

CANOPY, MICROENVIRONMENT, AND NITROGEN EFFECTS ON
SUMMER RECOVERY OF TALL FESCUE

by

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INTRODUCTION

Cool season grasses are often used for hay or silage. Farmers often apply nitrogen fertilizer at medium to high rates in the spring to produce high yields. Harvesting tall dense canopies of cool season grasses sometimes depletes stands, particularly with liberal applications of nitrogen fertilizer. This problem has been severe when making harvests during clear, warm summer weather (Colby et al., 1965). McKee et al. (1967) encountered more severe stand losses from defoliating spring-accumulated tall fescue (Festuca arundinaca Shreb.) canopies than frequently clipped stands, but could not associate tiller losses with nonstructural carbohydrate status. Frequently clipped tillers and stands were apparently better able to cope with the microenvironment created in harvested canopies.

Plants growing in dense canopies usually lose much of the photosynthetic capability in basal leaves (Wolf and Blaser, 1972). Prolonged periods of low light intensity reduce the specific leaf weight (Wolf and Blaser, 1972) and leaf protein (Blenkinsop and Dale, 1974). Basal leaves on tillers are usually the oldest leaves and age decreases photosynthetic activity (Brown et al., 1966). Leaves in low light situations at the base of dense canopies usually senesce rapidly resulting in low leaf areas in basal canopy strata (Brown et al., 1966). Thus, defoliating dense canopies causes stubbles with small leaf areas of low photosynthetic ability. Open stubbles after cutting allow most of the radiation to penetrate to raise temperatures of soils and plant tissues. Grasses in vegetative stages regrow by

cell division and elongation in the apical meristem region near or slightly below the soil surface. Metabolic activities in this area are sensitive to temperature. High temperature of the air near the soil or in the surface soil undoubtedly restrict leaf growth, re-establishment of the individual tillers, and yields.

Cell elongation is very sensitive to moisture stress. Leaf enlargement is depressed by leaf water potentials at -3 to -4 bars (Boyer, 1970). Increased radiation on the plant surfaces augments transpiration (Tanner and Lemon, 1962). Increasing air temperatures increase rates of transpiratory water loss and tension on plant water (Huang and Chang, 1974).

Grass regrowth is associated with the status of non-structural carbohydrates (TNC) in plants. These compounds represent a pool whose concentration is a balance between photosynthetic input and energy-demanding activities of plants. They are readily available energy substrates and raw material for cell growth. Thus regrowth is a function of the balance between current photosynthetic activity and TNC (Ward and Blaser, 1961). Plants with low or high TNC are more or less dependent, respectively, on a residual leaf area to re-establish canopies.

Temperature increases augment metabolic activity of plant tissues. Respiration of labile substrates which produces energy (oxidative phosphorylation), increases with temperature beyond points where photosynthesis and growth are retarded. At high temperatures, more energy is required to maintain cellular mechanisms under

accelerated entropy (Semikhatova, 1969). Thus, high temperatures cause depletion of TNC for non-growth functions and reduce the potential plant regrowth rates.

Dense canopies of plants maintain mild microclimates in basal regions, as very low irradiance and cool temperatures are maintained (Peacock, 1975). Leaves and tillers developing under low light have thin cuticles and other features which sensitize them to moisture stress under high light and temperature conditions (Shearman and Beard, 1973; Wilkinson and Beard, 1975).

Defoliation of dense canopies increases irradiance and temperatures near the soil level dramatically (Peacock, 1975, and Cowett and Sprague, 1963). Thus, the change in microenvironment after defoliation of dense canopies probably hampers recovery of plants through effects on soil, air, and tissue temperatures; on carbohydrate metabolism and water stress. It is likely that physiological/morphological conditions in tillers developed in tall dense canopies aggravated by microenvironment changes resulting from sudden canopy removal are responsible for tiller losses and poor regrowth.

This investigation is composed of three experiments with tall fescue. The objectives of Experiment I were to characterize stubble canopies and microenvironments as affected by spring mowing managements and nitrogen rates, and to study regrowth after harvesting in June. The objectives of Experiment II were to characterize stubble microenvironments as affected by shading treatment and irrigation, and to study regrowth from the stubbles as affected by spring nitrogen

rate, irrigation, and shading. The objectives in Experiment III were to investigate the effect of controlled air temperature on regrowth response when potting soil was not allowed to equilibrate with growth chamber air temperature.

I. Canopy Microenvironment and Regrowth of Tall Fescue
With Mowing and Nitrogen in Spring

INTRODUCTION AND REVIEW OF LITERATURE

Cool season grasses are often used for hay or silage, with high fertilization rates used to produce economically high yields. Harvesting high yielding canopies, particularly those with high nitrogen fertility has often resulted in tiller losses and poor regrowth, particularly in the summer season (Colby et al., 1965; Cowling and Lockyer, 1970; Hallock et al., 1965; Schmidt and Tenpas, 1965). Colby et al., with orchardgrass, Dactylis glomerata L., noted this phenomenon when summer harvests were followed by clear weather and high temperature. Cowling and Lockyer (1970) noted stand thinning in ryegrass, Lolium sp., with N rates of 200 kg/ha or more. Schmidt and Tenpas (1965) attributed poor survival of timothy, Phleum pratense L., and orchardgrass to "fertilizer burn". Nitrogen at 448 kg/ha severely thinned stands of tall fescue, Festuca arundinacea Schreb. (cv. Kentucky 31), without damaging Coastal bermudagrass, Cynodon dactylon L. (Hallock et al., 1965). High canopy yields at harvest appear to influence the phenomenon as frequent harvests (more than 2-3 harvests per year) decreases the severity of the stand loss (Jung et al., 1972, and Smith et al., 1973). Cutting at advanced growth stages contributes to the stand depletion (McKee et al., 1967). Smith et al. (1973) found that harvesting grass-alfalfa, Medicago sativa L. mixtures when grasses were in late stem elongation, early anthesis, and ripe seed stages caused grass stand depletion.

Leaf growth originates in the basal meristems of tillers in the canopy; also, new tillers develop from the canopy base or from rhizomes. As canopies grow, the herbage reduces light penetration causing very low light intensity in basal regions. Thus, new growth in accumulating canopies develops in progressively darker, cooler, and more humid microenvironments.

On overcast days, temperature gradients between ambient air canopy layers are small. On bright days, temperature within a canopy stratum is closely associated with the amount of solar radiation intercepted in that stratum (Peacock, 1975b). Thus, in tall, unharvested canopies, air in upper strata is warmer than ambient and 10-15 C cooler near the soil level. Shorter canopies thus have more radiant energy and warmer temperatures near the soil level than tall ones. Radiation not reflected or absorbed by the canopy strata is absorbed or reflected by the soil surface, thereby raising temperatures of the surface layers of soil. Thus, short or sparse canopies often are associated with elevated soil temperatures (Cowett and Sprague, 1963). Basal portions of tall as compared to short canopies have less air movement and loss of water vapor to the ambient air because of smaller vapor density gradients. Artificial shading of soybean, Glycine max Merr., stands lowered soil surface temperatures and decreased water use by creating a "humidity blanket" (Allen, 1975). Fritschen and Shaw (1961) pointed out that evapotranspiration is controlled by radiant energy interception by corn canopies.

Plant organs that develop under basal microclimates of low light

intensity are often poorly adapted to intense sunlight. Wilkinson and Beard (1975) found thin cuticles and poor vascular development in 'Merion' bluegrass, Poa pratensis L., leaves developed under low light. Alfalfa leaves that matured under artificial shades had lower NCE rates than unshaded leaves (Wolf and Blaser, 1972). Aging of leaves causes loss of photosynthetic capacity (Brown et al., 1966). Thus, basal leaves and tillers of dense canopies are in a poor position and microenvironment to support growth of plants when suddenly exposed to full sunlight after cutting tall, dense canopies.

Defoliation management of grass swards alters the structure of canopies and thus the microclimates. Peacock (1975b) associated changes in air and soil temperature profiles with the extent of regrowth. He measured a temperature gradient of -17 C between air at 30 cm and at the soil surface in a 55 cm canopy of ryegrass. Hart et al. (1971) increased light interception and reduced tillering by leaving tall stubble residues and clipping less frequently. Colby et al. (1965) found increased leaf areas and cooler soil temperatures as stubble heights of orchardgrass increased. Thin stands of alfalfa had higher soil and air temperatures than dense stands; however, dense stands produced fewer tillers per plant (Cowett and Sprague, 1963). Rhodes (1971) showed that ryegrass cultivars producing high yields with frequent cuttings also developed high LAIs in the base of canopies. Tanner and Lemon (1962) stressed the importance of leaf area for transpiration and shading the soil surface.

Plant response to microenvironment should be mediated by the canopy history. Clipping tall dense canopies of tall fescue to short

stubbles causes the remaining LAI to be almost nil. Peacock (1975), when defoliating a 55 cm canopy of perennial ryegrass, Lolium perenne L., (LAI = 5.6) to 5 cm, found a stubble LAI of 0.3. The air temperature at 2.5 cm increased to 34 C with 70 percent light penetration of 650 W/m^2 incident light. Such temperature effects are very important as Peacock (1975a) and Watts (1972) reported that soil temperature in the apical region of grass plants controlled leaf extension. Magalhaes et al. (1976) reported declining leaf expansion of soybeans with increasing temperature over the range of 25-40 C; also nitrate reductase was irreversibly inactivated at 36 C.

Leaf area remaining after defoliation and TNC status of remaining tissue have been positively associated with leaf growth of tillers and development of new tillers, (Ward and Blaser, 1961). Smith (1974), Youngner and Nudge (1976), and Brown and Blaser (1970) showed that regrowth responses to stubble leaf area and TNC level were temperature dependent, high temperatures decreasing regrowth responses. Light intensity to the base of grass tillers increases sharply after defoliation. Paulsen and Smith (1969) found that shade during the summer months increased yields of orchardgrass while Eagles (1972) reports increases in relative growth rate up to 144 W/m^2 and then declines. He showed consistent declines in leaf extension with increasing light intensity beyond 144 W/m^2 in orchardgrass.

In this experiment, different types of canopies were obtained by using three spring cutting frequencies at two stubble heights with two nitrogen rates. Measurements included light penetration and temperatures of canopy stubbles, monitoring temperature shifts from

unharvested to defoliated canopies, and growth responses from the canopies and microclimates.

PROCEDURES

This experiment was conducted in 1975 and 1976 on second and third year stands of Ky 31 tall fescue, respectively. The experiments were located on Greendale silt loam (Fluventic Dystrochrepts; fine-loamy, siliceous, mesic) in 1975 and Groseclose sil (Typic Hapludults; clayey, mixed, mesic) in 1976. The soil pH was about 6.5. A mixed 20% P_2O_5 (8.7% P) - 20% K_2O (16.6% K) fertilizer was applied at the rate of 448 kg/ha.

The experimental design was a split-plot, randomized complete block with four replications. Nitrogen rates of 50 and 160 kg/ha as NH_4NO_3 comprised the main plots treatments. The split-plot treatments were combinations of cutting to 4 and 8 cm stubble heights biweekly, monthly, and accumulating canopies during the whole season. All 6 treatments were mowed to the stubble heights on a given date in June. An unharvested check comprised the seventh treatment. All plots were mowed during the fourth week in March to four cm and the N fertilizer was applied.

The June harvests (June 9, 1975, and June 29, 1976) were made with a 91 cm sickle bar mower. A mower strip was cut down the center of the plot; the forage was raked and bagged and then mowed with a rotary mower to trim the stubble evenly. Forage was dried at 70 C in a forced draft oven and weighed. The spring harvests were made with a 51 cm rotary mower with a grass catcher. In 1976, 25 kg/ha of N was uniformly applied to the whole experiment 10 days before the June harvests to avoid nitrogen stress as a variable caused by the

harvest schedules, and variable amounts of herbage removed.

Prior to and after the June harvests, solar radiation penetrating to the 2 cm level in all canopies was measured with a selenium photocell wired to a microammeter, and expressed as percent of incoming solar radiation at the top of the canopy. In 1975, temperatures of soil at a depth of 0.6 cm, air at 2.5 cm and shoots were measured with copper-constantan thermocouples. The air temperature thermocouples were shaded in a semi-cylinder of translucent plastic with the bottom side removed. Shoot temperature thermocouples made of .0025 cm wires were inserted under the outside green sheath at ca. 2.5 cm. Temperatures were measured with a millivolt amplifier-recorder. In 1976, temperatures were measured with thermistor probes and a Yellow Springs Instruments electronic thermometer. Radiation flux density was monitored with an Eppley pyranometer and spot radiation measurements were made with a Lambda Instruments radiation meter.

After harvesting the spring canopy growths, stubble samples were taken for stubble weight, specific leaf weight, leaf area, and total non-structural carbohydrates. Non-structural carbohydrates were extracted with .02 N HCl and reducing power was determined with an automated ferricyanide reduction technique (Wolf and Elmore, 1975). Forage regrowth above the stubble heights was harvested 7 and 14 days after the June harvests in 1975 and 1976, respectively. Ground cover (%) was estimated after 30 days of regrowth.

RESULTS AND DISCUSSION

1. Canopy Accumulation: The forage yields of canopies accumulated for various periods and cut to two stubble heights in June are yields accrued since the last scheduled spring harvest for each treatment, Table I-1. The June harvesting date was delayed in 1976 to accumulate more forage because of drought. There were large disparities in yield between years in the frequently clipped treatments. Rainfall was very low in April, May, and early June of 1976. In both years, there was a significant increase in canopy yields and densities from the high nitrogen rate, when averaged for all managements. In 1975, biweekly managements gave the lowest canopy yields, monthly treatments were intermediate and the unharvested canopies gave the highest yields. Within the monthly and biweekly cutting frequencies, stubble heights caused no yield differences. In the spring-accumulated canopies, mowing to 4 as compared to 8 cm removed more of the canopy growth thereby giving higher yields. The 1976 data show low canopy yields during the final regrowth period prior to June clipping. This occurred even though it was delayed three weeks. Plots clipped monthly made no more regrowth than plots clipped biweekly; however, canopies accumulated all spring produced the highest yields.

While the year effect was not analyzed statistically, it appears that spring clipping of canopies depressed regrowth more severely during the dry spring of 1976 as compared to the wet 1975 spring season.

Table I-1. Canopy yield (g/m^2) and light penetration (LP) (% of incoming solar radiation) at 2 cm prior to harvest as affected by spring nitrogen rates and clipping managements.†

Clipping managements	Nitrogen, kg/ha												
	50					160					Mean		
	g/m ²	g/m ²	LP, %	g/m ²	LP, %	g/m ²	g/m ²	LP, %	g/m ²	LP, %			
1975	1976	1975	1975	1976	1975	1976	1975	1976	1975	1976			
Stubble height													
Frequency													
	cm												
Biweekly	4	102	51	33	138	111	14	120d	96n	24a*			
	8	73	36	21	134	126	8	103d	91n	15b			
Monthly	4	327	59	10	474	182	3	400c	120n	6c			
	8	401	56	6	427	166	3	414c	111n	5c			
Spring	4	684	569	6	962	754	3	823a	662m	5c			
accumulated	8	447	410	8	695	540	2	571b	528m	5c			
Mean		339y	198y	13y*	471x	331x	5x	405	264	9			

†All plots were clipped to the designated stubble heights on June 9, 1975, and June 29, 1976.

*Means in rows or columns followed by common letters are not significantly different at .05 level of probability.

Light penetration to the tiller bases prior to harvest in 1975 canopies was depressed in the high nitrogen canopies, Table I-1. Clipping management, averaged across nitrogen rates, also reduced light penetration significantly. Both the monthly and unclipped canopies allowed only 5 to 6% of incident solar radiation to penetrate the 2 cm layer of canopies. The canopies cut biweekly had significantly more light penetration to the 2 cm level, particularly with 4 cm stubble residues. Regression analyses show that light penetration was related in a logarithmic negative fashion to canopy yield before harvesting, (light penetration = $63 - 19.14 \log_{10} X$, $r^2 = .53$,*** where X = harvested canopy yields). Pearce et al. (1967) showed similar trends, when using LAI as the dependent variable. The data from spring accumulated plots are similar to those of Peacock (1975) who found light penetration to the base of perennial ryegrass 55 cm high to be essentially nil.

Due to malfunctioning equipment, light penetration data for pre and post-harvesting of tall fescue canopies were not reliable in 1976. However, measurements taken 10 days prior to harvesting indicated that canopies from the monthly and biweekly clips had similar light penetration; also, spring (uncut) accumulated canopies had considerably higher light penetration to canopy bases than in 1975. This is attributed to higher yields and denser canopies in 1975 than in 1976. The 1975 spring accumulated canopies were in a green seed growth stage, and the high nitrogen plants were about 50% lodged in 1975. In 1976, the plants matured early and were in the late green

seed stage but there was no lodging due to the poor growth because of drought.

Leaf area indices (LAI) for stubbles remaining after the June, 1975 harvest show no significant effect from nitrogen rates on stubble LAI, Table I-1. However, there is a consistent trend for slightly higher LAIs in stubbles with high than for low N for the 4 treatments that had been cut at monthly or biweekly intervals. Stubble LAIs as influenced by spring cutting managements were rather consistent. Leaving 8 cm as compared to 4 cm stubbles, at all harvest frequencies, increased leaf area. Stubble LAIs were considerably higher in canopies which were harvested during the spring season, as compared to accumulated canopies; where the stubble LAIs were especially low with the 4 cm stubble at N₁₆₀. Similar trends occurred during 1976. The year effect was not statistically analyzed, but 1975 LAIs averaged across all treatments were only 60% of the 1976 data. The lower LAI values in 1975 than in 1976 are attributed to less light reaching the basal canopy layers due to the higher yield in 1975 than in 1976. Davies (1966) and others observed low stubble LAIs in highly nitrogen fertilized stands.

Specific leaf weights (SLW) were depressed by 160 as compared to 50 kg N/ha in 1975, Table I-2. The more rapid growth of leaves with high than low N would tend to lower dry matter content of leaves (Pellett and Roberts, 1963). Also, very low light intensities at basal canopy layers due to high yields per se would reduce SLW (Wolf and Blaser, 1972). Management also affected SLW, values for monthly and biweekly managements at both clipping heights were

Table I-2. Stubble leaf area index (LAI) and specific leaf weight (SLW, mg/cm²) as affected by spring nitrogen rate and harvest management. 1975.

Clipping management Stubble height	Nitrogen, kg/ha							
	50		160		Mean			
	LAI	SLW mg/cm ²	LAI	SLW mg/cm ²	LAI	SLW mg/cm ²		
Biweekly	4	.58	4	5.3	.79	4.4	.68b*	4.8a*
	8	1.15	8	5.1	1.44	3.8	1.29a	4.4ab
Monthly	4	.66	4	4.7	.83	3.4	.69b	4.0ab
	8	1.11	8	4.5	1.40	3.5	1.28a	4.0ab
Spring accumulated	4	.24	4	4.2	.13	3.3	.19c	3.7b
	8	.82	8	4.5	.93	3.4	.87b	3.9b
Mean		.74x*		4.7m	.93x	3.6n	.84	4.1
							(1.41)†	

*Numbers in columns or rows followed by common letters are NSD at .05 level.

†1976 mean.

similar, but the 4 cm biweekly harvest produced leaves that were significantly higher in SLW than those of the two treatments where canopies were accumulated.

The stands of vegetative tillers were not affected by N rates during either year, Table I-3. During 1975, tiller populations in the spring-accumulated canopies tended to be lower than for the 4 treatments harvested biweekly or monthly; however, tiller stands were significantly inferior only to biweekly 4 cm clips. Such trends for mowing managements were not significant in 1976. These trends in tiller stands agree with data by Hart et al. (1971) for summer tall fescue growth. Cowett and Sprague (1963) noted declines in tillering in alfalfa dense canopies and low basal light intensity was encountered as canopies accumulated during spring.

Yields of live stubble (Table I-4) show no significant nitrogen rate effect in either year. Average stubble yields for all treatments were 30% less in 1976 than in 1975. Management effects are essentially clipping height effects as canopies cut to 4 cm stubbles yielded consistently lower than their 8 cm counterparts during both years.

2. Post-Harvesting Effects: After cutting the fescue canopies in June, light penetration to the 2 cm level in stubbles was significantly influenced, Table I-5. Nitrogen rate did not affect light penetration significantly, when clipping managements were averaged. There was a sharp effect of clipping management, fescue clipped to 8 cm allowed less penetration of the incoming radiation than for the 4 cm stubble. The monthly and biweekly cuttings to 8 cm stubbles

Table I-3. Populations of vegetative tillers as affected by nitrogen rates and clipping management during spring.

Clipping management	Stubble height	Nitrogen, kg/ha					
		50		160		Mean	
		Tillers/dm ²		Tillers/dm ²		Tillers/dm ²	
Frequency	cm	1975	1976	1975	1976	1975	1976
Biweekly	4	82	65	72	62	77a	64mn
	8	74	60	69	65	71a	62mn
Monthly	4	56	65	48	58	52ab	61mn*
	8	59	75	55	61	57ab	68n
Spring accumulated	4	45	43	47	50	46b	46m
	8	40	47	48	54	44b	51mn
Mean		59	59	56	58	57	58

*Numbers in individual columns followed by common letters are NSD at .05 level.

Table I-4. Yields of live stubble as affected by nitrogen rates and clipping managements during spring.

Clipping management	Stubble Frequency height	Nitrogen, kg/ha					
		50		160		Mean	
		1975	1976	1975	1976	1975	1976
	cm						
Biweekly	4	72	57	60	62	66b	59o
	8	169	122	157	117	163a	119m
Monthly	4	67	66	68	76	67b*	71no*
	8	154	102	203	109	178a	106mn
Spring accumulated	4	81	55	104	50	93b	52o
	8	151	94	173	111	162a	102mn
Means		116x	83r	128x	87r	122	85

*Values followed by common letters are NSD at .05 level.

Table I-5. Light penetration to the 2 cm level (% of incoming solar radiation) in canopies immediately after the June cutting as affected by nitrogen and clipping managements in spring, 1975.

Clipping management		Nitrogen, kg/ha		
Frequency	Stubble height	50	160	Mean
		—— % of solar radiation ——		
		cm		
Biweekly	4	72	55	64bc*
	8	31	17	24d
Monthly	4	69	65	67ab
	8	30	39	34d
Spring accumulated	4	76	75	75a
	8	48	57	53c
Unharvested check	-	9	3	6e
Mean		48x	45x	46

*Values followed by common letters are NSD at .05 level.

allowed less light penetration than for other treatments. Linear regression of treatment means of stubble LAI and light penetration gave a significant negative relationship (light penetration = $92 - 49.7X$, $X = \text{LAI}$, $r = -.92^{**}$). The difference in light penetration before and after harvesting spring-accumulated canopies was very large, Table I-5. As unharvested canopies accumulated during spring there was presumably a gradual decline in basal light as yield and height increased during spring. Upon harvesting dense canopies with dimly lit basal microenvironments, a sudden shift from 6% to 75% of full sunlight resulted in the canopies with 4 cm stubbles. This could have severe impacts on plant regrowth.

Temperatures measured during the 1100-1600 hour period on the day of cutting (Table I-6, I-6a) were taken only in periods of strong direct sunlight, and should approach maximum daily temperatures. Solar radiation flux density during the period of temperature measurements was 850 W/m^2 in 1975. The average soil temperatures in the N_{50} and N_{160} treatments were similar. The soil at 0.6 cm for biweekly cut plots tended to be 2-3 C cooler than for the less frequently mowed plots. Usually, the 8 cm stubbles for each mowing frequency caused 1-2 C cooler temperature than the companion 4 cm stubble. The unharvested check with a large canopy was 5-10 C cooler at 0.6 cm than the defoliated treatments. Air temperature for 1975 (Table I-6) at 2.5 cm were similar for the N rates. The biweekly clipped plots tended to be cooler at 2.5 cm than the less frequently defoliated plots, significantly cooler than spring-accumulated fescue clipped to 8 cm. Temperatures at 2.5 cm were similar for

Table I-6. Temperatures† of soil at 0.6 cm (T_s), air at 2.5 cm (T_a), and plant tissue at soil level (T_t) as affected by nitrogen rates and clipping managements in spring. (Air at 1.5 m 28 C). 1976.

Clipping management	Stubble height	Nitrogen, kg/ha								
		50			160			Mean		
Frequency	cm	T_s	T_a	T_t ‡	T_s	T_a	T_t	T_s	T_a	T_t
		C								
Biweekly	4	24	31	26	25	28	26	25bc*	29b*	26bc*
	8	26	30	25	25	29	25	26bc	29b	25bc
Monthly	4	26	29	26	27	28	26	27ac	29b	26bc
	8	26	30	26	25	29	26	26bc	29ab	26bc
Spring accumulated	4	29	31	29	29	32	29	29a	31a	29a
	8	28	30	27	27	30	27	27ab	30ab	27ab
Unharvested check	-	25	27	25	23	28	23	24c	27b	24c
Means		26	30	27	26	29	26	26	29.5	26

*Values in a column followed by common letters are NSD at .05 level.

†Temperatures measured during the 1300-1600 hour period.

‡Tissue temperatures measured in the shoot at soil level.

Table I-6a. Temperatures† of soil at 0.6 cm (T_s), air at 2.5 cm (T_a), and plant tissue (T_t) as affected by nitrogen rates and clipping managements in spring. (Air at 1.5 meters, 27 C). 1975.

Clipping management	Stubble height	Nitrogen, kg/ha								
		50			160			Mean		
		T_s	T_a	T_t ‡	T_s	T_a	T_t	T_s	T_a	T_t
	cm	C								
Biweekly	4	27	33	32	27	33	32	27c*	33b*	32a*
	8	26	33	31	25	32	30	25d	33b	30a
Monthly	4	30	36	32	29	33	32	29b	34ab	32a
	8	27	35	31	28	34	32	28c	34ab	32a
Spring accumulated	4	30	35	31	30	34	32	30a	35ab	32a
	8	29	34	33	29	37	31	29b	36a	32a
Unharvested check	-	20	23	23	19	23	23	20e	23c	23b
Means		27	33	30	27	33	30	27	33	30

*Values in a column followed by common letters are NSD at .05 level.

†Temperatures measured during 1300-1600 hours period.

‡Tissue temperatures measured in the shoot 2.5 cm above the soil.

fescue defoliated to 4 or 8 cm, and temperatures for the unharvested check were 10-13 C cooler than in all defoliated treatments. Tissue temperatures in 1975 at 2.5 cm above the soil surface in shoots show similar temperatures for nitrogen rates or defoliation practices. Shoot temperatures tended to be 1-4 C cooler than the air at similar heights in canopies. The air at 1.5 meters was 27 C during the period of measurement, generally lower than temperatures in stubble canopies.

In 1976, there were several rains totaling 195 mm during a 2-week period prior to the defoliation date, hence, moisture in the soil profile was near field capacity during the period when measurements were made. The air at 1.5 meters was 28 C, and radiation flux density at the top of the stubble canopy was 850 W/m^2 . The temperatures of stubble canopies in soil, air, or tissue were similar for N rates, Table I-6a. Tissue temperatures measured in shoots at the soil surface were always within 1 C of the soil temperature. The high soil moisture and cooling effects from evapotranspiration after harvest probably contributed to lower temperatures in 1976 as compared to 1975. The high light penetration allowed by the short stubble canopies, low in LAI, was a strong contributor to soil air and tissue temperature. Light penetration (%) was correlated with temperatures of soil ($r^2 = .65^{***}$), air ($r^2 = .38^{**}$), and tissue ($r^2 = .40^{**}$).

The temperatures reported here compare well with data by Peacock (1975b). He reported air temperatures of 34 C at 2.5 cm in freshly defoliated perennial ryegrass. With an LAI of 0.3, he found

ca. 70% light penetration to the soil and soil temperatures of 26 C at 2.5 cm during a period of 700 W/m^2 of solar radiation. On over-cast days, the canopy and soil temperatures were similar to that of the ambient air.

Total non-structural carbohydrates in stubble were affected by N rates only in 1975 where high N significantly lowered % TNC in stubble, Table I-7. In both years, the management effects were insignificant. Carbohydrates were much higher in 1976 than in 1975. The delayed harvest in 1976 with slow growth probably caused TNC to accumulate rather than being metabolized into new growth. Brown and Blaser (1970) reported buildups of TNC in orchardgrass under moisture stress. Smith (1974) reported that the effects of leaf area and initial TNC of tillers on stubble TNC during regrowth disappeared at anthesis in potted timothy tillers at ca. 24-29%.

In 1975, the 14-day regrowth of leaves above the stubble was higher with N_{160} as compared to N_{50} , Table I-8. However, the N x management interaction was significant as leaf yields for managements differed with N rates. With biweekly cuttings, there was a sharp increase in regrowth with 8 as compared with 4 cm stubbles with the N_{160} as compared to N_{50} . When accumulated canopies were cut to 4 cm stubbles, the regrowths of leaves were similar for the 2 N rates but increased with N rate for 8 cm stubble. With monthly cuttings, the leaf yields increased similarly with N rates for both stubble heights. The similar regrowths for N rates after cutting accumulated canopies to 4 cm stubbles indicates that this treatment had adverse effects on basal tillers as all other cuttings showed increased yields for

Table I-7. Total non-structural carbohydrates % of dry matter in stubble tiller bases as affected by nitrogen rates and clipping managements during spring.

Clipping management	Stubble height	Nitrogen, kg/ha					
		50		160		Mean	
		1975	1976	1975	1976	1975	1976
	cm	————— % of dry matter —————					
Biweekly	4	16	25	15	27	16a*	26r*
	8	20	27	13	21	16a	24r
Monthly	4	21	28	12	20	16a	24r
	8	19	28	16	27	17a	27r
Spring accumulated	4	20	27	16	25	18a	26r
	8	19	29	17	23	18a	26r
Mean		19x*	27m*	15y	24m	17	25.5

*Values followed by common letters are NSD at .05 level.

Table I-8. Regrowth above stubble heights and ground cover 14 days after harvesting tall fescue canopies with different nitrogen rates and clipping management during spring, 1975.

Clipping management Frequency	Stubble height	Nitrogen, kg/ha					
		50	160	Mean	50	160	Mean
	cm	g/m ²			% cover		
Biweekly	4	48c*	74bc	61	72	65	68m*
	8	64bc	111a	88	94	95	94l
Monthly	4	52bc	74bc	68	62	49	56no
	8	47c	73bc	60	82	68	75m
Spring accumulated	4	73bc	73bc	73	52	27	39p
	8	56bc	82b	68	77	56	66mo
Means		58x*	81y	70	73x	60x	67

*Values followed by common letters are NSD at .05 level. Nitrogen X cutting management interaction is significant (<.05) for regrowth.

the high N rate.

In 1976, regrowth as shown by leaf heights during 7 days after harvesting, was higher at N_{160} than at N_{50} , Table I-9. However, there were no clipping management differences when averaged across N rates. Apparently in this experiment, the potentially desirable effects on leaf growth by differential LAIs created by clipping management were masked by the high TNCs in the stubble. However, leaf regrowth above the stubble was not correlated with TNC content of stubble, leaf area or yield of stubble.

Data on ground cover, 14 days after harvesting in 1975, show strong influences of spring canopy management on summer stands, Table I-8. Nitrogen rate effects, averaged across spring managements, were not significant. The fescue clipped biweekly during spring to an 8 cm stubble retained an excellent cover. The spring-accumulated canopies cut to 4 cm stubbles had the poorest cover in June. The other treatments were intermediate in ground cover. Canopies with N_{160} lodged in late May, and such areas were practically barren as late as 30 days after cutting in 1975. With spring-accumulated canopies, the regrowth consisted of the apex blades in the vertically growing tillers. The frequently clipped canopies consisted of semi-horizontal tillers that produced a ground cover rapidly.

Tiller density changes during 30 days after harvest indicate that canopies that had been clipped to 4 cm stubbles in June showed the greatest increases in tillering, Table I-10. Fescue clipped frequently to 4 cm in spring lost an average of $11.5 \text{ tillers/dm}^2$,

Table I-9. Leaf regrowth above stubble (g/m^2) during 7 days after harvesting tall fescue with various nitrogen rates and clipping managements during spring, 1976.

Clipping management		Nitrogen, kg/ha		
Frequency	Stubble heights	50	160	Mean
	cm	g/m^2		
Biweekly	4	19	30	24a*
	8	17	33	25a
Monthly	4	21	26	23a
	8	15	24	19a
Unharvested till June	4	17	27	22a
	8	17	31	24a
Mean	-	17x*	28y	23

*Values followed by common letters are NSD at .05 level.

Table I-10. Net change in tiller density per dm^2 during 30 days after June harvest as affected by nitrogen and clipping management in spring, 1976.

Clipping management		Nitrogen, kg/ha		
Frequency	Stubble height	50	160	Means
	cm	tillers/ dm^2		
Biweekly	4	-11	-12	-11.5c*
	8	0	- 2	- 1.0b
Monthly	4	0	+ 1	.5b
	8	- 2	0	- 1.0b
Spring accumulated	4	8	11	+ 9.5a
	8	4	0	+ 2.0b
Means		.167x*	.33x	.25

*Values followed by common letters are NSD at .05 level.

while the spring-accumulated stands harvested at 4 cm gained about 9.5 tillers/dm². These changes could be equilibrations of the tiller populations to a feasible mid-summer level.

These results show milder microclimates in frequently clipped or grazed pasture sods than for defoliating dense canopies as harvesting for hay or silage. The 28 C surface soil temperature optimum for perennial ryegrass (Peacock, 1975) and corn (Watts, 1972) was exceeded after cutting the spring-accumulated canopies, particularly during periods of low soil moisture. Grazing managements that leave considerable LAIs would be desirable for temperature control to augment regrowth. Rapid regrowth of perennial species is very desirable to inhibit invasion of undesirable species such as crabgrass. Desirable tall fescue regrowth was usually obtained with biweekly or monthly cutting to 8 cm stubble heights. Spring seasons with high yields and dense canopies causing low light intensities in basal layers were characterized by poor summer recovery. High nitrogen-fertility rates often result in severe shifts in micro-environment after cutting dense accumulating reproductive growth in spring.

II. Summer Recovery of Tall Fescue as Influenced by Soil Moisture, Nitrogen, and Shading

INTRODUCTION WITH REVIEW OF LITERATURE

Stand losses of temperate grasses in warm seasons after defoliation of high yielding canopies have been widely reported (Colby et al., 1965, in Massachusetts; McKee et al., 1967, in Virginia; and Cowling and Lockyer, 1970, in Great Britain). Data from Virginia (previous section) show that harvesting tall dense canopies causes large shifts in microenvironments around basal portions of tall fescue tillers. Peacock (1975b) reported that soil and air temperatures increased dramatically after tall canopies of perennial ryegrass were defoliated. A newly defoliated hay crop stubble usually has a very small leaf area index (LAI) (Peacock, 1975b). Such basal leaves subjected to low light situations have low productive capability with alfalfa (Wolf and Blaser, 1972). Tiller populations are often reduced by dense canopies (Hart, 1971). Young tillers in a dense canopy must develop in dim light environments that reduces photosynthetic capability. Wilkinson and Beard (1975) found thin cuticles in Kentucky bluegrass (Poa pratensis L. cv Merion) while Shearman and Beard (1973) noted increased intercellular space in bentgrasses where preconditioned in darkness. These features could sensitize plants to microenvironmental stress.

Perennial grass tillers must regenerate leaf areas to survive independently after defoliation. The energy and precursors for plant tissue regeneration come from a blend of current stored reserves and

photosynthates. Reserve substances must provide the initial impetus when in the absence of leaf areas (Ward and Blaser, 1961). High temperatures often hamper the development of leaf area from these metabolites (Smith, 1974). Top growth of grasses in the vegetative state occurs by cell division and elongation at the apical meristem and in the collar area of the leaf developing inside sheaths. The apical region in many temperate grasses occurs at or below the soil surface. In this region is the mechanism which channels growth substrates into leaf tissue. Being situated near the soil level or just below makes this metabolically active tissue vulnerable to shifts in temperature in basal centimeters of the canopy and at soil surface. High solar radiation penetration into canopies and to the soil level cause increased temperatures of the air and surface soil (Peacock, 1975; Cowett and Sprague, 1963). Peacock (1975) stressed that soil temperature at the 0-2 cm level controlled leaf extension growth in Lolium perenne L. Duff and Beard (1974) observed decreases in leaf growth at 35 C and tiller death at 40 C in bentgrass, Agrostis palustris L.

High solar radiation also increases water stress. Eagles (1973) observed declines in orchardgrass, Dactylis glomerata L., leaf extension, and relative growth rate in irradiances greater than 144 W/m^2 . Tanner and Lemon (1962) point out that radiation absorption by leaves increases transpiration. Huang and Chang (1974) observed that stem diameter fluctuations in tobacco were closely related to air temperature and radiation level around leaves. They attributed this to tension on water in xylem vessels by increased transpiration. Changes

in vapor pressure deficit caused by increases in temperature in the canopy hamper regrowth. Ford and Thorne (1974) observed that increased relative humidity gave increased growth rates due to low transpiration rates and plant water stress.

Cell enlargement is sensitive to water stress. Boyer (1970) found that leaf enlargement of corn (Zea mays L.), soybeans (Glycine max Merr.), and sunflower (Helianthus annuus L.) were decreased by leaf water tensions of only -3 or -4 bars. Through transpiration, a plant organ decreases its temperature by latent heat of vaporization. Plants can reduce transpiration by stomatal closure but this increases tissue temperature by increasing sensible heat content (Tanner and Lemon, 1962), unless radiant energy input is reduced.

Mulches and shades have been used to modify microenvironments. Barkley et al. (1965) used straw, fiber, and sawdust mulches to increase moisture retention and reduce evaporation. Straw and fiber mulches also decreased soil surface temperatures. Adams (1965) maintained a 3-7 C lower soil surface temperature in a grain sorghum field with straw versus bare soil. Pallas (1971) et al. showed that Saran shade cloths reduced light penetration uniformly at all wave lengths. Allen (1975) lowered canopy air and soil temperatures in soybeans with shade cloth canopies that also reduced water use.

The objective of this experiment was to study summer regrowth of tall fescue after harvesting dense spring-accumulated canopies with N differentials to create large shifts in microenvironments. The microenvironment of the stubble (low in leaf area) was altered by shading and irrigation treatments.

PROCEDURES

This experiment was established in March of 1975 and 1976 on a good stand of tall fescue (Festuca arundinacea Shreb. cv. Kentucky 31) grown on Lodi loam (Typic Hapludults, clayey, kaolinitic, mesic). The soil pH was 6.6 and 448 kg/ha of a 8.7% P (20% P_2O_5) and 16.6% K (20% K_2O) mixed fertilizer was applied. The plots were uniformly mowed to 4 cm the fourth week in March when nitrogen variables 50 and 160 kg/ha were also applied. The experimental design was a split plot randomized complete block. Irrigation vs. no irrigation treatments comprised the main plots. The subplot treatments consisted of the factorial combinations of 50 and 160 kg/ha N with 3 shading treatments (full sun, 73% shade cloth, and hay left in place). The growth was accumulated and harvested on 6-22-75 and 6-15-76. The irrigated plots received 2.5 cm of water one day before harvesting the canopies. The canopies were mowed to a 4 cm stubble with a sickle bar mower and herbage was dried at 70 C for yield determinations.

Stubbles were sampled for leaf area and non-structural carbohydrates. Soils were sampled for gravimetric moisture determinations.

Radiation flux density at 2 cm as % of incident solar radiation was measured after shades were in place with a selenium photocell wired to a microammeter. Temperatures of soil at 0.6 cm, air at 2.5 cm, and shoot tissue at ca. 2.5 cm were measured in 1975 with Cu-constantan thermocouples and a millivolt amplifier-recorder. In 1976, all temperatures were measured with thermistor probes and a

Yellow Springs Instruments electronic thermometer; however, shoot tissue temperatures were measured at the soil level in 1976.

Temperatures were measured between 1200-1500 hours during periods of full sunshine. Solar irradiance was monitored with an Eppley pyranometer and with a Lambda Instruments Radiometer.

Leaf elongation was measured at intervals during the regrowth period. Tiller counts were made in fixed quadrats within three days after harvest and one month later. Specific leaf weight (mg/cm^2) of stubble leaves was measured by determining the leaf area of randomly selected leaves with a photoplanimeter and weighing the dried tissue. Leaf area index was calculated by weighing green leaves from a stubble separation and dividing by SLW. Carbohydrates (TNC) were determined in stubble by extracting tissue with .02 N HCl at 100 C for one hour. The hydrolysate was tested for reducing sugars using an automated ferricyanide reduction technique of Wolf and Ellmore (1975).

RESULTS AND DISCUSSION

Stubble and Microenvironment. Nitrogen at 160 kg/ha (N_{160}) increased the spring accumulated canopy yields in 1975 and 1976 over those for N_{50} , Table II-1. Due to the unusually dry 1976 spring season, average yields were only 70% of those for 1975. These canopies were in an early ripe seed stage at harvest.

The stubble characteristics in 1975 (Table II-2) show that stubble yields tended to be lower with N_{160} as compared to N_{50} but not significantly. Leaf area indices of the stubbles were small, particularly with N_{160} , Table II-2. The low specific leaf weights (SLW) with N_{160} versus N_{50} are attributed to dense canopies and low light in basal canopy layers with high N. Wolf and Blaser (1972) showed that SLW of alfalfa declined with density of canopies due to progressively lower irradiation. Cowling and Lockyer (1970) observed decreases in dry matter content of herbage as N rate increased. Nonstructural carbohydrates were not affected by nitrogen rate, TNCs being high with both N rates. The TNC values were above the postulated 16% critical level beyond which regrowth in perennial ryegrass fails to respond as proposed by Davies (1965).

Soil moisture in the top 10 cm averaged 23% and 15% in 1975 in irrigated and unirrigated plots, respectively, the lower value being near field capacity moisture for the Lodi soil. In 1976, the moisture levels were 14% and 5%, 5% approximating the wilting point.

Irradiation at 2 cm above the soil expressed as percent of incident radiation, shows that shading treatments decreased light

Table II-1. Yields of accumulated forage harvested in June as affected by nitrogen during two spring seasons.

Nitrogen	Year	
	1975	1976
kg/ha	g/m ²	
50	578n*	378b
160	730m	536a
Mean	654	457

*Values in columns followed by common letters are not significant at <.05 level of probability.

Table II-2. Effect of nitrogen rate on yield of live stubble tissue, specific leaf weight (SLW), leaf area index (LAI), and total non-structural carbohydrates (TNC) of shoot bases in stubbles, 1975.

N Rate kg/ha	Yield g/m ²	LAI	SLW mg/cm ²	TNC % of dry matter
50	57.6	.33	5.11	20.7
160	46.8	.12	3.79	19.6
	NSD .05	<.05	<.05	NSD .05

penetration as compared to the full sun treatment, Table II-3. The low values with cut hay left in place in 1975 is attributed to the large hay yields, Table II-1.

Soil, air, and plant temperatures were measured during periods of bright sunlight, approximately 815 and 830 W/m² for 1975 and 1976, respectively. Soil temperatures were not lowered by irrigation in 1975, whereas irrigation lowered temperatures for all shading treatments in 1976, Table II-4. In 1975, moisture in unirrigated plots was near field capacity, thus evaporative cooling of the surface soil was probably similar to irrigated soil. With shade cloth and hay cover, soil temperatures were significantly lower than in the unshaded plots. In 1975, plots with hay cover were cooler than shade cloth plots only with irrigation. In 1976, the temperature of soil with shade or hay cover were similar but cooler than for sunlit plots. Each of the three shade treatments had lower soil temperatures in 1976 with irrigation than its unirrigated counterpart. A 4 C decrease in soil temperature due to irrigation in 1976 is significant as Peacock's (1975a) curve for leaf elongation with soil temperatures indicates a rapid decline for perennial ryegrass after a 28 C optimum with no growth at 40 C.

Air temperatures at 2.5 cm, as affected by irrigation, showed trends similar to those of soil temperatures, Table II-5. Air temperatures during both years with all shade treatments declined with irrigation, the differentials being larger in 1976. During 1975, the air temperature with a hay cover declined more than the other shade

Table II-3. Irradiation at 2 cm above soil surface after harvesting canopies as affected by spring nitrogen rate and shading treatments.

<u>Nitrogen rate</u> kg/ha	<u>Shade treatments</u>					
	<u>Full sun</u>		<u>Shade cloth</u>		<u>Hay cover</u>	
	1975	1976	1975	1976	1975	1976
	———— % of incident solar radiation ————					
50	71	55	15	21	3.1	26
160	75	60	14	33	3.5	16

Table II-4. Soil temperature at 0.6 cm as affected by pre-harvest irrigation and shading treatments. (Air at 1.5 m, 28 C in 1975, and 29 C in 1976.)

Shade treatment	Irrigated					
	No		Yes		Means	
	1975	1976	1975	1976	1975	1976
	C					
Full Sun	32a*	31m	32a	27o	32	29r
Shade Cloth	27b	28no	28b	25p	27	26s
Hay Cover	25bc	28no	22c	25p	23	26s
Means	28x*	29y	27x	25w		

*Values in rows or columns with common letters are NSD at .05 level. Nitrogen effect was not significant and is not shown here.

Table II-5. Air temperature at 2.5 cm as affected by pre-harvest irrigation and shading treatments.

Shade treatment	Irrigated					
	No		Yes		Means	
	1975	1976	1975	1976	1975	1976
	C					
Full Sun	40a*	41g	38ab	36h	39m	38v
Shade Cloth	35ab	35h	34bc	33i	34.5n	34w
Hay Cover	36ab	36h	31c	32i	33.5n	34w
Mean	37x	37r	35y	34s		

*Values followed by common letters not significantly different at .05 level of probability. Irrigation X shade interaction was significant at <.05 level of probability.

(All comparisons are within years only.)

treatments under irrigation (significant interaction). The sharp decline in air temperature with the hay cover under irrigation is partially attributed to high evaporation as hay was probably moist from the irrigation during the previous day. The air at 2.5 cm for the full sun treatment was always warmer than for the shade cloth or hay treatments. The cooler air temperatures under shade cloth or hay would decrease water loss by decreasing the vapor pressure deficit between the outside atmosphere and leaf internal surfaces.

In 1975, tissue temperatures, measured in shoots at 2.5 cm heights, showed trends similar to the 2.5 cm air temperatures, but were usually 2-4 degrees lower, Table II-6. When averaging all shade treatments, there was no significant irrigation effect in 1975, whereas in 1976 irrigation reduced shoot temperatures by 4 C. In 1975, when soil moisture was high for irrigation and no irrigation, the shoot temperatures under hay cover declined with irrigation, other shade treatments being similar with irrigation and without irrigation (significant interaction). In 1976, the shoot temperatures of all three shade treatments were cooler with irrigation than their unirrigated counterparts. Averages across irrigations show that shoots in full sun were 3 C higher than the other shade treatments. Temperatures of shoots at the soil level seldom deviated more than 2 C from the soil temperatures in 1976.

Irrigation and shading both lowered soil, plant, and stubble air (2.5 cm) temperatures below potentially harmful levels. The data presented here probably approach the extreme temperatures

Table II-6. Shoot temperatures† in stubble as affected by pre-harvest irrigation and shading treatments.

Shade treatment	Irrigated					
	No		Yes		Means	
	1975	1976	1975	1976	1975	1976
	C					
Full Sun	35a*	34m	36a	28n	35.5	30n
Shade Cloth	33ab	28n	32ab	26o	32.5	27i
Hay Cover	34ab	29n	30b	25o	32.0	27i
Means	34x	30r	33x	26s		

*Values followed by common letters are NSD at .05 level.

†1975 temperatures were measured in shoots at ca. 2.5 cm. 1976 temperatures were measured in shoots at the soil surface. The irrigation X shade interaction was significant at <.05 level of probability in 1975.

encountered during the day of measurement. However, scans of pyranometer traces indicate that typical June days, during four to six midday hours, have intermittent radiation levels as high as those encountered during these experiments.

Plant Response. Leaf extension is a sensitive measure of micro-environmental stresses. Leaf extension, during two days after harvest in June 1975, show a significant interaction between irrigation and shade treatments, Table II-7. In unirrigated plots, the shade treatments did not stimulate leaf elongation; however, under irrigation, leaf extension was about 33% higher under shade cloth or hay cover than under full sun. Leaf growth under the full sun treatment with and without irrigation was similar. Thus added soil moisture augmented leaf elongation where shading treatments decreased irradiance and soil, plant, and air temperatures. With irrigation, there was a significant increase in leaf elongation with the high as compared to the low N rate, but nitrogen rates without irrigation did not influence leaf elongation.

In 1976, the large moisture differentials due to irrigation caused sharp increases in leaf elongation with irrigation, Figure II-1. One day after harvest, the moisture effect on leaf elongation was already evident while the nitrogen effect was not significant at either moisture level. By day 5, the significant irrigation response was evident along with a strong interaction between moisture and nitrogen. Without irrigation, leaf elongation did not respond to N; however, elongation was sharply more with high than low N when irrigated.

Table II-7. Leaf extension during two days of regrowth as affected by irrigation, nitrogen rate, and shade treatment, 1975.

Shade treatment	Irrigated					
	No			Yes		
	50	160	Mean	50	160	Mean
	mm					
Full Sun	35	34	34b*	38	40	39b
Shade Cloth	39	39	39b	49	57	53a
Hay in Place	36	36	36b	45	56	51a
Mean	37s*	36s	36x*	44rs	51r	48y

*Means followed by common letters are not significantly different at <.05 level of probability.

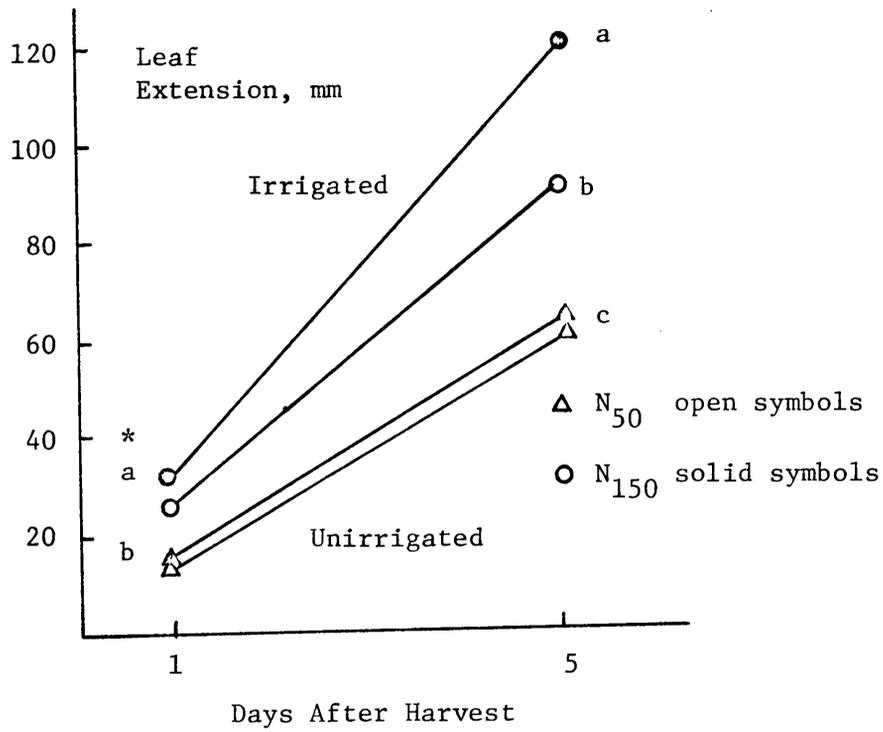


Figure II-1. Leaf extension as affected by spring nitrogen and pre-harvest irrigation. 1976.
 *Points within date followed by common letters are NSD at .05 level.

In 1976, shading environments tended to stimulate leaf elongation at day 1, and values with full sun were lowest (not significant on day 5, Figure II-2). During 1976 when soil moisture differentials were large, the full sun plants without irrigation, showed a 25% depression in leaf length at 5 days as compared to the average of the shaded and hay cover plots. In irrigated plots, the depression was only 12%. However, these differences were not significant. Thus, leaving hay to protect stubble could be beneficial during moisture stress.

Leaf elongation in the shading treatments within moisture levels did not differ during the first day with irrigated and unirrigated plots, averaging 30.3 and 14.8 mm/day, respectively. Average elongation rate (mm/day) over the next 4 days for irrigated and unirrigated plots were 19 and 12 mm/day respectively (calculated from graphs). The leaves on irrigated plants elongated rapidly initially and then the rate declined; whereas, unirrigated plants elongated at a slower uniform rate during the 5-day period.

The nitrogen and shading treatment relationships show that leaf elongation did not differ during the first day, Figure II-3. At the end of five days, the plants under shade cloth and hay at N_{160} gave the best leaf growth. The full sun plants at N_{160} responded similarly to the shaded plants at N_{50} . The sun plants at N_{50} had the least leaf elongation but not significantly lower than in the shaded plants at N_{50} . Leaf elongation appears to be sensitive to nitrogen nutrition but radiation penetration into the stubble with the parallel effects on microenvironmental parameters mediates the N response.

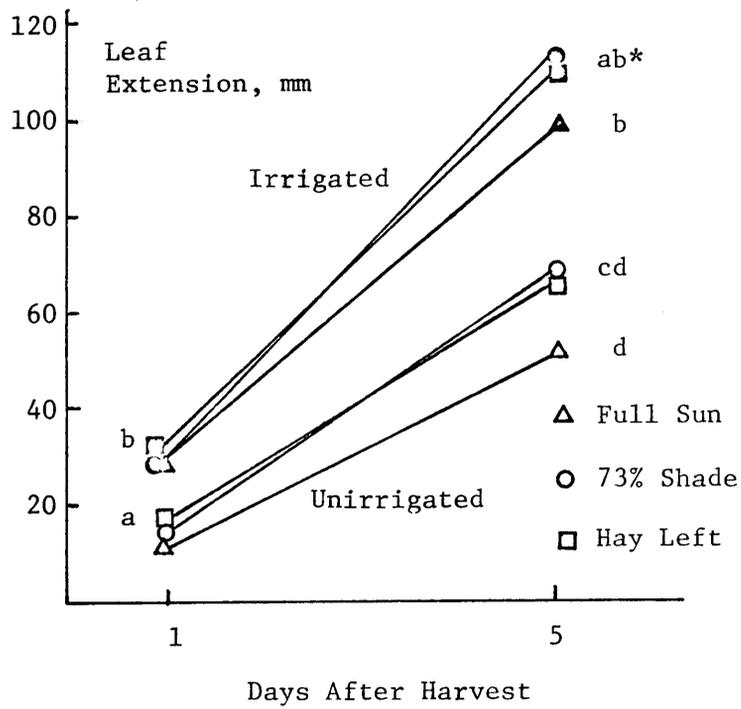


Figure II-2. Leaf extension as affected by pre-harvest irrigation and post-harvest shade treatments. 1976.
 *Points followed by common letters are NSD at .05 level.

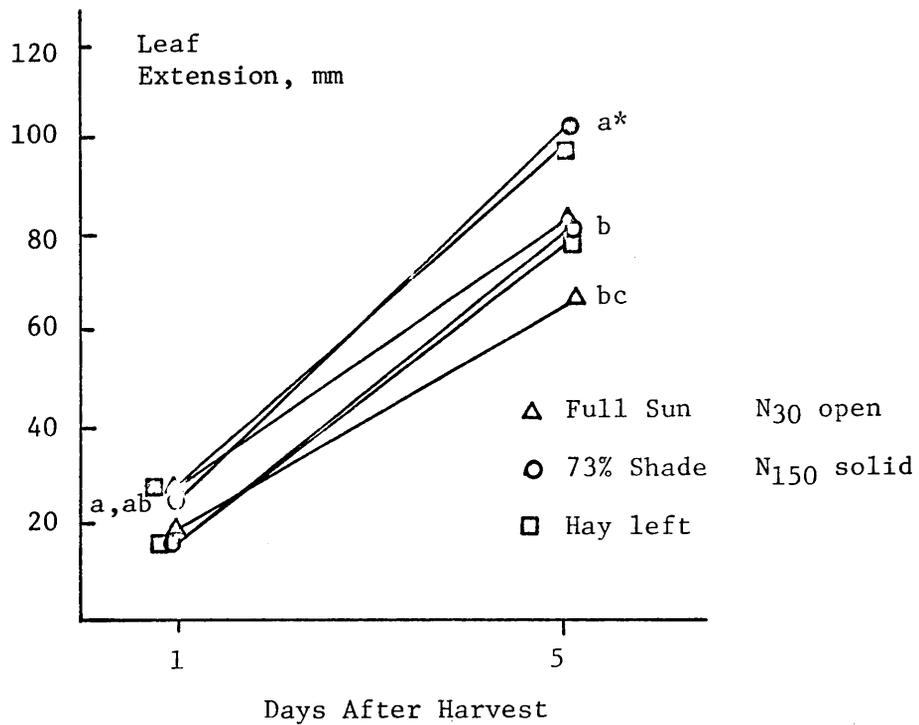


Figure II-3. Leaf extension as affected by spring nitrogen and post-harvest shade treatments. 1976.
 *Points followed by common letters with dates are NSD at .05.

Yield of leaf regrowth above the stubble in 1976, Table II-8, shows responses to irrigation, nitrogen and shading that parallel the leaf elongation data. Without irrigation, the shade treatments within nitrogen rate did not influence leaf yields but N_{160} gave higher yields than N_{50} . With irrigation, the shade effect was significant at N_{160} , the unshaded plants yielding less than either of the shaded plots. Added nitrogen did not increase the yield of the unshaded plants even with irrigation.

During a month after harvesting accumulated canopies in 1975, most of the treatments showed tiller losses, Table II-9. The high nitrogen rate tended to cause high tiller losses but N_{50} lost significantly fewer tillers than for N_{160} , only with irrigation. When averaging shade treatments, N_{160} increased tiller losses by 10 percentage points over N_{50} . The shading treatments gave inconsistent data on tiller densities. Irrigation, when averaging all treatments, reduced tiller losses by 10 percentage points but this was not significant.

In 1976, tillers increased in most of the treatments, Table II-9. The average effect of increased nitrogen was an increased tillering by 11 percentage points. Shading levels did not affect tiller populations, although there was a non-significant gain in unirrigated plots with hay cover as compared to shade cloth. The unshaded N_{50} plots without irrigation showed net losses in 1976.

Tiller losses in 1975 could be due to a stress on carbohydrate reserves as indicated in literature citations. However, the TNC status of plants was not different for the two N rates, and was

Table II-8. Yield of regrowth above the stubble two weeks after harvest as affected by spring nitrogen, pre-harvest irrigation, and shade treatments, 1976.

Shade treatment	Irrigated					
	No			Yes		
	Nitrogen, kg/ha					
	50	160	Mean	50	160	Mean
g/m ²						
Full Sun	64e*	83de	73.5	93cd	107bcd	100.0
Shade Cloth	76de	107bcd	91.5	101bcd	139a	120.0
Hay Left	86de	100cd	93.0	123abc	155a	139.0
Mean	75t*	97s	86.05y	105s	133r	119.00x

*Means within the appropriate comparisons with common letters are NSD at .05 level. Irrigation, nitrogen, and shading effects are all significant.

Table II-9. Net change (%) in vegetative tiller density during the month following harvest as affected by pre-harvest irrigation, spring nitrogen rate, and shading treatments.

Shade treatment	Irrigated					
	No			Yes		
	Nitrogen, kg/ha					
	50	160	Mean	50	160	Mean
----- % change -----						
<u>1975</u>						
Full Sun	-18	-27	-22	- 4	- 4	- 4
Shade Cloth	- 3	-45	-24	+ 4	-26	-11
Hay Left	-13	+10	- 2	+10	-17	- 4
Mean	-11b*	-21b	-16	+ 3a	-16b	- 6.2
<u>1976</u>						
Full Sun	- 3	+15	+ 6b	+ 8	+28	+18a
Shade Cloth	+ 1	+12	+ 6b	+ 6	+43	+24a
Hay Left	+ 3	+24	+13ab	+ 5	+25	+15a
Mean	+ 1.4n	+17m	+ 8.7y	+ 6.3m	32m	19x

*Values within years followed by common letters are NSD at .05 level.

higher than the critical level of 16%, above which perennial ryegrass fails to respond. A 'critical' TNC level was not noted in the literature for tall fescue. Stubble leaf area probably has minimal impacts on the carbohydrate pool of the tillers because of low SLW and probably low photosynthetic capability. The effect of shading treatments on regrowth (leaf elongation) is undoubtedly many-faceted. Leaf elongation was negatively related to radiation penetration into the stubble ($r^2 = -.40^*$). Temperatures of tiller bases was closely correlated with light penetration ($r^2 = .76^{***}$). Blade elongation was not sufficiently explained by tissue temperature ($r^2 = .24NS$). Moisture stress in the plants increases with air temperatures causing vapor pressure gradients between leaves and atmosphere. This is probably accentuated in plant tissue developed under low light situations as in dense canopies. The sensitivity of leaf elongation to water stress in conjunction with the influences of soil temperature in the vicinity of apical regions of tillers probably explains the responses of leaf elongation to shade treatments and irrigation. Prolonged soil moisture stress was a problem after the 1975 harvest, when only 15 mm of rainfall occurred during the 3 weeks after harvest. High temperatures in the plant micro-environment and moisture stresses probably contribute significantly to the stand losses and poor regrowth of stubbles with low leaf areas after spring accumulation and harvesting tall dense canopies.

The results of this experiment have implications to research techniques and to farm practices. Farm and research forage harvest practices that defoliate and remove herbage in one pass as with direct

cutting for silage or windrow drying of hay may subject the stubble to greater microenvironmental stress than practices that allow field drying in place. In forage variety and management research, it is common to remove all forage immediately after cutting for yield determinations. Artificial shade as with hay cover in this experiment gave greater regrowth rates than for unshaded plants where cut canopies were immediately removed. These higher regrowth rates were associated with lower temperatures of air, shoot tissues, and surface soil.

III. Growth of Tall Fescue Tillers in Controlled Temperatures

INTRODUCTION WITH REVIEW OF LITERATURE

Summer growth of cool season grasses is often depressed during periods of moisture stress and high temperatures when evapotranspiration exceeds precipitation. Stand depletions have occurred when highly fertilized temperate grasses were harvested in summer (Colby et al., 1965; Cowling and Lockyer, 1970; Hallock et al., Schmidt and Tenpas, 1965). That this phenomenon usually occurs during warm seasons indicates adverse physiological conditions resulting from high fertility that are aggravated by temperature and/or moisture stress. Air temperature at the top of a sod on clear, warm days can be 10-15 C higher than ambient air at 1.5 meters (standard weather shelter). Thus, severe high temperature stress could occur in grass stubble during periods of mild ambient air temperatures.

Metabolically, high temperatures increase mitochondrial respiration (Watschke et al., 1973). Ormrod (1961) found dark respiration in rice doubled with increased temperatures from 4.4 to 15 C and again from 15 to 26 C. Watschke et al., (1973) found lower photosynthesis, a higher CO₂ compensation point, and lower photorespiration at 35 than at 23 C. Younis (1965) showed that high temperatures decrease nitrate reductase activity in corn.

Robson (1970) reported that, while photosynthetic rates of cool season grasses were not affected over a broad temperature range, photosynthate partitioning varied with temperatures; high temperatures

favored shoot over root growth. Meristematic activities are affected by high temperatures. White clover (Trifolium repens L.) leaf initiation (Beinhart, 1963) and tiller bud initiation of orchardgrass (Dactylis glomerata L.) (Brown and Blaser, 1970) were both depressed by high temperatures. High temperatures (28 C +) generally depress yields for bluegrass (Poa pratensis L.) and orchardgrass (Watschke et al., 1970; Baker and Jung, 1968, respectively).

Added increments of nitrogen increase yields and growth rates but decrease dry matter percent of plants (Pellett and Roberts, 1963). McLeod (1965) observed that added increments of N augment the rapidity and completeness of incorporation of plant reserve substances into etiolated regrowth in the dark. In general, nitrogen decreases the percent of reserve substances and increases foliar growth which may sensitize plants to temperature stress (Auda et al., 1966; Pellett and Roberts, 1963; and Watschke et al., 1970).

Grass growth responds to soil temperatures, and increasing evidence shows that this is of major importance. Leaf extension rate, a sensitive measure of environmental and metabolic stress, reacts rapidly to soil temperature changes (Peacock, 1970). Leaf growth occurs by cell division and elongation at the base of shoots. During the vegetative stage of most temperate grasses, the growth region occurs within 2 cm under or near the soil surface. With soil temperature at 1 to 2 cm held constant, air temperature may fluctuate widely without major effects on leaf extension rates (Peacock, 1970). Watts (1972) controlled the temperature of the apex of young corn (Zea mays L.) plants independently of air and root temperatures. Leaf

expansion increased with increasing apical temperatures up to 28 C with a Q10 of 2. Peacock (1975) showed an optimum apical temperature for Lolium perenne L. of 28 C, and a zero growth rate at 40 C.

Soil and nutrient solution media equilibrate more rapidly to approach air temperature in small containers than does soil in the field (Kniewel, 1973). Grass growth being highly sensitive to surface soil temperature suggests that studies of temperature response in controlled environments should be associated with controlled or monitored temperatures of growth media.

This experiment was designed to investigate the effects of temperature and nitrogen regimes on regrowth of tall fescue (Festuca arundinacea Schreb. cv. Kentucky 31).

PROCEDURES

Four clones of Kentucky 31 tall fescue were selected from a sparse field stand in September, 1975. Single tillers in the 3 to 4 leaf stage were established in pots of a Groseclose silt loam (Typic hapludults, clayey, mixed mesic) peat 3:1 v/v mixture with clones comprising replications. The soil had a pH of 6.4, P, K, and Ca were present in amounts such that growth was not limited. Ammonium nitrate was added at 30 and 150 kg/ha of N (N_{30} and N_{150}). Moisture was maintained near field capacity by watering to weights indicated by a desorption curve for the substrate mix established by the pressure membrane technique described by Richards (1965).

The plants were placed in growth chambers with day/night temperatures of 37/29 (high), 29/21 (medium), and 21/13 C (low) after a 25-day establishment period in a greenhouse. Light was provided by sixteen 183 cm (165 watt) Westinghouse CS/SHO fluorescent tubes and twelve 25 watt incandescent bulbs. The radiation flux density at the top of the plants was 506 microEinsteins/m²/sec with a daylength of 12 hours.

Soil temperature fluctuations were minimized by placing pots in water baths at 24 C. The daytime soil temperatures at 1 cm were 29, 26, and 24 C for the high, medium, and low temperature regimes, respectively. The plants were defoliated to a 4 cm stubble when placed in the growth chamber on October 6. The first harvest was made 6 days after leaf length measurements were made; a 16-day regrowth period, during which leaf blade length measurements were

made 1, 6, and 16 days after clipping. Tillers per pot were recorded and plants were again defoliated. After a third 19-day regrowth period, the plants were defoliated for leaf area determination. After a final 11-day regrowth period, the plants were harvested for total plant yield.

RESULTS AND DISCUSSION

Leaf elongation during the first 6-day regrowth period was not affected by temperature, Table III-1. The high N rate increased the average leaf lengths 27 percent for temperature treatments combined. The N response was consistent with temperature as the temperature x nitrogen interaction was not significant. Six days after cutting, the tall fescue plants had average leaf regrowths of 10.6 cm for N₃₀ and 14.5 cm for N₁₅₀. Most of the regrowth consisted of one to two leaf blades per tiller.

The plants were then defoliated to 4 cm and allowed to regrow for 16 days. Most tillers were left without leaves. Leaves for the 21 C plants elongated 92 percent faster than 29 and 37 C plants at N₁₅₀ during the first day after defoliation, Figure III-1. By the 2-6 day period the elongation rates due to temperatures declined or leveled off; however, the leaf elongation rate at 21 C at N₁₅₀ continued to decline. The first-day leaf regrowths for temperatures combined were 77 percent lower with N₃₀ than N₁₅₀.

At N₃₀ with 21 C plants leaves elongated 35 and 100 percent faster than at 37 and 29 C respectively during day 1. During the 2-6 day period at N₃₀ leaf elongation rates were lower at 29 and 21 C than for plants at 37 C. This trend generally continued through the 7-16 day period. The elongation rates at all temperatures, during the 2-6 day period, were maintained in the 7-16 day period.

Nitrogen did not affect tillering per pot, Table III-2. The significant temperature x nitrogen interaction was attributed to

Table III-1. Effect of temperature and nitrogen on leaf elongation during the first six-day period in the growth chamber.

N, kg/ha	Temperature (C)			Mean
	21	29	37	
	Leaf length, cm			
30	10.7b*	10.6b	10.6b	10.6
150	16.7a	13.5a	13.4a	14.5
Mean	13.7	12.05	12.00	

*Means followed by similar letters do not differ significantly at the 0.05 level of probability.

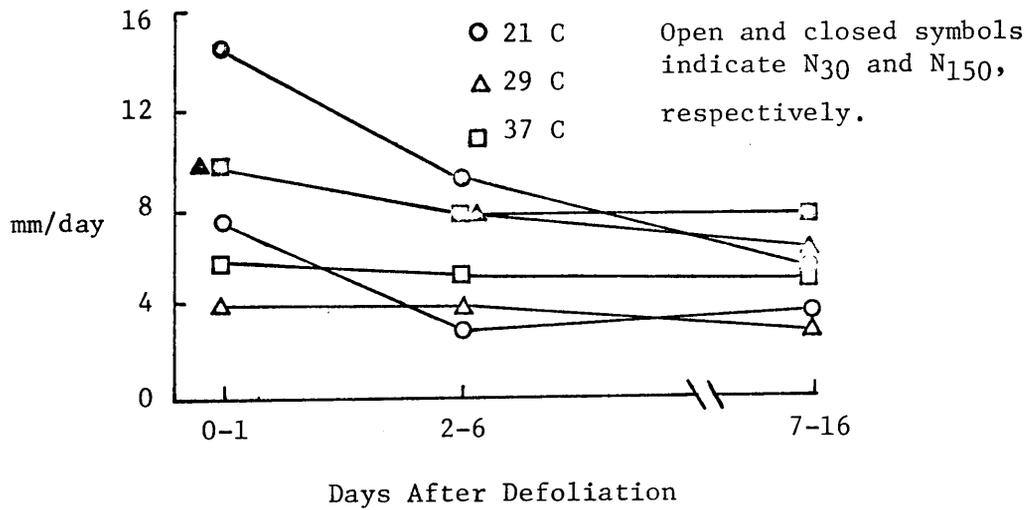


Figure III-1. Average leaf elongation rates by periods as affected by temperature and N rate.

Table III-2. Tillering as influenced by temperature and nitrogen over the term of the experiment.

N, kg/ha	Temperature (C)			Mean
	21	29	37	
	tillers/pot			
30	5.9ab*	4.5ab	5.0ab	5.1
150	3.2b	6.6a	5.9ab	5.2
Mean	4.5	5.5	5.4	

*Means followed by similar letters do not differ significantly at the 0.05 level of probability. Temperature X nitrogen interaction was significant at 0.05 level of probability.

similar tillering for the 3 temperatures at N_{30} , whereas for N_{150} tillering was poorest at 21 C and tended to be highest at 29 C.

Leaf areas per tiller during the final 19-day regrowth period show that N_{150} increased the leaf area per tiller under all temperatures (not significant at 29 or 37 C), Table III-3. The N_{150} versus the N_{30} rate increased the leaf area per tiller by more than 300 percent at 21 C; increases were smaller at higher temperatures. Leaf areas per pot indicate that increasing temperatures did not affect leaf area within an N rate. The high rate of N almost doubled the leaf area per pot and per tiller, when data for temperatures were averaged.

Finally, after the plants regrew for 11 days, all tissue above the soil was harvested. Data show higher yields for N_{150} as compared to N_{30} , Table III-4. Yields averaged across N rates were higher at 37 C than at the two lower temperatures. The temperature x nitrogen interaction was significant as yields at N_{30} tended to be lowest at 29 C but at N_{150} the plants at 37 C tended to yield more than for the other two temperatures.

The small differences in leaf extension to a wide range of air temperatures (21-37 C) was notable. Robson (1972) showed near maximum leaf growth of tall fescue at 25 C followed by declines at high temperatures. He used Sl70 tall fescue, a cultivar adapted to comparatively cool temperature environments in the British Isles. Such a cultivar may have lower temperature optima than cultivars adapted to high summer temperatures in the southeastern United States.

Table III-3. Leaf areas per tiller and per pot as influenced by temperature and nitrogen during 19 days of regrowth.

N, kg/ha	Temperature (C)			Mean
	21	29	37	
	cm ² /tiller			
30	5.6b*	6.4b	7.4b	6.4b
150	22.9a	9.2b	11.4b	14.5a
Mean	14.2x	7.8y	9.4y	
	<u>21C</u>	<u>29C</u>	<u>37C</u>	<u>Mean</u>
	cm ² /pot			
30	30b	28b	37b	32x
150	64a	61a	62a	62y
Mean	47x	44.5x	49x	

*Means followed by similar letters do not differ significantly at the 0.05 level of probability.

Table III-4. Yield of leaves plus stubble after a final 11-day regrowth period as affected by temperature and nitrogen.

Nitrogen kg/ha	Temperature, C			Means
	21	29	37	
	mg/pot			
30	470ab*	291b	330ab	363y
150	400ab	430ab	650a	493x
Means	435no	360n	490o	

*Values without common letters are significantly different at $<.05$.
Temperature X nitrogen interaction was significant at <0.05 .

Also for this experiment, the maintenance of high leaf blade elongation rates at 37 C air temperatures is probably associated with maintaining a lower soil than air temperature, soil temperatures at 1-2 cm being 24, 26, and 29 C for the 21, 29, and 37 C air temperature treatments, respectively. Observations from Fribourg et al. (1967) indicate that such soil-air temperature differentials are common in grass sods. Watschke et al. (1967, 1970) and Brown and Blaser (1970), with bluegrasses and orchardgrass, respectively, reported severely depressed foliage yields at 35 as compared to 23 to 25 C. Because soil temperatures strongly influence leaf growth (Peacock, 1974, 1975; and Watts, 1972), it is not surprising that these data differ from those from controlled environment experiments where small pots of growth medium equilibrate with air temperature.

The high as compared to the low nitrogen rate produced more leaf elongation and maintained higher leaf elongation rates over a long period. Initial leaf elongation rates were 100 percent higher at the 21 C temperature regime than for the 29 and 27 C temperature regimes. This surge of regrowth of plants with no leaf area present is probably due to higher concentrations of a stored metabolite for cell elongation (probably non-structural carbohydrates, TNC). Plants growing at cool temperatures accumulate high levels of TNC (Brown and Blaser, 1970). It is likely that high metabolites, cool temperatures and favorable moisture in the presence of high nitrogen accelerated cell division and elongation, causing leaves to elongate rapidly. Unfortunately, carbohydrate data were not obtained to

substantiate this phenomenon. Data on leaf area production per pot from this experiment indicate that leaf elongation and leaf area accumulation responded similarly under all temperatures.

Tillering responses to the treatment regimes were confounded by the development of more reproductive culms at 21 C than at higher temperatures. Culm development at 21 C occurred earlier at the high N than at the low N rate, thus allowing longer periods for vegetative tiller development for the low N plants. It has been shown that floral culm development usually deters tillering (Davies, 1972). Elongated culms were absent at the two higher temperature regimes. Brown and Blaser (1970) found depressed tillering at 35 C with orchardgrass, but soil and air temperatures in the growth chamber experiment were similar. Tiller initiation results from meristematic activity near or below the soil surface, which is undoubtedly sensitive to soil temperature.

Under the conditions of this experiment, air temperature had a minor influence on leaf area development or plant yield. This departure from other published reports is attributed to maintaining lower soil than air temperatures as compared to similar air and soil temperatures in most conventional growth chamber experiments. The range of temperatures in the surface 2 cm of 24-29 C includes the optimum soil temperature of 28 C given for grasses by Peacock (1975) and Watts (1972). The results of this experiment apply to field conditions where soil temperatures are usually lower than air temperatures under good pasture management.

This experiment was conducted in conjunction with field investigations of canopy microenvironments. Observations of high temperatures at the soil surface after clipping tall dense sods prompted this study. It is important to note there was no tiller mortality in this experiment at high temperatures. In field experiments some plants with similar high N nutrition and similar high air temperatures in the canopy die after being defoliated. Maintaining high soil moisture in the growth chamber and the lower irradiances in growth chambers than under field condition, probably ameliorated the plant stress. Also, the plants in this pot experiment did not develop dense canopies to moderate the microclimate at the basal shoot areas; thus sudden defoliation did not cause sharp microenvironment changes.

Further investigations of the effect of soil temperature differences at given air temperatures and different basal microenvironments for dense and sparse canopies would help to elucidate this problem. This is important as leaf growth originates by cell division and expansion in the apical meristems in vegetative grass shoots at or below the soil level. Peacock (1975) indicates that the site of perception of the temperature effect on grass growth is this apical region with maximum leaf extension rates in Lolium perenne occurring at 28 C in the top cm of soil. Atkin and Barton (1970) showed a similar maximum temperature for Zea mays L. and found larger amounts of root exudates containing endogenous growth regulators at 28 C than at either lower or higher temperatures. It is clear that grass growth response to temperature is a multifaceted problem. To

effectively study temperature effects on plant growth, particularly in controlled environment chambers, soil and air temperatures must be monitored and controlled. These data indicate that poor regrowth after defoliation of tall fescue is probably more closely associated with temperatures of the surface soil layers than with air temperature in canopies.

SUMMARY

June harvesting of accumulated spring canopies of tall fescue (especially with nitrogen fertilization) is often followed by poor regrowth or partial stand losses. The poor regrowth and stand losses were postulated to be associated with the sharp changes and adverse microenvironments after cutting tall canopies. Three experiments were established to elucidate this problem.

Canopies and microenvironments resulting from spring managements and nitrogen rates on tall fescue were characterized in Experiment I. Regrowth of newly defoliated, spring-accumulated tall fescue stands under different microenvironments altered by shading treatments and pre-harvest irrigation was investigated in Experiment II. Regrowth responses of tall fescue tillers under controlled air and growth medium temperatures were investigated in Experiment III.

Experiment I: Spring mowing management and nitrogen rates had distinct influences on canopy characteristics. Light penetration into canopies cut every two weeks was higher than for canopies accumulated during spring. High light penetrations in canopies before cutting were associated with high specific leaf weight and leaf area index (LAI) in basal tissue stubbles. Nonstructural carbohydrate (TNC) concentrations were high in all treatments due to late stage of growth development in the June harvests. Post-harvest light regimes in stubbles were related to stubble leaf areas, being highest in spring accumulated canopies with low LAI. Cutting at high stubble heights increased stubble LAI, and reduced air and

stubble temperatures. Temperatures of soil, air in stubble, and plant tissue increased with increased light penetration. The highest temperatures occurred in stubbles of spring accumulated canopies. The high nitrogen treatment increased plant regrowth rate. High and rather uniform TNC probably masked effects of differential LAI on regrowth. Harvesting spring-accumulated canopies in June increased light penetration by 50-60 percentage points and increased temperatures by 5-15 C in the stubble, canopy, and soil.

Experiment II: Shading defoliated stubbles of spring-accumulated tall fescue with shade cloth or by leaving a hay cover decreased light penetration as compared to unshaded stubble and this was associated with 4-10 C lower soil, air, and plant tissue temperatures. Irrigating the canopies a day before cutting caused 2-10 C lower temperatures in the stubble and soil than for no irrigation. Extension rate of leaves was greatest under high nitrogen, particularly in irrigated plants. Both shade treatments enhanced leaf extension as compared to plants in full sun. Tiller survival was enhanced by irrigation but not by shading on high nitrogen. Tillering and tiller losses were high during the dry 1976 as compared to the moist 1975 season. Hot, dry periods after harvest caused high tiller losses in all treatments.

Experiment III: Air temperature regimes in growth chambers had no influence on tillering or regrowth of tillers when soil temperatures were held lower than air temperatures. Soil temperatures achieved approximated field soil temperatures under sods. High

nitrogen enhanced leaf elongation and yields over the range of air temperatures.

When considering all of the results, the large shifts in microclimate after canopy defoliation depress regrowth of tall fescue tillers. The size of the change in stubble environment can be decreased by harvesting one or more times during the spring period. Increasing air temperature per se probably has less influence on regrowth than increased soil temperatures. Leaving tall stubbles can decrease light penetration and stubble and soil temperatures. Defoliating canopies during periods of adequate soil moisture can decrease the microenvironmental stress. The practice of allowing herbage to wilt or dry in the field allows plants to make some regrowth under mild microclimates before being subjected to stress conditions. During brief periods with hay cover, rapid elongation of blades should increase LAI, shade the stubble and soil, and ameliorate microenvironmental stress, after the hay is removed. Cutting, with direct removal of forage, would be less harmful during cloudy as compared to bright sunny days. Research techniques, where cut herbage is immediately removed for weight determinations, may reduce yields and stands of grasses as compared to conventional field drying of hay as practiced by many farmers.

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CANOPY, MICROENVIRONMENT, AND NITROGEN EFFECTS ON
SUMMER RECOVERY OF TALL FESCUE

by

William Clayton Stringer

(ABSTRACT)

Stand losses in temperate grasses after summer defoliation of tall canopies inspired an investigation of microenvironmental and plant responses in tall fescue. Microenvironment and regrowth of tall fescue in response to mowing managements and nitrogen rates in spring that created different canopy structures was studied. In early spring, 50 and 160 kg/ha of N were applied. Mowing managements were: clipping at 4 or 8 cm biweekly, monthly, and in late June. In late June all 6 treatments were mowed to prescribed stubble heights with a seventh unmowed check. Canopy light regimes, leaf area index, and regrowth of tillers were monitored along with soil, air, and shoot temperatures in stubbles after the June harvest. Mowing more frequently in spring decreased canopy yields of the June harvest, but increased leaf area (LAI) of stubbles as compared to spring-accumulated canopies. High nitrogen decreased specific leaf weights (SLW) in stubble leaves and increased LAI except in spring-accumulated canopies. Increased LAI decreased light penetration and canopy temperatures. Temperatures were highest in harvested spring-accumulated stubbles with a shift of 4-10 C between unharvested and harvested stands while radiation penetration into the stubble increased from 5 to 75% of total. Some large stand losses occurred in

lodged portions of harvested spring-accumulated plots. Generally, regrowth yields were not affected by prior clipping managements. Concentration of TNC was uniformly high with all treatments.

Experiment II had altered microenvironments (no shade, 73% shaded and plots with mown hay left in place) after June-harvested stubble of tall fescue accumulated with 50 and 160 kg/ha nitrogen. These shade treatments were subplots of irrigated and unirrigated main plots. Temperatures of soil, air, and shoot tissue and stubble light penetration were monitored. Leaf elongation was measured at intervals after harvest. Shading and hay decreased light penetration and temperatures of soil, air, and shoots as compared to unshaded stubble canopies. Irrigated plots were cooled to a lower temperature by shading than unirrigated plots. Leaf elongation and regrowth were greater for the two shaded than for the unshaded treatment. Leaf elongation was better in irrigated than unirrigated plots, responses from shading being the best without irrigation. Leaf elongation was increased at N_{160} as compared to N_{50} , particularly under irrigation. Tiller populations were not influenced by shading treatments whereas irrigation increased tillering and survival after cutting tall canopies. Tillers decreased during a dry July of one year and increased during the moist July of another year while high nitrogen augmented these losses and gains.

Experiment III investigated the response of defoliated tall fescue tillers to nitrogen at 21, 29, and 37 C air temperatures in growth chambers. Soil temperatures were held lower than air temperatures. Under these conditions air temperature had little influence

on tillering or leaf growth of tall fescue tillers.

Canopy accumulation in spring decreases stubble LAIs. Temperature and radiation shifts occur in the stubble portion after harvesting accumulated canopies. Leaving forage in place as in wilting or field drying forage moderates the stubble microenvironment. Harvesting with ample soil moisture enhances regrowth rate and survival.