Growth Pattern and Phenological Development of Major Graminoids on the Northern Plains

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Growth Pattern and Phenological Development of Western Wheatgrass on the Northern Plains

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Intact grassland ecosystems are complex; exceedingly more complex than the most complicated machines ever built by humans. Knowledge and understanding of the growth pattern and phenological development of the major forage grasses are fundamentally essential for generation of biologically effective management strategies with inclusivity of all biotic and abiotic components of grassland ecosystems in the Northern Plains.

The inspirational goals of this study were developed by Dr. Warren C. Whitman (c. 1950) and Dr. Harold Goetz (1963) which were to gain quantitative knowledge of each component species and to provide a pathway essential for the understanding of relationships of ecosystem components that would result in the development and establishment of scientific standards for proper management of grazinglands in the Northern Plains.

This growth pattern and phenological development study of the major forage graminoids was conducted during the growing seasons of 1983-1986 and 1987-1989 with data collected biweekly June-August. The study included 3 cool season, 2 warm season, 1 upland sedge, 1 naturalized, and 2 domesticated grasses. The study sites were located at the NDSU Dickinson Research Extension Center ranch near Manning in western North Dakota and consisted of 143 acres (58 ha) of two seeded domesticated grasslands and 720 acres (291 ha) of native rangeland pastures separated into three management treatments, each with two replications, with data collection sites established on sandy, shallow, and silty ecological sites. Each ecological site of the grazed treatments had matching paired plots, one grazed and the other with an ungrazed exclosure.

Study Area

The physiography of the study area consists of the Unglaciated section of the Missouri Plateau (Fenneman 1931, 1946; Hunt 1974). The landscape surface is highly eroded fluvial sedimentary deposits of material removed from the uplifted Rocky Mountains. Most of the deposition occurred from slow meandering streams during the Laramide Orogeny and during the 20 to 30 million years of the late Cretaceous and early Tertiary Periods following the uplift. Intense widespread erosion of these sediments occurred from about 5 to 3 million years ago during the late Pliocene Epoch (Bluemle 2000). The extensive erosion during this period removed about 500 to 1000 feet of sediments (Fenneman 1931) forming a landscape with well developed integrated drainage systems of broad mature valleys and gently rolling uplands containing widely spaced large hills and buttes with erosion resistant caps raising 500 to 650 feet above the plain (Bluemle 2000).

The soils of western North Dakota developed from eroded Tertiary fluvial sedimentary deposits in the Ustic-Frigid soil moisture-temperature regime. The Ustic soil moisture regime is typical of semi arid climates. The Frigid soil temperature regime has mean annual soil temperatures of less than 47° F (8° C) (Soil Survey Staff 1975). These soils are primarily Typic Borolls (semi arid cool Mollisols) and support vegetation of mid and short grasses of the Mixed Grass Prairie (Manske 2008b).

The current "native" plant species in the Northern Plains did not originate here. All of the plant species have migrated into the region by different mechanisms and at different times and rates. The present plant species have flora affinities to northern, eastern, western, Rocky Mountain, and Great Basin plant communities (Zaczkowski 1972). This wide mix of plant species was formed from remnants of previously existing plant communities. The climate changed about 5,000 years ago to conditions like those of the present, with cycles of wet and dry periods (Bluemle 1977, 1991; Manske 1994). The large diversity of plant species that make up the current mixed grass prairie permits dynamic responses to changes in climatic conditions by increasing the combination of plant species favored by any set of climatic conditions (Manske 2008a).

Long-Term Weather

The NDSU Dickinson Research Extension Center ranch is located in Dunn County in western North Dakota, at 47° 14' north latitude, 102° 50' west longitude. Mean annual temperature is 42.3° F (5.7° C). January is the coldest month, with mean temperature of 14.6° F (-9.7° C). July and August are the warmest months with mean temperatures of 69.7° F (20.9° C) and 68.6° F (20.3° C), respectively. Long-term (1982-2012) mean annual precipitation is 16.91 inches (429.61 mm). The perennial plant growing season precipitation (April to October) is 14.13 inches (358.97 mm) and is 83.6% of annual precipitation. June has the greatest monthly precipitation at 3.27 inches (83.08 mm). The precipitation received during the 3-month period of May, June, and July (8.26 inches, 209.80 mm) accounts for 48.8% of the annual precipitation.

Growing season months with water deficiency disrupt plant growth rates and are identified from monthly temperature and precipitation data by the Emberger ombrothermic diagram technique. Long-term (1983-2012) 30 year reoccurrence rates (table 1) show relatively low rates of water deficiency reoccurring during April (16.7%), May and June (10.0%), moderate rates during July and October (36.7%), and high rates during August (56.7%) and September (60.0%). Long-term occurrence of water deficiency conditions was 33.3% of the growing season months, for a mean of 2.0 water deficient months per each 6.0 month growing season (15 Apr-15 Oct).

Growing Season Precipitation

The growing season precipitation information collected during the grass leaf height study has been grouped into two periods with the first period occurring during 1983 to 1986 and the second period occurring during 1987 to 1989.

Mean growing season precipitation of 1983-1986 (table 2) was 14.11 inches (99.9% of LTM). None of the four 6 month growing seasons received precipitation at less than 80% of LTM. One growing season, 1986, received precipitation at near 130% of LTM. The rate of water deficiency occurrence during the four growing seasons was 29.2%, for a mean of 1.75 water deficient months per growing season (table 3). The growing season of 1984 had 3.0 months in water deficiency. The growing seasons of 1983 and 1986 had 1.5 months in water deficiency each. The growing season of 1985 had 1.0 month in water deficiency.

Mean growing season precipitation of 1987-1989 (table 4) was low at 9.14 inches (64.7% of LTM). The growing season of 1987 received 11.53 inches (81.6% of LTM) precipitation. The growing season of 1989 received 10.60 inches (75.0% of LTM) precipitation. The growing season of 1988 received only 5.30 inches (37.5% of LTM) precipitation and was dry. The rate of water deficiency occurrence during the three growing seasons was 61.1%, for a mean of 3.7 water deficient months per growing season (table 5). The growing seasons of 1987 and 1989 had 3.0 months in water deficiency each. The growing season of 1988 had 5.0 months of its 6 month growing season in water deficiency conditions. That is comparable to 2 other growing seasons with high water deficiency conditions. The growing season of 1934 had 4.5 months in water deficiency and the growing season of 1936 had 5.5 months in water deficiency.

Table 1. Growing season months with water deficiency, DREC ranch, 1983-2012.

	Apr	May	Jun	Jul	Aug	Sep	Oct	# Months	% 6 Months 15 Apr-15 Oct
Total	5	3	3	11	17	18	11	60.0	33.3
% of 30 Years	16.7	10.0	10.0	36.7	56.7	60.0	36.7		

Table 2. Precipitation in inches and percent of long-term mean for perennial plant growing season months, DREC ranch, 1983-1986.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-Term Mean 1982-2012	1.44	2.56	3.27	2.43	1.70	1.42	1.31	14.13	16.91
1983	0.21	1.53	3.26	2.56	4.45	0.86	0.72	13.59	15.55
% of LTM	14.58	59.77	99.69	105.35	261.76	60.56	54.96	96.18	91.96
1984	2.87	0.00	5.30	0.11	1.92	0.53	0.96	11.69	12.88
% of LTM	199.31	0.00	162.08	4.53	112.94	37.32	73.28	82.73	76.17
1985	1.24	3.25	1.58	1.07	1.84	1.69	2.13	12.80	15.13
% of LTM	86.11	126.95	48.32	44.03	108.24	119.01	162.60	90.59	89.47
1986	3.13	3.68	2.58	3.04	0.46	5.29	0.18	18.36	22.96
% of LTM	217.36	143.75	78.90	125.10	27.06	372.54	13.74	129.94	135.78
1983-1986	1.86	2.12	3.18	1.70	2.17	2.09	1.00	14.11	16.63
% of LTM	129.34	82.62	97.25	69.75	127.50	147.36	76.15	99.86	98.34

Table 3. Growing season months with water deficiency conditions that caused water stress in perennial plants, DREC ranch, 1983-1986.

	APR	MAY	JUN	JUL	AUG	SEP	OCT	# Months	% 6 Months 15 Apr-15 Oct
1983	■					■		1.5	25.0
1984		■		■		■		3.0	50.0
1985				■				1.0	16.7
1986					■		■	1.5	25.0
#	**1**	**1**	**0**	**2**	**1**	**2**	**1**	**7.0**	**29.2**
%	**25.0**	**25.0**	**0.0**	**50.0**	**25.0**	**50.0**	**25.0**		

Table 4. Precipitation in inches and percent of long-term mean for perennial plant growing season months, DREC ranch, 1987-1989.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-Term Mean 1982-2012	1.44	2.56	3.27	2.43	1.70	1.42	1.31	14.13	16.91
1987	0.10	1.38	1.15	5.39	2.65	0.78	0.08	11.53	14.13
% of LTM	6.94	53.91	35.17	221.81	155.88	54.93	6.11	81.60	83.56
1988	0.00	1.85	1.70	0.88	0.03	0.73	0.11	5.30	9.03
% of LTM	0.00	72.27	51.99	36.21	1.76	51.41	8.40	37.51	53.40
1989	2.92	1.73	1.63	1.30	1.36	0.70	0.96	10.60	13.07
% of LTM	202.78	67.58	49.85	53.50	80.00	49.30	73.28	75.02	77.29
1987-1989	1.01	1.65	1.49	2.52	1.35	0.74	0.38	9.14	12.08
% of LTM	69.91	64.58	45.67	103.84	79.22	51.88	29.26	64.71	71.42

Table 5. Growing season months with water deficiency conditions that caused water stress in perennial plants, DREC ranch, 1987-1989.

	APR	MAY	JUN	JUL	AUG	SEP	OCT	# Months	% 6 Months 15 Apr-15 Oct
1987	■		■			■	■	3.0	50.0
1988	■		■	■	■	■	■	5.0	83.3
1989				■	■	■		3.0	50.0
#	**2**	**0**	**2**	**2**	**2**	**3**	**2**	**11.0**	**61.1**
%	**66.7**	**0.0**	**66.7**	**66.7**	**66.7**	**100.0**	**66.7**		

Procedures

The 1983-1989 Study

Grass tiller leaf heights were determined for reproductive lead tillers, vegetative tillers, robust vegetative tillers, and secondary tillers on a biweekly sampling period from June through August. Each leaf of ten ungrazed tillers of each study species was measured with a meter stick to the nearest 0.1 cm from ground level to the tips of the extended leaves. Basal leaf heights were measured for grass species in which the leaves and stalks were distinctly separate. Stalk leaf heights were measured for grass species where leaves are attached to the culm during vegetative stages and fruiting stages.

Degree of leaf senescence was estimated as percent dryness for each leaf. Percent dryness for basal leaves was considered from the apex to ground level. Percent dryness for stalk leaves was considered for the blade only. The categories of dryness were: 0%, 2%, 25%, 50%, 75%, 98% and 100% dry. Start of senescence was considered to be dryness greater than 2%. Leaves with less than 50% senescent tissue were designated to be photosynthetically active.

Grass flower stalk heights were determined by measurements from ground level to the tip of the stalk or the apex of the top floret. The awns, if present, were not included in the height measurements. The phenological stages of flower stalk development were recorded as: flower stalk developing (FSD), head emergence (HE), anthesis (Ant), seeds developing (SD), and seeds being shed (SBS). Recording the flower stalk development stages started when stalk enlargement or swelling was outwardly noticeable; prior development is not detectable without destruction of the tiller. The swelling of the stalk, traditionally called the boot stage, was categorized as the flower stalk developing stage. Head emergence is a short duration stage but easily defined when the flower head emerges from the sheath and rapidly elongates to near full height. Anthesis (flowering) is also a short duration stage but easily defined by the exposure of the anthers and stigmas. Needle and thread is usually cleistogamous that self-fertilizes without opening and exposing the anthers and stigmas. Following fertilization, the seeds develop through milk, dough, and mature stages which are difficult to differentiate on small grass seeds. These seed progression stages have been separated into more easily defined categories of seeds developing for the early seed stages and seeds being shed for the mature seed stages when seeds could be easily removed from the inflorescence by wind, by gentle rubbing, or when it could be observed that some seeds had already been dropped. Sometimes a floret will abort the seed production process resulting in failure of viable seeds to materialize. This condition could be revealed in the data set as earlier than normal recordings of seeds being shed.

During 1983 to 1986, the paired plot sample sites with silty, and shallow soil types were managed by ungrazed and grazed treatments of the twice-over rotation strategy. During 1987 to 1989, the paired plot sample sites with silty, and shallow soil types were managed by long-term nongrazed treatments, and by ungrazed and grazed treatments of the traditional seasonlong practice and the twice-over rotation strategy. A few western wheatgrass tillers were measured on sandy and clay soils but were insufficient to include in this evaluation report.

Designation of Tiller Types

Reproductive lead tillers are second year tillers derived from carryover tillers that were vegetative tillers during the previous growing season. The portions of the carryover leaves that have intact cell walls will regreen with active chlorophyll early in the growing season and provide photosynthate for rapid growth of new current years leaves. Two and three new leaves are produced during May and the fourth full leaf is produced before early June. The anthesis (flowering) period can occur between mid June to late July with some early first flowers occurring before 21 June. No new leaves are produced after the anthesis stage, during the seed development stages. Tillers that flower early usually produce 5 or 6 stalk leaves and tillers that flower later usually produce 7 or 8 stalk leaves. Reproductive lead tillers are terminal at the end of the growing season; their apical meristem was used up producing a flower head.

Vegetative tillers are first year tillers derived from previous growing season initiated fall tillers and from early spring initiated secondary tillers and have escaped hormonal control by a lead tiller. These tillers are the primary forage tillers with rapid growth rates, usually producing 5 to 8 leaves during the growing season. The apical meristem remains vegetative, permitting these tillers to overwinter as carryover tillers and becoming reproductive lead tillers during the successive growing season.

Robust vegetative tillers are uncommon first year tillers that grow amongst normal vegetative tillers, but that atypically can produce more leaves than the conventional 8 leaves, usually 9 or 10 leaves,

with an occasional rare robust tiller producing 12 or up to 16 leaves in one growing season. The unconventional leaves greater than 8 are vulnerable to short periods of water stress subject to senescence which can result in robust tillers with unaffected leaves 6, 7, and 8 remaining green and affected leaves 9, 10, and 11 completely senescent.

Secondary tillers are young current growing season tillers usually initiated from axillary buds during May to July that remain hormonally controlled by a dominant lead tiller that has proprietary access to all resources slowing rates of growth. Reproductive lead tillers have a high nutrient demand during the period of anthesis through early seed development stages causing withholding of essential nutrient flow to the secondary tillers which results in nearly stopping growth and leaf development. Some secondary tillers can remain at the 2 or 3 leaf stage for longer than a month or two. The high nutrient demand periods of lead tillers coincides with the period of high secondary tiller terminations. The secondary tillers that survive and produce 4 leaves become independent from the hormone control of the lead tiller and transform into vegetative tillers with rapid growth rates.

Results

Western wheatgrass, *Pascopyrum smithii* (Rydb.) A. Love, is a member of the grass family, Poaceae, tribe, Triticeae, syn., *Elymis smithii*, (Rydb.) Gould*, Agropyron smithii* Rydb., and is a native, long-lived perennial, monocot, cool-season, mid grass, that is tolerant of cold, drought, and periodic flooding, has a high tolerance to alkali and saline soils, and moderately shade tolerant. The first North Dakota record is Potter and Greene 1958. Early aerial growth consists of basal leaves arising from rhizome tiller buds. Leaf blades are 5-25 cm (2-10 in) long, 2-4 mm wide, stiff, thick, deeply ridged on the upper surface, tapering to a point. The split sheath has overlapping margins that open toward the top and has a brown or purplish base. The collar is not well defined, continuous, and medium broad. The ligule is a short flat membrane less than 1 mm long. The auricles are long and clasping, sometimes purplish. The creeping rhizome system is extensive. The aggressive rhizomes are primarily in the top 7.6-10.2 cm(3-4 in) of soil. The frequent branches are 15-91 cm (6-36 in) long, produce single or small groups of aerial stems per node at short progressive intervals. The extensive root system has tough, white or light colored main roots 0.5-1.5 mm thick arising from stem crowns and rhizome nodes growing vertically downward regularly producing profuse quantities of short branches that almost completely occupy the soil. Depth of root penetration varies with soil conditions, usually ranging from 1.2 m (4 ft) to 2.1 m (7 ft) deep. Regeneration is primarily asexual propagation by rhizome tiller buds. Seedling success is low as a result of competition from established plants. Flower stalks are erect, hollow, 30-90 cm (11.8-35 in) tall. Inflorescence is an erect compact spike, 3-16 cm (1.2-6.3 in) long, with overlapping solitary spikelets of 3 to 8 florets. Flower period is late June to mid July. Aerial parts are highly palatable to livestock. Fire consumes aerial parts halting the process of the four major defoliation resistence mechanisms and causing great reductions in biomass production and tiller density. This summary information on growth development and regeneration of Western wheatgrass was based on works of Weaver 1954, Stevens 1963, Zaczkowski 1972, Dodds 1979, Great Plains Flora Association 1986, Trimenstein 1999, Larson and Johnson 2007, Ogle et al. 2009, and Stubbendieck et al. 2011.

During the seven years of this study, the number of western wheatgrass tillers measured was 8279 with 5481 on silty soils and 2798 on shallow soils (tables 6 and 7). The collection protocol required measurement on all available flower stalks and ten vegetative tillers on each sample site each collection period, amounting to 360 tillers per year on the twice-over treatment and 120 tillers per year on the seasonlong and nongrazed treatments. During the 3 growing seasons with low precipitation amounts, less than ten tillers were measured each collection period. The reductions in sample numbers would indicate the degree of negative affect from reduced precipitation. This affect is designated as collection efficiency on tables 6 and 7.

Table 6. Number of tillers measured from management treatments on silty soils.

Tiller Type	Twice-over 1983-1986		Twice-over 1987-1989		Seasonlong 1987-1989		Nongrazed 1987-1989
	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed
Flower Stalk	56	97	36	49	5	9	0
Vegetative	1228	1607	383	236	141	83	146
Robust	65	82	2	0	1	0	0
Secondary	102	179	335	336	107	131	65
Subtotal	1451	1965	756	621	254	223	211
Total	3416		1377		477		211
Sum total	5481						
Collection Efficiency	113%		60%		64%		59%

Table 7. Number of tillers measured from management treatments on shallow soils.

Tiller Type	Twice-over 1983-1986		Twice-over 1987-1989		Seasonlong 1987-1989		Nongrazed 1987-1989
	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed
Flower Stalk	13	41	19	10	2	3	1
Vegetative	528	883	254	165	20	38	74
Robust	20	23	1	0	0	0	0
Secondary	54	153	213	214	14	28	27
Subtotal	615	1100	487	389	36	69	102
Total	1715		876		105		102
Sum total	2798						
Collection Efficiency	58%		39%		14%		28%

Reproductive Lead Tillers

The second year reproductive lead tillers had the fastest rate of growth and development until mid to late July with production of 3.5 new leaves by mid May and 4.5 new leaves by early June. Some early growth tillers reached the boot stage (FSD) around early to mid June. Flower stalk development occurred very rapidly with the early lead tillers progressing through head emergence (HE) and reaching early first flower before 21 June. About 87% of the lead tillers reached anthesis (Ant) from late June to mid July. Early flowering tillers usually produced 5 or 6 leaves and later flowering tillers usually produced 7 or 8 leaves. Late developing lead tillers reached anthesis by late July. No new leaves were produced after the anthesis stage. Seeds developed (SD) through the milk and dough stages during July and early August with most seeds reaching maturity (SBS) from mid August to late August or early September (table 8). The apical meristem of reproductive lead tillers can no longer produce leaf buds after it had produced flower buds and these tillers were terminated at the end of the growing season.

Growth and development data of western wheatgrass reproductive lead tillers on silty soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 and 1987 to 1989 are on table 9.

Reproductive lead tillers with 5 to 8 leaves on the twice-over strategy during 1983 to 1986 composed 4.9% of the total population with 97 tillers (table 6) that had a mean flower stalk height of 33.6 cm, during the growing season a mean of 3.2 leaves (49.8%) were photosynthetically active with a mean leaf height of 24.4 cm and the tallest leaf averaged 30.3 cm tall (table 9).

Reproductive lead tillers with 5 to 8 leaves on the ungrazed treatment during 1983 to 1986 composed 3.9% of the total population with 56 tillers (table 6) that had a mean flower stalk height of 31.4 cm, during the growing season a mean of 2.9 leaves (44.2%) were photosynthetically active with a mean leaf height of 27.1 cm and the tallest leaf averaged 32.0 cm tall (table 9).

Reproductive lead tillers with 5 to 8 leaves on the twice-over strategy during 1987 to 1989 composed 7.9% of the total population with 49 tillers (table 6) that had a mean flower stalk height of 34.9 cm, during the growing season a mean of 2.2 leaves (34.1%) were photosynthetically active with a mean leaf height of 23.8 cm and the tallest leaf averaged 25.4 cm tall (table 9).

Reproductive lead tillers with 5 to 8 leaves on the ungrazed treatment during 1987 to 1989 composed 4.8% of the total population with 36 tillers (table 6) that had a mean flower stalk height of 37.4 cm, during the growing season a mean of 2.7 leaves (41.5%) were photosynthetically active with a mean leaf height of 26.7 cm and the tallest leaf averaged 30.4 cm tall (table 9).

Growth and development data of western wheatgrass reproductive lead tillers on shallow soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 and 1987 to 1989 are on table 10.

Reproductive lead tillers with 5 to 8 leaves on the twice-over strategy during 1983 to 1986 composed 3.7% of the total population with 41 tillers (table 7) that had a mean flower stalk height of 42.1 cm, during the growing season a mean of 3.7 leaves (56.2%) were photosynthetically active with a mean leaf height of 25.0 cm and the tallest leaf averaged 31.1 cm tall (table 10).

Reproductive lead tillers with 5 to 8 leaves on the ungrazed treatment during 1983 to 1986 composed 2.1% of the total population with 13 tillers (table 7) that had a mean flower stalk height of 48.1 cm, during the growing season a mean of 3.3 leaves (50.2%) were photosynthetically active with a mean leaf height of 31.9 cm and the tallest leaf averaged 39.1 cm tall (table 10).

Reproductive lead tillers with 5 to 8 leaves on the twice-over strategy during 1987 to 1989 composed 2.6% of the total population with 10 tillers (table 7) that had a mean flower stalk height of 29.9 cm, during the growing season a mean of 4.2 leaves (64.1%) were photosynthetically active with a mean leaf height of 19.0 cm and the tallest leaf averaged 23.7 cm tall (table 10).

Reproductive lead tillers with 5 to 8 leaves on the ungrazed treatment during 1987 to 1989 composed 3.9% of the total population with 19 tillers (table 7) that had a mean flower stalk height of 36.5 cm, during the growing season a mean of 2.7 leaves (42.2%) were photosynthetically active with a mean leaf height of 23.5 cm and the tallest leaf averaged 25.4 cm tall (table 10).

All of the reproductive lead tillers measured during this study were not grazed including the tillers

located on grazed treatments. The not grazed tillers remaining on the grazed treatments tended to have slightly shorter mean leaf heights and mean tallest leaf heights which were not significantly different than the not grazed tillers on the ungrazed treatments on both the silty and shallow soils during the 1983-1986 and 1987-1989 periods (tables 9 and 10). It is not believed that grazed treatments cause reproductive lead tillers to produce slightly shorter leaf heights. It is surmised that grazing cattle have a disproportional rate of selection for taller tillers than for shorter tillers leaving a distorted sample population of not grazed tillers with slightly shorter leaf heights.

Leaves grow and senesce in about the same order of their appearance. This study has designated that leaves with less than 50% senescent tissue to be photosynthetically active. Tillers growing on the twice-over treatment tended to have greater photosynthetically active leaves than the tillers growing on the ungrazed treatment. Reproductive lead tillers located on the grazed twice-over treatment had 0.4 more (6.2%) photosynthetically active leaves than the tillers located on the ungrazed treatment (tables 9 and 10).

Reproductive lead tillers composed a low percentage of the total measured tiller population. Reproductive lead tillers located on the twice-over treatment composed 6.4% and 3.2% and the tillers located on the ungrazed treatment composed 4.4% and 3.0% of the total tiller population on silty soils and shallow soils, respectively. Reproductive lead tillers measured on the seasonlong and nongrazed treatments were at insufficient quantities to include in this evaluation (tables 6 and 7).

Table 8. Phenological stages of flower stalk development for western wheatgrass, 1983-1986.

6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
FSD	FSD				
	HE	HE	HE		
	Ant	Ant	Ant		
		SD	SD	SD	
				SBS	SBS

FSD	flower stalk developing
HE	head emergence
Ant	anthesis (flowering)
SD	seeds developing
SBS	seeds being shed

Table 9. Growth and development of western wheatgrass reproductive lead tillers on silty soils managed with twice-over grazing and ungrazed treatments, 1983-1986, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
Stalk Height cm	37.6	21.3	29.9	25.7	46.9	40.1
% Active Leaf	66.7	63.6	51.9	53.6	36.4	26.7
Leaf Height cm	22.4	26.0	18.9	27.5	26.3	25.3
Tallest Leaf cm	33.8	32.1	21.9	33.7	32.0	28.4
Ungrazed 1983-1986						
Stalk Height cm	23.2	14.3	43.2	37.9	32.4	37.4
% Active Leaf	60.0	80.0	36.4	41.7	27.3	20.0
Leaf Height cm	22.3	26.5	30.5	28.8	29.2	25.1
Tallest Leaf cm	25.1	37.2	33.8	33.2	34.9	28.0
Twice-over 1987-1989						
Stalk Height cm	-	26.9	45.0	28.3	48.1	26.4
% Active Leaf	-	45.5	55.6	25.0	22.2	22.2
Leaf Height cm	-	20.9	21.5	25.3	29.8	21.6
Tallest Leaf cm	-	24.6	24.0	25.3	29.8	23.5
Ungrazed 1987-1989						
Stalk Height cm	-	26.2	55.9	34.2	-	33.3
% Active Leaf	-	40.0	66.7	50.0	-	9.1
Leaf Height cm	-	23.9	26.5	26.3	-	30.2
Tallest Leaf cm	-	26.7	31.4	33.4	-	30.2

Table 10. Growth and development of western wheatgrass reproductive lead tillers on shallow soils managed with twice-over grazing and ungrazed treatments, 1983-1986, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
Stalk Height cm	-	30.9	37.1	50.0	49.2	43.5
% Active Leaf	-	63.0	50.0	55.6	44.4	50.0
Leaf Height cm	-	22.0	24.5	27.1	27.2	24.2
Tallest Leaf cm	-	29.0	30.2	34.2	33.9	28.2
Ungrazed 1983-1986						
Stalk Height cm	-	36.4	61.8	44.8	53.3	44.3
% Active Leaf	-	57.1	54.5	38.9	26.7	38.5
Leaf Height cm	-	27.5	29.6	28.4	42.7	31.4
Tallest Leaf cm	-	35.8	42.3	30.9	49.0	37.6
Twice-over 1987-1989						
Stalk Height cm	23.5	25.1	37.9	24.8	41.3	26.7
% Active Leaf	50.0	75.0	71.5	60.0	50.0	75.0
Leaf Height cm	22.1	15.6	15.8	18.4	23.2	18.6
Tallest Leaf cm	26.1	20.4	22.2	21.3	31.0	21.3
Ungrazed 1987-1989						
Stalk Height cm	-	27.8	41.3	33.6	43.2	-
% Active Leaf	-	33.3	60.0	33.3	66.7	-
Leaf Height cm	-	24.9	23.7	18.4	27.0	-
Tallest Leaf cm	-	27.6	26.0	18.8	29.1	-

Vegetative Tillers

The vegetative tillers had the second fastest rate of active growth and development continuing until mid to late July. Early new leaf development was rapid with production of 3.3 new leaves by mid May, 3.8 new leaves by late May, and 85% of vegetative tillers had 5 or 6 leaves during early June. Between early June and early July, vegetative tillers with 7 or 8 leaves had increased from 15% to 38% of the population. The percentage of vegetative tillers with 7 leaves stopped increasing during late July and the tillers with 8 leaves stopped increasing by early August. While the older vegetative tillers with 5 or 6 leaves were moving up to become tillers with 7 or 8 leaves, about 60% of the subordinate secondary tillers had received greater quantities of essential nutrients after the lead tillers had completed the anthesis and early seed development stages, permitting the secondary tillers to produce their 4th leaf and obtain their independence, followed by rapid production of leaves 5 and 6. As a result, the percent vegetative tiller population with 5 or 6 leaves did not drop below 50% during the growing season (figure 1).

Growth and development data of western wheatgrass vegetative tillers on silty soils managed with the twice-over strategy during 1983 to 1986 are on table 11.

Vegetative tillers with 5 leaves composed 33.8% of the population with 543 tillers (table 6), during the growing season a mean of 3.3 leaves (66.7%) were photosynthetically active with a mean leaf height of 15.2 cm and the tallest leaf averaged 18.2 cm tall (table 11).

Vegetative tillers with 6 leaves composed 33.4% of the population with 537 tillers (table 6), during the growing season a mean of 3.6 leaves (59.8%) were photosynthetically active with a mean leaf height of 16.4 cm and the tallest leaf averaged 19.4 cm tall (table 11).

Vegetative tillers with 7 leaves composed 20.4% of the population with 327 tillers (table 6), during the growing season a mean of 4.2 leaves (59.5%) were photosynthetically active with a mean leaf height of 18.6 cm and the tallest leaf averaged 22.3 cm tall (table 11).

Vegetative tillers with 8 leaves composed 12.5% of the population with 200 tillers (table 6), during the growing season a mean of 5.3 leaves (66.7%) were photosynthetically active with a mean leaf height of 18.4 cm and the tallest leaf averaged 22.7 cm tall (table 11).

Growth and development data of western wheatgrass vegetative tillers on silty soils managed with the ungrazed treatment during 1983 to 1986 are on table 12.

Vegetative tillers with 5 leaves composed 30.1% of the population with 369 tillers (table 6), during the growing season a mean of 2.8 leaves (56.7%) were photosynthetically active with a mean leaf height of 18.3 cm and the tallest leaf averaged 21.3 cm tall (table 12).

Vegetative tillers with 6 leaves composed 36.1% of the population with 443 tillers (table 6), during the growing season a mean of 3.3 leaves (54.2%) were photosynthetically active with a mean leaf height of 20.0 cm and the tallest leaf averaged 23.4 cm tall (table 12).

Vegetative tillers with 7 leaves composed 20.8% of the population with 256 tillers (table 6), during the growing season a mean of 3.8 leaves (54.7%) were photosynthetically active with a mean leaf height of 21.8 cm and the tallest leaf averaged 25.1 cm tall (table 12).

Vegetative tillers with 8 leaves composed 13.0% of the population with 160 tillers (table 6), during the growing season a mean of 4.8 leaves (60.4%) were photosynthetically active with a mean leaf height of 22.4 cm and the tallest leaf averaged 25.5 cm tall (table 12).

Growth and development data of western wheatgrass vegetative tillers on silty soils managed with the twice-over strategy during 1987 to 1989 are on table 13.

Vegetative tillers with 5 leaves composed 74.6% of the population with 176 tillers (table 6), during the growing season a mean of 3.3 leaves (66.7%) were photosynthetically active with a mean leaf height of 14.0 cm and the tallest leaf averaged 16.5 cm tall (table 13).

Vegetative tillers with 6 leaves composed 18.6% of the population with 44 tillers (table 6), during the growing season a mean of 3.0 leaves (50.0%) were photosynthetically active with a mean leaf height of 14.5 cm and the tallest leaf averaged 17.2 cm tall (table 13).

Vegetative tillers with 7 leaves composed 5.9% of the population with 14 tillers (table 6), during the growing season a mean of 3.7 leaves (52.4%) were photosynthetically active with a mean leaf height of 14.7 cm and the tallest leaf averaged 17.3 cm tall (table 13).

Vegetative tillers with 8 leaves composed 0.9% of the population with 2 tillers (table 6), during the growing season a mean of 3.7 leaves (45.8%) were photosynthetically active with a mean leaf height of 18.5 cm and the tallest leaf averaged 22.1 cm tall (table 13).

Growth and development data of western wheatgrass vegetative tillers on silty soils managed with the seasonlong practice during 1987 to 1989 are on table 14.

Vegetative tillers with 5 leaves composed 80.7% of the population with 67 tillers (table 6), during the growing season a mean of 3.0 leaves (60.0%) were photosynthetically active with a mean leaf height of 13.1 cm and the tallest leaf averaged 15.2 cm tall (table 14).

Vegetative tillers with 6 leaves composed 15.7% of the population with 13 tillers (table 6), during the growing season a mean of 2.3 leaves (38.9%) were photosynthetically active with a mean leaf height of 15.7 cm and the tallest leaf averaged 16.7 cm tall (table 14).

Vegetative tillers with 7 leaves composed 3.6% of the population with 3 tillers (table 6), during the growing season a mean of 3.5 leaves (50.0%) were photosynthetically active with a mean leaf height of 21.0 cm and the tallest leaf averaged 24.6 cm tall (table 14).

Vegetative tillers with 8 leaves composed 0.0% of the population with 0 tillers (table 14).

Growth and development data of western wheatgrass vegetative tillers on silty soils managed with the nongrazed treatment during 1987 to 1989 are on table 15.

Vegetative tillers with 5 leaves composed 67.8% of the population with 99 tillers (table 6), during the growing season a mean of 2.8 leaves (56.7%) were photosynthetically active with a mean leaf height of 17.0 cm and the tallest leaf averaged 19.6 cm tall (table 15).

Vegetative tillers with 6 leaves composed 26.7% of the population with 39 tillers (table 6), during the growing season a mean of 3.2 leaves (53.3%) were photosynthetically active with a mean leaf height of 19.7 cm and the tallest leaf averaged 23.5 cm tall (table 15).

Vegetative tillers with 7 leaves composed 4.1% of the population with 6 tillers (table 6), during the growing season a mean of 3.0 leaves (42.9%) were photosynthetically active with a mean leaf height of 20.0 cm and the tallest leaf averaged 25.7 cm tall (table 15).

Vegetative tillers with 8 leaves composed 1.4% of the population with 2 tillers (table 6), during the growing season a mean of 3.0 leaves (37.5%) were photosynthetically active with a mean leaf height of 22.7 cm and the tallest leaf averaged 27.5 cm tall (table 15).

Growth and development data of western wheatgrass vegetative tillers on shallow soils managed with the twice-over strategy during 1983 to 1986 are on table 16.

Vegetative tillers with 5 leaves composed 46.7% of the population with 412 tillers (table 7), during the growing season a mean of 3.0 leaves (60.0%) were photosynthetically active with a mean leaf height of 14.6 cm and the tallest leaf averaged 17.0 cm tall (table 16).

Vegetative tillers with 6 leaves composed 35.7% of the population with 315 tillers (table 7), during the growing season a mean of 3.8 leaves (63.9%) were photosynthetically active with a mean leaf height of 14.7 cm and the tallest leaf averaged 17.9 cm tall (table 16).

Vegetative tillers with 7 leaves composed 14.3% of the population with 126 tillers (table 7), during the growing season a mean of 4.2 leaves (59.5%) were photosynthetically active with a mean leaf height of 16.4 cm and the tallest leaf averaged 19.6 cm tall (table 16).

Vegetative tillers with 8 leaves composed 3.4% of the population with 30 tillers (table 7), during the growing season a mean of 5.3 leaves (66.7%) were photosynthetically active with a mean leaf height of 18.0 cm and the tallest leaf averaged 21.7 cm tall (table 16).

Growth and development data of western wheatgrass vegetative tillers on shallow soils

managed with the ungrazed treatment during 1983 to 1986 are on table 17.

Vegetative tillers with 5 leaves composed 42.0% of the population with 222 tillers (table 7), during the growing season a mean of 2.8 leaves (56.7%) were photosynthetically active with a mean leaf height of 15.2 cm and the tallest leaf averaged 17.9 cm tall (table 17).

Vegetative tillers with 6 leaves composed 35.2% of the population with 186 tillers (table 7), during the growing season a mean of 3.5 leaves (59.8%) were photosynthetically active with a mean leaf height of 16.6 cm and the tallest leaf averaged 20.0 cm tall (table 17).

Vegetative tillers with 7 leaves composed 16.1% of the population with 85 tillers (table 7), during the growing season a mean of 3.8 leaves (53.6%) were photosynthetically active with a mean leaf height of 20.0 cm and the tallest leaf averaged 23.2 cm tall (table 17).

Vegetative tillers with 8 leaves composed 6.6% of the population with 35 tillers (table 7), during the growing season a mean of 4.5 leaves (56.3%) were photosynthetically active with a mean leaf height of 21.0 cm and the tallest leaf averaged 23.7 cm tall (table 17).

Growth and development data of western wheatgrass vegetative tillers on shallow soils managed with the twice-over strategy during 1987 to 1989 are on table 18.

Vegetative tillers with 5 leaves composed 80.6% of the population with 133 tillers (table 7), during the growing season a mean of 3.0 leaves (60.0%) were photosynthetically active with a mean leaf height of 11.7 cm and the tallest leaf averaged 13.7 cm tall (table 18).

Vegetative tillers with 6 leaves composed 17.0% of the population with 28 tillers (table 7), during the growing season a mean of 3.5 leaves (58.4%) were photosynthetically active with a mean leaf height of 9.9 cm and the tallest leaf averaged 11.3 cm tall (table 18).

Vegetative tillers with 7 leaves composed 1.2% of the population with 2 tillers (table 7), during the growing season a mean of 3.5 leaves (50.0%) were photosynthetically active with a mean leaf height of 11.6 cm and the tallest leaf averaged 14.3 cm tall (table 18).

Vegetative tillers with 8 leaves composed 1.2% of the population with 2 tillers (table 7), during the growing season a mean of 4.0 leaves (50.0%) were photosynthetically active with a mean leaf height of 12.9 cm and the tallest leaf averaged 16.3 cm tall (table 18).

Growth and development data of western wheatgrass vegetative tillers on shallow soils managed with the seasonlong practice during 1987 to 1989 are on table 19.

Vegetative tillers with 5 leaves composed 68.4% of the population with 26 tillers (table 7), during the growing season a mean of 3.3 leaves (66.7%) were photosynthetically active with a mean leaf height of 14.1 cm and the tallest leaf averaged 17.3 cm tall (table 19).

Vegetative tillers with 6 leaves composed 26.3% of the population with 10 tillers (table 7), during the growing season a mean of 2.5 leaves (41.7%) were photosynthetically active with a mean leaf height of 12.3 cm and the tallest leaf averaged 14.6 cm tall (table 19).

Vegetative tillers with 7 leaves composed 5.3% of the population with 2 tillers (table 7), during the growing season a mean of 3.5 leaves (50.0%) were photosynthetically active with a mean leaf height of 12.3 cm and the tallest leaf averaged 15.4 cm tall (table 19).

Vegetative tillers with 8 leaves composed 0.0% of the population with 0 tillers (table 19).

Growth and development data of western wheatgrass vegetative tillers on shallow soils managed with the nongrazed treatment during 1987 to 1989 are on table 20.

Vegetative tillers with 5 leaves composed 52.7% of the population with 39 tillers (table 7), during the growing season a mean of 3.0 leaves (60.0%) were photosynthetically active with a mean leaf height of 19.9 cm and the tallest leaf averaged 22.8 cm tall (table 20).

Vegetative tillers with 6 leaves composed 24.3% of the population with 18 tillers (table 7), during the growing season a mean of 3.3 leaves (54.2%) were photosynthetically active with a mean leaf height of 20.4 cm and the tallest leaf averaged 24.4 cm tall (table 20).

Vegetative tillers with 7 leaves composed 18.9% of the population with 14 tillers (table 7), during the growing season a mean of 3.5 leaves (50.0%) were photosynthetically active with a mean leaf height of 20.7 cm and the tallest leaf averaged 24.8 cm tall (table 20).

Vegetative tillers with 8 leaves composed 4.1% of the population with 3 tillers (table 7), during the growing season a mean of 4.0 leaves (50.0%) were photosynthetically active with a mean leaf height of 19.4 cm and the tallest leaf averaged 27.9 cm tall (table 20).

Not all the leaves on a grass tiller are photosynthetic during the entire growing season. Leaves grow and senesce in the order they appear. The first and second leaves are usually dry by early June. The rate of leaf senescence can be rapid during water deficiency periods and slow during periods with adequate precipitation. During senescence, leaves translocate cell components to other plant parts. The senesced leaf has less weight and has very low nutritional quality. The greater the number of leaves not senescent, the greater the tiller nutritional quality.

The growing conditions on the ungrazed treatment of both silty and shallow soils tended to have slightly greater rates of tiller leaf senescence than the growing conditions on the twice-over treatment. The decrease in the number of photosynthetically active leaves occurs for tillers from the ungrazed treatment on silty and shallow soils after mid July resulting in a mean of 3.7 active leaves per tiller. The decrease in the number of photosynthetically active leaves occurs for tillers from the twice-over treatment on silty and shallow soils after late July resulting in a mean of 4.1 active leaves per tiller. Tillers on the twice-over treatment have 0.4 more photosynthetically active leaves than the tillers on the ungrazed treatment (table 21)

All of the vegetative tillers with 5 to 8 leaves measured during this study were not grazed including the tillers located on grazed treatments. The not grazed tillers remaining on the grazed treatments tended to have slightly shorter mean leaf heights and mean tallest leaf heights which were not significantly different than the not grazed tillers on the ungrazed treatments on both the silty and shallow soils during the 1983-1986 and 1987-1989 periods (tables 11 to 20). It is not believed that grazed treatments cause vegetative tillers to produce slightly shorter leaf heights. It is surmised that grazing cattle have a disproportional rate of selection for taller tillers than for shorter tillers leaving a distorted sample population of not grazed tillers with slightly shorter leaf heights.

Leaves grow and senesce in about the same order of their appearance. This study has designated that leaves with less than 50% senescent tissue to be photosynthetically active. Tillers growing on the twice-over treatment tended to have greater photosynthetically active leaves than the tillers growing on the ungrazed, seasonlong, and nongrazed treatments. Vegetative tillers with 5 to 8 leaves located on the twice-over treatment had 0.4 (6.2%), 0.5 (7.7%), and 0.4 (6.2%) more photosynthetically active leaves than the tillers located on the ungrazed, seasonlong, and nongrazed treatments on silty soils, respectively. Vegetative tillers with 5 to 8 leaves located on twice-over treatment had 0.4 (6.2%), 0.4 (6.2%), and 0.1 (1.5%) more photosynthetically active leaves than the tillers located on the ungrazed, seasonlong, and nongrazed treatments on shallow soils, respectively.

Vegetative tillers with 5 to 8 leaves composed a high percentage of the total measured tiller population during the 1983 to 1986 period and composed a moderate percentage of the population during the 1987-1989 period. Vegetative tillers located on the twice-over treatment composed 81.8% and 80.3%, and tillers located on the ungrazed treatment composed 84.6% and 85.9% during the 1983 to 1986 period on silty soils and shallow soils, respectively. During the 1987 to 1989 period, vegetative tillers located on the twice-over treatment composed 38.0% and 42.4%, tillers located on the seasonlong treatment composed 37.2% and 55.1%, and tillers located on the nongrazed treatment composed 69.2% and 72.5% of the total tiller population on silty soils and shallow soils, respectively.

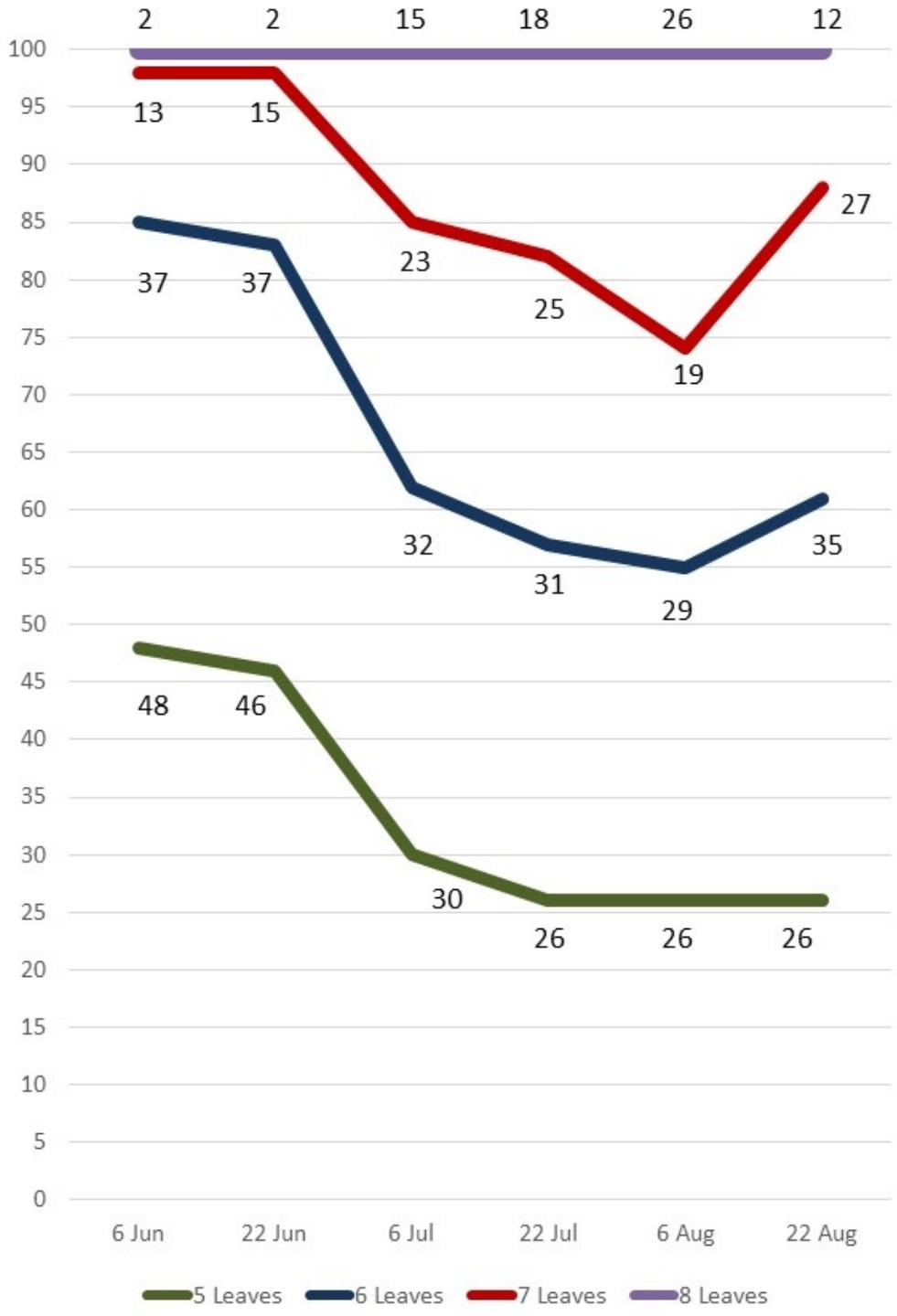

Figure 1. Percent of vegetative tiller population with 5, 6, 7, and 8 leaves.

Table 11. Growth and development of western wheatgrass vegetative tillers with 5, 6, 7, and 8 leaves on silty soils managed with the twice-over strategy, 1983-1986.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	48.2	46.0	29.7	26.0	26.7	26.1
% Active Leaf	80.0	80.0	60.0	60.0	60.0	60.0
Leaf Height cm	13.9	16.0	15.0	17.6	13.1	15.7
Tallest Leaf cm	18.4	19.3	18.4	19.9	15.3	17.9
6 Leaves						
% Population	37.0	36.4	32.4	31.0	28.7	34.7
% Active Leaf	66.7	66.7	66.7	58.4	50.0	50.0
Leaf Height cm	15.8	16.7	14.8	16.8	16.5	17.9
Tallest Leaf cm	21.3	21.0	17.8	19.4	17.8	19.3
7 Leaves						
% Population	13.0	15.3	22.5	25.0	19.8	26.9
% Active Leaf	57.1	71.4	57.1	57.1	57.1	57.1
Leaf Height cm	17.1	17.8	20.4	19.6	17.3	19.4
Tallest Leaf cm	21.4	23.6	23.7	23.0	20.6	21.6
8 Leaves						
% Population	1.9	2.3	15.3	18.1	24.8	12.3
% Active Leaf	62.5	62.5	62.5	75.0	62.5	75.0
Leaf Height cm	18.5	18.2	13.8	19.0	18.1	23.0
Tallest Leaf cm	23.4	23.8	20.7	22.7	20.7	25.0
% Population	100.1	100.0	99.9	100.1	100.0	100.0

Table 12. Growth and development of western wheatgrass vegetative tillers with 5, 6, 7, and 8 leaves on silty soils managed with the ungrazed treatment, 1983-1986.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	41.1	39.9	31.3	25.0	22.6	20.4
% Active Leaf	80.0	60.0	60.0	60.0	40.0	40.0
Leaf Height cm	15.9	16.6	19.2	19.3	19.5	19.5
Tallest Leaf cm	21.7	19.8	21.5	21.6	22.0	21.4
6 Leaves						
% Population	39.3	43.9	39.1	29.4	37.3	27.3
% Active Leaf	66.7	66.7	66.7	41.7	50.0	33.3
Leaf Height cm	18.7	17.0	20.2	21.8	20.9	21.1
Tallest Leaf cm	25.4	21.5	24.1	23.2	23.6	22.6
7 Leaves						
% Population	16.8	13.8	19.5	24.2	16.7	34.1
% Active Leaf	57.1	57.1	57.1	57.1	57.1	42.9
Leaf Height cm	21.0	19.1	22.9	22.2	23.1	22.5
Tallest Leaf cm	27.0	23.4	25.7	24.3	25.8	24.5
8 Leaves						
% Population	2.8	2.5	10.2	21.5	23.5	18.2
% Active Leaf	50.0	62.5	62.5	62.5	62.5	62.5
Leaf Height cm	21.3	18.7	21.7	24.1	23.9	24.5
Tallest Leaf cm	26.3	22.6	25.7	26.8	25.9	25.7
% Population	100.0	100.1	100.1	100.1	100.1	100.0

Table 13. Growth and development of western wheatgrass vegetative tillers with 5, 6, 7, and 8 leaves on silty soils managed with the twice-over strategy, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	68.8	50.0	100.0	58.5	100.0	70.9
% Active Leaf	60.0	60.0	80.0	60.0	80.0	60.0
Leaf Height cm	11.3	15.1	19.6	12.0	11.6	14.5
Tallest Leaf cm	13.5	17.7	24.3	13.3	14.3	15.9
6 Leaves						
% Population	28.1	33.3	0.0	34.1	0.0	16.4
% Active Leaf	50.0	50.0	-	50.0	-	50.0
Leaf Height cm	10.7	17.4	-	13.2	-	16.8
Tallest Leaf cm	12.2	19.1	-	15.7	-	21.7
7 Leaves						
% Population	3.1	14.3	0.0	6.1	0.0	10.9
% Active Leaf	57.1	66.7	-	42.9	-	42.9
Leaf Height cm	9.4	17.4	-	14.1	-	18.0
Tallest Leaf cm	11.0	19.9	-	14.8	-	23.3
8 Leaves						
% Population	0.0	2.4	0.0	1.2	0.0	1.8
% Active Leaf	-	37.5	-	62.5	-	37.5
Leaf Height cm	-	26.9	-	9.8	-	18.7
Tallest Leaf cm	-	30.2	-	13.7	-	22.5
% Population	100.0	100.0	100.0	99.9	100.0	100.0

Table 14. Growth and development of western wheatgrass vegetative tillers with 5, 6, 7, and 8 leaves on silty soils managed with the traditional seasonlong practice, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	100.0	48.1	100.0	64.3	100.0	68.4
% Active Leaf	60.0	60.0	80.0	40.0	80.0	40.0
Leaf Height cm	14.2	12.6	12.3	16.2	13.2	10.2
Tallest Leaf cm	15.7	15.1	14.0	18.2	17.1	11.0
6 Leaves						
% Population	0.0	33.3	0.0	32.1	0.0	31.6
% Active Leaf	-	50.0	-	33.3	-	33.3
Leaf Height cm	-	19.9	-	18.1	-	9.1
Tallest Leaf cm	-	22.8	-	18.2	-	9.2
7 Leaves						
% Population	0.0	18.5	0.0	3.6	0.0	0.0
% Active Leaf	-	42.9	-	57.1	-	-
Leaf Height cm	-	20.4	-	21.5	-	-
Tallest Leaf cm	-	24.0	-	25.2	-	-
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	99.9	100.0	100.0	100.0	100.0

Table 15. Growth and development of western wheatgrass vegetative tillers with 5, 6, 7, and 8 leaves on silty soils managed with the long-term nongrazed treatment, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	48.2	30.8	78.3	90.9	100.0	60.0
% Active Leaf	60.0	60.0	80.0	40.0	60.0	40.0
Leaf Height cm	15.2	16.3	20.2	17.5	18.8	14.2
Tallest Leaf cm	17.8	18.6	24.4	20.0	20.0	16.9
6 Leaves						
% Population	50.0	38.5	21.7	9.1	0.0	40.0
% Active Leaf	66.7	33.3	66.7	50.0	-	50.0
Leaf Height cm	16.1	21.0	25.9	20.9	-	14.7
Tallest Leaf cm	20.5	23.2	29.9	26.7	-	17.0
7 Leaves						
% Population	1.8	23.1	0.0	0.0	0.0	0.0
% Active Leaf	57.1	28.6	-	-	-	-
Leaf Height cm	16.1	23.9	-	-	-	-
Tallest Leaf cm	25.5	25.9	-	-	-	-
8 Leaves						
% Population	0.0	7.7	0.0	0.0	0.0	0.0
% Active Leaf	-	37.5	-	-	-	-
Leaf Height cm	-	22.7	-	-	-	-
Tallest Leaf cm	-	27.5	-	-	-	-
% Population	100.0	100.1	100.0	100.0	100.0	100.0

Table 16. Growth and development of western wheatgrass vegetative tillers with 5, 6, 7, and 8 leaves on shallow soils managed with the twice-over strategy, 1983-1986.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	55.7	48.2	35.5	47.5	58.3	24.2
% Active Leaf	60.0	60.0	60.0	60.0	60.0	60.0
Leaf Height cm	13.9	15.0	12.9	16.1	14.9	15.0
Tallest Leaf cm	16.7	18.0	15.1	17.4	17.0	17.7
6 Leaves						
% Population	38.0	40.4	33.9	30.5	8.3	37.6
% Active Leaf	66.7	66.7	66.7	66.7	66.7	50.0
Leaf Height cm	14.6	13.7	15.1	16.2	13.8	14.9
Tallest Leaf cm	19.3	18.0	17.8	20.2	15.8	16.4
7 Leaves						
% Population	5.1	10.6	25.8	15.6	16.7	23.8
% Active Leaf	57.1	57.1	57.1	71.4	57.1	57.1
Leaf Height cm	17.3	13.7	17.8	17.1	15.1	17.6
Tallest Leaf cm	22.8	18.9	20.6	18.8	17.4	19.1
8 Leaves						
% Population	1.3	0.9	4.8	6.5	16.7	14.6
% Active Leaf	75.0	75.0	50.0	75.0	62.5	62.5
Leaf Height cm	12.8	16.2	16.3	24.3	19.6	19.0
Tallest Leaf cm	16.2	23.0	19.1	29.0	22.0	21.1
% Population	100.1	100.1	100.0	100.1	100.0	100.2

Table 17. Growth and development of western wheatgrass vegetative tillers with 5, 6, 7, and 8 leaves on shallow soils managed with the ungrazed treatment, 1983-1986.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	70.4	29.1	35.7	32.6	30.8	30.5
% Active Leaf	60.0	60.0	60.0	60.0	60.0	40.0
Leaf Height cm	13.9	14.6	15.6	14.2	17.3	15.7
Tallest Leaf cm	18.7	17.0	17.7	16.5	18.8	18.7
6 Leaves						
% Population	26.8	45.9	30.4	37.8	41.0	36.6
% Active Leaf	66.7	58.4	66.7	58.4	50.0	58.4
Leaf Height cm	15.4	15.1	16.8	15.2	18.4	18.5
Tallest Leaf cm	20.6	19.1	20.5	18.1	21.4	20.1
7 Leaves						
% Population	2.8	18.6	23.2	20.2	10.3	25.0
% Active Leaf	42.9	57.1	57.1	57.1	57.1	50.0
Leaf Height cm	19.7	17.6	22.8	18.3	22.3	19.5
Tallest Leaf cm	23.7	21.9	26.3	21.0	25.0	21.1
8 Leaves						
% Population	0.0	6.5	10.7	9.5	17.9	8.1
% Active Leaf	-	50.0	62.5	62.5	62.5	50.0
Leaf Height cm	-	20.1	23.4	21.2	22.1	18.3
Tallest Leaf cm	-	25.0	26.4	23.7	23.2	20.3
% Population	100.0	100.1	100.0	100.1	100.0	100.2

Table 18. Growth and development of western wheatgrass vegetative tillers with 5, 6, 7, and 8 leaves on shallow soils managed with the twice-over strategy, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	64.8	91.7	100.0	67.6	100.0	82.9
% Active Leaf	40.0	60.0	80.0	60.0	80.0	40.0
Leaf Height cm	7.9	13.9	13.8	10.7	16.5	7.6
Tallest Leaf cm	8.6	15.8	17.3	12.8	19.2	8.2
6 Leaves						
% Population	29.6	8.3	0.0	29.7	0.0	17.1
% Active Leaf	50.0	16.7	-	66.7	-	50.0
Leaf Height cm	11.7	8.2	-	10.0	-	9.7
Tallest Leaf cm	12.6	8.2	-	10.9	-	13.4
7 Leaves						
% Population	1.9	0.0	0.0	2.7	0.0	0.0
% Active Leaf	57.1	-	-	42.9	-	-
Leaf Height cm	10.5	-	-	12.6	-	-
Tallest Leaf cm	13.5	-	-	15.1	-	-
8 Leaves						
% Population	3.7	0.0	0.0	0.0	0.0	0.0
% Active Leaf	50.0	-	-	-	-	-
Leaf Height cm	12.9	-	-	-	-	-
Tallest Leaf cm	16.3	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.0

Table 19. Growth and development of western wheatgrass vegetative tillers with 5, 6, 7, and 8 leaves on shallow soils managed with the traditional seasonlong practice, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	37.5	0.0	100.0	0.0	0.0	50.0
% Active Leaf	60.0	-	80.0	-	-	60.0
Leaf Height cm	14.3	-	18.0	-	-	9.9
Tallest Leaf cm	18.3	-	20.9	-	-	12.8
6 Leaves						
% Population	50.0	0.0	0.0	0.0	0.0	33.3
% Active Leaf	66.7	-	-	-	-	16.7
Leaf Height cm	14.1	-	-	-	-	10.5
Tallest Leaf cm	18.6	-	-	-	-	10.5
7 Leaves						
% Population	12.5	0.0	0.0	0.0	0.0	16.7
% Active Leaf	71.4	-	-	-	-	28.6
Leaf Height cm	11.0	-	-	-	-	13.5
Tallest Leaf cm	15.7	-	-	-	-	15.1
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0		100.0			100.0

Table 20. Growth and development of western wheatgrass vegetative tillers with 5, 6, 7, and 8 leaves on shallow soils managed with the long-term nongrazed treatment, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	33.3	0.0	77.8	100.0	100.0	64.3
% Active Leaf	80.0	-	80.0	40.0	80.0	40.0
Leaf Height cm	15.0	-	18.8	31.8	18.6	15.2
Tallest Leaf cm	19.7	-	22.2	32.5	21.9	17.6
6 Leaves						
% Population	39.4	38.5	22.2	0.0	0.0	21.4
% Active Leaf	66.7	33.3	83.3	-	-	33.3
Leaf Height cm	18.3	20.9	26.1	-	-	16.4
Tallest Leaf cm	23.1	23.2	31.3	-	-	20.0
7 Leaves						
% Population	21.2	53.8	0.0	0.0	0.0	14.3
% Active Leaf	57.1	42.9	-	-	-	0.0
Leaf Height cm	21.0	20.3	-	-	-	-
Tallest Leaf cm	27.1	22.4	-	-	-	-
8 Leaves						
% Population	6.1	7.7	0.0	0.0	0.0	0.0
% Active Leaf	50.0	50.0	-	-	-	-
Leaf Height cm	17.7	21.0	-	-	-	-
Tallest Leaf cm	25.7	30.0	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.0

Table 21. Number of photosynthetically active leaves for western wheatgrass vegetative tillers with 5, 6, 7, and 8 leaves on ungrazed and twice-over treatments on silty and shallow soils, 1983-1986.

Leaves/Tiller	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug	Mean
Silty							
Ungrazed							
5 Leaves	4	3	3	3	2	2	2.8
6 Leaves	4	4	4	3	3	2	3.3
7 Leaves	4	4	4	4	4	3	3.8
8 Leaves	4	5	5	5	5	4	4.7
	4.0	4.0	4.0	3.8	3.5	2.8	3.7
Twice-over							
5 Leaves	4	4	3	3	3	3	3.3
6 Leaves	4	4	4	4	3	3	3.7
7 Leaves	4	5	4	4	4	4	4.2
8 Leaves	5	5	5	6	5	6	5.3
	4.3	4.5	4.0	4.3	3.8	4.0	4.1
Shallow							
Ungrazed							
5 Leaves	3	3	3	3	3	2	2.8
6 Leaves	4	4	4	3	3	3	3.5
7 Leaves	4	4	4	4	4	3	3.8
8 Leaves	4	4	5	5	5	4	4.5
	3.8	3.8	4.0	3.8	3.8	3.0	3.7
Twice-over							
5 Leaves	3	3	3	3	3	3	3.0
6 Leaves	4	4	4	4	4	3	3.8
7 Leaves	4	4	4	5	4	4	4.2
8 Leaves	6	6	5	6	5	4	5.3
	4.3	4.3	4.0	4.5	4.0	3.5	4.1

Robust Vegetative Tillers

The robust vegetative tillers are uncommon vegetative tillers that produce 9 or 10 leaves during the same period that common vegetative tillers produce 5 to 8 leaves. Robust tillers grow amongst normal tillers and there is no obvious differences in habitat characteristics. During growing seasons with normal precipitation conditions, robust tillers make up about 2.5% of the total tiller population and about 5.0% of the vegetative tiller population on the grazed twice-over treatment and make up about 1.9% of the total tiller population and 5.0% of the vegetative tiller population on the ungrazed treatment. During growing seasons with below normal precipitation conditions, robust tillers are not present on the grazed twice-over treatment and make up about 0.3% of the total tiller population and about 0.5% of the vegetative tiller population on the ungrazed treatment.

Growth and development data of western wheatgrass robust tillers on silty soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 are on table 22.

Robust vegetative tillers with 9 or 10 leaves on the twice-over strategy composed 4.2% of the total population with 82 tillers (table 6), during the growing season a mean of 5.8 leaves (61.5%) were photosynthetically active with a mean leaf height of 21.9 cm and the tallest leaf averaged 26.2 cm tall (table 22).

Robust vegetative tillers with 9 or 10 leaves on the ungrazed treatment composed 4.5% of the total population with 65 tillers (table 6), during the growing season a mean of 5.3 leaves (55.9%) were photosynthetically active with a mean leaf height of 24.3 cm and the tallest leaf averaged 27.6 cm tall (table 22).

Only 3 robust vegetative tillers with 9 or 10 leaves were measured on all of the treatments during 1987 to 1989 (table 6)

Growth and development data of western wheatgrass robust tillers on shallow soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 are on table 23.

Robust vegetative tillers with 9 or 10 leaves on the twice-over strategy composed 2.1% of the total population with 23 tillers (table 7), during the growing season a mean of 6.0 leaves (63.4%) were photosynthetically active with a mean leaf height of 21.3 cm and the tallest leaf averaged 24.9 cm tall (table 23).

Robust vegetative tillers with 9 or 10 leaves on the ungrazed treatment composed 3.3% of the total population with 20 tillers (table 7), during the growing season a mean of 5.8 leaves (61.3%) were photosynthetically active with a mean leaf height of 22.2 cm and the tallest leaf averaged 26.6 cm tall (table 23).

Only 1 robust vegetative tiller with 9 or 10 leaves was measured on all of the treatments during 1987 to 1989 (table 7)

All of the robust vegetative tillers with 9 or 10 leaves measured during this study were not grazed including the tillers located on grazed treatments. The not grazed tillers remaining on the grazed treatments tended to have slightly shorter mean leaf heights and mean tallest leaf heights which were not significantly different than the not grazed tillers on the ungrazed treatments on both the silty and shallow soils during the 1983 to1986 period (tables 22 and 23). It is not believed that grazed treatments cause robust vegetative tillers to produce slightly shorter leaf heights. It is surmised that grazing cattle have a disproportional rate of selection for taller tillers than for shorter tillers leaving a distorted sample population of not grazed tillers with slightly shorter leaf heights.

Leaves grow and senesce in about the same order of their appearance. This study has designated that leaves with less than 50% senescent tissue to be photosynthetically active. Tillers growing on the twice-over treatment tended to have greater photosynthetically active leaves than the tillers growing on the ungrazed treatment. Robust vegetative tillers with 9 or 10 leaves located on the twice-over treatment had 0.5 (5.3%) and 0.2 (2.1%) more photosynthetically active leaves than the tillers located on the ungrazed treatment on silty soil and shallow soil, respectively.

Robust vegetative tillers with 9 or 10 leaves composed an extremely low percentage of the total measured tiller population during the 1983 to 1986 period and were all but nonexistent during the 1987 to 1989 period. Robust vegetative tillers located on the twice-over treatment composed 4.2% and 2.1%, and tillers located on the ungrazed treatment composed 4.5% and 3.3% on silty soils and shallow soils, respectively. During the 1987 to 1989 period, 3 and 1 robust vegetative tillers were measured on silty soils and shallow soils, respectively (tables 6 and 7).

Table 22. Growth and development of western wheatgrass robust tillers on silty soils managed with twice-over grazing and ungrazed treatments, 1983-1986.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
% Population	-	1.5	2.3	6.2	12.6	8.0
% Active Leaf	-	57.9	55.6	62.6	68.4	63.2
Leaf Height cm	-	21.7	18.3	21.5	22.3	25.5
Tallest Leaf cm	-	29.3	22.8	25.6	25.5	27.9
Ungrazed 1983-1986						
% Population	-	-	0.7	8.7	18.8	6.5
% Active Leaf	-	-	66.7	55.3	57.9	43.6
Leaf Height cm	-	-	22.2	23.8	27.8	23.5
Tallest Leaf cm	-	-	29.0	26.4	30.0	24.8

Table 23. Growth and development of western wheatgrass robust tillers on shallow soils managed with twice-over grazing and ungrazed treatments, 1983-1986.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
% Population	-	-	-	1.9	18.2	6.9
% Active Leaf	-	-	-	61.2	68.4	60.6
Leaf Height cm	-	-	-	24.3	17.6	22.1
Tallest Leaf cm	-	-	-	28.5	20.9	25.3
Ungrazed 1983-1986						
% Population	-	-	11.4	2.0	8.7	15.8
% Active Leaf	-	-	57.9	55.6	68.4	63.2
Leaf Height cm	-	-	17.2	22.3	21.6	27.5
Tallest Leaf cm	-	-	21.6	27.6	25.4	31.7

Secondary Tillers

The secondary tillers had very slow rates of growth and development because these subordinate tillers were hormonally controlled by a dominant lead tiller that regulated the flow of essential nutrients. During growing seasons with normal precipitation conditions, secondary tillers made up about 9.1% of the total tiller population on the grazed twice-over treatment and made up about 7.0% of the ungrazed treatment. During growing seasons with below normal precipitation conditions, secondary tillers made up about 54.1% of the total tiller population on the grazed twice-over treatment and made up about 44.3% on the ungrazed treatment. During growing seasons with below normal precipitation, only about 45.9% of the total tiller population were able to produce more than 4 leaves on the grazed twice-over treatment and about 55.7% of the tillers were able to produce more than 4 leaves on the ungrazed treatment.

Growth and development data of western wheatgrass secondary tillers on silty soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 and 1987 to 1989 are on table 24.

Secondary tillers with 2 to 4 leaves on the twice-over strategy during 1983 to 1986 composed 9.1% of the total population with 179 tillers (table 6), during the growing season a mean of 2.1 leaves (60.1%) were photosynthetically active with a mean leaf height of 13.4 cm and the tallest leaf averaged 14.7 cm tall (table 24).

Secondary tillers with 2 to 4 leaves on the ungrazed treatment during 1983 to 1986 composed 7.0% of the total population with 102 tillers (table 6), during the growing season a mean of 2.0 leaves (58.4%) were photosynthetically active with a mean leaf height of 15.6 cm and the tallest leaf averaged 17.3 cm tall (table 24).

Secondary tillers with 2 to 4 leaves on the twice-over strategy during 1987to 1989 composed 54.1% of the total population with 336 tillers (table 6), during the growing season a mean of 2.1 leaves (60.9%) were photosynthetically active with a mean leaf height of 12.1 cm and the tallest leaf averaged 13.2 cm tall (table 24).

Secondary tillers with 2 to 4 leaves on the ungrazed treatment during 1987 to 1989 composed 44.3% of the total population with 335 tillers (table 6), during the growing season a mean of 2.0 leaves (59.3%) were photosynthetically active with a mean leaf height of 17.1 cm and the tallest leaf averaged 19.4 cm tall (table 24).

Growth and development data of western wheatgrass secondary tillers on shallow soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 and 1987 to 1989 are on table 25.

Secondary tillers with 2 to 4 leaves on the twice-over strategy during 1983 to 1986 composed 13.9% of the total population with 153 tillers (table 7), during the growing season a mean of 2.2 leaves (64.0%) were photosynthetically active with a mean leaf height of 13.1 cm and the tallest leaf averaged 15.1 cm tall (table 25).

Secondary tillers with 2 to 4 leaves on the ungrazed treatment during 1983 to 1986 composed 8.8% of the total population with 54 tillers (table 7), during the growing season a mean of 2.1 leaves (61.0%) were photosynthetically active with a mean leaf height of 14.7 cm and the tallest leaf averaged 16.1 cm tall (table 25).

Secondary tillers with 2 to 4 leaves on the twice-over strategy during 1987to 1989 composed 55.0% of the total population with 214 tillers (table 7), during the growing season a mean of 2.1 leaves (61.1%) were photosynthetically active with a mean leaf height of 11.2 cm and the tallest leaf averaged 12.4 cm tall (table 25).

Secondary tillers with 2 to 4 leaves on the ungrazed treatment during 1987 to 1989 composed 43.7% of the total population with 213 tillers (table 7), during the growing season a mean of 2.0 leaves (58.7%) were photosynthetically active with a mean leaf height of 16.7 cm and the tallest leaf averaged 18.4 cm tall (table 25).

All of the secondary tillers measured during this study were not grazed including the tillers located on grazed treatments. The not grazed tillers remaining on the grazed treatments tended to have slightly shorter mean leaf heights and mean tallest leaf heights which were not significantly different than the not grazed tillers on the ungrazed treatments on both the silty and shallow soils during the 1983-1986 and 1987-1989 periods (tables 24 and 25). It is not believed that grazed treatments cause secondary tillers to produce slightly shorter leaf heights. It is surmised that grazing cattle have a disproportional rate of selection for taller tillers than for shorter tillers

leaving a distorted sample population of not grazed tillers with slightly shorter leaf heights.

Leaves grow and senesce in about the same order of their appearance. This study has designated that leaves with less than 50% senescent tissue to be photosynthetically active. Tillers growing on the twice-over treatment tended to have greater photosynthetically active leaves than the tillers growing on the ungrazed treatment. Secondary tillers located on the twice-over treatment had 0.1 (2.9%) and 0.1 (2.9%) more photosynthetically active leaves than the tillers located on the ungrazed treatment on silty soil and shallow soil, respectively.

Secondary tillers composed a low percentage of the total measured tiller population during the 1983 to 1986 period with normal precipitation conditions. The quantity of secondary tillers greatly increased during the 1987 to 1989 period with below normal precipitation conditions and composed a moderate percentage of the total population. During the 1983 to 1986 period, secondary tillers located on the twice-over treatment composed 9.1% and 13.9%, and tillers located on the ungrazed treatment composed 7.0% and 8.8% of the total tiller population on silty soils and shallow soils, respectively. During the 1987 to 1989 period, secondary tillers located on the twice-over treatment composed 54.1% and 55.0%, and tillers located on the ungrazed treatment composed 44.3% and 43.7% of the total tiller population on silty soils and shallow soils, respectively. During the growing season with below normal precipitation conditions greater than 40% of the total tiller population that should have been producing 5 to 8 leaves were inhibited to the production of 4 or less leaves.

Table 24. Growth and development of western wheatgrass secondary tillers on silty soils managed with the twice-over grazing and ungrazed treatments, 1983-1986, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
% Population	25.0	14.9	13.0	8.6	7.9	3.5
% Active Leaf	71.4	71.4	71.4	57.1	42.9	46.5
Leaf Height cm	12.7	11.8	11.8	18.1	10.1	15.9
Tallest Leaf cm	14.2	13.2	13.5	20.5	10.1	16.6
Ungrazed 1983-1986						
% Population	24.1	11.6	6.5	5.3	1.6	3.7
% Active Leaf	71.4	78.6	75.0	53.6	25.0	46.5
Leaf Height cm	14.4	13.5	16.7	18.0	15.5	15.3
Tallest Leaf cm	16.0	16.4	19.8	19.6	15.5	16.2
Twice-over 1987-1989						
% Population	55.6	62.5	77.6	39.3	80.6	58.6
% Active Leaf	57.1	57.1	71.4	57.1	57.1	42.9
Leaf Height cm	9.5	12.1	12.4	12.5	14.3	11.6
Tallest Leaf cm	11.4	12.6	14.0	13.2	16.0	11.7
Ungrazed 1987-1989						
% Population	44.0	45.7	59.4	30.2	66.2	50.4
% Active Leaf	71.4	55.6	71.4	42.9	71.4	42.9
Leaf Height cm	15.3	19.4	20.0	12.8	19.6	15.4
Tallest Leaf cm	18.2	20.2	22.8	17.4	22.5	15.4

Table 25. Growth and development of western wheatgrass secondary tillers on shallow soils managed with twice-over grazing and ungrazed treatments, 1983-1986, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
% Population	8.1	16.7	7.5	23.9	27.3	11.6
% Active Leaf	71.4	73.2	71.4	53.6	57.1	57.1
Leaf Height cm	15.5	12.7	8.8	15.0	10.9	15.8
Tallest Leaf cm	18.5	14.5	12.1	16.1	12.6	16.7
Ungrazed 1983-1986						
% Population	18.4	17.1	8.6	3.0	6.5	6.3
% Active Leaf	71.4	73.2	71.4	50.0	50.0	50.0
Leaf Height cm	11.3	12.7	14.8	13.0	23.5	12.6
Tallest Leaf cm	13.2	15.2	16.2	15.0	24.3	12.8
Twice-over 1987-1989						
% Population	43.8	79.7	60.4	37.3	76.5	57.8
% Active Leaf	42.9	66.7	71.4	71.4	71.4	42.9
Leaf Height cm	8.9	11.5	11.8	8.4	16.5	9.8
Tallest Leaf cm	8.9	13.5	13.4	9.3	19.2	9.9
Ungrazed 1987-1989						
% Population	29.9	48.9	79.5	50.6	77.8	23.9
% Active Leaf	71.4	66.7	71.4	42.9	71.4	28.6
Leaf Height cm	15.0	15.0	15.9	17.6	17.9	18.5
Tallest Leaf cm	17.1	16.7	19.0	18.9	20.1	18.5

Discussion

Western wheatgrass, *Pascopyrum smithii,* is a native, long-lived perennial, cool season, mid grass, monocot, of the grass family that is abundant on healthy mixed grass prairie plant communities. Western wheatgrass can grow on sandy, shallow, silty, overflow, clay, and thin claypan ecological sites. It grows better on silty and shallow sites. Western wheatgrass is tolerant of cold, drought, and periodic flooding, has a high tolerance to alkali and saline soils, and moderately shade tolerant. Western wheatgrass tillers live for two growing seasons; the first growing season as a vegetative tiller and the second season as a reproductive lead tiller. Early season activity starts by regreening with active chlorophyll the portions of the carryover leaves that have intact cell walls from the previous growing season vegetative tillers. The green portion of the carryover leaves provides large quantities of carbohydrates and energy for the production of new leaves.

New leaf growth of western wheatgrass started in early to mid April, leaf growth rate increased during May and June, and then become much slower during July. The tillers derived from carryover tillers that developed into reproductive lead tillers produced four new leaves by mid May and produced an additional leaf and a half by early June. Early flower stalk growth and development (FSD) began to swell around early to mid June. Early lead tillers progressed rapidly through head emergence (HE) and reached early first flower before 21 June. About 87% of lead tillers reached anthesis (Ant) during late June to mid July. Early flowering tillers usually produced 5 or 6 leaves and late flowering tillers usually produced 7 or 8 leaves. Late developing lead tillers reached anthesis by late July. No new leaves were produced after the anthesis stage. Seeds developed (SD) through the milk and dough stages during July and early August with most seeds reaching maturity (SBS) from mid August to late August with some maturing in early September.

The vegetative tillers derived from the previous seasons fall tillers and the current seasons early spring initiated tillers were not inhibited by lead tiller hormones and produced 3.3 new leaves by mid May, 3.8 new leaves by late May, and 85% and 15% of the vegetative tillers had produced 5 or 6 new leaves and 7 or 8 new leaves during early June, respectively. Some vegetative tillers with 5 and 6 leaves continue to produce an additional leaf or two. The quantity of vegetative tillers with 7 leaves stopped increasing in late July and the tillers with 8 leaves stopped increasing in early August. After the reproductive lead tillers had completed the anthesis and early seed development stages, greater quantities of essential nutrients were released to the subordinate secondary tillers, with about 60% producing their fourth leaf and obtaining their independence, followed by rapid production of leaves 5 and 6 during July and August.

About 2.5% of the tiller population on the twice-over treatment and about 1.9% of the tiller population on the ungrazed treatment develop robust growth and produced 9 or 10 and rarely up to 16 new leaves during growing seasons with normal precipitation conditions. However, the robust tillers grow amongst normal tillers with 5 to 8 leaves and have no obvious differences in habitat characteristics. The mean leaf heights of the robust tillers were not any taller than those of the normal tillers. The only noticeable difference was the uncommonly greater number of leaves.

Secondary tillers are derived from vegetative growth of axillary buds. The tillers that were initiated during the growing season were hormonally controlled by a dominated lead tiller that has proprietary access to all essential nutrients available to the secondary tillers. This arrangement had positive and negative affects. Most of the time, the secondary tillers have access to greater quantities of essential nutrients than a seedling would have, which ensures secondary tillers with superior survivability. Thus, a high percentage of secondary tillers live and grow for two growing seasons, and almost no grass seedlings develop into mature plants. However, during periods of water stress or other problematic conditions, lead tillers restrict nutrient flow to secondary tillers resulting in very slow rates of growth or tiller termination. During some growing seasons, secondary tillers can remain at the 2 or 3 leaf stage for a month or two. When secondary tillers produce their fourth leaf, they have adequate leaf area to photosynthesize their own carbon energy and develop a large enough root system for self sustaining nutrient resource uptake.

An increase in the quantity of secondary tillers initiated from axillary buds requires specialized grazing management designed to manipulate the hormones that regulate axillary bud meristematic tissue. With an increase in secondary tiller production, greater quantities of forage vegetative tillers provide greater quantities of nutrients, mainly crude protein, that meet a lactating cows requirements during mid July to mid October. Traditional grazing practices have low quantities of forage value

vegetative and secondary tillers after mid July, thus provide forage with nutrient quality below the requirements of modern lactating cows.

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Growth Pattern and Phenological Development of Needle and Thread on the Northern Plains

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Intact grassland ecosystems are complex; exceedingly more complex than the most complicated machines ever built by humans. Knowledge and understanding of the growth pattern and phenological development of the major forage grasses are fundamentally essential for generation of biologically effective management strategies with inclusivity of all biotic and abiotic components of grassland ecosystems in the Northern Plains.

The inspirational goals of this study were developed by Dr. Warren C. Whitman (c. 1950) and Dr. Harold Goetz (1963) which were to gain quantitative knowledge of each component species and to provide a pathway essential for the understanding of relationships of ecosystem components that would result in the development and establishment of scientific standards for proper management of grazinglands in the Northern Plains.

This growth pattern and phenological development study of the major forage graminoids was conducted during the growing seasons of 1983-1986 and 1987-1989 with data collected biweekly June-August. The study included 3 cool season, 2 warm season, 1 upland sedge, 1 naturalized, and 2 domesticated grasses. The study sites were located at the NDSU Dickinson Research Extension Center ranch near Manning in western North Dakota and consisted of 143 acres (58 ha) of two seeded domesticated grasslands and 720 acres (291 ha) of native rangeland pastures separated into three management treatments, each with two replications, with data collection sites established on sandy, shallow, and silty ecological sites. Each ecological site of the grazed treatments had matching paired plots, one grazed and the other with an ungrazed exclosure.

Study Area

The physiography of the study area consists of the Unglaciated section of the Missouri Plateau (Fenneman 1931, 1946; Hunt 1974). The landscape surface is highly eroded fluvial sedimentary deposits of material removed from the uplifted Rocky Mountains. Most of the deposition occurred from slow meandering streams during the Laramide Orogeny and during the 20 to 30 million years of the late Cretaceous and early Tertiary Periods following the uplift. Intense widespread erosion of these sediments occurred from about 5 to 3 million years ago during the late Pliocene Epoch (Bluemle 2000). The extensive erosion during this period removed about 500 to 1000 feet of sediments (Fenneman 1931) forming a landscape with well developed integrated drainage systems of broad mature valleys and gently rolling uplands containing widely spaced large hills and buttes with erosion resistant caps raising 500 to 650 feet above the plain (Bluemle 2000).

The soils of western North Dakota developed from eroded Tertiary fluvial sedimentary deposits in the Ustic-Frigid soil moisture-temperature regime. The Ustic soil moisture regime is typical of semi arid climates. The Frigid soil temperature regime has mean annual soil temperatures of less than 47° F (8° C) (Soil Survey Staff 1975). These soils are primarily Typic Borolls (semi arid cool Mollisols) and support vegetation of mid and short grasses of the Mixed Grass Prairie (Manske 2008b).

The current "native" plant species in the Northern Plains did not originate here. All of the plant species have migrated into the region by different mechanisms and at different times and rates. The present plant species have flora affinities to northern, eastern, western, Rocky Mountain, and Great Basin plant communities (Zaczkowski 1972). This wide mix of plant species was formed from remnants of previously existing plant communities. The climate changed about 5,000 years ago to conditions like those of the present, with cycles of wet and dry periods (Bluemle 1977, 1991; Manske 1994). The large diversity of plant species that make up the current mixed grass prairie permits dynamic responses to changes in climatic conditions by increasing the combination of plant species favored by any set of climatic conditions (Manske 2008a).

Long-Term Weather

The NDSU Dickinson Research Extension Center ranch is located in Dunn County in western North Dakota, at 47° 14' north latitude, 102° 50' west longitude. Mean annual temperature is 42.3° F (5.7° C). January is the coldest month, with mean temperature of 14.6° F (-9.7° C). July and August are the warmest months with mean temperatures of 69.7° F (20.9° C) and 68.6° F (20.3° C), respectively. Long-term (1982-2012) mean annual precipitation is 16.91 inches (429.61 mm). The perennial plant growing season precipitation (April to October) is 14.13 inches (358.97 mm) and is 83.6% of annual precipitation. June has the greatest monthly precipitation at 3.27 inches (83.08 mm). The precipitation received during the 3-month period of May, June, and July (8.26 inches, 209.80 mm) accounts for 48.8% of the annual precipitation.

Growing season months with water deficiency disrupt plant growth rates and are identified from monthly temperature and precipitation data by the Emberger ombrothermic diagram technique. Long-term (1983-2012) 30 year reoccurrence rates (table 1) show relatively low rates of water deficiency reoccurring during April (16.7%), May and June (10.0%), moderate rates during July and October (36.7%), and high rates during August (56.7%) and September (60.0%). Long-term occurrence of water deficiency conditions was 33.3% of the growing season months, for a mean of 2.0 water deficient months per each 6.0 month growing season (15 Apr-15 Oct).

Growing Season Precipitation

The growing season precipitation information collected during the grass leaf height study has been grouped into two periods with the first period occurring during 1983 to 1986 and the second period occurring during 1987 to 1989.

Mean growing season precipitation of 1983-1986 (table 2) was 14.11 inches (99.9% of LTM). None of the four 6 month growing seasons received precipitation at less than 80% of LTM. One growing season, 1986, received precipitation at near 130% of LTM. The rate of water deficiency occurrence during the four growing seasons was 29.2%, for a mean of 1.75 water deficient months per growing season (table 3). The growing season of 1984 had 3.0 months in water deficiency. The growing seasons of 1983 and 1986 had 1.5 months in water deficiency each. The growing season of 1985 had 1.0 month in water deficiency.

Mean growing season precipitation of 1987-1989 (table 4) was low at 9.14 inches (64.7% of LTM). The growing season of 1987 received 11.53 inches (81.6% of LTM) precipitation. The growing season of 1989 received 10.60 inches (75.0% of LTM) precipitation. The growing season of 1988 received only 5.30 inches (37.5% of LTM) precipitation and was dry. The rate of water deficiency occurrence during the three growing seasons was 61.1%, for a mean of 3.7 water deficient months per growing season (table 5). The growing seasons of 1987 and 1989 had 3.0 months in water deficiency each. The growing season of 1988 had 5.0 months of its 6 month growing season in water deficiency conditions. That is comparable to 2 other growing seasons with high water deficiency conditions. The growing season of 1934 had 4.5 months in water deficiency and the growing season of 1936 had 5.5 months in water deficiency.

Table 1. Growing season months with water deficiency, DREC ranch, 1983-2012.

	Apr	May	Jun	Jul	Aug	Sep	Oct	# Months	% 6 Months 15 Apr-15 Oct
Total	5	3	3	11	17	18	11	60.0	33.3
% of 30 Years	16.7	10.0	10.0	36.7	56.7	60.0	36.7		

Table 2. Precipitation in inches and percent of long-term mean for perennial plant growing season months, DREC ranch, 1983-1986.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-Term Mean 1982-2012	1.44	2.56	3.27	2.43	1.70	1.42	1.31	14.13	16.91
1983	0.21	1.53	3.26	2.56	4.45	0.86	0.72	13.59	15.55
% of LTM	14.58	59.77	99.69	105.35	261.76	60.56	54.96	96.18	91.96
1984	2.87	0.00	5.30	0.11	1.92	0.53	0.96	11.69	12.88
% of LTM	199.31	0.00	162.08	4.53	112.94	37.32	73.28	82.73	76.17
1985	1.24	3.25	1.58	1.07	1.84	1.69	2.13	12.80	15.13
% of LTM	86.11	126.95	48.32	44.03	108.24	119.01	162.60	90.59	89.47
1986	3.13	3.68	2.58	3.04	0.46	5.29	0.18	18.36	22.96
% of LTM	217.36	143.75	78.90	125.10	27.06	372.54	13.74	129.94	135.78
1983-1986	1.86	2.12	3.18	1.70	2.17	2.09	1.00	14.11	16.63
% of LTM	129.34	82.62	97.25	69.75	127.50	147.36	76.15	99.86	98.34

Table 3. Growing season months with water deficiency conditions that caused water stress in perennial plants, DREC ranch, 1983-1986.

	APR	MAY	JUN	JUL	AUG	SEP	OCT	# Months	% 6 Months 15 Apr-15 Oct
1983	■					■		1.5	25.0
1984		■		■		■		3.0	50.0
1985				■				1.0	16.7
1986					■		■	1.5	25.0
#	**1**	**1**	**0**	**2**	**1**	**2**	**1**	**7.0**	**29.2**
%	**25.0**	**25.0**	**0.0**	**50.0**	**25.0**	**50.0**	**25.0**		

Table 4. Precipitation in inches and percent of long-term mean for perennial plant growing season months, DREC ranch, 1987-1989.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-Term Mean 1982-2012	1.44	2.56	3.27	2.43	1.70	1.42	1.31	14.13	16.91
1987	0.10	1.38	1.15	5.39	2.65	0.78	0.08	11.53	14.13
% of LTM	6.94	53.91	35.17	221.81	155.88	54.93	6.11	81.60	83.56
1988	0.00	1.85	1.70	0.88	0.03	0.73	0.11	5.30	9.03
% of LTM	0.00	72.27	51.99	36.21	1.76	51.41	8.40	37.51	53.40
1989	2.92	1.73	1.63	1.30	1.36	0.70	0.96	10.60	13.07
% of LTM	202.78	67.58	49.85	53.50	80.00	49.30	73.28	75.02	77.29
1987-1989	1.01	1.65	1.49	2.52	1.35	0.74	0.38	9.14	12.08
% of LTM	69.91	64.58	45.67	103.84	79.22	51.88	29.26	64.71	71.42

Table 5. Growing season months with water deficiency conditions that caused water stress in perennial plants, DREC ranch, 1987-1989.

	APR	MAY	JUN	JUL	AUG	SEP	OCT	# Months	% 6 Months 15 Apr-15 Oct
1987	■		■			■	■	3.0	50.0
1988	■		■	■	■	■	■	5.0	83.3
1989				■	■	■		3.0	50.0
#	**2**	**0**	**2**	**2**	**2**	**3**	**2**	**11.0**	**61.1**
%	**66.7**	**0.0**	**66.7**	**66.7**	**66.7**	**100.0**	**66.7**		

Procedures

The 1983-1989 Study

Grass tiller leaf heights were determined for reproductive lead tillers, vegetative tillers, and secondary tillers on a biweekly sampling period from June through August. Each leaf of ten ungrazed tillers of each study species was measured with a meter stick to the nearest 0.1 cm from ground level to the tips of the extended leaves. Basal leaf heights were measured for grass species in which the leaves and stalks were distinctly separate. Stalk leaf heights were measured for grass species where leaves are attached to the culm during vegetative stages and fruiting stages.

Degree of leaf senescence was estimated as percent dryness for each leaf. Percent dryness for basal leaves was considered from the apex to ground level. Percent dryness for stalk leaves was considered for the blade only. The categories of dryness were: 0%, 2%, 25%, 50%, 75%, 98% and 100% dry. Start of senescence was considered to be dryness greater than 2%. Leaves with less than 50% senescent tissue were designated to be photosynthetically active.

Grass flower stalk heights were determined by measurements from ground level to the tip of the stalk or the apex of the top floret. The awns, if present, were not included in the height measurements. The phenological stages of flower stalk development were recorded as: flower stalk developing (FSD), head emergence (HE), anthesis (Ant), seeds developing (SD), and seeds being shed (SBS). Recording the flower stalk development stages started when stalk enlargement or swelling was outwardly noticeable; prior development is not detectable without destruction of the tiller. The swelling of the stalk, traditionally called the boot stage, was categorized as the flower stalk developing stage. Head emergence is a short duration stage but easily defined when the flower head emerges from the sheath and rapidly elongates to near full height. Anthesis (flowering) is also a short duration stage but easily defined by the exposure of the anthers and stigmas. Needle and thread is usually cleistogamous that self-fertilizes without opening and exposing the anthers and stigmas. Following fertilization, the seeds develop through milk, dough, and mature stages which are difficult to differentiate on small grass seeds. These seed progression stages have been separated into more easily defined categories of seeds developing for the early seed stages and seeds being shed for the mature seed stages when seeds could be easily removed from the inflorescence by wind, by gentle rubbing, or when it could be observed that some seeds had already been dropped. Sometimes a floret will abort the seed production process resulting in failure of viable seeds to materialize. This condition could be revealed in the data set as earlier than normal recordings of seeds being shed.

During 1983 to 1986, the paired plot sample sites with sandy, shallow, silty and clay soil types were managed by ungrazed and grazed treatments of the twice-over rotation strategy. During 1987 to 1989, the paired plot sample sites with sandy, shallow, and silty soil types were managed by long-term nongrazed treatments, and by ungrazed and grazed treatments of the traditional seasonlong practice and the twice-over rotation strategy.

Designation of Tiller Types

Reproductive lead tillers are second year tillers derived from carryover tillers that were vegetative tillers during the previous growing season. The portions of the carryover leaves that have intact cell walls will regreen with active chlorophyll early in the growing season and provide photosynthate for rapid growth of new current years leaves. New leaf development resumed early spring in mid April but growth was slow until early or mid May. The anthesis (flowering) period can occur between late May and late June with all first flowers usually occurring before 21 June. No new leaves are produced after the anthesis stage, during the seed development stages. Flower stalks have 1 or 2 very small leaves and usually produce 2 to 7 basal leaves. Reproductive lead tillers are terminal at the end of the growing season; their apical meristem was used up producing a flower head.

Vegetative tillers are first year tillers derived from previous growing season initiated fall tillers and from early spring initiated secondary tillers that have escaped hormonal control by a lead tiller. Vegetative tillers produced 3.5 new leaves before early June. These tillers are the primary forage tillers with rapid growth rates, usually producing 5 to 7 basal leaves and occasionally producing leaves 8 and 9 during the growing season. The apical meristem remains vegetative, permitting these tillers to overwinter as carryover tillers and becoming reproductive lead tillers during the successive growing season.

Secondary tillers are young current growing season tillers usually with 2 to 4 basal leaves that initiated from axillary buds during May to July and that remain hormonally controlled by a dominant lead tiller that has proprietary access to all resources

slowing rates of growth. The secondary tillers can become independent from the hormone control of the lead tiller and transform into vegetative tillers with rapid growth rates during July and August. A large quantity of secondary fall tillers develop from crown buds during August.

Results

Needle and Thread, *Hesperostipa comata* (Trin. & Rupr.) Barkworth, is a member of the grass family, Poaceae, tribe, Stipeae, Syn.: *Stipa comata* Trin. & Rupr., and is a native, long lived perennial, monocot, cool-season, mid grass, that is highly drought resistant. The first North Dakota record is Bergman 1910. Early aerial growth consists of basal leaves arising from crown tiller buds. Needle and thread consistently reaches the 3.5 (+) new leaf stage by 1 June, however, it rarely retains more than 2 full basal leaves during the early portion of the growing season, eliminating it as an indicator of physiological grazing readiness of native grasses. Basal leaf blades are 10-30 cm (3.9-11.8 in) long, 1-3 mm wide, tapering to a point, with strong ridges on upper surface. Leaves roll inward when dry. The split sheath has overlapping translucent margins. The indistinct collar is continuous and narrow. The ligule is a conspicuous membrane, 3-6 mm long, continuous with sheath margins, often split or frayed. The auricles are absent. This grass is generally considered to be exclusively a bunch grass, however, under proper management, short rhizome tillers can be produced. The extensive fibrous root system is primarily shallow with greater than 50% of the biomass in the top 18 cm (7 in) of soil. The main roots are 1 mm thick and branch profusely with numerous lateral roots. The lateral spread extends 36 cm (14 in) outward from the crown. Several main roots descend down to 91 cm (3 ft) deep with a few main roots extending to 1.8 m (5 ft) deep. Regeneration is primarily asexual propagation by crown tillers. Seedling success is low as a result of poor gemination and competition from established plants. Flower stalks are erect, 30-60 cm(12-24 in) tall. Inflorescence is a narrow panicle with several loosely spreading ascending branches, each with several one flowered spikelets. Flowers are rarely observable because of the prevalence of self fertilization (cleistogamy) within the closed sheath. Floret has a hard sharp pointed base and tip with a 10-13 cm (4-5 in) long awn that curls as it dries, twisting the seed into the soil. Flower period is late May to late June. The sharp pointed seed with a long awn can cause problems for livestock in hay, however, they rarely cause problems for grazing livestock. Leaves are highly palatable to livestock. Fire top kills aerial parts and fire can consume the entire crown when the soil is dry. Fire halts the processes of the four major defoliation resistance mechanisms and causes great reductions in biomass and tiller density. This summary information on growth development and regeneration of Needle and thread was based on works of Stevens 1963, Zaczkowski 1972, Dodds 1979, Great Plains Flora Association 1986, Zlatnik 1999, Ogle et al. 2006, Larson and Johnson 2007, and Stubbendieck et al. 2011.

During the seven years of this study, the number of needle and thread tillers measured was 16,098 with 4673 tillers on sandy soils, 4646 tillers on shallow soils, 5164 tillers on silty soils, and 1615 tillers on clay soils (tables 6, 7, 8, and 9). The collection protocol required measurement on all available flower stalks and ten vegetative tillers on each sample site each collection period, amounting to 360 tillers per year on the twice-over treatment and 120 tillers per year on the seasonlong and nongrazed treatments. During the 3 growing seasons with low precipitation amounts, less than ten tillers were measured each collection period. The reductions in sample numbers would indicate the degree of negative affect from reduced precipitation. This affect is designated as collection efficiency on tables 6, 7, 8, and 9.

Table 6. Number of tillers measured from management treatments on sandy soils.

Tiller Type	Twice-over 1983-1986		Twice-over 1987-1989		Seasonlong 1987-1989	Nongrazed 1987-1989
	Ungrazed	Grazed	Ungrazed	Grazed	Grazed	Ungrazed
Flower Stalk	348	187	82	98	44	45
Vegetative	420	439	222	185	58	57
Secondary	740	626	426	358	174	164
Subtotal	1508	1252	730	641	276	266
Total	2760		1371			
Sum total				4673		
Collection Efficiency	105%	87%	68%	59%	38%	74%

Table 7. Number of tillers measured from management treatments on shallow soils.

Tiller Type	Twice-over 1983-1986		Twice-over 1987-1989		Seasonlong 1987-1989	Nongrazed 1987-1989
	Ungrazed	Grazed	Ungrazed	Grazed	Grazed	Ungrazed
Flower Stalk	361	198	89	111	41	48
Vegetative	392	471	245	157	73	90
Secondary	751	551	408	395	163	102
Subtotal	1504	1220	742	663	277	240
Total	2724		1405			
Sum total				4646		
Collection Efficiency	104%	85%	69%	61%	38%	74%

Table 8. Number of tillers measured from management treatments on silty soils.

Tiller Type	Twice-over 1983-1986		Twice-over 1987-1989		Seasonlong 1987-1989	Nongrazed 1987-1989
	Ungrazed	Grazed	Ungrazed	Grazed	Grazed	Ungrazed
Flower Stalk	356	197	110	103	78	47
Vegetative	594	450	236	135	80	101
Secondary	795	602	413	415	336	116
Subtotal	1745	1249	759	653	494	264
Total	2994		1412			
Sum total				5164		
Collection Efficiency	121%	87%	70%	60%	69%	73%

Table 9. Number of tillers measured from management treatments on clay soils.

Tiller Type	Twice-over 1983-1986		Twice-over 1987-1989		Seasonlong 1987-1989		Nongrazed 1987-1989
	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed
Flower Stalk	231	103					
Vegetative	212	235					
Secondary	486	348					
Subtotal	929	686					
Total	1615						
Sum total							
Collection Efficiency	65%	48%					

Reproductive Lead Tillers

The second year reproductive lead tillers had the fastest rate of growth and development until mid to late July with production of 3.5 new leaves by late May. Reproductive lead tillers reach the boot stage (FSD) during late May to late June. Flower stalk development occurred very rapidly with the lead tillers progressing through head emergence (HE) during early to late June and reaching the flower stage during the 4 week period of early to late June. Needle and thread can be cleistogamous (self-fertilizing) rarely exposing the anthesis and stigmas. No new leaves were produced after the anthesis stage. Seeds developed (SD) through the milk and dough stages during mid June to early July with most seeds reaching maturity (SBS) during mid July, and some seeds are held through late summer (table 10). The apical meristem of reproductive lead tillers can no longer produce leaf buds after it had produced flower buds and these tillers were terminated at the end of the growing season.

Growth and development data of needle and thread reproductive lead tillers on sandy soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 are on table 11.

Reproductive lead tillers with 2 to 7 basal leaves on the twice-over strategy during 1983 to 1986 composed 14.9% of the total population with 187 tillers (table 6) that had a mean flower stalk height of 33.8 cm, during the growing season a mean of 19.9% leaves were photosynthetically active with a mean basal leaf height of 23.4 cm and the tallest leaf averaged 27.4 cm tall (table 11).

Reproductive lead tillers with 2 to 7 basal leaves on the ungrazed treatment during 1983 to 1986 composed 23.1% of the total population with 348 tillers (table 6) that had a mean flower stalk height of 38.6 cm, during the growing season a mean of 18.7% leaves were photosynthetically active with a mean basal leaf height of 23.4 cm and the tallest leaf averaged 27.8 cm tall (table 11).

Growth and development data of needle and thread reproductive lead tillers on shallow soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 are on table 12.

Reproductive lead tillers with 2 to 7 basal leaves on the twice-over strategy during 1983 to 1986 composed 16.2% the total population with 198 tillers (table 7) that had a mean flower stalk height of 25.9 cm, during the growing season a mean of 19.9% leaves were photosynthetically active with a mean basal leaf height of 23.8 cm and the tallest leaf averaged 36.2 cm tall (table 12).

Reproductive lead tillers with 2 to 7 basal leaves on the ungrazed treatment during 1983 to 1986 composed 24.0% the total population with 361 tillers (table 7) that had a mean flower stalk height of 32.0 cm, during the growing season a mean of 19.8% leaves were photosynthetically active with a mean basal leaf height of 27.4 cm and the tallest leaf averaged 39.2 cm tall (table 12).

Growth and development data of needle and thread reproductive lead tillers on silty soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 are on table 13.

Reproductive lead tillers with 2 to 7 basal leaves on the twice-over strategy during 1983 to 1986 composed 15.8% of the total population with 197 tillers (table 8) that had a mean flower stalk height of 30.7 cm, during the growing season a mean of 22.6% leaves were photosynthetically active with a mean basal leaf height of 26.5 cm and the tallest leaf averaged 35.8 cm tall (table 13).

Reproductive lead tillers with 2 to 7 basal leaves on the ungrazed treatment during 1983 to 1986 composed 20.4% of the total population with 356 tillers (table 8) that had a mean flower stalk height of 37.5 cm, during the growing season a mean of 20.9% leaves were photosynthetically active with a mean basal leaf height of 22.5 cm and the tallest leaf averaged 27.4 cm tall (table 13).

Growth and development data of needle and thread reproductive lead tillers on clay soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 are on table 14.

Reproductive lead tillers with 2 to 7 basal leaves on the twice-over strategy during 1983 to 1986 composed 15.0% of the total population with 103 tillers (table 9) that had a mean flower stalk height of 28.6 cm, during the growing season a mean of 20.6% leaves were photosynthetically active with a mean basal leaf height of 19.3 cm and the tallest leaf averaged 21.5 cm tall (table 14).

Reproductive lead tillers with 2 to 7 basal leaves on the ungrazed treatment during 1983 to 1986 composed 24.9% of the total population with 231 tillers (table 9) that had a mean flower stalk height of

35.2 cm, during the growing season a mean of 24.2% leaves were photosynthetically active with a mean basal leaf height of 20.0 cm and the tallest leaf averaged 27.8 cm tall (table 14).

Growth and development data of needle and thread reproductive lead tillers on sandy soils managed with the twice-over strategy and the ungrazed treatment and the seasonlong and nongrazed treatments during 1987 to 1989 are on table 15.

Reproductive lead tillers with 2 to 7 basal leaves on the twice-over strategy during 1987 to 1989 composed 15.3% of the total population with 98 tillers (table 6) that had a mean flower stalk height of 29.3 cm, during the growing season a mean of 25.6% leaves were photosynthetically active with a mean basal leaf height of 19.0 cm and the tallest leaf averaged 22.4 cm tall (table 15).

Reproductive lead tillers with 2 to 7 basal leaves on the ungrazed treatment during 1987 to 1989 composed 11.2% of the total population with 82 tillers (table 6) that had a mean flower stalk height of 33.8 cm, during the growing season a mean of 23.1% leaves were photosynthetically active with a mean basal leaf height of 20.8 cm and the tallest leaf averaged 22.8 cm tall (table 15).

Reproductive lead tillers with 2 to 7 basal leaves on the seasonlong treatment during 1987 to 1989 composed 15.9% of the total population with 44 tillers (table 6) that had a mean flower stalk height of 33.2 cm, during the growing season a mean of 15.1% leaves were photosynthetically active with a mean basal leaf height of 21.5 cm and the tallest leaf averaged 24.4 cm tall (table 15).

Reproductive lead tillers with 2 to 7 basal leaves on the nongrazed treatment during 1987 to 1989 composed 16.9% of the total population with 45 tillers (table 6) that had a mean flower stalk height of 38.2 cm, during the growing season a mean of 15.4% leaves were photosynthetically active with a mean basal leaf height of 31.1 cm and the tallest leaf averaged 33.6 cm tall (table 15).

Growth and development data of needle and thread reproductive lead tillers on shallow soils managed with the twice-over strategy and the ungrazed treatment and the seasonlong and nongrazed treatments during 1987 to 1989 are on table 16.

Reproductive lead tillers with 2 to 7 basal leaves on the twice-over strategy during 1987 to 1989 composed 16.7% of the total population with 111 tillers (table 7) that had a mean flower stalk height of 27.7 cm, during the growing season a mean of 19.7% leaves were photosynthetically active with a mean basal leaf height of 21.2 cm and the tallest leaf averaged 23.6 cm tall (table 16).

Reproductive lead tillers with 2 to 7 basal leaves on the ungrazed treatment during 1987 to 1989 composed 12.0% of the total population with 89 tillers (table 7) that had a mean flower stalk height of 30.2 cm, during the growing season a mean of 19.3% leaves were photosynthetically active with a mean basal leaf height of 16.8 cm and the tallest leaf averaged 20.4 cm tall (table 16).

Reproductive lead tillers with 2 to 7 basal leaves on the seasonlong treatment during 1987 to 1989 composed 14.8% of the total population with 41 tillers (table 7) that had a mean flower stalk height of 27.9 cm, during the growing season a mean of 18.7% leaves were photosynthetically active with a mean basal leaf height of 19.3 cm and the tallest leaf averaged 21.8 cm tall (table 16).

Reproductive lead tillers with 2 to 7 basal leaves on the nongrazed treatment during 1987 to 1989 composed 20.0% of the total population with 48 tillers (table 7) that had a mean flower stalk height of 33.5 cm, during the growing season a mean of 12.7% leaves were photosynthetically active with a mean basal leaf height of 23.7 cm and the tallest leaf averaged 26.0 cm tall (table 16).

Growth and development data of needle and thread reproductive lead tillers on silty soils managed with the twice-over strategy and the ungrazed treatment and the seasonlong and nongrazed treatments during 1987 to 1989 are on table 17.

Reproductive lead tillers with 2 to 7 basal leaves on the twice-over strategy during 1987 to 1989 composed 15.8% of the total population with 103 tillers (table 8) that had a mean flower stalk height of 32.0 cm, during the growing season a mean of 27.2% leaves were photosynthetically active with a mean basal leaf height of 25.9 cm and the tallest leaf averaged 30.5 cm tall (table 17).

Reproductive lead tillers with 2 to 7 basal leaves on the ungrazed treatment during 1987 to 1989 composed 14.5% of the total population with 110 tillers (table 8) that had a mean flower stalk height of 34.7 cm, during the growing season a mean of 25.9% leaves were photosynthetically active with a mean basal leaf height of 20.6 cm and the tallest leaf averaged 23.2 cm tall (table 17).

Reproductive lead tillers with 2 to 7 basal leaves on the seasonlong treatment during 1987 to 1989 composed 15.8% of the total population with 78 tillers (table 8) that had a mean flower stalk height of 29.0 cm, during the growing season a mean of 18.1% leaves were photosynthetically active with a mean basal leaf height of 18.7 cm and the tallest leaf averaged 20.5 cm tall (table 17).

Reproductive lead tillers with 2 to 7 basal leaves on the nongrazed treatment during 1987 to 1989 composed 17.8% of the total population with 47 tillers (table 8) that had a mean flower stalk height of 35.4 cm, during the growing season a mean of 11.6% leaves were photosynthetically active with a mean basal leaf height of 19.4 cm and the tallest leaf averaged 22.4 cm tall (table 17).

All of the reproductive lead tillers measured during this study were not grazed including the tillers located on grazed treatments. The not grazed tillers remaining on the grazed treatments tended to have slightly shorter mean flower stalk heights, mean basal leaf heights, and mean tallest leaf heights which were not significantly different than the not grazed tillers on the ungrazed treatments on the sandy, shallow, silty, and clay soils during the 1983-1986 period. The mean flower stalk heights were slightly lower on the grazed treatments than on the ungrazed treatments on the sandy, shallow, and silty soils during the 1987-1989 period. It is not believed that grazed treatments cause reproductive lead tillers to produce slightly shorter flower stalk and basal leaf heights. It is surmised that grazing cattle have a disproportional rate of selection for taller tillers than for shorter tillers leaving a distorted sample population of not grazed tillers with slightly shorter leaf heights.

Leaves grow and senesce in about the same order of their appearance. This study has designated that leaves with less than 50% senescent tissue to be photosynthetically active. Tillers growing on the twice-over treatment tended to have similar low quantity of photosynthetically active leaves (20.8%) as the tillers growing on the ungrazed treatment (20.9%). Flower stalk basal leaves senesce rapidly following the anthesis stage.

Reproductive lead tillers composed a relatively low percentage of the total measured tiller population. Reproductive lead tillers located on the twice-over treatment composed 15.5% (685 tillers) and 15.9% (312 tillers) and the reproductive tillers located on the ungrazed treatment composed 22.8% (1296 tillers) and 12.6% (281 tillers) of the total tiller population during the 1983-1986 period and the 1987-1989 period, respectively. Reproductive lead tillers located on the seasonlong and nongrazed treatments composed 15.6% (163 tillers) and 18.2% (140 tillers) of the total population during the 1987-1989 period, respectively.

Table 10. Phenological stages of flower stalk development for needle and thread, 1983-1986.

6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
FSD	FSD				
HE	HE				
Ant	Ant				
	SD	SD			
			SBS	SBS	SBS

FSD	flower stalk developing
HE	head emergence
Ant	anthesis (flowering)
SD	seeds developing
SBS	seeds being shed

Table 11. Growth and development of needle and thread reproductive lead tillers on sandy soils managed with twice-over grazing and ungrazed treatments, 1983-1986.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
Stalk Height cm	28.6	36.6	35.2	34.1	35.7	32.7
% Active Leaf	66.7	44.7	5.6	2.2	0.0	0.0
Leaf Height cm	20.8	25.3	35.1	12.3	-	-
Tallest Leaf cm	28.8	33.3	35.1	12.3	-	-
Ungrazed 1983-1986						
Stalk Height cm	25.3	33.3	41.7	42.6	43.6	45.0
% Active Leaf	64.0	47.9	0.0	0.0	0.0	0.0
Leaf Height cm	20.9	25.8	-	-	-	-
Tallest Leaf cm	30.1	35.5	-	-	-	-

Table 12. Growth and development of needle and thread reproductive lead tillers on shallow soils managed with twice-over grazing and ungrazed treatments, 1983-1986.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
Stalk Height cm	26.0	23.1	28.8	26.1	26.5	24.6
% Active Leaf	66.7	44.4	8.0	0.0	0.0	0.0
Leaf Height cm	16.8	21.3	33.4	-	-	-
Tallest Leaf cm	23.8	26.2	58.5	-	-	-
Ungrazed 1983-1986						
Stalk Height cm	28.4	26.0	26.7	40.6	30.3	40.0
% Active Leaf	55.6	54.9	0.0	8.3	0.0	0.0
Leaf Height cm	18.6	22.7	-	40.9	-	-
Tallest Leaf cm	24.8	29.8	-	62.9	-	-

Table 13. Growth and development of needle and thread reproductive lead tillers on silty soils managed with twice-over grazing and ungrazed treatments, 1983-1986.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
Stalk Height cm	24.2	22.3	38.2	35.6	31.8	32.3
% Active Leaf	72.2	52.5	11.1	0.0	0.0	0.0
Leaf Height cm	18.0	18.9	42.6	-	-	-
Tallest Leaf cm	27.7	25.5	54.1	-	-	-
Ungrazed 1983-1986						
Stalk Height cm	22.2	37.3	43.2	42.4	38.2	41.9
% Active Leaf	61.1	51.2	11.1	2.2	0.0	0.0
Leaf Height cm	19.9	28.6	15.0	26.3	-	-
Tallest Leaf cm	28.1	37.5	17.6	26.3	-	-

Table 14. Growth and development of needle and thread reproductive lead tillers on clay soils managed with twice-over grazing and ungrazed treatments, 1983-1986.

Clay	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
Stalk Height cm	21.1	22.9	34.2	30.5	29.8	33.2
% Active Leaf	64.3	50.0	5.6	3.7	0.0	0.0
Leaf Height cm	13.9	20.2	29.1	14.0	-	-
Tallest Leaf cm	17.2	25.5	29.1	14.0	-	-
Ungrazed 1983-1986						
Stalk Height cm	30.6	26.8	31.1	38.5	43.9	40.0
% Active Leaf	61.5	55.8	28.0	0.0	0.0	0.0
Leaf Height cm	16.6	21.7	21.8	-	-	-
Tallest Leaf cm	25.4	28.6	29.3	-	-	-

Table 15. Growth and development of needle and thread reproductive lead tillers on sandy soils managed with twice-over grazing and ungrazed treatments and the seasonlong and nongrazed treatments, 1987-1989.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1987-1989						
Stalk Height cm	30.6	24.2	44.8	17.9	37.0	21.1
% Active Leaf	65.0	28.6	60.0	0.0	0.0	0.0
Leaf Height cm	19.7	19.6	17.8	-	-	-
Tallest Leaf cm	26.5	20.2	20.6	-	-	-
Ungrazed 1987-1989						
Stalk Height cm	30.6	24.5	46.2	28.7	46.5	26.3
% Active Leaf	65.0	8.3	60.0	5.0	0.0	0.0
Leaf Height cm	19.7	21.4	21.6	20.6	-	-
Tallest Leaf cm	26.5	21.4	22.7	20.6	-	-
Seasonlong 1987-1989						
Stalk Height cm	32.3	26.4	42.2	24.3	48.1	25.6
% Active Leaf	50.0	24.0	16.7	0.0	0.0	0.0
Leaf Height cm	23.5	22.0	19.0	-	-	-
Tallest Leaf cm	30.3	24.0	19.0	-	-	-
Nongrazed 1987-1989						
Stalk Height cm	32.3	28.4	63.2	28.6	46.6	29.9
% Active Leaf	50.0	33.3	0.0	9.1	0.0	0.0
Leaf Height cm	25.9	22.9	-	44.5	-	-
Tallest Leaf cm	30.2	26.0	-	44.5	-	-

Table 16. Growth and development of needle and thread reproductive lead tillers on shallow soils managed with twice-over grazing and ungrazed treatments and the seasonlong and nongrazed treatments, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1987-1989						
Stalk Height cm	25.8	19.6	44.7	20.0	37.6	18.6
% Active Leaf	55.6	7.1	55.6	0.0	0.0	0.0
Leaf Height cm	15.7	32.3	15.5	-	-	-
Tallest Leaf cm	20.6	32.3	18.0	-	-	-
Ungrazed 1987-1989						
Stalk Height cm	25.8	22.5	45.1	27.4	42.1	18.3
% Active Leaf	55.6	0.0	60.0	0.0	0.0	0.0
Leaf Height cm	15.7	-	17.9	-	-	-
Tallest Leaf cm	20.6	-	20.2	-	-	-
Seasonlong 1987-1989						
Stalk Height cm	29.0	25.6	39.3	21.5	31.7	20.3
% Active Leaf	42.9	9.1	60.0	0.0	0.0	0.0
Leaf Height cm	17.5	19.1	21.2	-	-	-
Tallest Leaf cm	21.2	19.1	25.1	-	-	-
Nongrazed 1987-1989						
Stalk Height cm	24.1	42.5	52.9	17.8	37.7	26.2
% Active Leaf	65.0	11.1	0.0	0.0	0.0	0.0
Leaf Height cm	19.1	28.3	-	-	-	-
Tallest Leaf cm	21.6	30.3	-	-	-	-

Table 17. Growth and development of needle and thread reproductive lead tillers on silty soils managed with twice-over grazing and ungrazed treatments and the seasonlong and nongrazed treatments, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1987-1989						
Stalk Height cm	31.4	29.2	48.6	20.7	40.9	21.3
% Active Leaf	70.0	20.0	40.0	0.0	33.3	0.0
Leaf Height cm	19.0	29.6	23.5	-	31.6	-
Tallest Leaf cm	26.4	33.7	30.3	-	31.6	-
Ungrazed 1987-1989						
Stalk Height cm	31.4	24.7	53.0	26.0	44.7	28.3
% Active Leaf	70.0	8.3	40.0	15.0	0.0	22.2
Leaf Height cm	19.0	23.1	25.4	16.9	-	18.8
Tallest Leaf cm	26.4	23.1	28.3	18.2	-	20.2
Seasonlong 1987-1989						
Stalk Height cm	27.6	24.7	40.1	24.3	35.7	21.8
% Active Leaf	50.0	28.6	30.0	0.0	0.0	0.0
Leaf Height cm	16.9	20.1	19.2	-	-	-
Tallest Leaf cm	19.6	21.9	19.9	-	-	-
Nongrazed 1987-1989						
Stalk Height cm	28.7	27.9	53.7	22.2	42.2	37.7
% Active Leaf	61.1	8.3	0.0	0.0	0.0	0.0
Leaf Height cm	21.7	17.0	-	-	-	-
Tallest Leaf cm	21.7	17.0	-	-	-	-

Vegetative Tillers

The vegetative tillers had the second fastest rate of growth and development continuing until mid to late July. Early new leaf development for vegetative tillers arise from fall tillers produced from crown tiller buds during August of the previous growing season. The rate of growth greatly increased during early or mid May resulting in tillers with 3.5 leaves during late May. During mid to late July the rate of growth decreased resulting in tillers with 5 to 7 basal leaves. A few of the vegetative tillers with 5 to 7 basal leaves added leaves 8 and 9 during July and August (figure 1).

Growth and development data of needle and thread vegetative tillers on sandy soils managed with the twice-over strategy during 1983 to 1986 are on table 18.

Vegetative tillers with 5 leaves composed 79.3% of the population with 348 tillers, during the growing season a mean of 2.7 leaves (53.3%) were photosynthetically active with a mean leaf height of 13.3 cm and the tallest leaf averaged 17.1 cm tall (table 18).

Vegetative tillers with 6 leaves composed 16.2% of the population with 71 tillers, during the growing season a mean of 2.7 leaves (45.8%) were photosynthetically active with a mean leaf height of 15.2 cm and the tallest leaf averaged 20.3 cm tall (table 18).

Vegetative tillers with 7 leaves composed 4.3% of the population with 19 tillers, during the growing season a mean of 2.5 leaves (35.7%) were photosynthetically active with a mean leaf height of 15.0 cm and the tallest leaf averaged 20.8 cm tall (table 18).

Vegetative tillers with 8 leaves composed 0.2% of the population with 1 tiller, during the growing season a mean of 1.0 leaves (12.5%) were photosynthetically active with a mean leaf height of 15.5 cm and the tallest leaf averaged 16.5 cm tall (table 18).

Vegetative tillers with 9 leaves composed 0.0% of the population with 0 tillers (table 18).

Growth and development data of needle and thread vegetative tillers on sandy soils managed with the ungrazed treatment during 1983 to 1986 are on table 19.

Vegetative tillers with 5 leaves composed 83.8% of the population with 352 tillers, during the growing season a mean of 2.3 leaves (45.0%) were photosynthetically active with a mean leaf height of 16.0 cm and the tallest leaf averaged 20.6 cm tall (table 19).

Vegetative tillers with 6 leaves composed 15.2% of the population with 64 tillers, during the growing season a mean of 2.4 leaves (40.3%) were photosynthetically active with a mean leaf height of 16.8 cm and the tallest leaf averaged 22.1 cm tall (table 19).

Vegetative tillers with 7 leaves composed 0.7% of the population with 3 tillers, during the growing season a mean of 2.2 leaves (31.0%) were photosynthetically active with a mean leaf height of 15.4 cm and the tallest leaf averaged 22.1 cm tall (table 19).

Vegetative tillers with 8 leaves composed 0.0% of the population with 0 tillers (table 19).

Vegetative tillers with 9 leaves composed 0.2% of the population with 1 tiller, during the growing season a mean of 0.5 leaves (5.6%) were photosynthetically active with a mean leaf height of 13.2 cm and the tallest leaf averaged 20.5 cm tall (table 19).

Growth and development data of needle and thread vegetative tillers on shallow soils managed with the twice-over strategy during 1983 to 1986 are on table 20.

Vegetative tillers with 5 leaves composed 68.6% of the population with 323 tillers, during the growing season a mean of 2.4 leaves (48.3%) were photosynthetically active with a mean leaf height of 10.9 cm and the tallest leaf averaged 13.1 cm tall (table 20).

Vegetative tillers with 6 leaves composed 26.5% of the population with 125 tillers, during the growing season a mean of 2.8 leaves (45.9%) were photosynthetically active with a mean leaf height of 11.5 cm and the tallest leaf averaged 15.4 cm tall (table 20).

Vegetative tillers with 7 leaves composed 4.9% of the population with 23 tillers, during the growing season a mean of 2.4 leaves (33.9%) were photosynthetically active with a mean leaf height of 13.7 cm and the tallest leaf averaged 18.6 cm tall (table 20).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 20).

Growth and development data of needle and thread vegetative tillers on shallow soils managed with the ungrazed treatment during 1983 to 1986 are on table 21.

Vegetative tillers with 5 leaves composed 86.7% of the population with 340 tillers, during the growing season a mean of 2.6 leaves (51.7%) were photosynthetically active with a mean leaf height of 12.5 cm and the tallest leaf averaged 16.3 cm tall (table 21).

Vegetative tillers with 6 leaves composed 12.0% of the population with 47 tillers, during the growing season a mean of 2.7 leaves (45.8%) were photosynthetically active with a mean leaf height of 12.3 cm and the tallest leaf averaged 16.0 cm tall (table 21).

Vegetative tillers with 7 leaves composed 1.3% of the population with 5 tillers, during the growing season a mean of 2.3 leaves (33.3%) were photosynthetically active with a mean leaf height of 10.5 cm and the tallest leaf averaged 15.8 cm tall (table 21).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 21).

Growth and development data of needle and thread vegetative tillers on silty soils managed with the twice-over strategy during 1983 to 1986 are on table 22.

Vegetative tillers with 5 leaves composed 77.8% of the population with 350 tillers, during the growing season a mean of 2.8 leaves (55.0%) were photosynthetically active with a mean leaf height of 12.1 cm and the tallest leaf averaged 15.2 cm tall (table 22).

Vegetative tillers with 6 leaves composed 20.0% of the population with 90 tillers, during the growing season a mean of 3.2 leaves (52.8%) were photosynthetically active with a mean leaf height of 12.1 cm and the tallest leaf averaged 16.3 cm tall (table 22).

Vegetative tillers with 7 leaves composed 2.0% of the population with 9 tillers, during the growing season a mean of 1.5 leaves (21.4%) were photosynthetically active with a mean leaf height of 13.7 cm and the tallest leaf averaged 15.9 cm tall (table 22).

Vegetative tillers with 8 leaves composed 0.2% of the population with 1 tiller, during the growing season a mean of 1.5 leaves (18.8%) were photosynthetically active with a mean leaf height of 12.7 cm and the tallest leaf averaged 16.0 cm tall (table 22).

Vegetative tillers with 9 leaves composed 0.0% of the population with 0 tillers (table 22).

Growth and development data of needle and thread vegetative tillers on silty soils managed with the ungrazed treatment during 1983 to 1986 are on table 23.

Vegetative tillers with 5 leaves composed 81.1% of the population with 482 tillers, during the growing season a mean of 2.6 leaves (51.7%) were photosynthetically active with a mean leaf height of 15.1 cm and the tallest leaf averaged 19.0 cm tall (table 23).

Vegetative tillers with 6 leaves composed 16.5% of the population with 98 tillers, during the growing season a mean of 3.1 leaves (51.4%) were photosynthetically active with a mean leaf height of 15.7 cm and the tallest leaf averaged 20.7 cm tall (table 23).

Vegetative tillers with 7 leaves composed 2.0% of the population with 12 tillers, during the growing season a mean of 1.6 leaves (23.2%) were photosynthetically active with a mean leaf height of 18.8 cm and the tallest leaf averaged 23.0 cm tall (table 23).

Vegetative tillers with 8 leaves composed 0.2% of the population with 1 tiller, during the growing season a mean of 1.0 leaves (12.5%) were photosynthetically active with a mean leaf height of 15.4 cm and the tallest leaf averaged 17.9 cm tall (table 23).

Vegetative tillers with 9 leaves composed 0.2% of the population with 1 tiller, during the growing season a mean of 2.5 leaves (27.8%) were photosynthetically active with a mean leaf height of 14.3 cm and the tallest leaf averaged 20.5 cm tall (table 23).

Growth and development data of needle and thread vegetative tillers on clay soils managed with

the twice-over strategy during 1983 to 1986 are on table 24.

Vegetative tillers with 5 leaves composed 77.9% of the population with 183 tillers, during the growing season a mean of 2.6 leaves (51.7%) were photosynthetically active with a mean leaf height of 12.3 cm and the tallest leaf averaged 15.1 cm tall (table 24).

Vegetative tillers with 6 leaves composed 20.9% of the population with 49 tillers, during the growing season a mean of 3.1 leaves (51.4%) were photosynthetically active with a mean leaf height of 12.9 cm and the tallest leaf averaged 17.0 cm tall (table 24).

Vegetative tillers with 7 leaves composed 1.3% of the population with 3 tillers, during the growing season a mean of 1.5 leaves (21.4%) were photosynthetically active with a mean leaf height of 9.4 cm and the tallest leaf averaged 12.5 cm tall (table 24).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 24).

Growth and development data of needle and thread vegetative tillers on clay soils managed with the ungrazed treatment during 1983 to 1986 are on table 25.

Vegetative tillers with 5 leaves composed 83.0% of the population with 176 tillers, during the growing season a mean of 2.5 leaves (50.0%) were photosynthetically active with a mean leaf height of 13.1 cm and the tallest leaf averaged 16.1 cm tall (table 25).

Vegetative tillers with 6 leaves composed 13.2% of the population with 28 tillers, during the growing season a mean of 2.7 leaves (45.0%) were photosynthetically active with a mean leaf height of 14.2 cm and the tallest leaf averaged 17.5 cm tall (table 25).

Vegetative tillers with 7 leaves composed 3.3% of the population with 7 tillers, during the growing season a mean of 1.5 leaves (21.4%) were photosynthetically active with a mean leaf height of 8.6 cm and the tallest leaf averaged 11.0 cm tall (table 25).

Vegetative tillers with 8 leaves composed 0.5% of the population with 1 tiller, during the growing season a mean of 2.0 leaves (25.0%) were photosynthetically active with a mean leaf height of 10.7 cm and the tallest leaf averaged 12.4 cm tall (table 25).

Vegetative tillers with 9 leaves composed 0.0% of the population with 0 tillers (table 25).

Growth and development data of needle and thread vegetative tillers on sandy soils managed with the twice-over strategy during 1987 to 1989 are on table 26.

Vegetative tillers with 5 leaves composed 82.7% of the population with 153 tillers, during the growing season a mean of 3.3 leaves (66.7%) were photosynthetically active with a mean leaf height of 11.8 cm and the tallest leaf averaged 14.6 cm tall (table 26).

Vegetative tillers with 6 leaves composed 13.5% of the population with 25 tillers, during the growing season a mean of 3.3 leaves (54.2%) were photosynthetically active with a mean leaf height of 14.9 cm and the tallest leaf averaged 18.7 cm tall (table 26).

Vegetative tillers with 7 leaves composed 3.2% of the population with 6 tillers, during the growing season a mean of 3.5 leaves (50.0%) were photosynthetically active with a mean leaf height of 9.2 cm and the tallest leaf averaged 11.1 cm tall (table 26).

Vegetative tillers with 8 leaves composed 0.5% of the population with 1 tiller, during the growing season a mean of 3.0 leaves (37.5%) were photosynthetically active with a mean leaf height of 14.5 cm and the tallest leaf averaged 21.4 cm tall (table 26).

Vegetative tillers with 9 leaves composed 0.0% of the population with 0 tillers (table 26).

Growth and development data of needle and thread vegetative tillers on sandy soils managed with the ungrazed treatment during 1987 to 1989 are on table 27.

Vegetative tillers with 5 leaves composed 80.2% of the population with 178 tillers, during the growing season a mean of 3.0 leaves (60.0%) were photosynthetically active with a mean leaf height of 15.1 cm and the tallest leaf averaged 20.2 cm tall (table 27).

Vegetative tillers with 6 leaves composed 16.2% of the population with 36 tillers, during the growing season a mean of 2.5 leaves (41.7%) were photosynthetically active with a mean leaf height of 13.8 cm and the tallest leaf averaged 17.5 cm tall (table 27).

Vegetative tillers with 7 leaves composed 3.6% of the population with 8 tillers, during the growing season a mean of 4.5 leaves (64.3%) were photosynthetically active with a mean leaf height of 14.2 cm and the tallest leaf averaged 22.7 cm tall (table 27).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 27).

Growth and development data of needle and thread vegetative tillers on sandy soils managed with the traditional seasonlong practice during 1987 to 1989 are on table 28.

Vegetative tillers with 5 leaves composed 86.2% of the population with 50 tillers, during the growing season a mean of 2.8 leaves (56.7%) were photosynthetically active with a mean leaf height of 13.6 cm and the tallest leaf averaged 17.0 cm tall (table 28).

Vegetative tillers with 6 leaves composed 12.1% of the population with 7 tillers, during the growing season a mean of 4.0 leaves (66.7%) were photosynthetically active with a mean leaf height of 10.3 cm and the tallest leaf averaged 15.9 cm tall (table 28).

Vegetative tillers with 7 leaves composed 1.7% of the population with 1 tiller, during the growing season a mean of 4.0 leaves (57.1%) were photosynthetically active with a mean leaf height of 13.8 cm and the tallest leaf averaged 21.3 cm tall (table 28).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 28).

Growth and development data of needle and thread vegetative tillers on sandy soils managed with the long-term nongrazed treatment during 1987 to 1989 are on table 29.

Vegetative tillers with 5 leaves composed 94.7% of the population with 54 tillers, during the growing season a mean of 3.2 leaves (64.0%) were photosynthetically active with a mean leaf height of 16.7 cm and the tallest leaf averaged 22.3 cm tall (table 29).

Vegetative tillers with 6 leaves composed 5.3% of the population with 3 tillers, during the growing season a mean of 4.0 leaves (66.7%) were photosynthetically active with a mean leaf height of 18.2 cm and the tallest leaf averaged 29.4 cm tall (table 29).

Vegetative tillers with 7, 8, and 9 leaves composed 0.0% of the population with 0 tillers (table 29).

Growth and development data of needle and thread vegetative tillers on shallow soils managed with the twice-over strategy during 1987 to 1989 are on table 30.

Vegetative tillers with 5 leaves composed 80.9% of the population with 127 tillers, during the growing season a mean of 3.3 leaves (66.7%) were photosynthetically active with a mean leaf height of 9.3 cm and the tallest leaf averaged 12.1 cm tall (table 30).

Vegetative tillers with 6 leaves composed 16.6% of the population with 26 tillers, during the growing season a mean of 3.0 leaves (50.0%) were photosynthetically active with a mean leaf height of 9.0 cm and the tallest leaf averaged 12.8 cm tall (table 30).

Vegetative tillers with 7 leaves composed 2.5% of the population with 4 tillers, during the growing season a mean of 3.5 leaves (50.0%) were photosynthetically active with a mean leaf height of 7.5 cm and the tallest leaf averaged 9.4 cm tall (table 30).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 30).

Growth and development data of needle and thread vegetative tillers on shallow soils managed with the ungrazed treatment during 1987 to 1989 are on table 31.

Vegetative tillers with 5 leaves composed 84.9% of the population with 208 tillers, during the growing season a mean of 3.0 leaves (60.0%) were photosynthetically active with a mean leaf height of 11.3 cm and the tallest leaf averaged 15.5 cm tall (table 31).

Vegetative tillers with 6 leaves composed 13.5% of the population with 33 tillers, during the growing season a mean of 3.5 leaves (58.4%) were photosynthetically active with a mean leaf height of 9.4 cm and the tallest leaf averaged 12.9 cm tall (table 31).

Vegetative tillers with 7 leaves composed 0.8% of the population with 2 tillers, during the growing season a mean of 4.5 leaves (64.3%) were photosynthetically active with a mean leaf height of 16.1 cm and the tallest leaf averaged 24.7 cm tall (table 31).

Vegetative tillers with 8 leaves composed 0.4% of the population with 1 tiller, during the growing season a mean of 5.0 leaves (62.5%) were photosynthetically active with a mean leaf height of 18.5 cm and the tallest leaf averaged 25.2 cm tall (table 31).

Vegetative tillers with 9 leaves composed 0.4% of the population with 1 tiller, during the growing season a mean of 6.0 leaves (66.7%) were photosynthetically active with a mean leaf height of 13.9 cm and the tallest leaf averaged 18.7 cm tall (table 31).

Growth and development data of needle and thread vegetative tillers on shallow soils managed with the traditional seasonlong practice during 1987 to 1989 are on table 32.

Vegetative tillers with 5 leaves composed 75.3% of the population with 55 tillers, during the growing season a mean of 2.5 leaves (50.0%) were photosynthetically active with a mean leaf height of 10.7 cm and the tallest leaf averaged 13.6 cm tall (table 32).

Vegetative tillers with 6 leaves composed 24.7% of the population with 18 tillers, during the growing season a mean of 2.5 leaves (41.7%) were photosynthetically active with a mean leaf height of 11.6 cm and the tallest leaf averaged 15.7 cm tall (table 32).

Vegetative tillers with 7, 8, and 9 leaves composed 0.0% of the population with 0 tillers (table 32).

Growth and development data of needle and thread vegetative tillers on shallow soils managed with the long-term nongrazed treatment during 1987 to 1989 are on table 33.

Vegetative tillers with 5 leaves composed 90.0% of the population with 81 tillers, during the growing season a mean of 3.0 leaves (60.0%) were photosynthetically active with a mean leaf height of 16.8 cm and the tallest leaf averaged 21.8 cm tall (table 33).

Vegetative tillers with 6 leaves composed 8.9% of the population with 8 tillers, during the growing season a mean of 2.5 leaves (41.7%) were photosynthetically active with a mean leaf height of 13.9 cm and the tallest leaf averaged 16.2 cm tall (table 33).

Vegetative tillers with 7 leaves composed 0.0% of the population with 0 tillers (table 33).

Vegetative tillers with 8 leaves composed 1.1% of the population with 1 tiller, during the growing season a mean of 2.0 leaves (25.0%) were photosynthetically active with a mean leaf height of 21.5 cm and the tallest leaf averaged 29.2 cm tall (table 33).

Vegetative tillers with 9 leaves composed 0.0% of the population with 0 tillers (table 33).

Growth and development data of needle and thread vegetative tillers on silty soils managed with the twice-over strategy during 1987 to 1989 are on table 34.

Vegetative tillers with 5 leaves composed 88.9% of the population with 120 tillers, during the growing season a mean of 3.3 leaves (66.7%) were photosynthetically active with a mean leaf height of 11.8 cm and the tallest leaf averaged 14.0 cm tall (table 34).

Vegetative tillers with 6 leaves composed 10.4% of the population with 14 tillers, during the growing season a mean of 3.3 leaves (54.2%) were photosynthetically active with a mean leaf height of 10.8 cm and the tallest leaf averaged 14.9 cm tall (table 34).

Vegetative tillers with 7 leaves composed 0.7% of the population with 1 tiller, during the growing season a mean of 4.0 leaves (57.1%) were photosynthetically active with a mean leaf height of 14.6 cm and the tallest leaf averaged 18.7 cm tall (table 34).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 34).

Growth and development data of needle and thread vegetative tillers on silty soils managed with the ungrazed treatment during 1987 to 1989 are on table 35.

Vegetative tillers with 5 leaves composed 89.0% of the population with 210 tillers, during the growing season a mean of 3.0 leaves (60.0%) were photosynthetically active with a mean leaf height of 13.8 cm and the tallest leaf averaged 17.8 cm tall (table 35).

Vegetative tillers with 6 leaves composed 10.2% of the population with 24 tillers, during the growing season a mean of 2.7 leaves (45.8%) were photosynthetically active with a mean leaf height of 15.2 cm and the tallest leaf averaged 18.7 cm tall (table 35).

Vegetative tillers with 7 leaves composed 0.8% of the population with 2 tillers, during the growing season a mean of 4.0 leaves (57.1%) were photosynthetically active with a mean leaf height of 15.6 cm and the tallest leaf averaged 22.3 cm tall (table 35).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 35).

Growth and development data of needle and thread vegetative tillers on silty soils managed with the traditional seasonlong practice during 1987 to 1989 are on table 36.

Vegetative tillers with 5 leaves composed 93.8% of the population with 75 tillers, during the growing season a mean of 2.6 leaves (52.5%) were photosynthetically active with a mean leaf height of 10.4 cm and the tallest leaf averaged 13.0 cm tall (table 36).

Vegetative tillers with 6 leaves composed 6.3% of the population with 5 tillers, during the growing season a mean of 3.3 leaves (55.6%) were photosynthetically active with a mean leaf height of 11.6 cm and the tallest leaf averaged 17.1 cm tall (table 36).

Vegetative tillers with 7, 8, and 9 leaves composed 0.0% of the population with 0 tillers (table 36).

Growth and development data of needle and thread vegetative tillers on silty soils managed with the long-term nongrazed treatment during 1987 to 1989 are on table 37

Vegetative tillers with 5 leaves composed 73.3% the population with 74 tillers, during the growing season a mean of 3.0 leaves (60.0%) were photosynthetically active with a mean leaf height of 18.6 cm and the tallest leaf averaged 23.9 cm tall (table 37).

Vegetative tillers with 6 leaves composed 25.7% of the population with 26 tillers, during the growing season a mean of 3.7 leaves (61.1%) were photosynthetically active with a mean leaf height of 24.2 cm and the tallest leaf averaged 30.5 cm tall (table 37).

Vegetative tillers with 7 leaves composed 1.0% of the population with 1 tiller, during the growing season a mean of 4.0 leaves (57.1%) were photosynthetically active with a mean leaf height of 20.0 cm and the tallest leaf averaged 21.8 cm tall (table 37).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 37).

Not all the leaves on a grass tiller are photosynthetically active during the entire growing season. Leaves grow and senesce in the order they appear. The first leaves are usually dry by early June and the second leaves are usually dry by late June. The rate of leaf senescence can be rapid during water deficiency periods and slow during periods with adequate precipitation. During senescence, leaves translocate cell components to other plant parts. The senesced leaf has less weight and has very low nutritional quality. The greater number of leaves not senescent, the greater the tiller nutritional quality. This study has designated that leaves with less than 50% senescent tissue to be photosynthetically active.

The rate of leaf senescence of needle and thread vegetative tillers on sandy, shallow, silty and clay soils managed with the ungrazed and twice-over treatments during 1983 to 1986 that received adequate precipitation was very similar with the first and second leaves drying during June. Vegetative tillers with 5 to 7 leaves maintained 2.5 and 2.4 photosynthetically active leaves on the twice-over and ungrazed treatments through August, respectively. The tillers with 8 and 9 leaves maintained only 1.6 and 1.7 photosynthetically active leaves on the twice-over and ungrazed treatments, respectively.

The rate of leaf senescence of needle and thread vegetative tillers on sandy, shallow, and silty soils managed with the nongrazed, seasonlong, ungrazed, and twice-over treatments during 1987 to 1989 that had water deficiency during most of the growing season months was more severe than during the 1983 to 1986 period. Most tillers failed to produce leaf 8 and 9. Tillers on the nongrazed and seasonlong treatments maintained a mean of 2.6 and 2.4 photosynthetically active leaves during the growing season, respectively. Tillers on the twice-over and ungrazed treatment maintained a mean of 3.4 and 3.4 photosynthetically active leaves, respectively.

All of the vegetative tillers of needle and thread with 5 to 9 leaves measured during this study were not grazed including the tillers located on grazed treatments. The not grazed tillers remaining on the grazed treatments tended to have slightly shorter mean leaf heights and mean tallest leaf heights which were not significantly different than the not grazed tillers on the ungrazed and nongrazed treatments on the sandy, shallow, silty, and clay soils during the 1983-1986 period and on the sandy, shallow, and silty soils during the 1987-1989 period. It is not believed that grazed treatments cause vegetative tillers to produce slightly shorter leaf heights. It is surmised that grazing cattle have a disproportional rate of selection for taller tillers than for shorter tillers leaving a distorted sample population of not grazed tillers with slightly shorter leaf heights.

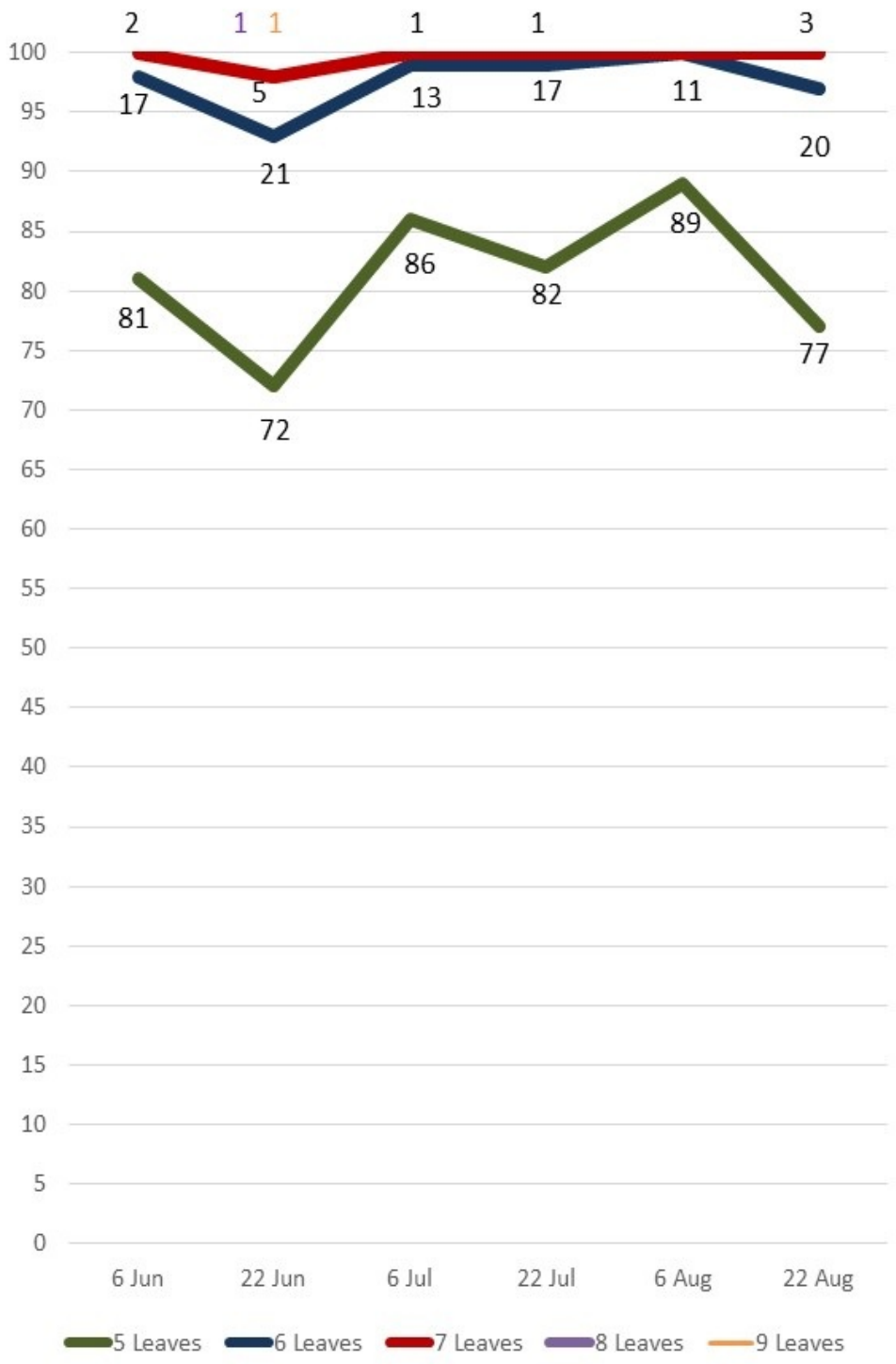

Figure 1. Percent of vegetative tiller population with 5 to 9 leaves.

Table 18. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on sandy soils managed with the twice-over strategy, 1983-1986.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	86.2	57.6	90.7	82.2	81.8	85.9
% Active Leaf	60.0	60.0	40.0	50.0	60.0	50.0
Leaf Height cm	14.4	10.9	14.0	13.6	14.4	12.4
Tallest Leaf cm	18.5	14.9	17.7	17.1	19.2	15.2
6 Leaves						
% Population	10.3	23.9	9.3	16.8	18.2	13.3
% Active Leaf	50.0	58.3	50.0	50.0	50.0	16.7
Leaf Height cm	20.3	12.4	16.1	15.4	15.1	12.1
Tallest Leaf cm	26.9	18.0	23.3	20.4	18.7	14.7
7 Leaves						
% Population	3.4	17.4	0.0	0.9	0.0	0.7
% Active Leaf	71.4	28.6	-	21.4	-	21.4
Leaf Height cm	19.2	12.0	-	20.2	-	8.7
Tallest Leaf cm	28.5	14.5	-	28.2	-	12.1
8 Leaves						
% Population	0.0	1.1	0.0	0.0	0.0	0.0
% Active Leaf	-	12.5	-	-	-	-
Leaf Height cm	-	15.5	-	-	-	-
Tallest Leaf cm	-	16.5	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	99.9	100.0	100.0	99.9	100.0	99.9

Table 19. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on sandy soils managed with the ungrazed treatment, 1983-1986.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	74.4	77.3	90.7	95..0	89.8	83.6
% Active Leaf	60.0	30.0	40.0	40.0	60.0	40.0
Leaf Height cm	17.2	15.2	15.2	16.9	15.9	15.4
Tallest Leaf cm	21.4	17.1	18.3	26.1	21.2	19.2
6 Leaves						
% Population	23.1	20.6	9.3	5.0	10.2	15.8
% Active Leaf	50.0	50.0	33.3	16.7	50.0	41.7
Leaf Height cm	18.8	17.3	17.1	11.1	24.1	12.3
Tallest Leaf cm	21.1	23.0	23.6	17.5	30.7	16.8
7 Leaves						
% Population	2.6	1.0	0.0	0.0	0.0	0.7
% Active Leaf	42.9	28.6	-	-	-	21.4
Leaf Height cm	21.3	12.7	-	-	-	12.1
Tallest Leaf cm	31.0	15.3	-	-	-	19.9
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	1.0	0.0	0.0	0.0	0.0
% Active Leaf	-	5.6	-	-	-	-
Leaf Height cm	-	13.2	-	-	-	-
Tallest Leaf cm	-	20.5	-	-	-	-
% Population	100.1	99.9	100.0	100.0	100.0	100.1

Table 20. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on shallow soils managed with the twice-over strategy, 1983-1986.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	78.9	73.8	85.7	83.2	90.6	40.9
% Active Leaf	60.0	50.0	40.0	40.0	60.0	40.0
Leaf Height cm	12.1	10.0	12.7	11.0	9.2	10.6
Tallest Leaf cm	15.0	11.6	14.3	13.1	11.6	13.0
6 Leaves						
% Population	18.4	21.4	14.3	16.0	9.4	47.7
% Active Leaf	66.7	50.0	50.0	41.7	50.0	16.7
Leaf Height cm	14.9	10.0	10.9	11.6	9.7	12.1
Tallest Leaf cm	20.1	11.8	14.7	14.4	16.2	15.0
7 Leaves						
% Population	2.6	4.8	0.0	0.8	0.0	11.4
% Active Leaf	57.1	42.9	-	21.4	-	14.3
Leaf Height cm	23.3	8.3	-	11.9	-	11.2
Tallest Leaf cm	33.2	11.9	-	17.1	-	12.0
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	99.9	100.0	100.0	100.0	100.0	100.0

Table 21. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on shallow soils managed with the ungrazed treatment, 1983-1986.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	82.1	88.9	83.0	90.6	95.1	83.8
% Active Leaf	60.0	50.0	40.0	50.0	60.0	50.0
Leaf Height cm	12.7	11.7	11.9	14.5	12.4	12.0
Tallest Leaf cm	16.7	13.5	14.1	21.7	16.2	15.4
6 Leaves						
% Population	17.9	9.9	14.9	9.4	4.9	14.1
% Active Leaf	50.0	58.3	50.0	25.0	50.0	41.7
Leaf Height cm	14.8	10.7	12.2	12.5	12.4	11.0
Tallest Leaf cm	16.0	12.7	16.8	14.8	20.4	15.3
7 Leaves						
% Population	0.0	1.2	2.1	0.0	0.0	2.1
% Active Leaf	-	28.6	57.1	-	-	14.3
Leaf Height cm	-	6.3	15.4	-	-	9.9
Tallest Leaf cm	-	12.1	19.8	-	-	15.5
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.0

Table 22. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on silty soils managed with the twice-over strategy, 1983-1986.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	78.9	65.5	83.3	75.4	97.4	80.1
% Active Leaf	60.0	50.0	60.0	50.0	60.0	50.0
Leaf Height cm	12.7	11.7	12.0	14.0	10.3	11.6
Tallest Leaf cm	15.1	14.2	17.3	17.2	12.5	14.8
6 Leaves						
% Population	21.1	31.0	16.7	22.1	2.6	17.0
% Active Leaf	50.0	58.3	50.0	50.0	50.0	58.3
Leaf Height cm	11.5	13.1	16.4	14.2	7.8	9.7
Tallest Leaf cm	13.7	18.9	20.3	17.8	12.5	14.5
7 Leaves						
% Population	0.0	2.3	0.0	2.5	0.0	2.8
% Active Leaf	-	28.6	-	21.4	-	14.3
Leaf Height cm	-	11.0	-	17.6	-	12.6
Tallest Leaf cm	-	15.2	-	19.4	-	13.0
8 Leaves						
% Population	0.0	1.1	0.0	0.0	0.0	0.0
% Active Leaf	-	18.8	-	-	-	-
Leaf Height cm	-	12.7	-	-	-	-
Tallest Leaf cm	-	16.0	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	99.9	100.0	100.0	100.0	99.9

Table 23. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on silty soils managed with the ungrazed treatment, 1983-1986.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	80.6	74.7	81.5	83.1	80.9	85.8
% Active Leaf	60.0	60.0	40.0	40.0	60..0	50.0
Leaf Height cm	12.6	13.6	16.2	17.0	17.1	14.2
Tallest Leaf cm	15.8	17.8	17.4	21.5	23.5	17.7
6 Leaves						
% Population	12.9	20.0	18.5	15.4	19.1	13.7
% Active Leaf	66.7	50.0	50.0	50.0	50.0	41.7
Leaf Height cm	13.4	16.6	17.3	16.8	16.6	13.6
Tallest Leaf cm	19.1	21.0	20.8	21.8	20.7	20.7
7 Leaves						
% Population	6.5	4.1	0.0	1.5	0.0	0.5
% Active Leaf	28.6	28.6	-	21.4	-	14.3
Leaf Height cm	19.6	13.8	-	16.1	-	25.5
Tallest Leaf cm	19.6	16.7	-	20.1	-	35.4
8 Leaves						
% Population	0.0	0.6	0.0	0.0	0.0	0.0
% Active Leaf	-	12.5	-	-	-	-
Leaf Height cm	-	15.4	-	-	-	-
Tallest Leaf cm	-	17.9	-	-	-	-
9 leaves						
% Population	0.0	0.6	0.0	0.0	0.0	0.0
% Active Leaf	-	27.8	-	-	-	-
Leaf Height cm	-	14.3	-	-	-	-
Tallest Leaf cm	-	20.5	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.0

Table 24. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on clay soils managed with the twice-over strategy, 1983-1986.

Clay	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	81.3	66.0	86.7	76.7	87.5	83.6
% Active Leaf	60.0	50.0	40.0	50.0	60.0	50.0
Leaf Height cm	14.3	9.9	13.1	14.1	10.9	11.7
Tallest Leaf cm	16.5	11.9	15.2	17.9	13.6	15.3
6 Leaves						
% Population	18.8	28.0	13.3	23.3	12.5	16.4
% Active Leaf	50.0	50.0	50.0	50.0	66.7	41.7
Leaf Height cm	11.0	10.1	14.6	16.8	10.7	14.1
Tallest Leaf cm	13.7	13.6	20.1	23.1	14.2	17.3
7 Leaves						
% Population	0.0	6.0	0.0	0.0	0.0	0.0
% Active Leaf	-	21.4	-	-	-	-
Leaf Height cm	-	9.4	-	-	-	-
Tallest Leaf cm	-	12.5	-	-	-	-
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.1	100.0	100.0	100.0	100.0	100.0

Table 25. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on clay soils managed with the ungrazed treatment, 1983-1986.

Clay	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	100.0	67.8	93.1	87.0	91.7	84.4
% Active Leaf	60.0	50.0	40.0	40.0	60.0	50.0
Leaf Height cm	14.4	11.2	14.4	12.1	14.4	11.9
Tallest Leaf cm	18.4	15.0	14.9	14.1	18.2	16.0
6 Leaves						
% Population	0.0	18.6	6.9	13.0	8.3	15.6
% Active Leaf	-	50.0	33.3	41.7	50.0	50.0
Leaf Height cm	-	14.7	11.2	13.0	18.5	13.4
Tallest Leaf cm	-	19.3	11.4	18.2	19.4	19.1
7 Leaves						
% Population	0.0	11.9	0.0	0.0	0.0	0.0
% Active Leaf	-	21.4	-	-	-	-
Leaf Height cm	-	13.7	-	-	-	-
Tallest Leaf cm	-	16.2	-	-	-	-
8 Leaves						
% Population	0.0	1.7	0.0	0.0	0.0	0.0
% Active Leaf	-	25.0	-	-	-	-
Leaf Height cm	-	10.7	-	-	-	-
Tallest Leaf cm	-	12.4	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.0

Table 26. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on sandy soils managed with the twice-over strategy, 1987-1989.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	78.1	91.7	100.0	86.4	100.0	75.4
% Active Leaf	60.0	60.0	80.0	60.0	80.0	60.0
Leaf Height cm	13.8	13.0	10.7	11.5	12.1	9.6
Tallest Leaf cm	15.8	17.4	13.1	14.3	15.6	11.1
6 Leaves						
% Population	21.9	8.3	0.0	10.2	0.0	16.9
% Active Leaf	50.0	66.7	-	50.0	-	50.0
Leaf Height cm	15.5	16.8	-	17.2	-	10.2
Tallest Leaf cm	15.9	24.6	-	22.7	-	11.6
7 Leaves						
% Population	0.0	0.0	0.0	1.7	0.0	7.7
% Active Leaf	-	-	-	57.1	-	42.9
Leaf Height cm	-	-	-	10.5	-	7.9
Tallest Leaf cm	-	-	-	13.0	-	9.1
8 Leaves						
% Population	0.0	0.0	0.0	1.7	0.0	0.0
% Active Leaf	-	-	-	37.5	-	-
Leaf Height cm	-	-	-	14.5	-	-
Tallest Leaf cm	-	-	-	21.4	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.0

Table 27. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on sandy soils managed with the ungrazed treatment, 1987-1989.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	65.3	90.0	100.0	92.5	100.0	80.3
% Active Leaf	60.0	60.0	60.0	60.0	80.0	40.0
Leaf Height cm	15.0	15.8	16.5	14.4	14.6	14.2
Tallest Leaf cm	19.1	21.2	23.5	20.9	19.1	17.7
6 Leaves						
% Population	28.0	10.0	0.0	7.5	0.0	15.2
% Active Leaf	66.7	33.3	-	33.3	-	33.3
Leaf Height cm	17.7	13.2	-	11.3	-	13.1
Tallest Leaf cm	23.8	15.5	-	11.5	-	19.3
7 Leaves						
% Population	6.7	0.0	0.0	0.0	0.0	4.5
% Active Leaf	71.4	-	-	-	-	57.1
Leaf Height cm	18.1	-	-	-	-	10.3
Tallest Leaf cm	28.5	-	-	-	-	16.8
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.0

Table 28. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on sandy soils managed with the seasonlong treatment, 1987-1989.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	100.0	100.0	100.0	100.0	100.0	73.3
% Active Leaf	60.0	40.0	60.0	60.0	80.0	40.0
Leaf Height cm	15.8	15.2	16.8	11.7	13.0	9.3
Tallest Leaf cm	20.3	17.8	20.2	12.3	20.4	11.2
6 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	23.2
% Active Leaf	-	-	-	-	-	66.7
Leaf Height cm	-	-	-	-	-	10.3
Tallest Leaf cm	-	-	-	-	-	15.9
7 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	3.3
% Active Leaf	-	-	-	-	-	57.1
Leaf Height cm	-	-	-	-	-	13.8
Tallest Leaf cm	-	-	-	-	-	21.3
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	99.8

Table 29. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on sandy soils managed with the nongrazed treatment, 1987-1989.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	88.9	88.9	100.0	100.0	0.0	95.5
% Active Leaf	60.0	60.0	80.0	60.0	-	60.0
Leaf Height cm	17.0	18.3	16.4	14.1	-	17.6
Tallest Leaf cm	25.6	23.6	20.6	18.6	-	23.3
6 Leaves						
% Population	11.1	11.1	0.0	0.0	0.0	4.5
% Active Leaf	83.3	50.0	-	-	-	66.7
Leaf Height cm	21.2	17.4	-	-	-	15.9
Tallest Leaf cm	31.6	25.1	-	-	-	31.5
7 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	0.0	100.0

Table 30. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on shallow soils managed with the twice-over strategy, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	76.3	92.9	100.0	88.6	100.0	69.8
% Active Leaf	60.0	60.0	80.0	60.0	80.0	60.0
Leaf Height cm	8.0	10.7	9.3	8.4	11.1	8.3
Tallest Leaf cm	8.9	14.2	12.7	11.6	14.4	10.6
6 Leaves						
% Population	21.1	7.1	0.0	11.4	0.0	24.5
% Active Leaf	50.0	50.0	-	50.0	-	50.0
Leaf Height cm	7.7	8.1	-	9.9	-	10.2
Tallest Leaf cm	8.9	12.6	-	17.5	-	12.3
7 Leaves						
% Population	2.6	0.0	0.0	0.0	0.0	5.7
% Active Leaf	42.9	-	-	-	-	57.1
Leaf Height cm	8.8	-	-	-	-	6.2
Tallest Leaf cm	11.5	-	-	-	-	7.2
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.0

Table 31. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on shallow soils managed with the ungrazed treatment, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	79.7	96.2	100.0	93.2	100.0	79.8
% Active Leaf	60.0	40.0	80.0	60.0	80.0	40.0
Leaf Height cm	10.0	10.2	14.2	10.5	12.7	10.4
Tallest Leaf cm	12.5	14.4	21.1	13.6	18.0	13.4
6 Leaves						
% Population	16.2	3.8	0.0	6.8	0.0	19.1
% Active Leaf	66.7	50.0	-	66.7	-	50.0
Leaf Height cm	10.3	6.7	-	9.5	-	11.0
Tallest Leaf cm	15.1	9.5	-	14.6	-	12.3
7 Leaves						
% Population	1.4	0.0	0.0	0.0	0.0	1.1
% Active Leaf	71.4	-	-	-	-	57.1
Leaf Height cm	21.6	-	-	-	-	10.6
Tallest Leaf cm	33.2	-	-	-	-	16.2
8 Leaves						
% Population	1.4	0.0	0.0	0.0	0.0	0.0
% Active Leaf	62.5	-	-	-	-	-
Leaf Height cm	18.5	-	-	-	-	-
Tallest Leaf cm	25.2	-	-	-	-	-
9 leaves						
% Population	1.4	0.0	0.0	0.0	0.0	0.0
% Active Leaf	66.7	-	-	-	-	-
Leaf Height cm	13.9	-	-	-	-	-
Tallest Leaf cm	18.7	-	-	-	-	-
% Population	100.1	100.0	100.0	100.0	100.0	100.0

Table 32. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on shallow soils managed with the seasonlong treatment, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	57.1	83.3	0.0	100.0	100.0	73.7
% Active Leaf	80.0	40.0	-	50.0	60.0	20.0
Leaf Height cm	10.4	11.9	-	13.3	10.2	7.5
Tallest Leaf cm	14.3	14.5	-	18.5	13.0	7.5
6 Leaves						
% Population	42.9	16.7	0.0	0.0	0.0	26.3
% Active Leaf	75.0	33.3	-	-	-	16.7
Leaf Height cm	10.9	13.3	-	-	-	10.6
Tallest Leaf cm	15.6	21.0	-	-	-	10.6
7 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	0.0	100.0	100.0	100.0

Table 33. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on shallow soils managed with the nongrazed treatment, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	100.0	91.7	100.0	89.7	100.0	76.2
% Active Leaf	60.0	40.0	80.0	40.0	80.0	60.0
Leaf Height cm	16.1	24.2	15.9	14.6	17.2	12.5
Tallest Leaf cm	22.5	26.2	21.1	18.9	24.8	17.4
6 Leaves						
% Population	0.0	0.0	0.0	10.3	0.0	23.8
% Active Leaf	-	-	-	50.0	-	33.3
Leaf Height cm	-	-	-	13.2	-	14.5
Tallest Leaf cm	-	-	-	17.5	-	14.8
7 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
8 Leaves						
% Population	0.0	8.3	0.0	0.0	0.0	0.0
% Active Leaf	-	25.0	-	-	-	-
Leaf Height cm	-	21.5	-	-	-	-
Tallest Leaf cm	-	29.2	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.0

Table 34. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on silty soils managed with the twice-over strategy, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	84.6	80.0	100.0	85.7	100.0	92.7
% Active Leaf	60.0	60.0	80.0	60.0	80.0	60.0
Leaf Height cm	9.0	13.3	17.5	10.0	12.4	8.7
Tallest Leaf cm	10.5	15.1	19.9	13.0	15.4	10.2
6 Leaves						
% Population	11.5	20.0	0.0	14.3	0.0	7.3
% Active Leaf	50.0	66.7	-	50.0	-	50.0
Leaf Height cm	13.7	9.2	-	9.5	-	10.7
Tallest Leaf cm	16.6	17.2	-	12.7	-	12.9
7 Leaves						
% Population	3.8	0.0	0.0	0.0	0.0	0.0
% Active Leaf	57.1	-	-	-	-	-
Leaf Height cm	14.6	-	-	-	-	-
Tallest Leaf cm	18.7	-	-	-	-	-
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	99.9	100.0	100.0	100.0	100.0	100.0

Table 35. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on silty soils managed with the ungrazed treatment, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	84.4	93.3	100.0	89.8	100.0	91.3
% Active Leaf	60.0	40.0	60.0	60.0	80.0	60.0
Leaf Height cm	12.2	14.5	16.7	13.8	14.7	11.0
Tallest Leaf cm	16.2	17.2	24.0	16.7	19.2	13.3
6 Leaves						
% Population	13.3	6.7	0.0	10.2	0.0	8.7
% Active Leaf	66.7	33.3	-	33.3	-	50.0
Leaf Height cm	11.4	21.4	-	13.6	-	14.2
Tallest Leaf cm	14.8	25.1	-	17.4	-	17.6
7 Leaves						
% Population	2.2	0.0	0.0	0.0	0.0	0.0
% Active Leaf	57.1	-	-	-	-	-
Leaf Height cm	15.6	-	-	-	-	-
Tallest Leaf cm	22.3	-	-	-	-	-
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	99.9	100.0	100.0	100.0	100.0	100.0

Table 36. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on silty soils managed with the seasonlong treatment, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	92.3	100.0	0.0	95.5	0.0	91.4
% Active Leaf	60.0	50.0	-	60.0	-	40.0
Leaf Height cm	10.1	12.9	-	10.8	-	7.9
Tallest Leaf cm	12.1	15.9	-	14.5	-	9.5
6 Leaves						
% Population	7.7	0.0	0.0	4.5	0.0	8.6
% Active Leaf	66.7	-	-	33.3	-	66.7
Leaf Height cm	15.7	-	-	10.5	-	8.5
Tallest Leaf cm	21.0	-	-	16.4	-	13.8
7 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	0.0	100.0	0.0	100.0

Table 37. Growth and development of needle and thread vegetative tillers with 5 to 9 leaves on silty soils managed with the nongrazed treatment, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	52.0	96.2	100.0	100.0	0.0	77.8
% Active Leaf	60.0	60.0	80.0	60.0	-	40.0
Leaf Height cm	19.0	17.5	19.3	19.8	-	17.4
Tallest Leaf cm	22.1	22.2	27.3	27.3	-	20.5
6 Leaves						
% Population	46.0	3.8	0.0	0.0	0.0	22.2
% Active Leaf	66.7	66.7	-	-	-	50.0
Leaf Height cm	16.9	30.6	-	-	-	25.2
Tallest Leaf cm	21.1	39.5	-	-	-	30.9
7 Leaves						
% Population	2.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	57.1	-	-	-	-	-
Leaf Height cm	20.0	-	-	-	-	-
Tallest Leaf cm	21.8	-	-	-	-	-
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	0.0	100.0

Secondary Tillers

The secondary tillers had very slow rates of growth and development until they produce their fourth leaf. During growing seasons with normal precipitation conditions (1983-1986), secondary tillers made up about 48.3% of the total tiller population on the grazed twice-over treatment and made up about 48.8% of the ungrazed treatment. During growing seasons with below normal precipitation conditions (1987-1989), secondary tillers made up a slightly greater proportion of the total tiller population, with 59.7% on the grazed twice-over strategy, 55.9% on the ungrazed treatment, 64.3% on the seasonlong, and 49.6% on the nongrazed treatments.

Growth and development data of needle and thread secondary tillers on sandy, shallow, silty, and clay soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 are on tables 38, 39, 40, and 41, respectively.

Secondary tillers with 2 to 4 leaves on sandy soils of the twice-over strategy composed 50.0% of the total population with 626 tillers (table 6), during the growing season 56.6% of the leaves were photosynthetically active with a mean leaf height of 14.7 cm and the tallest leaf averaged 16.6 cm tall (table 38).

Secondary tillers with 2 to 4 leaves on sandy soils of the ungrazed treatment composed 49.1% of the total tiller population with 740 tillers (table 6), during the growing season 61.3% of the leaves were photosynthetically active with a mean leaf height of 15.3 cm and the tallest leaf averaged 17.7 cm tall (table 38).

Secondary tillers with 2 to 4 leaves on shallow soils of the twice-over strategy composed 45.2% of the total tiller population with 551 tillers (table 7), during the growing season 58.6% of the leaves were photosynthetically active with a mean leaf height of 9.9 cm and the tallest leaf averaged 11.3 cm tall (table 39).

Secondary tillers with 2 to 4 leaves on shallow soils of the ungrazed treatment composed 49.9% of the total tiller population with 751 tillers (table 7), during the growing season 62.1% of the leaves were photosynthetically active with a mean leaf height of 13.3 cm and the tallest leaf averaged 15.5 cm tall (table 39).

Secondary tillers with 2 to 4 leaves on silty soils of the twice-over strategy composed 48.2% of the total tiller population with 602 tillers (table 8), during the growing season 57.0% of the leaves were photosynthetically active with a mean leaf height of 12.0 cm and the tallest leaf averaged 14.0 cm tall (table 40).

Secondary tillers with 2 to 4 leaves on silty soils of the ungrazed treatment composed 45.6% of the total tiller population with 795 tillers (table 8), during the growing season 59.5% of the leaves were photosynthetically active with a mean leaf height of 15.8 cm and the tallest leaf averaged 17.8 cm tall (table 40).

Secondary tillers with 2 to 4 leaves on clay soils of the twice-over strategy composed 50.7% of the total tiller population with 348 tillers (table 9), during the growing season 62.0% of the leaves were photosynthetically active with a mean leaf height of 11.1 cm and the tallest leaf averaged 13.0 cm tall (table 41).

Secondary tillers with 2 to 4 leaves on clay soils of the ungrazed treatment composed 52.3% of the total tiller population with 486 tillers (table 9), during the growing season 59.0% of the leaves were photosynthetically active with a mean leaf height of 13.8 cm and the tallest leaf averaged 16.1 cm tall (table 41).

Growth and development data of needle and thread secondary tillers on sandy, shallow, and silty soils managed with the twice-over strategy and the ungrazed treatment and with the seasonlong and nongrazed treatments during 1987 to 1989 are on tables 42, 43, and 44, respectively.

Secondary tillers with 2 to 4 leaves on sandy soils of the twice-over strategy composed 55.9% of the total tiller population with 358 tillers (table 6), during the growing season 69.3% of the leaves were photosynthetically active with a mean leaf height of 11.0 cm and the tallest leaf averaged 13.2 cm tall (table 42).

Secondary tillers with 2 to 4 leaves on sandy soils of the ungrazed treatment composed 58.4% of the total tiller population with 426 tillers (table 6), during the growing season 64.7% of the leaves were photosynthetically active with a mean leaf height of 14.6 cm and the tallest leaf averaged 17.1 cm tall (table 42).

Secondary tillers with 2 to 4 leaves on sandy soils of the seasonlong treatment composed 63.0% of the total tiller population with 174 tillers (table 6), during the growing season 64.1% of the leaves were photosynthetically active with a mean leaf height of 13.4 cm and the tallest leaf averaged 16.5 cm tall (table 42).

Secondary tillers with 2 to 4 leaves on sandy soils of the nongrazed treatment composed 61.7% of the total tiller population with 164 tillers (table 6), during the growing season 66.0% of the leaves were photosynthetically active with a mean leaf height of 19.0 cm and the tallest leaf averaged 23.1 cm tall (table 42).

Secondary tillers with 2 to 4 leaves on shallow soils of the twice-over strategy composed 59.6% of the total tiller population with 395 tillers (table 7), during the growing season 63.5% of the leaves were photosynthetically active with a mean leaf height of 9.6 cm and the tallest leaf averaged 11.0 cm tall (table 43).

Secondary tillers with 2 to 4 leaves on shallow soils of the ungrazed treatment composed 55.0% of the total tiller population with 408 tillers (table 7), during the growing season 65.1% of the leaves were photosynthetically active with a mean leaf height of 12.7 cm and the tallest leaf averaged 15.0 cm tall (table 43).

Secondary tillers with 2 to 4 leaves on shallow soils of the seasonlong treatment composed 58.8% of the total tiller population with 163 tillers (table 7), during the growing season 64.2% of the leaves were photosynthetically active with a mean leaf height of 10.6 cm and the tallest leaf averaged 14.8 cm tall (table 43).

Secondary tillers with 2 to 4 leaves on shallow soils of the nongrazed treatment composed 42.5% of the total tiller population with 102 tillers (table 7), during the growing season 56.4% of the leaves were photosynthetically active with a mean leaf height of 18.3 cm and the tallest leaf averaged 21.1 cm tall (table 43).

Secondary tillers with 2 to 4 leaves on silty soils of the twice-over strategy composed 63.6% of the total tiller population with 415 tillers (table 8), during the growing season 59.5% of the leaves were photosynthetically active with a mean leaf height of 10.0 cm and the tallest leaf averaged 11.2 cm tall (table 44).

Secondary tillers with 2 to 4 leaves on silty soils of the ungrazed treatment composed 54.4% of the total tiller population with 413 tillers (table 8), during the growing season 61.4% of the leaves were photosynthetically active with a mean leaf height of 14.9 cm and the tallest leaf averaged 16.8 cm tall (table 44).

Secondary tillers with 2 to 4 leaves on silty soils of the seasonlong treatment composed 68.0% of the total tiller population with 336 tillers (table 8), during the growing season 63.2% of the leaves were photosynthetically active with a mean leaf height of 11.5 cm and the tallest leaf averaged 13.1 cm tall (table 44).

Secondary tillers with 2 to 4 leaves on silty soils of the nongrazed treatment composed 43.9% of the total tiller population with 116 tillers (table 8), during the growing season 59.2% of the leaves were photosynthetically active with a mean leaf height of 16.6 cm and the tallest leaf averaged 19.7 cm tall (table 44).

All of the secondary tillers measured during this study were not grazed including the tillers located on grazed treatments. The not grazed tillers remaining on the grazed treatments tended to have slightly shorter mean leaf heights and mean tallest leaf heights which were not significantly different than the not grazed tillers on the ungrazed treatments on sandy, shallow, silty, and clay soils during the 1983-1986 period (tables 38, 39, 40, and 41) and on the sandy, shallow, and silty soils during the 1987-1989 period (tables 42, 43, and 44). It is not believed that grazed treatments cause secondary tillers to produce slightly shorter leaf heights. It is surmised that grazing cattle have a disproportional rate of selection for taller tillers than for shorter tillers leaving a distorted sample population of not grazed tillers with slightly shorter leaf heights.

Leaves grow and senesce in about the same order of their appearance. This study has designated that leaves with less than 50% senescent tissue to be photosynthetically active. Tillers growing on the twice-over treatment tended to have slightly lower photosynthetically active leaves (58.6%) than the tillers growing on the ungrazed treatment (60.5%), during the growing seasons with normal precipitation conditions (1983 to 1986). During the growing seasons with below normal precipitation conditions (1987 to 1989), secondary tillers growing on the twice-over treatment had greater photosynthetically active leaves (64.1%) than secondary tillers growing on the ungrazed treatment (63.6%), the traditional

seasonlong practice (63.8%), and the long-term nongrazed treatment (60.5%).

Secondary tillers composed a high percentage of the total measured tiller population during the 1983 to 1986 period with normal precipitation conditions with 48.3% on the grazed twice-over strategy and 48.8% on the ungrazed treatment. The quantity of secondary tillers increased during the 1987 to 1989 period with below normal precipitation conditions and composed 59.7% on the grazed twice-over strategy, 55.9% on the ungrazed treatment, 64.3% on the traditional seasonlong practice, and 49.6% on the long-term nongrazed treatment.

Table 38. Growth and development of needle and thread secondary tillers on sandy soils managed with the twice-over grazing and ungrazed treatments, 1983-1986.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
% Population	75.0	55.3	64.2	56.9	72.5	47.1
% Active Leaf	57.1	57.1	57.1	57.1	57.1	53.8
Leaf Height cm	15.8	13.3	15.2	15.5	13.4	15.1
Tallest Leaf cm	17.0	13.6	16.7	17.3	16.6	18.2
Ungrazed 1983-1986						
% Population	66.7	64.5	64.5	80.2	59.5	53.4
% Active Leaf	77.8	56.3	57.1	62.5	57.1	57.1
Leaf Height cm	14.3	15.0	15.3	16.4	14.6	16.3
Tallest Leaf cm	18.0	15.6	16.9	18.6	17.9	19.0

Table 39. Growth and development of needle and thread secondary tillers on shallow soils managed with the twice-over grazing and ungrazed treatments, 1983-1986.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
% Population	66.4	58.6	57.4	51.8	73.3	33.5
% Active Leaf	77.8	57.1	57.1	57.1	57.1	45.5
Leaf Height cm	10.7	9.6	9.0	11.5	9.3	9.3
Tallest Leaf cm	13.0	10.5	9.7	12.7	10.3	11.6
Ungrazed 1983-1986						
% Population	76.3	69.4	60.2	73.5	65.8	55.9
% Active Leaf	66.7	66.7	57.1	62.5	57.1	62.5
Leaf Height cm	15.4	10.8	12.2	14.6	13.8	13.2
Tallest Leaf cm	18.2	12.4	12.8	17.3	16.0	16.5

Table 40. Growth and development of needle and thread secondary tillers on silty soils managed with the twice-over grazing and ungrazed treatments, 1983-1986.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
% Population	82.4	56.7	64.4	50.8	68.0	44.7
% Active Leaf	77.8	50.0	57.1	50.0	57.1	50.0
Leaf Height cm	11.7	12.7	13.6	12.0	11.6	10.5
Tallest Leaf cm	14.7	13.3	14.9	14.6	14.4	12.0
Ungrazed 1983-1986						
% Population	72.3	52.5	77.3	58.9	60.8	47.6
% Active Leaf	66.7	62.5	57.1	56.3	57.1	57.1
Leaf Height cm	13.8	15.3	16.1	17.7	15.4	16.6
Tallest Leaf cm	15.2	17.4	17.7	19.2	17.6	19.7

Table 41. Growth and development of needle and thread secondary tillers on clay soils managed with the twice-over grazing and ungrazed treatments, 1983-1986.

Clay	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
% Population	69.2	51.5	80.5	50.7	86.7	49.0
% Active Leaf	88.9	54.5	57.1	57.1	57.1	57.1
Leaf Height cm	8.0	10.2	12.6	15.0	10.4	10.1
Tallest Leaf cm	12.1	10.8	13.6	16.9	12.4	12.3
Ungrazed 1983-1986						
% Population	80.0	68.4	63.3	83.1	64.7	60.7
% Active Leaf	66.7	66.7	57.1	56.3	57.1	50.0
Leaf Height cm	12.2	13.3	14.9	15.1	14.5	13.0
Tallest Leaf cm	15.2	15.6	16.5	17.6	16.2	15.4

Table 42. Growth and development of needle and thread secondary tillers on sandy soils managed with the twice-over grazing and ungrazed treatments and the seasonlong and nongrazed treatmetns, 1987-1989.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1987-1989						
% Population	55.6	87.9	98.1	53.2	75.8	48.4
% Active Leaf	77.8	66.7	71.4	71.4	71.4	57.1
Leaf Height cm	12.4	10.5	11.6	9.8	12.0	9.8
Tallest Leaf cm	13.4	11.4	14.8	12.0	15.6	11.9
Ungrazed 1987-1989						
% Population	55.6	84.1	89.1	62.3	77.3	47.6
% Active Leaf	66.7	57.1	75.0	57.1	75.0	57.1
Leaf Height cm	13.7	13.6	18.1	15.0	14.6	12.6
Tallest Leaf cm	14.9	14.3	23.7	16.4	18.3	14.9
Seasonlong 1987-1989						
% Population	85.0	92.3	94.4	78.6	81.8	25.0
% Active Leaf	81.3	50.0	75.0	57.1	71.4	50.0
Leaf Height cm	12.6	12.3	14.1	14.2	17.4	9.5
Tallest Leaf cm	14.7	13.8	18.9	16.6	23.4	11.7
Nongrazed 1987-1989						
% Population	85.7	78.6	55.6	78.0	100.0	43.6
% Active Leaf	88.9	57.1	50.0	57.1	71.4	71.4
Leaf Height cm	20.6	16.1	17.8	18.1	22.3	18.9
Tallest Leaf cm	23.1	17.8	22.5	22.4	26.4	26.6

Table 43. Growth and development of needle and thread secondary tillers on shallow soils managed with the twice-over grazing and ungrazed treatments and the seasonlong and nongrazed treatmetns, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1987-1989						
% Population	47.2	87.9	92.6	70.8	79.4	58.3
% Active Leaf	57.1	66.7	71.4	57.1	71.4	57.1
Leaf Height cm	9.3	9.1	11.1	8.6	10.6	8.6
Tallest Leaf cm	9.9	9.6	13.7	10.4	13.0	9.4
Ungrazed 1987-1989						
% Population	55.7	79.4	94.4	63.3	85.0	29.4
% Active Leaf	66.7	66.7	71.4	57.1	71.4	57.1
Leaf Height cm	11.0	12.1	14.3	11.7	15.2	12.1
Tallest Leaf cm	11.7	13.2	17.4	13.2	18.6	16.1
Seasonlong 1987-1989						
% Population	53.3	85.7	100.0	56.1	93.1	58.7
% Active Leaf	87.5	62.5	75.0	36.4	66.7	57.1
Leaf Height cm	10.2	10.7	11.7	9.1	11.8	10.2
Tallest Leaf cm	16.7	17.9	15.0	12.6	14.3	12.0
Nongrazed 1987-1989						
% Population	69.5	36.8	55.6	23.7	88.9	47.5
% Active Leaf	66.7	28.6	71.4	57.1	71.4	42.9
Leaf Height cm	15.9	27.1	17.3	16.1	17.7	15.4
Tallest Leaf cm	17.7	27.1	23.8	18.8	21.6	17.7

Table 44. Growth and development of needle and thread secondary tillers on silty soils managed with the twice-over grazing and ungrazed treatments and the seasonlong and nongrazed treatmetns, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1987-1989						
% Population	63.9	95.4	96.3	59.5	82.6	67.5
% Active Leaf	57.1	57.1	71.4	57.1	71.4	42.9
Leaf Height cm	8.8	10.2	12.2	11.3	8.6	8.8
Tallest Leaf cm	10.4	11.0	15.0	12.2	9.7	9.1
Ungrazed 1987-1989						
% Population	43.8	77.4	90.7	50.0	89.8	63.2
% Active Leaf	57.1	66.7	71.4	57.1	71.4	44.4
Leaf Height cm	12.9	11.6	17.1	15.1	17.1	15.4
Tallest Leaf cm	14.1	12.8	20.4	17.9	19.1	16.6
Seasonlong 1987-1989						
% Population	84.5	88.1	100.0	72.8	100.0	57.8
% Active Leaf	62.5	57.1	72.7	57.1	72.7	57.1
Leaf Height cm	12.6	10.4	14.2	10.1	11.8	9.8
Tallest Leaf cm	13.4	11.3	16.8	11.6	14.2	11.3
Nongrazed 1987-1989						
% Population	16.7	31.6	50.0	82.9	100.0	78.6
% Active Leaf	57.1	57.1	71.4	55.6	57.1	57.1
Leaf Height cm	18.7	10.8	19.0	16.7	16.8	17.7
Tallest Leaf cm	21.4	11.7	23.5	19.1	22.3	20.0

Discussion

Needle and thread*, Hesperostipa comata,* is a native, long-lived perennial, cool season, mid grass, monocot, of the grass family that is abundant on healthy mixed grass prairie plant communities. Needle and thread can grow on sandy, shallow, silty, overflow, and clay ecological sites. Needle and thread is drought resistant. Needle and thread tillers live for two growing seasons; the first growing season as a vegetative tiller and the second season as a reproductive lead tiller. Early season activity starts by regreening with active chlorophyll the portions of the carryover leaves that have intact cell walls from the previous growing season vegetative tillers. The green portion of the carryover leaves provides large quantities of carbohydrates and energy for the production of new leaves.

New leaf growth of needle and thread started in early to mid April, leaf growth rate increased during May and June, and then become much slower during July. The tillers derived from carryover tillers that developed into reproductive lead tillers produced 3.5 new leaves by late May consistently. The first and second leaves may be missing. Early flower stalk growth and development (FSD) began to swell around mid May to late June. Early lead tillers progressed rapidly through head emergence (HE) and reached first flower during early June. Most lead tillers reached anthesis (Ant) during early to late June. Flowering tillers had 1 or 2 very small stalk leaves and usually produced 2 to 7 basal leaves. No new leaves were produced after the anthesis stage. Seeds developed (SD) through the milk and dough stages during mid June to early July with most seeds reaching maturity (SBS) during mid July with some seeds held on the stalk during late summer.

The vegetative tillers derived from the previous seasons fall tillers and the current seasons early spring initiated tillers were not inhibited by lead tiller hormones and produced 3.5 new basal leaves by late May, and 97% of the vegetative tillers had produced 5 or 6 new basal leaves during early June. During the growing season 81.6% of the vegetative tillers produced 5 leaves, 16.3% produced 6 leaves, 2.0% produced 7 leaves, 0.1% produced 8 leaves, and 0.1% produced 9 leaves.

Secondary tillers are derived from vegetative growth of crown axillary buds. The tillers that were initiated during the growing season were hormonally controlled by a dominated lead tiller that has proprietary access to all essential nutrients available to the secondary tillers. This arrangement had positive and negative affects. Most of the time, the secondary tillers have access to greater quantities of essential nutrients than a seedling would have, which ensures secondary tillers with superior survivability. Thus, a high percentage of secondary tillers live and grow for two growing seasons, and almost no grass seedlings develop into mature plants. However, during periods of water stress or other problematic conditions, lead tillers restrict nutrient flow to secondary tillers resulting in very slow rates of growth or tiller termination. During high water deficiency conditions growing seasons, secondary tillers can remain at the 2 or 3 leaf stage for a month or two. The quantity of secondary tillers increased 11.4% on the twice-over and increased 7.1% on the ungrazed treatment during the growing seasons with high water deficiency conditions (1987-1989). When secondary tillers produce their fourth leaf, they have adequate leaf area to photosynthesize their own carbon energy and develop a large enough root system for self sustaining nutrient resource uptake.

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Growth Pattern and Phenological Development of Prairie Junegrass on the Northern Plains

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Intact grassland ecosystems are complex; exceedingly more complex than the most complicated machines ever built by humans. Knowledge and understanding of the growth pattern and phenological development of the major forage grasses are fundamentally essential for generation of biologically effective management strategies with inclusivity of all biotic and abiotic components of grassland ecosystems in the Northern Plains.

The inspirational goals of this study were developed by Dr. Warren C. Whitman (c. 1950) and Dr. Harold Goetz (1963) which were to gain quantitative knowledge of each component species and to provide a pathway essential for the understanding of relationships of ecosystem components that would result in the development and establishment of scientific standards for proper management of grazinglands in the Northern Plains.

This growth pattern and phenological development study of the major forage graminoids was conducted during the growing seasons of 1983-1986 and 1987-1989 with data collected biweekly June-August. The study included 3 cool season, 2 warm season, 1 upland sedge, 1 naturalized, and 2 domesticated grasses. The study sites were located at the NDSU Dickinson Research Extension Center ranch near Manning in western North Dakota and consisted of 143 acres (58 ha) of two seeded domesticated grasslands and 720 acres (291 ha) of native rangeland pastures separated into three management treatments, each with two replications, with data collection sites established on sandy, shallow, and silty ecological sites. Each ecological site of the grazed treatments had matching paired plots, one grazed and the other with an ungrazed exclosure.

Study Area

The physiography of the study area consists of the Unglaciated section of the Missouri Plateau (Fenneman 1931, 1946; Hunt 1974). The landscape surface is highly eroded fluvial sedimentary deposits of material removed from the uplifted Rocky Mountains. Most of the deposition occurred from slow meandering streams during the Laramide Orogeny and during the 20 to 30 million years of the late Cretaceous and early Tertiary Periods following the uplift. Intense widespread erosion of these sediments occurred from about 5 to 3 million years ago during the late Pliocene Epoch (Bluemle 2000). The extensive erosion during this period removed about 500 to 1000 feet of sediments (Fenneman 1931) forming a landscape with well developed integrated drainage systems of broad mature valleys and gently rolling uplands containing widely spaced large hills and buttes with erosion resistant caps raising 500 to 650 feet above the plain (Bluemle 2000).

The soils of western North Dakota developed from eroded Tertiary fluvial sedimentary deposits in the Ustic-Frigid soil moisture-temperature regime. The Ustic soil moisture regime is typical of semi arid climates. The Frigid soil temperature regime has mean annual soil temperatures of less than 47° F (8° C) (Soil Survey Staff 1975). These soils are primarily Typic Borolls (semi arid cool Mollisols) and support vegetation of mid and short grasses of the Mixed Grass Prairie (Manske 2008b).

The current "native" plant species in the Northern Plains did not originate here. All of the plant species have migrated into the region by different mechanisms and at different times and rates. The present plant species have flora affinities to northern, eastern, western, Rocky Mountain, and Great Basin plant communities (Zaczkowski 1972). This wide mix of plant species was formed from remnants of previously existing plant communities. The climate changed about 5,000 years ago to conditions like those of the present, with cycles of wet and dry periods (Bluemle 1977, 1991; Manske 1994). The large diversity of plant species that make up the current mixed grass prairie permits dynamic responses to changes in climatic conditions by increasing the combination of plant species favored by any set of climatic conditions (Manske 2008a).

Long-Term Weather

The NDSU Dickinson Research Extension Center ranch is located in Dunn County in western North Dakota, at 47° 14' north latitude, 102° 50' west longitude. Mean annual temperature is 42.3° F (5.7° C). January is the coldest month, with mean temperature of 14.6° F (-9.7° C). July and August are the warmest months with mean temperatures of 69.7° F (20.9° C) and 68.6° F (20.3° C), respectively. Long-term (1982-2012) mean annual precipitation is 16.91 inches (429.61 mm). The perennial plant growing season precipitation (April to October) is 14.13 inches (358.97 mm) and is 83.6% of annual precipitation. June has the greatest monthly precipitation at 3.27 inches (83.08 mm). The precipitation received during the 3-month period of May, June, and July (8.26 inches, 209.80 mm) accounts for 48.8% of the annual precipitation.

Growing season months with water deficiency disrupt plant growth rates and are identified from monthly temperature and precipitation data by the Emberger ombrothermic diagram technique. Long-term (1983-2012) 30 year reoccurrence rates (table 1) show relatively low rates of water deficiency reoccurring during April (16.7%), May and June (10.0%), moderate rates during July and October (36.7%), and high rates during August (56.7%) and September (60.0%). Long-term occurrence of water deficiency conditions was 33.3% of the growing season months, for a mean of 2.0 water deficient months per each 6.0 month growing season (15 Apr-15 Oct).

Growing Season Precipitation

The growing season precipitation information collected during the grass leaf height study has been grouped into two periods with the first period occurring during 1983 to 1986 and the second period occurring during 1987 to 1989.

Mean growing season precipitation of 1983-1986 (table 2) was 14.11 inches (99.9% of LTM). None of the four 6 month growing seasons received precipitation at less than 80% of LTM. One growing season, 1986, received precipitation at near 130% of LTM. The rate of water deficiency occurrence during the four growing seasons was 29.2%, for a mean of 1.75 water deficient months per growing season (table 3). The growing season of 1984 had 3.0 months in water deficiency. The growing seasons of 1983 and 1986 had 1.5 months in water deficiency each. The growing season of 1985 had 1.0 month in water deficiency.

Mean growing season precipitation of 1987-1989 (table 4) was low at 9.14 inches (64.7% of LTM). The growing season of 1987 received 11.53 inches (81.6% of LTM) precipitation. The growing season of 1989 received 10.60 inches (75.0% of LTM) precipitation. The growing season of 1988 received only 5.30 inches (37.5% of LTM) precipitation and was dry. The rate of water deficiency occurrence during the three growing seasons was 61.1%, for a mean of 3.7 water deficient months per growing season (table 5). The growing seasons of 1987 and 1989 had 3.0 months in water deficiency each. The growing season of 1988 had 5.0 months of its 6 month growing season in water deficiency conditions. That is comparable to 2 other growing seasons with high water deficiency conditions. The growing season of 1934 had 4.5 months in water deficiency and the growing season of 1936 had 5.5 months in water deficiency.

Table 1. Growing season months with water deficiency, DREC ranch, 1983-2012.

	Apr	May	Jun	Jul	Aug	Sep	Oct	# Months	% 6 Months 15 Apr-15 Oct
Total	5	3	3	11	17	18	11	60.0	33.3
% of 30 Years	16.7	10.0	10.0	36.7	56.7	60.0	36.7		

Table 2. Precipitation in inches and percent of long-term mean for perennial plant growing season months, DREC ranch, 1983-1986.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-Term Mean 1982-2012	1.44	2.56	3.27	2.43	1.70	1.42	1.31	14.13	16.91
1983	0.21	1.53	3.26	2.56	4.45	0.86	0.72	13.59	15.55
% of LTM	14.58	59.77	99.69	105.35	261.76	60.56	54.96	96.18	91.96
1984	2.87	0.00	5.30	0.11	1.92	0.53	0.96	11.69	12.88
% of LTM	199.31	0.00	162.08	4.53	112.94	37.32	73.28	82.73	76.17
1985	1.24	3.25	1.58	1.07	1.84	1.69	2.13	12.80	15.13
% of LTM	86.11	126.95	48.32	44.03	108.24	119.01	162.60	90.59	89.47
1986	3.13	3.68	2.58	3.04	0.46	5.29	0.18	18.36	22.96
% of LTM	217.36	143.75	78.90	125.10	27.06	372.54	13.74	129.94	135.78
1983-1986	1.86	2.12	3.18	1.70	2.17	2.09	1.00	14.11	16.63
% of LTM	129.34	82.62	97.25	69.75	127.50	147.36	76.15	99.86	98.34

Table 3. Growing season months with water deficiency conditions that caused water stress in perennial plants, DREC ranch, 1983-1986.

	APR	MAY	JUN	JUL	AUG	SEP	OCT	# Months	% 6 Months 15 Apr-15 Oct
1983	■					■		1.5	25.0
1984		■		■		■		3.0	50.0
1985				■				1.0	16.7
1986					■		■	1.5	25.0
#	**1**	**1**	**0**	**2**	**1**	**2**	**1**	**7.0**	**29.2**
%	**25.0**	**25.0**	**0.0**	**50.0**	**25.0**	**50.0**	**25.0**		

Table 4. Precipitation in inches and percent of long-term mean for perennial plant growing season months, DREC ranch, 1987-1989.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-Term Mean 1982-2012	1.44	2.56	3.27	2.43	1.70	1.42	1.31	14.13	16.91
1987	0.10	1.38	1.15	5.39	2.65	0.78	0.08	11.53	14.13
% of LTM	6.94	53.91	35.17	221.81	155.88	54.93	6.11	81.60	83.56
1988	0.00	1.85	1.70	0.88	0.03	0.73	0.11	5.30	9.03
% of LTM	0.00	72.27	51.99	36.21	1.76	51.41	8.40	37.51	53.40
1989	2.92	1.73	1.63	1.30	1.36	0.70	0.96	10.60	13.07
% of LTM	202.78	67.58	49.85	53.50	80.00	49.30	73.28	75.02	77.29
1987-1989	1.01	1.65	1.49	2.52	1.35	0.74	0.38	9.14	12.08
% of LTM	69.91	64.58	45.67	103.84	79.22	51.88	29.26	64.71	71.42

Table 5. Growing season months with water deficiency conditions that caused water stress in perennial plants, DREC ranch, 1987-1989.

	APR	MAY	JUN	JUL	AUG	SEP	OCT	# Months	% 6 Months 15 Apr-15 Oct
1987	■		■			■	■	3.0	50.0
1988	■		■	■	■	■	■	5.0	83.3
1989				■	■	■		3.0	50.0
#	**2**	**0**	**2**	**2**	**2**	**3**	**2**	**11.0**	**61.1**
%	**66.7**	**0.0**	**66.7**	**66.7**	**66.7**	**100.0**	**66.7**		

Procedures

The 1983-1989 Study

Grass tiller leaf heights were determined for reproductive lead tillers, vegetative tillers, and secondary tillers on a biweekly sampling period from June through August. Each leaf of ten ungrazed tillers of each study species was measured with a meter stick to the nearest 0.1 cm from ground level to the tips of the extended leaves. Basal leaf heights were measured for grass species in which the leaves and stalks were distinctly separate. Stalk leaf heights were measured for grass species where leaves are attached to the culm during vegetative stages and fruiting stages.

Degree of leaf senescence was estimated as percent dryness for each leaf. Percent dryness for basal leaves was considered from the apex to ground level. Percent dryness for stalk leaves was considered for the blade only. The categories of dryness were: 0%, 2%, 25%, 50%, 75%, 98% and 100% dry. Start of senescence was considered to be dryness greater than 2%. Leaves with less than 50% senescent tissue were designated to be photosynthetically active.

Grass flower stalk heights were determined by measurements from ground level to the tip of the stalk or the apex of the top floret. The awns, if present, were not included in the height measurements. The phenological stages of flower stalk development were recorded as: flower stalk developing (FSD), head emergence (HE), anthesis (Ant), seeds developing (SD), and seeds being shed (SBS). Recording the flower stalk development stages started when stalk enlargement or swelling was outwardly noticeable; prior development is not detectable without destruction of the tiller. The swelling of the stalk, traditionally called the boot stage, was categorized as the flower stalk developing stage. Head emergence is a short duration stage but easily defined when the flower head emerges from the sheath and rapidly elongates to near full height. Anthesis (flowering) is also a short duration stage but easily defined by the exposure of the anthers and stigmas. Needle and thread is usually cleistogamous that self-fertilizes without opening and exposing the anthers and stigmas. Following fertilization, the seeds develop through milk, dough, and mature stages which are difficult to differentiate on small grass seeds. These seed progression stages have been separated into more easily defined categories of seeds developing for the early seed stages and seeds being shed for the mature seed stages when seeds could be easily removed from the inflorescence by wind, by gentle rubbing, or when it could be observed that some seeds had already been dropped. Sometimes a floret will abort the seed production process resulting in failure of viable seeds to materialize. This condition could be revealed in the data set as earlier than normal recordings of seeds being shed.

During 1983 to 1986, the paired plot sample sites with sandy, shallow, silty and clay soil types were managed by ungrazed and grazed treatments of the twice-over rotation strategy. During 1987 to 1989, the paired plot sample sites with sandy, shallow, and silty soil types were managed by long-term nongrazed treatments, and by ungrazed and grazed treatments of the traditional seasonlong practice and the twice-over rotation strategy.

Designation of Tiller Types

Reproductive lead tillers are second year tillers derived from carryover tillers that were vegetative tillers during the previous growing season. The portions of the carryover leaves that have intact cell walls will regreen with active chlorophyll early in the growing season and provide photosynthate for rapid growth of new current years leaves. New leaf development resumed early spring in mid April but growth was slow until early or mid May. The anthesis (flowering) period can occur between early or mid June to mid July with a 5 week flower period. No new leaves are produced after the anthesis stage, during the seed development stages. Flower stalks had a few small leaves and usually produce 2 to 5 basal leaves and sometimes with 6 or 7 basal leaves. Reproductive lead tillers are terminal at the end of the growing season; their apical meristem was used up producing a flower head.

Vegetative tillers are first year tillers derived from previous growing season initiated fall tillers and from early spring initiated secondary tillers that have escaped hormonal control by a lead tiller. Vegetative tillers produced 3.5 new basal leaves by early June consistently. These tillers are the primary forage tillers with rapid growth rates, usually producing 5 to 7 basal leaves and occasionally producing leaves 8 and 9 during the growing season. The apical meristem remains vegetative, permitting these tillers to overwinter as carryover tillers and becoming reproductive lead tillers during the successive growing season.

Secondary tillers are young current growing season tillers usually with 2 to 4 basal leaves that initiated from axillary buds during May to July and that remain hormonally controlled by a dominant lead

tiller that has proprietary access to all resources slowing rates of growth. The secondary tillers can become independent from the hormone control of the lead tiller and transform into vegetative tillers with rapid growth rates during July and August. A large quantity of new leaves develop from crown buds during August.

Results

Prairie Junegrass, Koeleria macrantha (Ledeb.) Schult, is a member of the grass family, Poaceae, tribe, Poeae, Syn.: *Koeleria pyramidata* (Lam.) Beauv., *Koeleria cristata* (L.) Pers., and is a native, perennial, monocot, cool-season, mid grass, that is cold and heat tolerant, and drought resistant. The first North Dakota record is Bell 1907. Early aerial growth consists of basal leaves arising from crown tiller buds. Prairie Junegrass consistently reaches the 3.5 new leaf stage by 1 June and is an excellent indicator of physiological grazing readiness of native grasses. Basal leaf blades are 8-18 cm (3-7 in) long, 1-3 mm wide, thick, with broad ribs above and a boat prow shaped tip. The split sheath has overlapping translucent margins with short hairs. The indistinctive collar is continuous. The ligule is membranous, 1.5 mm long, often split, continuous with sheath margins, and fringed with hairs. The auricles are absent. The fibrous root system is primarily shallow, with the greatest concentration in the top 3 cm (1.2 in) of soil. The lateral spread is 20-25 cm (8-10 in) outward from the crown. Most main roots are 0.2 mm thick and remain in the top 46 cm (1.5 ft) of soil, with a few main roots descending down to 76 cm (2.5 ft). Regeneration is primarily asexual propagation by crown tillers. Seedling success is low, primarily because of low seed production, and resulting from poor seedling vigor and high mortality. Flower stalks are erect, 30-60 cm (12-24 in) tall. Inflorescence is a narrow, condensed, panicle, 5-15 cm (2-6 in) long, that opens during flowering becoming plume like, then contracting to narrow spike shape after flowering. Spikelets contain 2 florets. Flowers period is early June to mid July. Leaves are highly palatable to livestock. Fire top kills aerial parts and can consume the entire crown when the soil is dry. Fire halts the processes of the four major defoliation resistance mechanisms and causes great reductions in biomass production and tiller density. This summary information on growth development and regeneration of Prairie Junegrass was based on works of Weaver 1954, Stevens 1963, Zaczkowski 1972, Dodds 1979, Great Plains Flora Association 1986, Simonin 2000, Ogle et al. 2006, Larson and Johnson 2007, and Stubbendieck et al. 2011.

During the seven years of this study, the number of Prairie Junegrass tillers measured was 15,795 with 4442 tillers on sandy soils, 4628 tillers on shallow soils, 4771 tillers on silty soils, and 1954 tillers on clay soils (tables 6, 7, 8, and 9). The collection protocol required measurement on all available flower stalks and ten vegetative tillers on each sample site each collection period, amounting to 360 tillers per year on the twice-over treatment and 120 tillers per year on the seasonlong and nongrazed treatments. During the 3 growing seasons with low precipitation amounts, less than ten tillers were measured each collection period. The reductions in sample numbers would indicate the degree of negative affect from reduced precipitation. This affect is designated as collection efficiency on tables 6, 7, 8, and 9.

Table 6. Number of tillers measured from management treatments on sandy soils.

Tiller Type	Twice-over 1983-1986		Twice-over 1987-1989		Seasonlong 1987-1989	Nongrazed 1987-1989
	Ungrazed	Grazed	Ungrazed	Grazed	Grazed	Ungrazed
Flower Stalk	207	429	81	53	40	43
Vegetative	857	889	261	154	79	84
Secondary	231	329	235	225	126	119
Subtotal	1295	1647	577	432	245	246
Total	2942		1009			
Sum total				4442		
Collection Efficiency	90%	114%	53%	40%	68%	68%

Table 7. Number of tillers measured from management treatments on shallow soils.

Tiller Type	Twice-over 1983-1986		Twice-over 1987-1989		Seasonlong 1987-1989	Nongrazed 1987-1989
	Ungrazed	Grazed	Ungrazed	Grazed	Grazed	Ungrazed
Flower Stalk	449	195	92	70	39	40
Vegetative	925	828	320	187	77	96
Secondary	324	225	284	288	103	86
Subtotal	1698	1248	696	545	219	222
Total	2946		1241			
Sum total				4628		
Collection Efficiency	118%	87%	64%	50%	61%	62%

Table 8. Number of tillers measured from management treatments on silty soils.

Tiller Type	Twice-over 1983-1986		Twice-over 1987-1989		Seasonlong 1987-1989	Nongrazed 1987-1989
	Ungrazed	Grazed	Ungrazed	Grazed	Grazed	Ungrazed
Flower Stalk	439	206	69	87	70	43
Vegetative	874	745	276	156	132	107
Secondary	404	255	282	290	268	68
Subtotal	1717	1206	627	533	470	218
Total	2923		1160			
Sum total				4771		
Collection Efficiency	119%	84%	58%	49%	65%	61%

Table 9. Number of tillers measured from management treatments on clay soils.

Tiller Type	Twice-over 1983-1986		Twice-over 1987-1989		Seasonlong 1987-1989		Nongrazed 1987-1989
	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed
Flower Stalk	148	296					
Vegetative	561	531					
Secondary	153	265					
Subtotal	862	1092					
Total	1954						
Sum total							
Collection Efficiency	60%	76%					

Reproductive Lead Tillers

The second year reproductive lead tillers had the fastest rate of growth and development until mid to late July. Reproductive lead tillers reach the boot stage (FSD) during mid May to early June. Flower stalk development occurred very rapidly with the lead tillers progressing through head emergence (HE) during early to late June and reaching the flower stage during early or mid June to mid July. Most lead tillers reached anthesis (Ant) during the 5 week flower period lasting to mid July. No new leaves were produced after the anthesis stage. Seeds developed (SD) through the milk and dough stages during late June to late July with most seeds reaching maturity (SBS) from mid July to mid August (table 10). The apical meristem of reproductive lead tillers can no longer produce leaf buds after it had produced flower buds and these tillers were terminated at the end of the growing season.

Growth and development data of Prairie Junegrass reproductive lead tillers on sandy soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 are on table 11.

Reproductive lead tillers with 2 to 7 basal leaves on the twice-over strategy during 1983 to 1986 composed 26.0% of the total population with 429 tillers (table 6) that had a mean flower stalk height of 26.0 cm, during the growing season a mean of 11.7% leaves were photosynthetically active with a mean basal leaf height of 12.6 cm and the tallest leaf averaged 14.8 cm tall (table 11).

Reproductive lead tillers with 2 to 7 basal leaves on the ungrazed treatment during 1983 to 1986 composed 16.0% of the total population with 207 tillers (table 6) that had a mean flower stalk height of 25.4 cm, during the growing season a mean of 12.6% leaves were photosynthetically active with a mean basal leaf height of 12.6 cm and the tallest leaf averaged 14.4 cm tall (table 11).

Growth and development data of Prairie Junegrass reproductive lead tillers on shallow soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 are on table 12.

Reproductive lead tillers with 2 to 7 basal leaves on the twice-over strategy during 1983 to 1986 composed 15.6% of the total population with 195 tillers (table 7) that had a mean flower stalk height of 21.2 cm, during the growing season a mean of 14.7% leaves were photosynthetically active with a mean basal leaf height of 9.7 cm and the tallest leaf averaged 12.8 cm tall (table 12).

Reproductive lead tillers with 2 to 7 basal leaves on the ungrazed treatment during 1983 to 1986 composed 26.4% of the total population with 449 tillers (table 7) that had a mean flower stalk height of 24.0 cm, during the growing season a mean of 14.9% leaves were photosynthetically active with a mean basal leaf height of 10.9 cm and the tallest leaf averaged 13.6 cm tall (table 12).

Growth and development data of Prairie Junegrass reproductive lead tillers on silty soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 are on table 13.

Reproductive lead tillers with 2 to 7 basal leaves on the twice-over strategy during 1983 to 1986 composed 17.1% of the total population with 206 tillers (table 8) that had a mean flower stalk height of 24.8 cm, during the growing season a mean of 20.9% leaves were photosynthetically active with a mean basal leaf height of 9.7 cm and the tallest leaf averaged 12.1 cm tall (table 13).

Reproductive lead tillers with 2 to 7 basal leaves on the ungrazed treatment during 1983 to 1986 composed 25.6% of the total population with 439 tillers (table 8) that had a mean flower stalk height of 27.8 cm, during the growing season a mean of 16.1% leaves were photosynthetically active with a mean basal leaf height of 11.7 cm and the tallest leaf averaged 13.8 cm tall (table 13).

Growth and development data of Prairie Junegrass reproductive lead tillers on clay soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 are on table 14.

Reproductive lead tillers with 2 to 7 basal leaves on the twice-over strategy during 1983 to 1986 composed 27.1% of the total population with 296 tillers (table 9) that had a mean flower stalk height of 23.7 cm, during the growing season a mean of 20.0% leaves were photosynthetically active with a mean basal leaf height of 10.5 cm and the tallest leaf averaged 13.7 cm tall (table 14).

Reproductive lead tillers with 2 to 7 basal leaves on the ungrazed treatment during 1983 to 1986 composed 17.2% of the total population with 148 tillers (table 9) that had a mean flower stalk height of

25.1 cm, during the growing season a mean of 12.4% leaves were photosynthetically active with a mean basal leaf height of 12.9 cm and the tallest leaf averaged 16.6 cm tall (table 14).

Growth and development data of Prairie Junegrass reproductive lead tillers on sandy soils managed with the twice-over strategy and the ungrazed treatment and the seasonlong and nongrazed treatments during 1987 to 1989 are on table 15.

Reproductive lead tillers with 2 to 7 basal leaves on the twice-over strategy during 1987 to 1989 composed 12.3% of the total population with 53 tillers (table 6) that had a mean flower stalk height of 21.7 cm, during the growing season a mean of 25.7% leaves were photosynthetically active with a mean basal leaf height of 12.9 cm and the tallest leaf averaged 14.2 cm tall (table 15).

Reproductive lead tillers with 2 to 7 basal leaves on the ungrazed treatment during 1987 to 1989 composed 14.0% of the total population with 81 tillers (table 6) that had a mean flower stalk height of 24.2 cm, during the growing season a mean of 21.9% leaves were photosynthetically active with a mean basal leaf height of 12.4 cm and the tallest leaf averaged 15.1 cm tall (table 15).

Reproductive lead tillers with 2 to 7 basal leaves on the seasonlong treatment during 1987 to 1989 composed 16.3% of the total population with 40 tillers (table 6) that had a mean flower stalk height of 26.2 cm, during the growing season a mean of 20.8% leaves were photosynthetically active with a mean basal leaf height of 10.1 cm and the tallest leaf averaged 12.3 cm tall (table 15).

Reproductive lead tillers with 2 to 7 basal leaves on the nongrazed treatment during 1987 to 1989 composed 17.5% of the total population with 43 tillers (table 6) that had a mean flower stalk height of 26.9 cm, during the growing season a mean of 12.4% leaves were photosynthetically active with a mean basal leaf height of 10.6 cm and the tallest leaf averaged 14.1 cm tall (table 15).

Growth and development data of Prairie Junegrass reproductive lead tillers on shallow soils managed with the twice-over strategy and the ungrazed treatment and the seasonlong and nongrazed treatments during 1987 to 1989 are on table 16.

Reproductive lead tillers with 2 to 7 basal leaves on the twice-over strategy during 1987 to 1989 composed 12.8% of the total population with 70 tillers (table 7) that had a mean flower stalk height of 18.9 cm, during the growing season a mean of 13.4% leaves were photosynthetically active with a mean basal leaf height of 8.0 cm and the tallest leaf averaged 8.8 cm tall (table 16).

Reproductive lead tillers with 2 to 7 basal leaves on the ungrazed treatment during 1987 to 1989 composed 13.2% of the total population with 92 tillers (table 7) that had a mean flower stalk height of 22.6 cm, during the growing season a mean of 16.7% leaves were photosynthetically active with a mean basal leaf height of 11.7 cm and the tallest leaf averaged 14.0 cm tall (table 16).

Reproductive lead tillers with 2 to 7 basal leaves on the seasonlong treatment during 1987 to 1989 composed 17.8% of the total population with 39 tillers (table 7) that had a mean flower stalk height of 21.9 cm, during the growing season a mean of 20.0% leaves were photosynthetically active with a mean basal leaf height of 12.9 cm and the tallest leaf averaged 13.7 cm tall (table 16).

Reproductive lead tillers with 2 to 7 basal leaves on the nongrazed treatment during 1987 to 1989 composed 18.0% of the total population with 40 tillers (table 7) that had a mean flower stalk height of 22.0 cm, during the growing season a mean of 8.0% leaves were photosynthetically active with a mean basal leaf height of 12.4 cm and the tallest leaf averaged 15.5 cm tall (table 16).

Growth and development data of Prairie Junegrass reproductive lead tillers on silty soils managed with the twice-over strategy and the ungrazed treatment and the seasonlong and nongrazed treatments during 1987 to 1989 are on table 17.

Reproductive lead tillers with 2 to 7 basal leaves on the twice-over strategy during 1987 to 1989 composed 16.3% of the total population with 87 tillers (table 8) that had a mean flower stalk height of 22.9 cm, during the growing season a mean of 21.3% leaves were photosynthetically active with a mean basal leaf height of 9.9 cm and the tallest leaf averaged 12.3 cm tall (table 17).

Reproductive lead tillers with 2 to 7 basal leaves on the ungrazed treatment during 1987 to 1989 composed 11.0% of the total population with 69 tillers (table 8) that had a mean flower stalk height of 25.9 cm, during the growing season a mean of 18.2% leaves were photosynthetically active with a mean basal leaf height of 11.6 cm and the tallest leaf averaged 13.0 cm tall (table 17).

Reproductive lead tillers with 2 to 7 basal leaves on the seasonlong treatment during 1987 to 1989 composed 14.9% of the total population with 70 tillers (table 8) that had a mean flower stalk height of 22.4 cm, during the growing season a mean of 20.0% leaves were photosynthetically active with a mean basal leaf height of 9.9 cm and the tallest leaf averaged 12.5 cm tall (table 17).

Reproductive lead tillers with 2 to 7 basal leaves on the nongrazed treatment during 1987 to 1989 composed 19.7% of the total population with 43 tillers (table 8) that had a mean flower stalk height of 22.5 cm, during the growing season a mean of 20.2% leaves were photosynthetically active with a mean basal leaf height of 16.0 cm and the tallest leaf averaged 18.2 cm tall (table 17).

All of the reproductive lead tillers measured during this study were not grazed including the tillers located on grazed treatments. The not grazed tillers remaining on the grazed treatments tended to have slightly shorter mean flower stalk heights, mean basal leaf heights, and mean tallest leaf heights which were not significantly different than the not grazed tillers on the ungrazed treatments on the sandy, shallow, silty, and clay soils during the 1983-1986 and on the sandy, shallow, and silty soils during the 1987-1989 periods. It is not believed that grazed treatments cause reproductive lead tillers to produce slightly shorter flower stalk and basal leaf heights. It is surmised that grazing cattle have a disproportional rate of selection for taller tillers than for shorter tillers leaving a distorted sample population of not grazed tillers with slightly shorter leaf heights.

Leaves grow and senesce in about the same order of their appearance. This study has designated that leaves with less than 50% senescent tissue to be photosynthetically active. Reproductive lead tillers growing on the twice-over treatment tended to have greater levels of photosynthetically active leaves at 16.8% than the tillers growing on the ungrazed treatment at 14.0%. Reproductive lead tillers located on the grazed twice-over treatment had 2.8% more photosynthetically active leaves than the tillers located on the ungrazed treatment.

Reproductive lead tillers composed a low percentage of the total measured tiller population. Reproductive lead tillers located on the twice-over treatment composed 21.7% (1126 tillers) and 13.9% (210 tillers) and the reproductive tillers located on the ungrazed treatment composed 22.3% (1243 tillers) and 12.7% (242 tillers) of the total tiller population during the 1983-1986 period and the 1987-1989 period, respectively. Reproductive lead tillers located on the seasonlong and nongrazed treatments composed 16.0% (149 tillers) and 18.4% (126 tillers) of the total population during the 1987-1989 period, respectively.

Table 10. Phenological stages of flower stalk development for Prairie Junegrass, 1983-1986.

6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
FSD					
HE	HE				
	Ant	Ant			
		SD	SD		
			SBS	SBS	

FSD	flower stalk developing
HE	head emergence
Ant	anthesis (flowering)
SD	seeds developing
SBS	seeds being shed

Table 11. Growth and development of Prairie Junegrass reproductive lead tillers on sandy soils managed with twice-over grazing and ungrazed treatments, 1983-1986.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
Stalk Height cm	22.5	19.1	29.3	26.2	29.6	29.1
% Active Leaf	42.9	27.5	0.0	0.0	0.0	0.0
Leaf Height cm	12.6	12.5	-	-	-	-
Tallest Leaf cm	14.8	14.7	-	-	-	-
Ungrazed 1983-1986						
Stalk Height cm	24.2	19.8	30.3	23.3	28.0	26.7
% Active Leaf	48.0	23.5	0.0	0.0	0.0	3.8
Leaf Height cm	14.7	12.2	-	-	-	11.0
Tallest Leaf cm	19.1	13.1	-	-	-	11.0

Table 12. Growth and development of Prairie Junegrass reproductive lead tillers on shallow soils managed with twice-over grazing and ungrazed treatments, 1983-1986.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
Stalk Height cm	20.9	15.8	23.2	20.0	23.5	23.5
% Active Leaf	61.1	27.3	0.0	0.0	0.0	0.0
Leaf Height cm	9.7	9.6	-	-	-	-
Tallest Leaf cm	14.6	11.0	-	-	-	-
Ungrazed 1983-1986						
Stalk Height cm	16.9	20.6	28.1	24.6	26.5	27.4
% Active Leaf	55.6	34.0	0.0	0.0	0.0	0.0
Leaf Height cm	10.2	11.5	-	-	-	-
Tallest Leaf cm	14.2	13.0	-	-	-	-

Table 13. Growth and development of Prairie Junegrass reproductive lead tillers on silty soils managed with twice-over grazing and ungrazed treatments, 1983-1986.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
Stalk Height cm	19.6	20.5	26.7	25.7	29.4	26.6
% Active Leaf	57.1	36.1	0.0	6.7	7.1	18.5
Leaf Height cm	9.3	11.7	-	10.1	8.5	8.7
Tallest Leaf cm	13.2	14.0	-	10.6	8.5	14.2
Ungrazed 1983-1986						
Stalk Height cm	21.7	23.2	31.9	28.7	31.6	29.8
% Active Leaf	57.1	31.3	0.0	7.9	0.0	0.0
Leaf Height cm	14.7	14.0	-	6.3	-	-
Tallest Leaf cm	17.3	15.6	-	8.5	-	-

Table 14. Growth and development of Prairie Junegrass reproductive lead tillers on clay soils managed with twice-over grazing and ungrazed treatments, 1983-1986.

Clay	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
Stalk Height cm	16.8	17.9	23.6	25.2	29.9	28.5
% Active Leaf	64.3	46.9	0.0	8.7	0.0	0.0
Leaf Height cm	10.9	10.7	-	9.8	-	-
Tallest Leaf cm	14.5	13.8	-	12.9	-	-
Ungrazed 1983-1986						
Stalk Height cm	19.4	21.2	27.1	25.4	32.0	25.6
% Active Leaf	44.4	30.0	0.0	0.0	0.0	0.0
Leaf Height cm	14.0	11.8	-	-	-	-
Tallest Leaf cm	17.9	15.2	-	-	-	-

Table 15. Growth and development of Prairie Junegrass reproductive lead tillers on sandy soils managed with twice-over grazing and ungrazed treatments and the seasonlong and nongrazed treatments, 1987-1989.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1987-1989						
Stalk Height cm	8.5	23.1	29.0	15.3	29.5	24.7
% Active Leaf	80.0	14.3	60.0	0.0	0.0	0.0
Leaf Height cm	7.6	15.5	15.7	-	-	-
Tallest Leaf cm	10.3	15.5	16.9	-	-	-
Ungrazed 1987-1989						
Stalk Height cm	22.6	20.0	38.5	18.6	-	21.0
% Active Leaf	50.0	21.4	60.0	0.0	0.0	0.0
Leaf Height cm	11.5	11.5	14.1	-	-	-
Tallest Leaf cm	16.3	12.4	16.5	-	-	-
Seasonlong 1987-1989						
Stalk Height cm	22.1	24.5	34.5	23.8	32.5	19.7
% Active Leaf	66.7	8.3	50.0	0.0	0.0	0.0
Leaf Height cm	10.1	7.9	12.2	-	-	-
Tallest Leaf cm	15.0	7.9	14.1	-	-	-
Nongrazed 1987-1989						
Stalk Height cm	22.0	19.1	37.5	19.8	37.9	25.3
% Active Leaf	60.0	14.3	0.0	0.0	0.0	0.0
Leaf Height cm	11.8	9.3	-	-	-	-
Tallest Leaf cm	16.4	11.7	-	-	-	-

Table 16. Growth and development of Prairie Junegrass reproductive lead tillers on shallow soils managed with twice-over grazing and ungrazed treatments and the seasonlong and nongrazed treatments, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1987-1989						
Stalk Height cm	7.4	18.0	26.2	15.9	26.4	19.2
% Active Leaf	55.6	0.0	20.0	0.0	0.0	0.0
Leaf Height cm	5.5	-	10.4	-	-	-
Tallest Leaf cm	7.2	-	10.4	-	-	-
Ungrazed 1987-1989						
Stalk Height cm	17.5	17.2	32.4	17.0	31.1	20.1
% Active Leaf	55.6	0.0	44.4	0.0	0.0	0.0
Leaf Height cm	9.2	-	14.2	-	-	-
Tallest Leaf cm	13.1	-	14.8	-	-	-
Seasonlong 1987-1989						
Stalk Height cm	19.2	14.0	32.8	22.3	21.9	21.4
% Active Leaf	50.0	0.0	20.0	0.0	50.0	0.0
Leaf Height cm	11.6	-	16.6	-	10.5	-
Tallest Leaf cm	14.0	-	16.6	-	10.5	-
Nongrazed 1987-1989						
Stalk Height cm	19.2	23.4	31.6	22.5	-	13.2
% Active Leaf	48.0	0.0	0.0	0.0	0.0	0.0
Leaf Height cm	12.4	-	-	-	-	-
Tallest Leaf cm	15.5	-	-	-	-	-

Table 17. Growth and development of Prairie Junegrass reproductive lead tillers on silty soils managed with twice-over grazing and ungrazed treatments and the seasonlong and nongrazed treatments, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1987-1989						
Stalk Height cm	18.1	17.4	35.3	21.2	27.6	17.7
% Active Leaf	61.1	46.7	20.0	0.0	0.0	0.0
Leaf Height cm	9.3	11.1	9.4	-	-	-
Tallest Leaf cm	13.5	13.9	9.4	-	-	-
Ungrazed 1987-1989						
Stalk Height cm	18.1	17.3	36.1	25.9	38.8	19.3
% Active Leaf	61.1	8.3	40.0	0.0	0.0	0.0
Leaf Height cm	9.3	7.4	18.0	-	-	-
Tallest Leaf cm	13.5	7.4	18.0	-	-	-
Seasonlong 1987-1989						
Stalk Height cm	17.8	15.6	36.4	19.6	26.6	18.6
% Active Leaf	58.3	28.6	33.3	0.0	0.0	12.0
Leaf Height cm	9.4	9.2	11.1	-	-	-
Tallest Leaf cm	13.0	11.4	13.0	-	-	-
Nongrazed 1987-1989						
Stalk Height cm	17.3	20.0	24.1	23.7	30.8	18.9
% Active Leaf	60.0	11.1	100.0	0.0	0.0	0.0
Leaf Height cm	10.7	19.6	17.6	-	-	-
Tallest Leaf cm	14.9	19.6	20.2	-	-	-

Vegetative Tillers

The vegetative tillers had the second fastest rate of growth and development continuing until mid to late July. Early new leaf development for vegetative tillers arise from fall tillers produced from crown tiller buds during August of the previous growing season. The rate of growth greatly increased during early or mid May resulting in tillers with 3.5 leaves by 1 June. During mid to late July the rate of growth decreased resulting in tillers usually with 5 to 7 basal leaves. A few of the vegetative tillers added leaves 8 and 9 during the growing season (figure 1).

Growth and development data of Prairie Junegrass vegetative tillers on sandy soils managed with the twice-over strategy during 1983 to 1986 are on table 18.

Vegetative tillers with 5 leaves composed 59.2% of the population with 526 tillers, during the growing season a mean of 3.0 leaves (60.0%) were photosynthetically active with a mean leaf height of 7.7 cm and the tallest leaf averaged 9.3 cm tall (table 18).

Vegetative tillers with 6 leaves composed 33.3% of the population with 296 tillers, during the growing season a mean of 3.4 leaves (57.0%) were photosynthetically active with a mean leaf height of 7.4 cm and the tallest leaf averaged 9.6 cm tall (table 18).

Vegetative tillers with 7 leaves composed 7.3% of the population with 65 tillers, during the growing season a mean of 3.9 leaves (55.9%) were photosynthetically active with a mean leaf height of 7.3 cm and the tallest leaf averaged 9.7 cm tall (table 18).

Vegetative tillers with 8 leaves composed 0.1% of the population with 1 tiller, during the growing season a mean of 4.0 leaves (50.0%) were photosynthetically active with a mean leaf height of 10.9 cm and the tallest leaf averaged 13.5 cm tall (table 18).

Vegetative tillers with 9 leaves composed 0.1% of the population with 1 tiller, during the growing season a mean of 2.0 leaves (22.2%) were photosynthetically active with a mean leaf height of 8.0 cm and the tallest leaf averaged 9.2 cm tall (table 18).

Growth and development data of Prairie Junegrass vegetative tillers on sandy soils managed with the ungrazed treatment during 1983 to 1986 are on table 19.

Vegetative tillers with 5 leaves composed 54.7% of the population with 469 tillers, during the growing season a mean of 2.9 leaves (58.3%) were photosynthetically active with a mean leaf height of 9.3 cm and the tallest leaf averaged 11.4 cm tall (table 19).

Vegetative tillers with 6 leaves composed 35.7% of the population with 306 tillers, during the growing season a mean of 3.3 leaves (54.2%) were photosynthetically active with a mean leaf height of 9.5 cm and the tallest leaf averaged 12.0 cm tall (table 19).

Vegetative tillers with 7 leaves composed 9.3% of the population with 80 tillers, during the growing season a mean of 4.0 leaves (57.1%) were photosynthetically active with a mean leaf height of 9.5 cm and the tallest leaf averaged 12.4 cm tall (table 19).

Vegetative tillers with 8 leaves composed 0.2% of the population with 2 tillers, during the growing season a mean of 4.5 leaves (56.3%) were photosynthetically active with a mean leaf height of 9.4 cm and the tallest leaf averaged 14.2 cm tall (table 19).

Vegetative tillers with 9 leaves composed 0.0% of the population with 0 tillers (table 19).

Growth and development data of Prairie Junegrass vegetative tillers on shallow soils managed with the twice-over strategy during 1983 to 1986 are on table 20.

Vegetative tillers with 5 leaves composed 55.3% of the population with 458 tillers, during the growing season a mean of 2.8 leaves (56.7%) were photosynthetically active with a mean leaf height of 5.8 cm and the tallest leaf averaged 7.2 cm tall (table 20).

Vegetative tillers with 6 leaves composed 35.4% of the population with 293 tillers, during the growing season a mean of 3.3 leaves (55.6%) were photosynthetically active with a mean leaf height of 5.8 cm and the tallest leaf averaged 7.4 cm tall (table 20).

Vegetative tillers with 7 leaves composed 8.8% of the population with 73 tillers, during the growing season a mean of 4.2 leaves (60.7%) were

photosynthetically active with a mean leaf height of 5.8 cm and the tallest leaf averaged 7.8 cm tall (table 20).

Vegetative tillers with 8 leaves composed 0.5% of the population with 4 tillers, during the growing season a mean of 4.0 leaves (50.0%) were photosynthetically active with a mean leaf height of 5.9 cm and the tallest leaf averaged 8.5 cm tall (table 20).

Vegetative tillers with 9 leaves composed 0.0% of the population with 0 tillers (table 20).

Growth and development data of Prairie Junegrass vegetative tillers on shallow soils managed with the ungrazed treatment during 1983 to 1986 are on table 21.

Vegetative tillers with 5 leaves composed 52.8% of the population with 488 tillers, during the growing season a mean of 2.9 leaves (58.3%) were photosynthetically active with a mean leaf height of 6.6 cm and the tallest leaf averaged 8.0 cm tall (table 21).

Vegetative tillers with 6 leaves composed 37.6% of the population with 348 tillers, during the growing season a mean of 3.3 leaves (55.6%) were photosynthetically active with a mean leaf height of 6.6 cm and the tallest leaf averaged 8.3 cm tall (table 21).

Vegetative tillers with 7 leaves composed 9.2% of the population with 85 tillers, during the growing season a mean of 3.8 leaves (54.8%) were photosynthetically active with a mean leaf height of 7.0 cm and the tallest leaf averaged 9.2 cm tall (table 21).

Vegetative tillers with 8 leaves composed 0.4% of the population with 4 tillers, during the growing season a mean of 5.0 leaves (62.5%) were photosynthetically active with a mean leaf height of 6.0 cm and the tallest leaf averaged 8.4 cm tall (table 21).

Vegetative tillers with 9 leaves composed 0.0% of the population with 0 tillers (table 21).

Growth and development data of Prairie Junegrass vegetative tillers on silty soils managed with the twice-over strategy during 1983 to 1986 are on table 22.

Vegetative tillers with 5 leaves composed 55.3% of the population with 412 tillers, during the growing season a mean of 2.9 leaves (58.3%) were photosynthetically active with a mean leaf height of 8.6 cm and the tallest leaf averaged 12.7 cm tall (table 22).

Vegetative tillers with 6 leaves composed 34.9% of the population with 260 tillers, during the growing season a mean of 3.3 leaves (55.6%) were photosynthetically active with a mean leaf height of 7.5 cm and the tallest leaf averaged 9.4 cm tall (table 22).

Vegetative tillers with 7 leaves composed 8.5% of the population with 63 tillers, during the growing season a mean of 4.3 leaves (61.9%) were photosynthetically active with a mean leaf height of 7.3 cm and the tallest leaf averaged 9.7 cm tall (table 22).

Vegetative tillers with 8 leaves composed 1.2% of the population with 9 tillers, during the growing season a mean of 4.6 leaves (57.3%) were photosynthetically active with a mean leaf height of 8.3 cm and the tallest leaf averaged 11.3 cm tall (table 22).

Vegetative tillers with 9 leaves composed 0.1% of the population with 1 tiller, during the growing season a mean of 6.0 leaves (66.7%) were photosynthetically active with a mean leaf height of 5.2 cm and the tallest leaf averaged 8.1 cm tall (table 22).

Growth and development data of Prairie Junegrass vegetative tillers on silty soils managed with the ungrazed treatment during 1983 to 1986 are on table 23.

Vegetative tillers with 5 leaves composed 52.9% of the population with 462 tillers, during the growing season a mean of 2.9 leaves (58.3%) were photosynthetically active with a mean leaf height of 11.6 cm and the tallest leaf averaged 18.0 cm tall (table 23).

Vegetative tillers with 6 leaves composed 35.7% of the population with 312 tillers, during the growing season a mean of 3.3 leaves (55.6%) were photosynthetically active with a mean leaf height of 9.4 cm and the tallest leaf averaged 11.7 cm tall (table 23).

Vegetative tillers with 7 leaves composed 10.4% of the population with 91 tillers, during the

growing season a mean of 4.3 leaves (61.9%) were photosynthetically active with a mean leaf height of 9.4 cm and the tallest leaf averaged 12.2 cm tall (table 23).

Vegetative tillers with 8 leaves composed 0.9% of the population with 8 tillers, during the growing season a mean of 45 leaves (56.3%) were photosynthetically active with a mean leaf height of 11.7 cm and the tallest leaf averaged 16.1 cm tall (table 23).

Vegetative tillers with 9 leaves composed 0.1% of the population with 1 tiller, during the growing season a mean of 5.0 leaves (55.6%) were photosynthetically active with a mean leaf height of 8.1 cm and the tallest leaf averaged 10.7 cm tall (table 23).

Growth and development data of Prairie Junegrass vegetative tillers on clay soils managed with the twice-over strategy during 1983 to 1986 are on table 24.

Vegetative tillers with 5 leaves composed 61.2% of the population with 325 tillers, during the growing season a mean of 3.2 leaves (63.3%) were photosynthetically active with a mean leaf height of 6.6 cm and the tallest leaf averaged 8.2 cm tall (table 24).

Vegetative tillers with 6 leaves composed 33.0% of the population with 175 tillers, during the growing season a mean of 3.5 leaves (58.3%) were photosynthetically active with a mean leaf height of 6.8 cm and the tallest leaf averaged 8.4 cm tall (table 24).

Vegetative tillers with 7 leaves composed 5.1% of the population with 27 tillers, during the growing season a mean of 4.3 leaves (61.9%) were photosynthetically active with a mean leaf height of 7.0 cm and the tallest leaf averaged 9.6 cm tall (table 24).

Vegetative tillers with 8 leaves composed 0.6% of the population with 3 tillers, during the growing season a mean of 3.5 leaves (43.8%) were photosynthetically active with a mean leaf height of 9.7 cm and the tallest leaf averaged 11.2 cm tall (table 24).

Vegetative tillers with 9 leaves composed 0.2% of the population with 1 tiller, during the growing season a mean of 4.5 leaves (50.0%) were photosynthetically active with a mean leaf height of 6.6 cm and the tallest leaf averaged 9.3 cm tall (table 24).

Growth and development data of Prairie Junegrass vegetative tillers on clay soils managed with the ungrazed treatment during 1983 to 1986 are on table 25.

Vegetative tillers with 5 leaves composed 55.3% of the population with 310 tillers, during the growing season a mean of 3.0 leaves (60.0%) were photosynthetically active with a mean leaf height of 9.1 cm and the tallest leaf averaged 11.3 cm tall (table 25).

Vegetative tillers with 6 leaves composed 37.8% of the population with 212 tillers, during the growing season a mean of 3.1 leaves (51.4%) were photosynthetically active with a mean leaf height of 9.5 cm and the tallest leaf averaged 11.8 cm tall (table 25).

Vegetative tillers with 7 leaves composed 6.1% of the population with 34 tillers, during the growing season a mean of 3.5 leaves (50.0%) were photosynthetically active with a mean leaf height of 9.7 cm and the tallest leaf averaged 12.0 cm tall (table 25).

Vegetative tillers with 8 leaves composed 0.7% of the population with 4 tillers, during the growing season a mean of 4.0 leaves (50.0%) were photosynthetically active with a mean leaf height of 10.9 cm and the tallest leaf averaged 14.6 cm tall (table 25).

Vegetative tillers with 9 leaves composed 0.2% of the population with 1 tiller, during the growing season a mean of 4.0 leaves (44.4%) were photosynthetically active with a mean leaf height of 9.5 cm and the tallest leaf averaged 11.3 cm tall (table 25).

Growth and development data of Prairie Junegrass vegetative tillers on sandy soils managed with the twice-over strategy during 1987 to 1989 are on table 26.

Vegetative tillers with 5 leaves composed 70.8% of the population with 109 tillers, during the growing season a mean of 3.0 leaves (60.0%) were photosynthetically active with a mean leaf height of 5.8 cm and the tallest leaf averaged 6.7 cm tall (table 26).

Vegetative tillers with 6 leaves composed 26.0% of the population with 40 tillers, during the growing season a mean of 3.8 leaves (62.5%) were photosynthetically active with a mean leaf height of 6.5 cm and the tallest leaf averaged 8.5 cm tall (table 26).

Vegetative tillers with 7 leaves composed 3.2% of the population with 5 tillers, during the growing season a mean of 4.5 leaves (64.3%) were photosynthetically active with a mean leaf height of 7.4 cm and the tallest leaf averaged 10.2 cm tall (table 26).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 26).

Growth and development data of Prairie Junegrass vegetative tillers on sandy soils managed with the ungrazed treatment during 1987 to 1989 are on table 27.

Vegetative tillers with 5 leaves composed 72.0% of the population with 188 tillers, during the growing season a mean of 2.8 leaves (56.0%) were photosynthetically active with a mean leaf height of 9.5 cm and the tallest leaf averaged 11.4 cm tall (table 27).

Vegetative tillers with 6 leaves composed 23.4% of the population with 61 tillers, during the growing season a mean of 3.5 leaves (58.4%) were photosynthetically active with a mean leaf height of 9.5 cm and the tallest leaf averaged 11.8 cm tall (table 27).

Vegetative tillers with 7 leaves composed 4.6% of the population with 12 tillers, during the growing season a mean of 5.0 leaves (71.4%) were photosynthetically active with a mean leaf height of 9.2 cm and the tallest leaf averaged 13.7 cm tall (table 27).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 27).

Growth and development data of Prairie Junegrass vegetative tillers on sandy soils managed with the traditional seasonlong practice during 1987 to 1989 are on table 28.

Vegetative tillers with 5 leaves composed 72.2% of the population with 57 tillers, during the growing season a mean of 3.3 leaves (65.0%) were photosynthetically active with a mean leaf height of 6.9 cm and the tallest leaf averaged 8.6 cm tall (table 28).

Vegetative tillers with 6 leaves composed 25.3% of the population with 20 tillers, during the growing season a mean of 3.0 leaves (50.0%) were photosynthetically active with a mean leaf height of 8.5 cm and the tallest leaf averaged 11.0 cm tall (table 28).

Vegetative tillers with 7 leaves composed 2.5% of the population with 2 tillers, during the growing season a mean of 4.0 leaves (57.1%) were photosynthetically active with a mean leaf height of 7.5 cm and the tallest leaf averaged 13.7 cm tall (table 28).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 28).

Growth and development data of Prairie Junegrass vegetative tillers on sandy soils managed with the long-term nongrazed treatment during 1987 to 1989 are on table 29.

Vegetative tillers with 5 leaves composed 58.3% of the population with 49 tillers, during the growing season a mean of 3.0 leaves (60.0%) were photosynthetically active with a mean leaf height of 11.5 cm and the tallest leaf averaged 14.3 cm tall (table 29).

Vegetative tillers with 6 leaves composed 31.0% of the population with 26 tillers, during the growing season a mean of 3.0 leaves (50.0%) were photosynthetically active with a mean leaf height of 9.7 cm and the tallest leaf averaged 11.9 cm tall (table 29).

Vegetative tillers with 7 leaves composed 10.7% of the population with 9 tillers, during the growing season a mean of 5.0 leaves (71.1%) were photosynthetically active with a mean leaf height of 9.6 cm and the tallest leaf averaged 13.3 cm tall (table 29).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 29).

Growth and development data of Prairie Junegrass vegetative tillers on shallow soils managed with the twice-over strategy during 1987 to 1989 are on table 30.

Vegetative tillers with 5 leaves composed 74.3% of the population with 139 tillers, during the growing season a mean of 2.8 leaves (56.7%) were photosynthetically active with a mean leaf height of 6.3 cm and the tallest leaf averaged 7.8 cm tall (table 30).

Vegetative tillers with 6 leaves composed 23.0% of the population with 43 tillers, during the growing season a mean of 3.0 leaves (50.0%) were photosynthetically active with a mean leaf height of 5.8 cm and the tallest leaf averaged 7.8 cm tall (table 30).

Vegetative tillers with 7 leaves composed 2.7% of the population with 5 tillers, during the growing season a mean of 3.0 leaves (42.9%) were photosynthetically active with a mean leaf height of 5.0 cm and the tallest leaf averaged 5.8 cm tall (table 30).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 30).

Growth and development data of Prairie Junegrass vegetative tillers on shallow soils managed with the ungrazed treatment during 1987 to 1989 are on table 31.

Vegetative tillers with 5 leaves composed 76.3% of the population with 244 tillers, during the growing season a mean of 2.8 leaves (56.7%) were photosynthetically active with a mean leaf height of 8.2 cm and the tallest leaf averaged 10.2 cm tall (table 31).

Vegetative tillers with 6 leaves composed 20.9% of the population with 67 tillers, during the growing season a mean of 3.3 leaves (54.2%) were photosynthetically active with a mean leaf height of 6.9 cm and the tallest leaf averaged 9.0 cm tall (table 31).

Vegetative tillers with 7 leaves composed 2.8% of the population with 9 tillers, during the growing season a mean of 4.2 leaves (60.7%) were photosynthetically active with a mean leaf height of 6.5 cm and the tallest leaf averaged 9.2 cm tall (table 31).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 31).

Growth and development data of Prairie Junegrass vegetative tillers on shallow soils managed with the traditional seasonlong practice during 1987 to 1989 are on table 32.

Vegetative tillers with 5 leaves composed 70.1% of the population with 54 tillers, during the growing season a mean of 3.3 leaves (66.7%) were photosynthetically active with a mean leaf height of 8.7 cm and the tallest leaf averaged 11.2 cm tall (table 32).

Vegetative tillers with 6 leaves composed 28.6% of the population with 22 tillers, during the growing season a mean of 4.0 leaves (66.7%) were photosynthetically active with a mean leaf height of 7.7 cm and the tallest leaf averaged 9.9 cm tall (table 32).

Vegetative tillers with 7 leaves composed 1.3% of the population with 1 tiller, during the growing season a mean of 5.0 leaves (71.4%) were photosynthetically active with a mean leaf height of 7.7 cm and the tallest leaf averaged 11.3 cm tall (table 32).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 32).

Growth and development data of Prairie Junegrass vegetative tillers on shallow soils managed with the long-term nongrazed treatment during 1987 to 1989 are on table 33.

Vegetative tillers with 5 leaves composed 77.1% of the population with 74 tillers, during the growing season a mean of 2.6 leaves (52.0%) were photosynthetically active with a mean leaf height of 8.5 cm and the tallest leaf averaged 10.5 cm tall (table 33).

Vegetative tillers with 6 leaves composed 21.9% of the population with 21 tillers, during the growing season a mean of 3.3 leaves (54.2%) were photosynthetically active with a mean leaf height of 8.5 cm and the tallest leaf averaged 10.8 cm tall (table 33).

Vegetative tillers with 7 leaves composed 1.0% of the population with 1 tiller, during the growing season a mean of 1.0 leaf (14.3%) was photosynthetically active with a mean leaf height of 11.6 cm and the tallest leaf averaged 11.6 cm tall (table 33).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 33).

Growth and development data of Prairie Junegrass vegetative tillers on silty soils managed with the twice-over strategy during 1987 to 1989 are on table 34.

Vegetative tillers with 5 leaves composed 83.3% of the population with 130 tillers, during the growing season a mean of 3.2 leaves (63.3%) were photosynthetically active with a mean leaf height of 8.9 cm and the tallest leaf averaged 11.6 cm tall (table 34).

Vegetative tillers with 6 leaves composed 14.7% of the population with 23 tillers, during the growing season a mean of 3.3 leaves (55.6%) were photosynthetically active with a mean leaf height of 6.9 cm and the tallest leaf averaged 9.5 cm tall (table 34).

Vegetative tillers with 7 leaves composed 2.0% of the population with 3 tillers, during the growing season a mean of 4.5 leaves (64.3%) were photosynthetically active with a mean leaf height of 9.0 cm and the tallest leaf averaged 13.5 cm tall (table 34).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 34).

Growth and development data of Prairie Junegrass vegetative tillers on silty soils managed with the ungrazed treatment during 1987 to 1989 are on table 35.

Vegetative tillers with 5 leaves composed 68.1% of the population with 188 tillers, during the growing season a mean of 3.0 leaves (60.0%) were photosynthetically active with a mean leaf height of 9.7 cm and the tallest leaf averaged 12.8 cm tall (table 35).

Vegetative tillers with 6 leaves composed 27.9% of the population with 77 tillers, during the growing season a mean of 4.0 leaves (66.7%) were photosynthetically active with a mean leaf height of 8.0 cm and the tallest leaf averaged 10.3 cm tall (table 35).

Vegetative tillers with 7 leaves composed 4.0% of the population with 11 tillers, during the growing season a mean of 4.7 leaves (66.6%) were photosynthetically active with a mean leaf height of 9.0 cm and the tallest leaf averaged 12.9 cm tall (table 35).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 35).

Growth and development data of Prairie Junegrass vegetative tillers on silty soils managed with the traditional seasonlong practice during 1987 to 1989 are on table 36.

Vegetative tillers with 5 leaves composed 79.5% of the population with 105 tillers, during the growing season a mean of 2.6 leaves (52.0%) were photosynthetically active with a mean leaf height of 6.9 cm and the tallest leaf averaged 8.5 cm tall (table 36).

Vegetative tillers with 6 leaves composed 18.9% of the population with 25 tillers, during the growing season a mean of 3.4 leaves (56.3%) were photosynthetically active with a mean leaf height of 6.2 cm and the tallest leaf averaged 7.7 cm tall (table 36).

Vegetative tillers with 7 leaves composed 1.5% of the population with 2 tillers, during the growing season a mean of 5.0 leaves (71.4%) were photosynthetically active with a mean leaf height of 8.1 cm and the tallest leaf averaged 9.3 cm tall (table 36).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 36).

Growth and development data of Prairie Junegrass vegetative tillers on silty soils managed with the long-term nongrazed treatment during 1987 to 1989 are on table 37.

Vegetative tillers with 5 leaves composed 61.7 the population with 66 tillers, during the growing season a mean of 3.2 leaves (63.3%) were photosynthetically active with a mean leaf height of 10.4 cm and the tallest leaf averaged 13.2 cm tall (table 37).

Vegetative tillers with 6 leaves composed 37.4% of the population with 40 tillers, during the growing season a mean of 3.0 leaves (50.0%) were photosynthetically active with a mean leaf height of 12.5 cm and the tallest leaf averaged 17.4 cm tall (table 37).

Vegetative tillers with 7 leaves composed 0.9% of the population with 1 tiller, during the growing season a mean of 4.0 leaves (57.1%) were photosynthetically active with a mean leaf height of 10.9 cm and the tallest leaf averaged 14.2 cm tall (table 37).

Vegetative tillers with 8 and 9 leaves composed 0.0% of the population with 0 tillers (table 37).

Not all the leaves on a grass tiller are photosynthetically active during the entire growing season. Leaves grow and senesce in the order they appear. The first leaves are usually dry by early June and the second leaves are usually dry by late June. The rate of leaf senescence can be rapid during water deficiency periods and slow during periods with adequate precipitation. During senescence, leaves translocate cell components to other plant parts. The senesced leaf has less weight and has very low nutritional quality. The greater number of leaves not senescent, the greater the tiller nutritional quality.

The rate of leaf senescence of Prairie Junegrass vegetative tillers on sandy, shallow, silty and clay soils managed with the ungrazed and twice-over treatments during 1983 to 1986 that received adequate precipitation was very similar with the first and second leaves drying during June. The vegetative tillers with 5 to 7 leaves maintained 3.5 leaves on the twice-over strategy and 3.4 leaves on the ungrazed treatment. The tillers with 8 and 9 leaves maintained 4.4 and 4.5 photosynthetically active leaves on the twice-over strategy and ungrazed treatment, respectively.

The rate of leaf senescence of Prairie Junegrass vegetative tillers on sandy, shallow, and silty soils managed with the nongrazed, seasonlong, ungrazed, and twice-over treatments during 1987 to 1989 that had water deficiency during most of the growing season months was more severe than during the 1983 to 1986 period. All tillers failed to produce leaf 8 and 9. Tillers on the nongrazed and seasonlong treatments maintained a mean of 3.1 and 3.7 photosynthetically active leaves during the growing season, respectively. Tillers on the twice-over and ungrazed treatment maintained a mean of 3.5 and 3.7 photosynthetically active leaves, respectively.

All of the vegetative tillers of Prairie Junegrass with 5 to 9 leaves measured during this study were not grazed including the tillers located on grazed treatments. The not grazed tillers remaining on the grazed treatments tended to have slightly shorter mean leaf heights and mean tallest leaf heights which were not significantly different than the not grazed tillers on the ungrazed and nongrazed treatments on the sandy, shallow, silty, and clay soils during the 1983-1986 period and on the sandy, shallow, and silty soils during the 1987-1989 period. It is not believed that grazed treatments cause vegetative tillers to produce slightly shorter leaf heights. It is surmised that grazing cattle have a disproportional rate of selection for taller tillers than for shorter tillers leaving a distorted sample population of not grazed tillers with slightly shorter leaf heights.

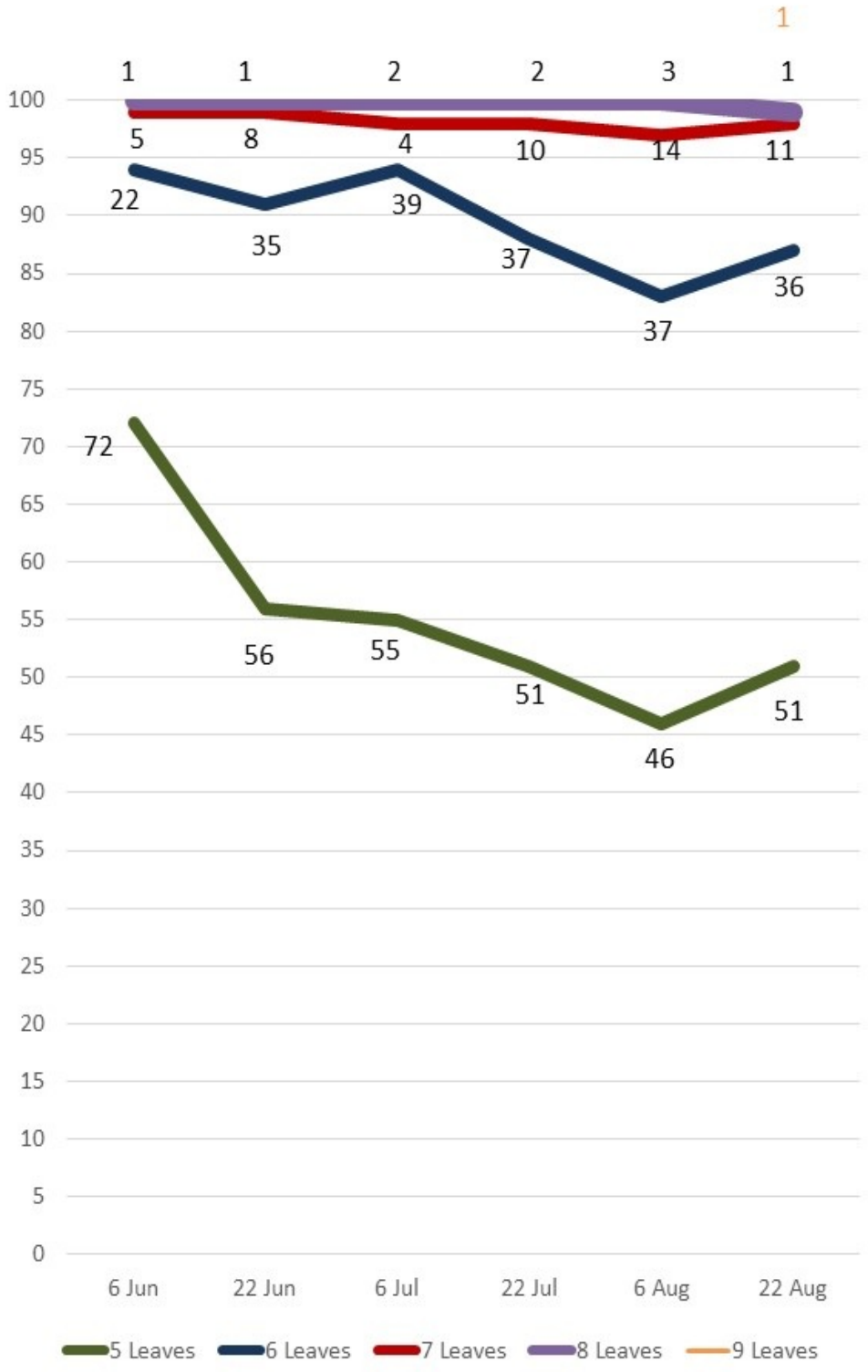

Figure 1. Percent of vegetative tiller population with 5 to 9 leaves.

Table 18. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on sandy soils managed with the twice-over strategy, 1983-1986.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	72.0	64.8	62.5	65.7	47.8	49.2
% Active Leaf	60.0	60.0	60.0	60.0	60.0	60.0
Leaf Height cm	7.8	7.8	7.0	7.9	7.2	8.2
Tallest Leaf cm	9.6	9.3	8.9	9.3	8.7	9.9
6 Leaves						
% Population	25.3	31.5	36.5	28.6	38.0	37.8
% Active Leaf	66.7	58.3	66.7	50.0	50.0	50.0
Leaf Height cm	6.7	7.6	8.7	7.0	6.8	7.7
Tallest Leaf cm	9.4	9.8	11.3	9.4	8.0	9.5
7 Leaves						
% Population	2.7	3.1	1.0	5.7	14.1	12.6
% Active Leaf	57.1	57.1	57.1	57.1	57.1	50.0
Leaf Height cm	8.5	7.3	4.7	7.6	7.7	8.1
Tallest Leaf cm	11.5	9.7	6.2	10.5	10.1	10.2
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.4
% Active Leaf	-	-	-	-	-	50.0
Leaf Height cm	-	-	-	-	-	10.9
Tallest Leaf cm	-	-	-	-	-	13.5
9 leaves						
% Population	0.0	0.6	0.0	0.0	0.0	0.0
% Active Leaf	-	22.2	-	-	-	-
Leaf Height cm	-	8.0	-	-	-	-
Tallest Leaf cm	-	9.2	-	-	-	-
% Population	100.0	100.0	100.0	100.0	99.9	100.0

Table 19. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on sandy soils managed with the ungrazed treatment, 1983-1986.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	79.4	59.0	48.9	67.4	52.7	38.4
% Active Leaf	60.0	60.0	60.0	60.0	60.0	50.0
Leaf Height cm	9.8	9.6	9.8	9.5	9.6	7.4
Tallest Leaf cm	12.2	11.6	11.9	11.7	11.6	9.5
6 Leaves						
% Population	19.0	33.9	41.3	26.9	33.9	47.0
% Active Leaf	66.7	50.0	50.0	58.3	50.0	50.0
Leaf Height cm	10.4	9.7	8.8	9.4	10.5	8.2
Tallest Leaf cm	13.4	12.0	10.9	11.8	13.2	10.5
7 Leaves						
% Population	1.6	6.6	9.8	5.1	13.4	14.7
% Active Leaf	71.4	42.9	57.1	57.1	57.1	57.1
Leaf Height cm	8.8	8.7	9.5	11.0	9.0	9.7
Tallest Leaf cm	12.8	10.8	12.7	13.9	11.3	12.6
8 Leaves						
% Population	0.0	0.5	0.0	0.6	0.0	0.0
% Active Leaf	-	50.0	-	62.5	-	-
Leaf Height cm	-	7.8	-	10.9	-	-
Tallest Leaf cm	-	13.4	-	15.0	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.1

Table 20. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on shallow soils managed with the twice-over strategy, 1983-1986.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	77.3	53.7	47.1	52.9	47.0	58.3
% Active Leaf	60.0	60.0	60.0	50.0	60.0	50.0
Leaf Height cm	6.0	6.0	5.8	6.2	5.7	5.0
Tallest Leaf cm	7.4	7.6	7.0	7.6	7.1	6.3
6 Leaves						
% Population	21.3	38.8	41.4	40.9	33.0	31.3
% Active Leaf	66.7	66.7	50.0	50.0	50.0	50.0
Leaf Height cm	5.6	5.9	6.1	6.2	5.5	5.5
Tallest Leaf cm	7.8	7.6	7.7	7.7	6.4	7.4
7 Leaves						
% Population	1.3	6.8	11.5	6.3	19.0	9.5
% Active Leaf	85.7	57.1	57.1	50.0	57.1	57.1
Leaf Height cm	4.5	6.2	6.0	7.1	5.6	5.6
Tallest Leaf cm	7.5	8.1	7.5	9.2	7.0	7.7
8 Leaves						
% Population	0.0	0.7	0.0	0.0	1.0	0.9
% Active Leaf	-	37.5	-	-	62.5	50.0
Leaf Height cm	-	7.8	-	-	6.9	3.0
Tallest Leaf cm	-	10.1	-	-	11.0	4.5
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	99.9	100.0	100.0	100.1	100.0	100.0

Table 21. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on shallow soils managed with the ungrazed treatment, 1983-1986.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	75.4	59.7	47.1	58.4	36.3	44.6
% Active Leaf	60.0	60.0	60.0	60.0	60.0	50.0
Leaf Height cm	7.0	6.9	6.7	6.6	6.2	6.1
Tallest Leaf cm	8.5	8.2	8.0	7.9	7.6	7.7
6 Leaves						
% Population	23.2	34.7	42.4	32.5	38.9	47.2
% Active Leaf	66.7	58.3	50.0	58.3	50.0	50.0
Leaf Height cm	5.7	7.1	6.8	6.7	6.5	6.7
Tallest Leaf cm	7.7	9.1	8.3	8.1	8.1	8.6
7 Leaves						
% Population	1.4	5.6	10.6	8.2	23.9	7.8
% Active Leaf	57.1	64.3	42.9	50.0	57.1	57.1
Leaf Height cm	7.5	6.4	6.8	7.2	6.5	7.6
Tallest Leaf cm	10.4	8.8	9.1	8.9	8.0	10.0
8 Leaves						
% Population	0.0	0.0	0.0	0.9	0.9	0.4
% Active Leaf	-	-	-	62.5	62.5	62.5
Leaf Height cm	-	-	-	5.3	7.6	5.2
Tallest Leaf cm	-	-	-	6.8	10.4	7.9
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.1	100.0	100.0	100.0

Table 22. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on silty soils managed with the twice-over strategy, 1983-1986.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	66.7	51.6	65.8	50.0	52.5	57.7
% Active Leaf	60.0	60.0	60.0	50.0	60.0	60.0
Leaf Height cm	9.9	8.8	9.5	8.4	7.7	7.3
Tallest Leaf cm	15.7	12.6	16.0	11.3	10.6	9.8
6 Leaves						
% Population	25.0	38.7	28.8	38.5	34.7	33.5
% Active Leaf	66.7	58.3	50.0	58.3	50.0	50.0
Leaf Height cm	6.3	7.8	8.6	8.7	6.9	6.8
Tallest Leaf cm	8.8	10.1	10.1	10.4	8.6	8.1
7 Leaves						
% Population	6.3	9.0	2.7	10.3	10.9	7.7
% Active Leaf	57.1	64.3	71.4	57.1	71.4	50.0
Leaf Height cm	6.3	7.7	5.7	9.0	7.4	7.8
Tallest Leaf cm	7.9	11.0	8.5	11.0	8.9	10.6
8 Leaves						
% Population	2.1	0.6	2.7	1.1	2.0	0.5
% Active Leaf	62.5	37.5	62.5	56.3	62.5	62.5
Leaf Height cm	10.4	11.1	6.7	10.5	5.2	5.8
Tallest Leaf cm	13.8	16.6	8.8	13.4	6.1	9.1
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.5
% Active Leaf	-	-	-	-	-	66.7
Leaf Height cm	-	-	-	-	-	5.2
Tallest Leaf cm	-	-	-	-	-	8.1
% Population	100.1	99.9	100.0	99.9	100.1	99.9

Table 23. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on silty soils managed with the ungrazed treatment, 1983-1986.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	77.4	61.3	44.0	54.1	40.7	45.2
% Active Leaf	60.0	60.0	60.0	60.0	60.0	50.0
Leaf Height cm	11.2	11.1	12.5	12.0	10.7	12.2
Tallest Leaf cm	17.5	17.2	19.9	18.7	16.2	18.2
6 Leaves						
% Population	19.4	32.1	50.0	34.9	38.9	37.7
% Active Leaf	66.7	58.3	50.0	50.0	50.0	58.3
Leaf Height cm	8.7	9.0	9.5	10.3	10.1	8.9
Tallest Leaf cm	11.6	11.6	11.5	12.3	12.3	10.6
7 Leaves						
% Population	3.2	6.6	6.0	10.5	16.7	15.1
% Active Leaf	71.4	64.3	71.4	50.0	57.1	57.1
Leaf Height cm	7.2	8.7	8.9	9.8	12.6	9.0
Tallest Leaf cm	10.6	11.9	12.8	11.1	15.0	11.6
8 Leaves						
% Population	0.0	0.0	0.0	0.5	3.7	1.5
% Active Leaf	-	-	-	62.5	62.5	43.8
Leaf Height cm	-	-	-	12.5	15.6	7.0
Tallest Leaf cm	-	-	-	19.7	18.8	9.9
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.5
% Active Leaf	-	-	-	-	-	55.6
Leaf Height cm	-	-	-	-	-	8.1
Tallest Leaf cm	-	-	-	-	-	10.2
% Population	100.0	100.0	100.0	100.0	100.0	100.0

Table 24. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on clay soils managed with the twice-over strategy, 1983-1986.

Clay	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	81.3	63.2	63.0	61.7	70.6	52.9
% Active Leaf	80.0	60.0	60.0	60.0	60.0	60.0
Leaf Height cm	6.8	6.1	6.5	7.6	6.4	5.9
Tallest Leaf cm	9.3	7.5	7.9	9.3	7.9	7.1
6 Leaves						
% Population	15.6	33.3	30.4	31.9	23.5	40.2
% Active Leaf	66.7	58.3	50.0	58.3	66.7	50.0
Leaf Height cm	6.7	6.4	7.1	7.4	6.7	6.5
Tallest Leaf cm	9.0	8.1	8.7	8.8	7.7	7.9
7 Leaves						
% Population	3.1	3.4	6.5	5.7	5.9	5.2
% Active Leaf	71.4	57.1	57.1	50.0	71.4	64.3
Leaf Height cm	6.7	8.9	5.0	7.2	7.6	6.5
Tallest Leaf cm	10.5	10.6	8.2	9.5	9.5	9.0
8 Leaves						
% Population	0.0	0.0	0.0	0.7	0.0	1.1
% Active Leaf	-	-	-	37.5	-	50.0
Leaf Height cm	-	-	-	6.3	-	13.1
Tallest Leaf cm	-	-	-	7.5	-	14.8
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.6
% Active Leaf	-	-	-	-	-	50.0
Leaf Height cm	-	-	-	-	-	6.6
Tallest Leaf cm	-	-	-	-	-	9.3
% Population	100.0	99.9	99.9	100.0	100.0	100.0

Table 25. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on clay soils managed with the ungrazed treatment, 1983-1986.

Clay	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	69.4	55.6	51.6	61.4	64.3	42.9
% Active Leaf	60.0	60.0	60.0	60.0	60.0	60.0
Leaf Height cm	9.1	8.0	10.6	9.5	8.8	8.5
Tallest Leaf cm	11.6	10.0	13.2	11.7	10.6	10.8
6 Leaves						
% Population	30.6	37.3	45.2	33.1	27.1	46.4
% Active Leaf	50.0	58.3	50.0	50.0	50.0	50.0
Leaf Height cm	9.2	8.6	11.3	9.1	10.2	8.3
Tallest Leaf cm	11.5	10.4	14.4	11.6	12.1	10.5
7 Leaves						
% Population	0.0	4.8	3.2	5.5	8.6	9.3
% Active Leaf	-	57.1	42.9	57.1	42.9	50.0
Leaf Height cm	-	7.3	10.7	8.9	12.6	8.8
Tallest Leaf cm	-	9.5	12.3	11.3	15.5	11.3
8 Leaves						
% Population	0.0	2.4	0.0	0.0	0.0	0.7
% Active Leaf	-	50.0	-	-	-	50.0
Leaf Height cm	-	12.6	-	-	-	9.1
Tallest Leaf cm	-	16.4	-	-	-	12.7
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.7
% Active Leaf	-	-	-	-	-	44.4
Leaf Height cm	-	-	-	-	-	9.5
Tallest Leaf cm	-	-	-	-	-	11.3
% Population	100.0	100.1	100.0	100.0	100.0	100.0

Table 26. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on sandy soils managed with the twice-over strategy, 1987-1989.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	56.0	82.4	100.0	75.6	0.0	69.7
% Active Leaf	60.0	60.0	80.0	60.0	-	40.0
Leaf Height cm	5.6	6.4	4.7	6.3	-	5.8
Tallest Leaf cm	6.1	8.0	5.3	7.9	-	6.2
6 Leaves						
% Population	40.0	17.6	0.0	24.4	0.0	24.2
% Active Leaf	66.7	66.7	-	66.7	-	50.0
Leaf Height cm	6.6	6.2	-	6.8	-	6.3
Tallest Leaf cm	7.3	9.6	-	9.9	-	7.0
7 Leaves						
% Population	4.0	0.0	0.0	0.0	0.0	6.1
% Active Leaf	71.4	-	-	-	-	57.1
Leaf Height cm	6.8	-	-	-	-	8.0
Tallest Leaf cm	8.1	-	-	-	-	12.2
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	0.0	100.0

Table 27. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on sandy soils managed with the ungrazed treatment, 1987-1989.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	61.0	90.9	100.0	78.0	0.0	69.5
% Active Leaf	60.0	60.0	80.0	60.0	-	20.0
Leaf Height cm	11.9	7.6	12.1	9.0	-	6.8
Tallest Leaf cm	14.3	9.7	15.4	11.0	-	6.8
6 Leaves						
% Population	25.6	9.1	0.0	20.3	0.0	30.5
% Active Leaf	66.7	66.7	-	66.7	-	33.3
Leaf Height cm	10.8	9.0	-	9.3	-	8.9
Tallest Leaf cm	13.9	11.1	-	11.3	-	10.8
7 Leaves						
% Population	13.4	0.0	0.0	1.7	0.0	0.0
% Active Leaf	71.4	-	-	71.4	-	-
Leaf Height cm	14.4	-	-	3.9	-	-
Tallest Leaf cm	19.9	-	-	7.5	-	-
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	0.0	100.0

Table 28. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on sandy soils managed with the seasonlong treatment, 1987-1989.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	84.6	75.0	100.0	76.2	100.0	59.4
% Active Leaf	60.0	70.0	80.0	60.0	80.0	40.0
Leaf Height cm	7.5	7.7	7.8	8.2	6.4	3.9
Tallest Leaf cm	9.5	10.3	9.4	9.7	8.0	4.6
6 Leaves						
% Population	15.4	25.0	0.0	19.0	0.0	37.5
% Active Leaf	66.7	33.3	-	66.7	-	33.3
Leaf Height cm	8.8	11.5	-	7.5	-	6.0
Tallest Leaf cm	11.5	14.1	-	9.5	-	8.7
7 Leaves						
% Population	0.0	0.0	0.0	4.8	0.0	3.1
% Active Leaf	-	-	-	57.1	-	57.1
Leaf Height cm	-	-	-	6.5	-	8.5
Tallest Leaf cm	-	-	-	14.2	-	13.1
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.0

Table 29. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on sandy soils managed with the nongrazed treatment, 1987-1989.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	46.7	36.4	100.0	53.8	100.0	57.9
% Active Leaf	60.0	40.0	80.0	60.0	80.0	40.0
Leaf Height cm	12.4	11.4	13.2	8.3	16.0	7.7
Tallest Leaf cm	15.0	12.3	16.3	10.4	22.1	9.8
6 Leaves						
% Population	33.3	63.6	0.0	30.8	0.0	31.6
% Active Leaf	50.0	50.0	-	50.0	-	50.0
Leaf Height cm	11.9	9.0	-	6.9	-	10.9
Tallest Leaf cm	15.3	10.2	-	8.5	-	13.6
7 Leaves						
% Population	20.0	0.0	0.0	15.4	0.0	10.5
% Active Leaf	57.1	-	-	71.4	-	85.7
Leaf Height cm	10.3	-	-	7.3	-	11.1
Tallest Leaf cm	14.3	-	-	9.4	-	16.2
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.0

Table 30. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on shallow soils managed with the twice-over strategy, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	95.5	91.7	100.0	75.0	100.0	57.7
% Active Leaf	60.0	60.0	80.0	60.0	80.0	0.0
Leaf Height cm	4.6	6.6	5.2	6.5	8.5	-
Tallest Leaf cm	5.5	8.1	6.1	7.8	11.6	-
6 Leaves						
% Population	4.5	8.3	0.0	25.0	0.0	35.2
% Active Leaf	66.7	50.0	-	50.0	-	33.3
Leaf Height cm	4.3	6.6	-	6.2	-	6.2
Tallest Leaf cm	6.3	8.6	-	7.7	-	8.4
7 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	7.0
% Active Leaf	-	-	-	-	-	42.9
Leaf Height cm	-	-	-	-	-	5.0
Tallest Leaf cm	-	-	-	-	-	5.8
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	99.9

Table 31. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on shallow soils managed with the ungrazed treatment, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	64.0	91.5	100.0	81.5	100.0	73.1
% Active Leaf	60.0	60.0	80.0	60.0	80.0	0.0
Leaf Height cm	8.2	6.0	7.9	8.3	10.5	-
Tallest Leaf cm	9.5	7.1	9.9	10.0	14.4	-
6 Leaves						
% Population	34.9	6.4	0.0	16.9	0.0	21.3
% Active Leaf	66.7	50.0	-	50.0	-	50.0
Leaf Height cm	7.4	6.3	-	6.7	-	7.2
Tallest Leaf cm	9.8	8.9	-	8.2	-	9.0
7 Leaves						
% Population	1.2	2.1	0.0	1.5	0.0	5.6
% Active Leaf	71.4	57.1	-	57.1	-	57.1
Leaf Height cm	4.5	3.8	-	9.0	-	8.7
Tallest Leaf cm	6.8	6.1	-	12.5	-	11.3
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.1	100.0	100.0	99.9	100.0	100.0

Table 32. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on shallow soils managed with the seasonlong treatment, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	66.7	76.9	100.0	64.0	100.0	62.5
% Active Leaf	60.0	60.0	80.0	60.0	80.0	60.0
Leaf Height cm	11.1	8.3	14.2	6.4	4.3	7.9
Tallest Leaf cm	13.2	9.1	20.8	8.0	6.7	9.1
6 Leaves						
% Population	33.3	23.1	0.0	36.0	0.0	31.3
% Active Leaf	66.7	66.7	-	66.7	-	66.7
Leaf Height cm	8.2	7.9	-	6.8	-	8.0
Tallest Leaf cm	11.2	10.0	-	9.0	-	9.5
7 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	6.3
% Active Leaf	-	-	-	-	-	71.4
Leaf Height cm	-	-	-	-	-	7.7
Tallest Leaf cm	-	-	-	-	-	11.3
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.1

Table 33. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on shallow soils managed with the nongrazed treatment, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	80.8	62.5	100.0	78.6	0.0	65.2
% Active Leaf	60.0	60.0	80.0	40.0	-	20.0
Leaf Height cm	9.9	9.4	7.3	6.7	-	8.4
Tallest Leaf cm	11.4	10.3	12.7	9.5	-	8.4
6 Leaves						
% Population	15.4	37.5	0.0	21.4	0.0	34.8
% Active Leaf	66.7	50.0	-	33.3	-	66.7
Leaf Height cm	7.7	10.4	-	7.4	-	8.5
Tallest Leaf cm	11.0	12.5	-	9.2	-	10.5
7 Leaves						
% Population	3.8	0.0	0.0	0.0	0.0	0.0
% Active Leaf	14.3	-	-	-	-	-
Leaf Height cm	11.6	-	-	-	-	-
Tallest Leaf cm	11.6	-	-	-	-	-
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	0.0	100.0

Table 34. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on silty soils managed with the twice-over strategy, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	90.0	100.0	100.0	80.0	100.0	68.6
% Active Leaf	60.0	60.0	80.0	40.0	80.0	60.0
Leaf Height cm	5.2	7.4	16.5	8.0	10.4	5.9
Tallest Leaf cm	6.2	9.3	21.3	11.8	12.7	8.5
6 Leaves						
% Population	10.0	0.0	0.0	16.9	0.0	28.6
% Active Leaf	50.0	-	-	50.0	-	66.7
Leaf Height cm	6.1	-	-	7.1	-	7.5
Tallest Leaf cm	8.8	-	-	9.0	-	10.6
7 Leaves						
% Population	0.0	0.0	0.0	3.1	0.0	2.9
% Active Leaf	-	-	-	71.4	-	57.1
Leaf Height cm	-	-	-	5.1	-	12.8
Tallest Leaf cm	-	-	-	7.0	-	19.9
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.1

Table 35. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on silty soils managed with the ungrazed treatment, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	68.1	66.7	100.0	67.1	100.0	64.0
% Active Leaf	60.0	40.0	80.0	40.0	80.0	60.0
Leaf Height cm	8.5	9.6	10.6	12.2	10.5	6.9
Tallest Leaf cm	10.5	12.5	13.7	17.7	14.8	7.3
6 Leaves						
% Population	25.3	33.3	0.0	28.2	0.0	34.0
% Active Leaf	66.7	66.7	-	66.7	-	66.7
Leaf Height cm	6.6	7.7	-	8.7	-	8.9
Tallest Leaf cm	9.1	10.0	-	12.3	-	9.7
7 Leaves						
% Population	6.6	0.0	0.0	4.7	0.0	2.0
% Active Leaf	71.4	-	-	57.1	-	71.4
Leaf Height cm	7.1	-	-	8.4	-	11.5
Tallest Leaf cm	10.5	-	-	11.0	-	17.1
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.0

Table 36. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on silty soils managed with the seasonlong treatment, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	87.5	89.5	100.0	73.8	0.0	74.4
% Active Leaf	50.0	60.0	40.0	60.0	-	50.0
Leaf Height cm	6.5	6.1	9.3	7.3	-	5.1
Tallest Leaf cm	8.0	7.6	11.9	9.0	-	6.2
6 Leaves						
% Population	12.5	10.5	0.0	26.2	0.0	20.9
% Active Leaf	66.7	58.3	-	50.0	-	50.0
Leaf Height cm	5.9	6.4	-	6.7	-	5.9
Tallest Leaf cm	7.0	8.6	-	8.1	-	7.0
7 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	4.7
% Active Leaf	-	-	-	-	-	71.4
Leaf Height cm	-	-	-	-	-	8.1
Tallest Leaf cm	-	-	-	-	-	9.3
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	0.0	100.0

Table 37. Growth and development of Prairie Junegrass vegetative tillers with 5 to 9 leaves on silty soils managed with the nongrazed treatment, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
5 Leaves						
% Population	41.7	35.3	94.1	87.5	50.0	77.8
% Active Leaf	60.0	60.0	80.0	60.0	80.0	40.0
Leaf Height cm	9.9	14.9	11.9	11.0	6.4	8.2
Tallest Leaf cm	11.3	19.2	15.3	15.4	8.1	9.7
6 Leaves						
% Population	58.3	58.8	5.9	12.5	50.0	22.2
% Active Leaf	66.7	50.0	66.7	50.0	66.7	0.0
Leaf Height cm	9.8	15.1	12.5	14.1	11.2	-
Tallest Leaf cm	11.5	19.9	16.0	23.1	16.6	-
7 Leaves						
% Population	0.0	5.9	0.0	0.0	0.0	0.0
% Active Leaf	-	57.1	-	-	-	-
Leaf Height cm	-	10.9	-	-	-	-
Tallest Leaf cm	-	14.2	-	-	-	-
8 Leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
9 leaves						
% Population	0.0	0.0	0.0	0.0	0.0	0.0
% Active Leaf	-	-	-	-	-	-
Leaf Height cm	-	-	-	-	-	-
Tallest Leaf cm	-	-	-	-	-	-
% Population	100.0	100.0	100.0	100.0	100.0	100.0

Secondary Tillers

The secondary tillers had very slow rates of growth and development until they produce their fourth leaf. During growing seasons with normal precipitation conditions (1983-1986), secondary tillers made up about 26.8% of the total tiller population on the grazed twice-over treatment and made up about 24.5% of the ungrazed treatment. During growing seasons with below normal precipitation conditions (1987-1989), secondary tillers made up a greater proportion of the total tiller population, with 61.7% on the grazed twice-over strategy, 48.3% on the ungrazed treatment, 61.9% on the seasonlong, and 48.3% on the nongrazed treatments.

Growth and development data of Prairie Junegrass secondary tillers on sandy, shallow, silty, and clay soils managed with the twice-over strategy and the ungrazed treatment during 1983 to 1986 are on tables 38, 39, 40, and 41, respectively.

Secondary tillers with 2 to 4 leaves on sandy soils of the twice-over strategy composed 20.0% of the total population with 329 tillers (table 6), during the growing season 66.4% of the leaves were photosynthetically active with a mean leaf height of 7.9 cm and the tallest leaf averaged 9.3 cm tall (table 38).

Secondary tillers with 2 to 4 leaves on sandy soils of the ungrazed treatment composed 17.8% of the total tiller population with 231 tillers (table 6), during the growing season 63.2% of the leaves were photosynthetically active with a mean leaf height of 8.9 cm and the tallest leaf averaged 9.9 cm tall (table 38).

Secondary tillers with 2 to 4 leaves on shallow soils of the twice-over strategy composed 18.0% of the total tiller population with 225 tillers (table 7), during the growing season 66.9% of the leaves were photosynthetically active with a mean leaf height of 5.5 cm and the tallest leaf averaged 6.6 cm tall (table 39).

Secondary tillers with 2 to 4 leaves on shallow soils of the ungrazed treatment composed 19.1% of the total tiller population with 324 tillers (table 7), during the growing season 70.7% of the leaves were photosynthetically active with a mean leaf height of 7.4 cm and the tallest leaf averaged 8.8 cm tall (table 39).

Secondary tillers with 2 to 4 leaves on silty soils of the twice-over strategy composed 21.1% of the total tiller population with 255 tillers (table 8), during the growing season 62.8% of the leaves were photosynthetically active with a mean leaf height of 7.1 cm and the tallest leaf averaged 8.6 cm tall (table 40).

Secondary tillers with 2 to 4 leaves on silty soils of the ungrazed treatment composed 23.5% of the total tiller population with 404 tillers (table 8), during the growing season 65.6% of the leaves were photosynthetically active with a mean leaf height of 9.0 cm and the tallest leaf averaged 10.2 cm tall (table 40).

Secondary tillers with 2 to 4 leaves on clay soils of the twice-over strategy composed 24.3% of the total tiller population with 265 tillers (table 9), during the growing season 61.4% of the leaves were photosynthetically active with a mean leaf height of 6.5 cm and the tallest leaf averaged 7.8 cm tall (table 41).

Secondary tillers with 2 to 4 leaves on clay soils of the ungrazed treatment composed 17.7% of the total tiller population with 153 tillers (table 9), during the growing season 63.1% of the leaves were photosynthetically active with a mean leaf height of 8.7 cm and the tallest leaf averaged 10.1 cm tall (table 41).

Growth and development data of Prairie Junegrass secondary tillers on sandy, shallow, and silty soils managed with the twice-over strategy and the ungrazed treatment and with the seasonlong and nongrazed treatments during 1987 to 1989 are on tables 42, 43, and 44, respectively.

Secondary tillers with 2 to 4 leaves on sandy soils of the twice-over strategy composed 52.1% of the total tiller population with 225 tillers (table 6), during the growing season 74.1% of the leaves were photosynthetically active with a mean leaf height of 7.2 cm and the tallest leaf averaged 9.0 cm tall (table 42).

Secondary tillers with 2 to 4 leaves on sandy soils of the ungrazed treatment composed 40.7% of the total tiller population with 235 tillers (table 6), during the growing season 65.5% of the leaves were photosynthetically active with a mean leaf height of 8.6 cm and the tallest leaf averaged 10.1 cm tall (table 42).

Secondary tillers with 2 to 4 leaves on sandy soils of the seasonlong treatment composed 51.4% of the total tiller population with 126 tillers (table 6), during the growing season 64.2% of the leaves were photosynthetically active with a mean leaf height of 7.0 cm and the tallest leaf averaged 8.2 cm tall (table 42).

Secondary tillers with 2 to 4 leaves on sandy soils of the nongrazed treatment composed 48.4% of the total tiller population with 119 tillers (table 6), during the growing season 74.9% of the leaves were photosynthetically active with a mean leaf height of 11.1 cm and the tallest leaf averaged 13.1 cm tall (table 42).

Secondary tillers with 2 to 4 leaves on shallow soils of the twice-over strategy composed 52.8% of the total tiller population with 288 tillers (table 7), during the growing season 68.9% of the leaves were photosynthetically active with a mean leaf height of 6.6 cm and the tallest leaf averaged 7.9 cm tall (table 43).

Secondary tillers with 2 to 4 leaves on shallow soils of the ungrazed treatment composed 40.8% of the total tiller population with 284 tillers (table 7), during the growing season 57.9% of the leaves were photosynthetically active with a mean leaf height of 8.0 cm and the tallest leaf averaged 9.0 cm tall (table 43).

Secondary tillers with 2 to 4 leaves on shallow soils of the seasonlong treatment composed 47.0% of the total tiller population with 103 tillers (table 7), during the growing season 70.4% of the leaves were photosynthetically active with a mean leaf height of 7.4 cm and the tallest leaf averaged 8.8 cm tall (table 43).

Secondary tillers with 2 to 4 leaves on shallow soils of the nongrazed treatment composed 38.7% of the total tiller population with 86 tillers (table 7), during the growing season 60.6% of the leaves were photosynthetically active with a mean leaf height of 7.8 cm and the tallest leaf averaged 8.8 cm tall (table 43).

Secondary tillers with 2 to 4 leaves on silty soils of the twice-over strategy composed 54.4% of the total tiller population with 290 tillers (table 8), during the growing season 60.1% of the leaves were photosynthetically active with a mean leaf height of 6.6 cm and the tallest leaf averaged 7.7 cm tall (table 44).

Secondary tillers with 2 to 4 leaves on silty soils of the ungrazed treatment composed 45.0% of the total tiller population with 282 tillers (table 8), during the growing season 65.9% of the leaves were photosynthetically active with a mean leaf height of 9.5 cm and the tallest leaf averaged 10.7 cm tall (table 44).

Secondary tillers with 2 to 4 leaves on silty soils of the seasonlong treatment composed 57.0% of the total tiller population with 268 tillers (table 8), during the growing season 54.7% of the leaves were photosynthetically active with a mean leaf height of 6.5 cm and the tallest leaf averaged 7.6 cm tall (table 44).

Secondary tillers with 2 to 4 leaves on silty soils of the nongrazed treatment composed 31.2% of the total tiller population with 68 tillers (table 8), during the growing season 60.7% of the leaves were photosynthetically active with a mean leaf height of 9.7 cm and the tallest leaf averaged 12.7 cm tall (table 44).

All of the secondary tillers measured during this study were not grazed including the tillers located on grazed treatments. The not grazed tillers remaining on the grazed treatments tended to have slightly shorter mean leaf heights and mean tallest leaf heights which were not significantly different than the not grazed tillers on the ungrazed treatments on sandy, shallow, silty, and clay soils during the 1983-1986 period (tables 38, 39, 40, and 41) and on the sandy, shallow, and silty soils during the 1987-1989 period (tables 42, 43, and 44). It is not believed that grazed treatments cause secondary tillers to produce slightly shorter leaf heights. It is surmised that grazing cattle have a disproportional rate of selection for taller tillers than for shorter tillers leaving a distorted sample population of not grazed tillers with slightly shorter leaf heights.

Leaves grow and senesce in about the same order of their appearance. This study has designated that leaves with less than 50% senescent tissue to be photosynthetically active. Tillers growing on the twice-over treatment tended to have greater photosynthetically active leaves (67.7%) than the tillers growing on the ungrazed treatment (63.1%) and the tillers growing on the seasonlong (63.1%) and nongrazed (65.4%) treatments, during the growing seasons with below normal precipitation conditions (1987 to 1989).

Secondary tillers composed a low percentage of the total measured tiller population during the 1983 to 1986 period with normal precipitation conditions with 20.9% on the grazed twice-over strategy and 19.5% on the ungrazed treatment. The quantity of secondary tillers greatly increased during the 1987 to 1989 period with below normal precipitation conditions and composed 53.1% on the grazed twice-over strategy and 42.2% on the ungrazed treatment and composed 51.8% on the grazed seasonlong practice and 39.4% on the long-term nongrazed treatment.

Table 38. Growth and development of Prairie Junegrass secondary tillers on sandy soils managed with the twice-over grazing and ungrazed treatments, 1983-1986.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
% Population	33.6	34.4	18.6	28.8	22.0	22.3
% Active Leaf	71.4	81.3	71.4	62.5	57.1	54.5
Leaf Height cm	7.9	7.4	9.9	7.9	7.1	7.1
Tallest Leaf cm	8.6	8.4	11.5	9.4	9.7	8.4
Ungrazed 1983-1986						
% Population	44.2	23.8	22.0	30.5	7.4	7.9
% Active Leaf	71.4	71.4	57.1	54.5	75.0	50.0
Leaf Height cm	9.0	8.2	9.9	8.9	8.4	8.8
Tallest Leaf cm	10.2	9.3	10.9	10.1	9.6	9.4

Table 39. Growth and development of Prairie Junegrass secondary tillers on shallow soils managed with the twice-over grazing and ungrazed treatments, 1983-1986.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
% Population	36.4	26.1	25.6	15.4	17.4	16.3
% Active Leaf	85.7	78.6	77.8	54.5	50.0	54.5
Leaf Height cm	5.6	5.7	4.6	6.0	6.1	5.2
Tallest Leaf cm	6.8	6.7	5.3	6.8	8.0	5.9
Ungrazed 1983-1986						
% Population	40.5	34.2	27.4	22.5	5.8	23.0
% Active Leaf	85.7	75.0	85.7	63.6	50.0	64.3
Leaf Height cm	6.3	6.9	6.4	7.4	7.4	9.8
Tallest Leaf cm	7.6	7.6	7.8	8.5	9.4	11.7

Table 40. Growth and development of Prairie Junegrass secondary tillers on silty soils managed with the twice-over grazing and ungrazed treatments, 1983-1986.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
% Population	55.6	21.7	37.1	25.0	15.1	14.5
% Active Leaf	77.8	81.8	71.4	45.5	50.0	50.0
Leaf Height cm	7.9	7.0	6.1	8.0	6.6	7.2
Tallest Leaf cm	9.0	8.5	7.4	9.4	8.8	7.3
Ungrazed 1983-1986						
% Population	43.1	35.4	29.4	34.7	10.0	29.4
% Active Leaf	66.7	75.0	71.4	54.5	57.1	68.8
Leaf Height cm	8.2	7.7	9.4	10.4	9.8	8.5
Tallest Leaf cm	8.3	8.6	11.0	10.8	12.9	9.7

Table 41. Growth and development of Prairie Junegrass secondary tillers on clay soils managed with the twice-over grazing and ungrazed treatments, 1983-1986.

Clay	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1983-1986						
% Population	53.6	40.4	36.1	35.3	36.3	17.5
% Active Leaf	71.4	75.0	55.6	54.5	57.1	54.5
Leaf Height cm	6.0	6.3	5.8	7.9	6.8	6.3
Tallest Leaf cm	6.8	7.4	8.0	9.0	8.7	6.7
Ungrazed 1983-1986						
% Population	47.1	20.3	18.4	23.0	12.5	16.2
% Active Leaf	85.7	81.8	42.9	54.5	57.1	56.3
Leaf Height cm	7.9	5.9	10.9	10.0	8.6	9.1
Tallest Leaf cm	9.8	6.7	12.3	11.4	10.0	10.2

Table 42. Growth and development of Prairie Junegrass secondary tillers on sandy soils managed with the twice-over grazing and ungrazed treatments and the seasonlong and nongrazed treatmetns, 1987-1989.

Sandy	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1987-1989						
% Population	46.8	77.0	97.6	55.9	100.0	37.1
% Active Leaf	77.8	77.8	71.4	85.7	75.0	57.1
Leaf Height cm	7.2	5.6	4.6	5.6	9.4	10.7
Tallest Leaf cm	8.5	6.6	8.6	6.4	10.8	13.2
Ungrazed 1987-1989						
% Population	43.4	67.3	88.4	38.5	0.0	26.1
% Active Leaf	71.4	66.7	75.0	57.1	-	57.1
Leaf Height cm	9.2	7.4	11.2	5.9	-	9.4
Tallest Leaf cm	10.5	8.6	14.5	7.0	-	10.0
Seasonlong 1987-1989						
% Population	72.9	81.0	84.2	50.0	88.9	11.1
% Active Leaf	69.2	62.5	75.0	57.1	71.4	50.0
Leaf Height cm	7.6	7.0	8.1	5.1	8.5	5.7
Tallest Leaf cm	8.3	8.2	9.6	6.0	10.4	6.7
Nongrazed 1987-1989						
% Population	76.6	72.5	59.1	36.6	63.6	24.0
% Active Leaf	88.9	71.4	75.0	71.4	71.4	71.4
Leaf Height cm	10.0	9.4	12.3	13.5	9.6	12.0
Tallest Leaf cm	11.2	10.7	15.4	14.9	10.4	15.8

Table 43. Growth and development of Prairie Junegrass secondary tillers on shallow soils managed with the twice-over grazing and ungrazed treatments and the seasonlong and nongrazed treatmetns, 1987-1989.

Shallow	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1987-1989						
% Population	62.1	76.5	91.1	49.2	84.2	37.7
% Active Leaf	85.7	66.7	75.0	85.7	71.4	28.6
Leaf Height cm	6.3	6.2	6.0	6.2	8.4	6.3
Tallest Leaf cm	6.7	7.2	7.7	6.9	11.2	7.8
Ungrazed 1987-1989						
% Population	46.6	61.8	87.8	45.8	72.7	14.3
% Active Leaf	66.7	66.7	71.4	71.4	71.4	0.0
Leaf Height cm	6.5	8.3	6.6	8.8	9.8	-
Tallest Leaf cm	6.9	9.2	7.8	9.6	11.5	-
Seasonlong 1987-1989						
% Population	60.0	69.0	77.3	13.8	84.2	46.7
% Active Leaf	83.3	64.3	75.0	71.4	71.4	57.1
Leaf Height cm	6.7	6.5	9.7	5.5	6.9	9.2
Tallest Leaf cm	8.3	7.7	11.9	6.7	7.2	10.9
Nongrazed 1987-1989						
% Population	58.1	57.9	15.0	50.0	0.0	32.4
% Active Leaf	77.8	71.4	75.0	50.0	-	28.6
Leaf Height cm	9.6	7.4	6.7	7.6	-	7.7
Tallest Leaf cm	10.9	8.2	7.6	9.6	-	7.8

Table 44. Growth and development of Prairie Junegrass secondary tillers on silty soils managed with the twice-over grazing and ungrazed treatments and the seasonlong and nongrazed treatmetns, 1987-1989.

Silty	6 Jun	22 Jun	6 Jul	22 Jul	6 Aug	22 Aug
Twice-over 1987-1989						
% Population	72.2	72.0	97.4	48.4	85.3	48.5
% Active Leaf	57.1	57.1	75.0	57.1	71.4	42.9
Leaf Height cm	5.2	7.4	8.7	6.1	7.3	4.8
Tallest Leaf cm	5.9	7.8	10.1	7.5	9.2	5.6
Ungrazed 1987-1989						
% Population	42.8	68.8	82.9	32.5	90.2	24.2
% Active Leaf	71.4	66.7	71.4	57.1	71.4	57.1
Leaf Height cm	7.8	9.8	10.9	10.2	10.8	7.4
Tallest Leaf cm	9.4	10.3	13.2	11.1	12.1	8.1
Seasonlong 1987-1989						
% Population	71.4	77.1	88.9	50.0	100.0	41.9
% Active Leaf	81.3	64.3	60.0	42.9	72.7	7.1
Leaf Height cm	5.3	6.2	9.6	6.1	8.3	3.5
Tallest Leaf cm	5.8	7.5	11.4	6.9	10.2	3.5
Nongrazed 1987-1989						
% Population	14.3	5.6	19.0	81.0	87.5	25.0
% Active Leaf	71.4	75.0	75.0	71.4	71.4	0.0
Leaf Height cm	8.8	14.1	11.4	7.8	6.5	-
Tallest Leaf cm	10.8	22.5	14.0	8.7	7.5	-

Discussion

Prairie Junegrass, *Koeleria macrantha,* is a native, long lived perennial, cool-season, mid grass, monocot, of the grass family that is abundant on heathy mixed grass prairie plant communities. Prairie Junegrass can grow on sandy, shallow, silty, clay, and thin claypan ecological sites. It is drought resistant, and cold and heat tolerant. Early aerial growth of lead tillers arises from carryover tillers, and basal leaves of vegetative tillers arise from fall tillers produced during the previous growing season and from early spring initiated crown tiller buds. New leaves are visible during mid April. Leaf growth is slow until early or mid May. Rapid growth produces 3.5 new leaves by 1 June. Early flower stalk growth reaches the boot stage duirng mid May to early June, progressing through head emergence during early to late June. Anthesis occurs during a 5 week period from early or mid June to mid July. Seeds develop through the milk and dough stages during late June to late July, mature, and are being shed during mid July to mid August.

Vegetative tillers produce 5 to 7 basal leaves by mid to late July when the rate of growth decreases. A few vegetative tillers continue growth and produce leaf 8 or 9 during the growing season. Tillers with 5 to 7 leaves maintain 3.5 and 3.4 photosynthetically active leaves and tillers with 8 or 9 leaves usually maintain 4.4 and 4.5 photosynthetically active leaves on the twice-over and ungrazed treatments, respectively during 1983 to 1986.

Secondary tillers develop during the growing season in May or June and grow slowly until they produce their fourth leaf, when they develop into vegetative tillers usually during July or August. Prairie Junegrass is a cool season grass and produce a relatively large quantity of new leaf growth during August.

Prairie Junegrass lead tillers and most vegetative tillers produce 3.5 new leaves by 1 June consistently and this grass species can be used as a reliable indicator of native rangeland grazing readiness. Prairie Junegrass is a valuable forage asset on the Northern Mixed Grass Prairie.

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