	142.13	81.01	107.80	21.00	26.25
	Mean	50.41	83.10	18.91	32.48	.40	.34	17.30	23.69	13.50	17.97	3.50	4.37

Appendix Table B. Ladino clover summary table showing effects of photoperiods, temperatures, and lengths of growing period on plant development.

Photop.	Wk.	Top weight (mg)		Root weight (mg)		R/t ratios		Top height (cm)		Root length (cm)		Number of leaves	
		65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F
10-hr.	1	1.00	.92	.30	.40	.30	.43	2.10	3.10	3.42	6.00	--	--
	2	1.12	1.47	.40	.52	.35	.35	3.30	4.27	6.52	7.40	--	--
	3	1.72	2.27	.67	.62	.39	.28	4.05	4.75	7.60	8.62	1.00	1.00
	4	3.00	2.57	.92	.70	.31	.28	4.52	4.87	9.45	9.25	2.00	1.25
	5	4.47	4.02	1.47	1.12	.32	.28	4.75	5.02	10.57	9.62	2.00	2.25
	6	6.57	6.15	2.32	1.65	.35	.26	5.00	5.40	11.90	10.90	2.25	2.25
	Total	17.88	17.40	6.08	5.01	2.02	1.88	23.72	27.41	49.46	51.79	6.25	5.75
	Mean	2.98	2.90	1.01	.83	.34	.31	3.95	4.57	8.24	8.63	2.08‡	1.92‡
11-hr.	1	.67	.57	.35	.35	.52	.62	2.77	2.25	4.15	3.20	--	--
	2	.90	1.65	.35	1.05	.41	.63	3.95	3.25	5.05	4.35	--	--
	3	1.25	2.15	.45	1.50	.36	.70	4.40	3.50	6.70	5.75	.50	.25
	4	2.00	2.82	.60	1.70	.30	.61	4.62	3.72	6.75	5.75	2.00	1.00
	5	2.95	4.20	1.12	1.92	.40	.46	4.95	4.92	9.60	6.35	2.00	2.00
	6	6.80	5.67	3.17	2.07	.47	.37	5.42	5.25	10.60	6.57	3.00	2.00
	Total	14.57	17.06	6.04	8.59	2.46	3.39	26.11	22.89	42.85	31.97	7.00	5.00
	Mean	2.43	2.84	1.01	1.43	.41	.56	4.35	3.81	7.14	5.33	2.33‡	1.67‡

‡ Each figure of the mean is the average of the 4th - 6th week.

Appendix Table B. Ladino clover (cont.)

Photop.	Wk.	Top weight (mg)		Root weight (mg)		R/T ratios		Top height (cm)		Root length (cm)		Number of leaves	
		65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F
12-hr.	1	.60	.62	.30	.25	.49	.43	2.22	2.17	4.07	2.37	--	--
	2	1.05	1.67	.35	1.32	.33	.79	3.80	3.17	6.07	4.25	--	--
	3	1.60	3.15	.52	1.42	.33	.48	4.37	3.30	6.65	6.25	.75	.75
	4	1.72	3.72	.67	1.95	.40	.53	4.55	3.77	7.20	6.32	2.00	1.00
	5	3.80	5.05	1.42	2.27	.38	.45	4.67	4.05	7.72	6.40	2.25	2.00
	6	14.27	5.75	5.67	2.52	.40	.45	6.85	4.67	12.42	8.57	3.75	2.25
	Total	23.04	19.96	8.93	9.73	2.33	3.13	26.46	21.13	44.13	34.16	8.00	5.25
	Mean	3.84	3.33	1.49	1.62	.39	.52	4.41	3.52	7.35	5.69	2.67‡	1.75 ‡
13-hr.	1	.55	.72	.22	.27	.41	.38	2.32	2.62	4.12	4.07	--	--
	2	.95	1.47	.32	1.12	.34	.77	3.87	3.52	5.45	4.62	--	--
	3	1.22	2.60	.57	1.67	.47	.68	4.00	3.85	5.57	5.70	.50	--
	4	2.22	3.40	.67	2.10	.30	.62	4.12	4.50	5.72	6.77	2.00	1.00
	5	2.80	5.32	.97	2.57	.39	.48	4.35	4.90	9.45	7.02	2.00	2.00
	6	5.00	9.42	1.72	4.52	.34	.48	4.95	5.60	9.92	8.52	2.25	2.75
	Total	12.74	22.93	4.47	12.25	2.25	3.41	23.61	24.99	40.23	36.70	6.25	5.75
	Mean	2.12	3.82	.74	2.04	.37	.57	3.93	4.16	6.70	6.12	2.08‡	1.92 ‡

‡ Each figure of the mean is the average of the 4th - 6th week.

Appendix Table B. Ladino clover (cont.)

Photop.	Wk.	Top weight (mg)		Root weight (mg)		R/T ratios		Top height (cm)		Root length (cm)		Number of leaves	
		65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F	65°F	75°F
14-hr.	1	.90	1.02	.55	.40	.62	.39	1.95	3.30	4.12	6.65	--	--
	2	1.57	2.65	.72	.85	.47	.32	3.90	4.77	7.12	7.90	--	.50
	3	3.42	6.70	1.42	2.32	.41	.34	4.47	6.87	7.40	11.02	1.25	2.00
	4	9.95	9.55	3.87	4.00	.38	.41	6.20	7.52	11.92	13.67	2.00	2.00
	5	18.67	20.00	6.30	7.02	.50	.35	8.30	8.77	13.55	15.60	2.50	3.50
	6	49.25	83.87	32.85	38.72	.67	.45	9.90	13.22	14.27	16.55	4.00	4.50
	Total	83.76	123.79	45.71	53.31	3.05	2.26	34.72	44.45	58.38	71.39	8.50	10.00
	Mean	13.96	20.63	7.62	8.88	.51	.38	5.79	7.41	9.73	11.90	2.83‡	3.33 ‡
15-hr.	1	.60	.90	.32	.37	.59	.42	2.02	3.07	4.52	7.50	--	--
	2	1.52	2.00	.57	.50	.39	.25	3.62	4.47	7.60	7.57	--	1.00
	3	4.60	5.55	1.57	1.62	.35	.30	5.10	5.97	9.67	9.42	1.00	1.75
	4	9.50	6.50	4.32	2.27	.46	.38	7.10	6.52	12.67	11.55	2.00	2.00
	5	16.87	20.02	8.15	6.25	.48	.30	7.92	9.40	13.20	15.35	2.25	3.00
	6	28.65	65.87	17.35	22.67	.61	.34	8.02	14.00	13.42	15.45	3.50	4.25
	Total	61.74	100.84	32.28	33.68	2.88	1.99	33.78	43.43	61.08	66.84	7.75	9.25
	Mean	10.29	16.81	5.38	5.61	.48	.33	5.63	7.24	10.18	11.14	2.58‡	3.08 ‡

‡ Each figure of the mean is the average of the 4th - 6th week.