Grazing Treatment Effects on Vegetative Tillering and Soil Rhizospheres of Western Wheatgrass

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Summary

This investigation improved the understanding of grazing treatment effects on the stimulation of grass defoliation resistance mechanisms. The study explored the effects from three grazing treatments and a long-term nongrazed control on grass vegetative tiller development from axillary buds and on the activity level of soil microorganisms in the rhizosphere. The results included three significant findings: the grazing treatment developed to stimulate the defoliation resistance mechanisms increased tiller density per square meter, rhizosphere volume per plant, and rhizosphere volume per cubic meter of soil.

Introduction

An incomplete understanding of the interrelated processes within grassland ecosystems is the main reason for the limited effectiveness of traditional management practices. A better understanding of the complex biological and ecological grassland processes will advance the development of effective grazing management strategies.

Grazing effects are often simplistically perceived to be just the removal of leaf material from grass plants. However, defoliation by grazing produces complex effects on grass plants. Different grazing management treatments cause diverse changes in plant growth, plant density, and the herbage biomass produced on grasslands (Manske 2003a). Traditional grazing management practices result in encumbered grassland ecosystems that produce at less-than-potential levels. These antiquated practices are not based on the biological requirements of plants or on the biogeochemical processes in the ecosystem and need to be replaced with effective strategies that improve grassland health and productivity. Biologically effective management strategies, such as the 4.5-month twice-over rotation system, produce advantageous biological effects by coordinating grazing with specific phenological growth stages to manipulate the defoliation resistance mechanisms that grass plants developed during their coevolution with herbivores (Manske 1994). Two defoliation resistance mechanisms of primary concern to grassland managers are grass vegetative reproduction by secondary tiller development from axillary buds and symbiotic soil organism activity in the rhizosphere.

Vegetative shoots are produced from a main shoot or lead tiller by vegetative reproduction, the physiological process of tillering (Manske 1998). Tillering is the development of a shoot from vertical growth of an axillary bud (Dahl 1995), and each tiller is a complete unit with roots, stem, and leaves. Defoliation stimulates tillering by reducing the influence of apical dominance, the physiological process by which the apical meristem and young leaves of a lead tiller exert hormonal regulation of axillary bud growth that inhibits development of vegetative tillers (Briske 1991, Murphy and Briske 1992, Briske and Richards 1994, Briske and Richards 1995, Manske 1996b). Stimulation of the tillering process in grass plants results in increased plant density and greater quantity and quality of aboveground herbage production (Manske 2003a).

The soil rhizosphere around perennial grass roots is the zone where a symbiotic relationship occurs between the roots of plants and microorganisms living in the soil. The rhizosphere organisms are bacteria, protozoa, nematodes, mites, small insects, and fungi. These organisms interact in a complex trophic web that is critical for energy and nutrient flow in grassland ecosystems (Manske and Caesar-TonThat 2002). Defoliation beneficially stimulates soil organism activity in the rhizosphere by increasing the amount of carbon compounds released from grass roots into the rhizosphere. Increased exudation of sugars, amino acids, glycosides, and other compounds from the roots of grass plants increases microorganism activity (Curl and Truelove 1986, Whipps 1990, Campbell and Greaves 1990). Bacterial growth in the rhizosphere is stimulated by the presence of simple carbon compounds from the exudates (Elliot 1978, Anderson *et al.* 1981, Curl and Truelove 1986, Whipps 1990). Protozoa and nematodes graze increasingly on the proliferating bacteria (Curl and Truelove 1986) and accelerate the biogeochemical cycling processes (Coleman *et al.* 1983). The activity of microbes in the rhizosphere increases the amount of nutrients available for plant growth (Allen and Allen 1990). Increased activity of rhizosphere fungi also benefits plant growth. Rhizosphere fungi are primarily vesicular-arbuscular

Laboratory Procedure

The basic research unit was the western wheatgrass plant. Tillers of each plant were categorized as lead, secondary, or fall types. The densities of the lead tillers, of the secondary and fall tillers, and of the total of all tillers were determined per square meter of soil surface for each sample period. The soil matrix of collected soil cores was carefully removed from between the rhizospheres around the roots of western wheatgrass plants. The roots and rhizospheres of other plant species were separated from the soil cores and discarded. The western wheatgrass rhizospheres were sprayed with a clear acrylic coating to prevent damage during further handling. The length and diameter of the rhizosphere around each root of every plant, including associated tillers, were measured in inches with a vernier caliper. The English measurements were converted to metric system values. During the process of extraction, some rhizospheres were damaged and small segments were detached from the root surface. The length measurements of damaged rhizospheres were the length of the root, including the regions of detached rhizosphere segments. The length and diameter measurements were used to determine the volume of the rhizosphere around each root. Data were analyzed on a per-plant basis, as a total of all plants per replication, and as a mean of the two replications per sample period. Differences between means of treatments were analyzed by a standard paired-plot t-test (Mosteller and Rourke 1973).

Results

Precipitation

Precipitation in 2002 (table 1) was greater than normal (134.21% LTM) and the growing season was categorized as wet. June, July, and August were wet months (>125% of LTM). September and October had water deficiencies (< 75% of LTM), and plants experienced water stress during September (Manske 2003b).

Tiller Density of Western Wheatgrass

The 4.5-m TOR treatment had greater numerical total tiller density for each sample period than the other treatments (table 2, figure 1). The mean total tiller density across the four monthly sample periods (June to September) was significantly greater ($P<0.05$) on the 4.5-m TOR treatment than on the 4.5-m SL, 6.0-m SL, and long-term nongrazed treatments. The mean total tiller density on the 4.5-m SL, 6.0-m SL, and long-term nongrazed treatments did not differ ($P<0.05$). The total tiller density on the 4.5-m TOR treatment was significantly greater ($P< 0.05$) than that on the 4.5-m SL and 6.0-m SL treatments during June, August, and September and greater ($P< 0.05$) than that on the long-term nongrazed treatment during June (table 2).

Lead tiller density (table 2, figure 2) on the 4.5-m TOR treatment was significantly greater ($P<0.05$) than that on the 4.5-m SL and 6.0-m SL treatments during June and September and greater ($P<0.05$) than that on the long-term nongrazed treatment during September.

Secondary tiller density (table 2, figure 3), including the fall tillers, was significantly greater ($P<0.05$) on the 4.5-m TOR treatments than on the 4.5-m SL treatment during June, July, and August and greater ($P<0.05$) on the 4.5-m TOR treatment than on the 6.0-m SL and long-term nongrazed treatments during June and August.

Sample pasture #1 of the 4.5-m TOR treatment was grazed in 2001 during the second stimulation period, mid June to late June. This is the period when light defoliation of western wheatgrass promotes the greatest increase in tiller numbers by stimulating vegetative reproduction processes. Western wheatgrass tiller density on the 4.5-m TOR treatment was significantly greater ($P<0.05$) than that on the 4.5-m SL, 6.0-m SL, and nongrazed treatments in June of 2002 (table 2, figure 1). In 2002, sample pasture #1 of the 4.5-m TOR treatment was grazed during the third stimulation period, early July to mid July. Western wheatgrass secondary tiller density on the 4.5-m TOR treatment was significantly greater ($P< 0.05$) than that on the 4.5-m SL, 6.0-m SL, and nongrazed treatments during August (table 2). Total tiller density on the 4.5-m TOR treatments was significantly greater ($P< 0.05$) than that on the 4.5-m SL and 6.0-m SL treatments during August and September (table 2).

Rhizosphere Volume per Plant

The rhizosphere volume per plant varied considerably during June and July, with little difference among treatments. Following the stimulation grazing period from early July to mid July, the rhizosphere volume per plant on sample pasture #1 of the 4.5-m TOR treatment greatly increased. The rhizosphere volume per plant (table 3, figure 4) on the 4.5-m TOR treatment was significantly greater ($P< 0.05$) than that on the 4.5-m SL and 6.0-m SL treatments in August and September and greater ($P< 0.05$) than that on the nongrazed treatment in September.

mycorrhizae (VAM) that form endomycorrhiza in which the vesicles, arbuscules, and hyphae of the fungus enter the cells and tissue of the host plant (Harley and Smith 1983). The symbiotic function of endomycorrhizal fungi in grassland plant rhizospheres is the nitrification of ammonia and the enhancement of the absorption of phosphorus, other mineral nutrients, and water (Moorman and Reeves 1979, Harley and Smith 1983, Allen and Allen 1990, Box and Hammond 1990, Marschner 1992, Manske 1996). Stimulation of the activity of rhizosphere organisms results in increased conversion of organic nitrogen into mineral nitrogen and in greater availability of water, minerals, and nutrients for the grass plants.

Both the tillering process and soil rhizosphere activity can be stimulated by grazing management that removes a small amount of leaf material while the plant is between the third-leaf stage and flowering growth stage (Manske 1999b). Grazing grass plants prior to the third-leaf stage negatively affects grass growth. Early seasonal growth of grass plants depends on carbohydrates stored in the roots, rhizomes, and stem bases (Trlica 1977), and prematurely grazed plants are unable to replenish adequate amounts of carbohydrates to support active growth (Coyne *et al*. 1995, Manske 1999a). Starting grazing after the third-leaf stage and before the flowering stage allows plants to establish sufficient leaf area to produce adequate photosynthetic assimilates to meet leaf growth requirements and allows all leaf bud primordia in the apical meristem to develop into leaf buds (Manske 1998). Little evidence has been found to suggest that defoliation after the flowering stage has beneficial stimulatory effects on grass growth (Manske 2000).

The objectives of this research project were to investigate the two primary defoliation resistance mechanisms by evaluating the effects from four management treatments on the response of western wheatgrass plants (*Agropyron smithii)* through comparison of quantitative differences in (1) the number of tillers per square meter and (2) the amount of soil rhizosphere activity as measured by the volume of rhizosphere in a known volume of soil.

Procedure

This project was conducted in 2002 at the NDSU Dickinson Research Extension Center ranch, located near the Knife River. The Ranch Headquarters is 20 miles north of Dickinson, in western North Dakota, U.S.A. (47° 14' N. lat., 102° 50' W. long.).

Treatments

The four treatments in this experiment were (1) 4.5-month twice-over rotation system (4.5-m TOR), (2) 4.5-month seasonlong (4.5-m SL), (3) 6.0-month seasonlong (6.0-m SL), and (4) long-term nongrazed control (NG). Livestock on the 4.5-month twice-over rotation management treatment followed a double rotation sequence through three native range pastures for 4.5 months (135 days) from early June until mid October. Each pasture was grazed for two periods, a stimulation period of about 15 days of grazing between early June and mid July (when grasses were in the third-leaf stage to anthesis phenophase), followed by a harvest period of about 30 days of grazing after mid July and prior to mid October. The first pasture grazed in the sequence was the last pasture grazed the previous year. Sample pasture #1 (4.5-m TOR) was grazed in 2001 from 13 June to 28 June during the second stimulation period and again from 13 August to 11 September during the harvest period. In 2002 it was grazed from 27 June to 12 July during the third stimulation period and again from 11 September to 10 October during the harvest period. Livestock on the 4.5-month seasonlong management treatment grazed one native range pasture for 4.5 months (135 days) from early June until mid October. Sample pasture #11 (4.5-m SL) was grazed in 2001 from 30 May to 11 October and in 2002 from 29 May to 10 October. Livestock on the 6.0-month seasonlong management treatment grazed one native range pasture for 6.0 months (183 days) from mid May until mid November. Sample pasture #7 (6.0-m SL) was grazed in 2001 from 9 May until 8 November and in 2002 from 9 May until 7 November. The long-term nongrazed (NG) management treatment had not been grazed, mowed, or burned for more than 30 years before the initiation of these research treatments.

Field Sample Collection Procedure

Replicated plant and soil samples were collected monthly. The collection dates were 25 June, 26 July, 30 August, 6 September, and 30 September. Field samples collected 30 August and 6 September were analyzed as one sample period. Eight samples were collected each period: two representative replications of western wheatgrass (*Agropyron smithii*) with an intact soil core from silty range sites on each of the four defoliation treatments. Plastic PVC pipe 3 inches (7.62 cm) in diameter and 4 inches (10.16 cm) long was forced into sample site soil. Intact soil-plant cores and pipe were excavated and transported to the laboratory.

Total Rhizosphere Volume

The rhizosphere volume per cubic meter of soil was not different ($P < 0.05$) among treatments during June (table 4). Following the stimulation grazing period from early July to mid July on the 4.5-m TOR treatment, the total rhizosphere volume per cubic meter of soil (table 4, figure 5) on that treatment was significantly greater ($P < 0.05$) than that on the 4.5-m SL and 6.0-m SL treatments during July, August, and September and greater ($P < 0.05$) than that on the nongrazed treatments during August and September.

Discussion

This study measured tiller density and rhizosphere volume on four management treatments across one growing season. This relatively small data set revealed important biological differences among the grazing management treatments.

The twice-over rotation system is designed to match defoliation periods with grass phenological stages of growth when the defoliation resistance mechanisms can be stimulated. The two primary mechanisms are vegetative tillering from axillary buds and activity of symbiotic soil organisms in the rhizosphere.

Stimulation of vegetative reproduction from the twice-over rotation grazing treatment during the previous year increased western wheatgrass tiller density. The increase carried over through the winter and resulted in greater tiller density on that treatment than on the other treatments in June of the study year. The tiller stimulation that resulted from the twice-over rotation grazing treatment during the year of the study increased the western wheatgrass tiller density so that it was greater on that biologically effective treatment than on the other grazing treatments during the entire later portion of the growing season.

The activity of symbiotic soil organisms, as indicated by the volume of the rhizosphere, increased on the twice-over rotation system following defoliation during the stimulation grazing period, which occurred on the sample area from early July to mid July in 2002. The rhizosphere volume per plant significantly increased on the twice-over rotation treatment following the stimulation grazing period, and the total rhizosphere volume in the soil increased following the stimulation period and remained significantly greater during the remainder of the growing season.

Conclusion

Grazing management strategies that are designed to stimulate grass defoliation resistance mechanisms meet the biological requirements of plants and enhance the biogeochemical processes in grassland ecosystems. Stimulation of these biological and ecological mechanisms increases the vegetative tillering process and the rhizosphere organism activity. Traditional management practices that are designed for other priorities than to meet plant requirements or enhance ecosystem processes impede the function of defoliation resistance mechanisms. Inhibition of these mechanisms reduces the development of grass vegetative tillers and the activity of rhizosphere organisms.

Acknowledgment

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Table 1. Precipitation in inches for growing-season months at Ranch Headquarters DREC, North Dakota.

	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Growing Season**
Long-term mean	1.41	2.04	3.36	2.75	1.85	1.39	1.24	14.04
2002	1.14	2.18	5.40	4.27	4.24	0.74	0.88	18.85
% of LTM	80.85	106.86	160.71	155.27	229.19	53.24	70.97	134.21

Table 2. Tiller density of western wheatgrass per square meter.

	Tiller Types	**June**	**July**	**August**	**September**
4.5-m TOR	Lead	1206.043a	657.842a	712.662a	986.763a
	Secondary	1206.042m	548.202m	1260.864m	438.562m
	Total	2412.087x	1206.043x	1973.526x	1425.324x
4.5-m SL	Lead	548.202b	548.202a	493.382a	548.202b
	Secondary	0.0n	109.641n	274.101n	109.641m
	Total	548.202y	657.842x	767.482y	657.842y
6.0-m SL	Lead	438.561b	328.921a	328.921a	438.562b
	Secondary	328.921o	219.281mn	493.382n	328.922m
	Total	767.482y	548.202x	822.303y	767.482y
Nongrazed	Lead	438.562ab	328.921a	712.663a	438.561b
	Secondary	109.641no	219.281mn	164.461n	767.483m
	Total	548.202y	548.202x	877.123xy	1206.044x

Means in the same column and followed by the same letter are not significantly different (P<0.05)

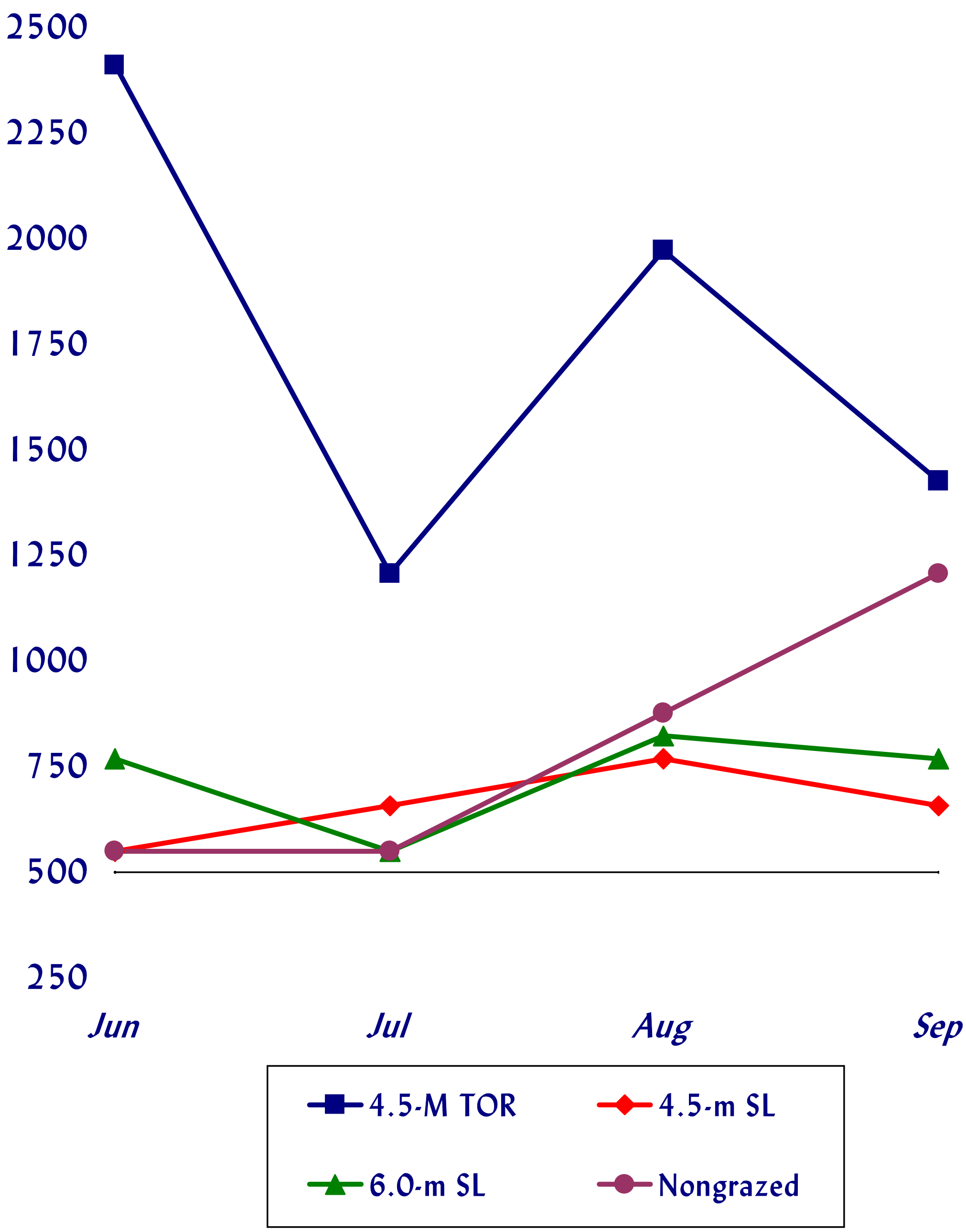

Figure 1. Total tiller density of western wheatgrass per square meter

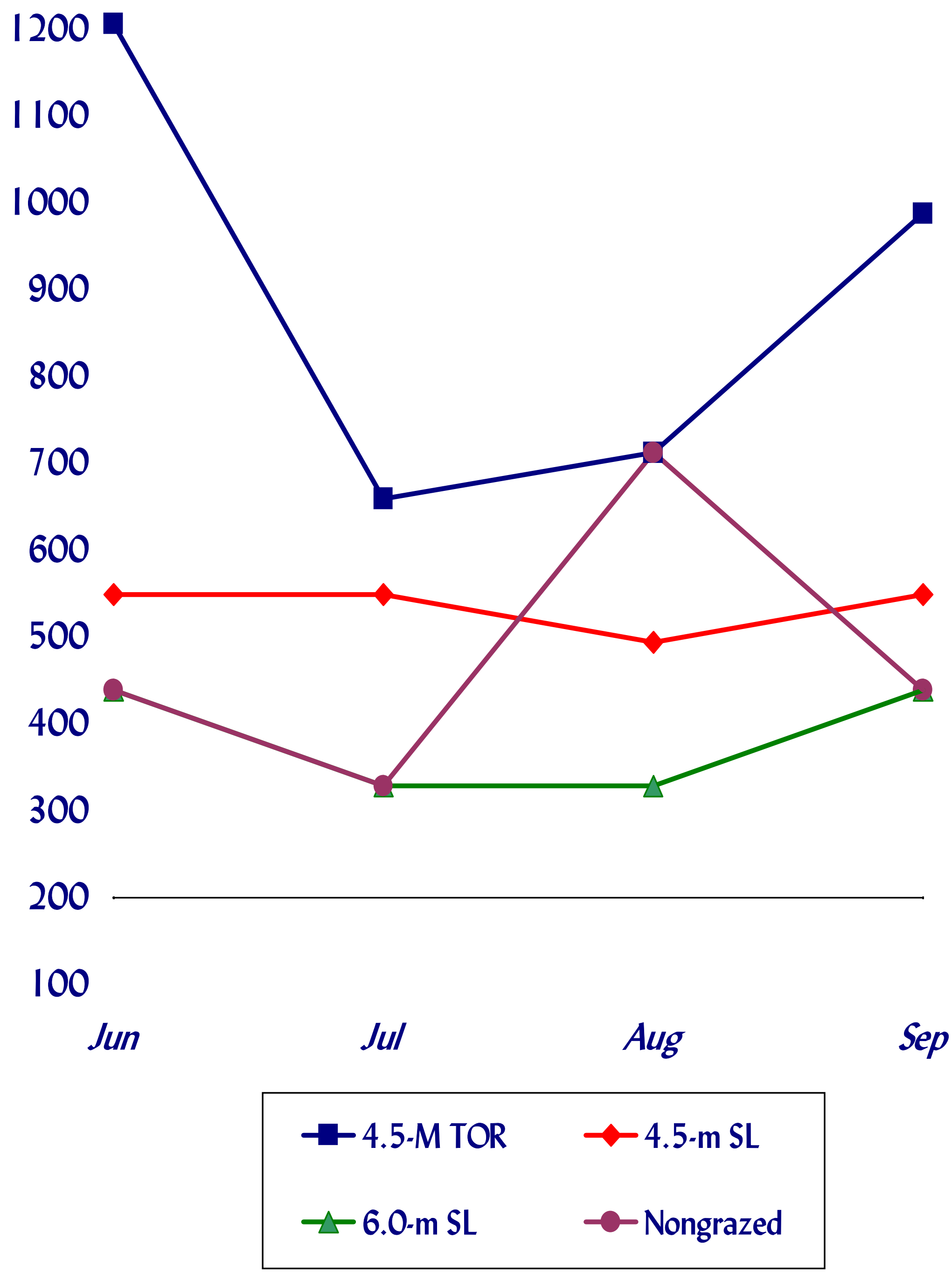

Figure 2. Lead tiller density of western wheatgrass per square meter

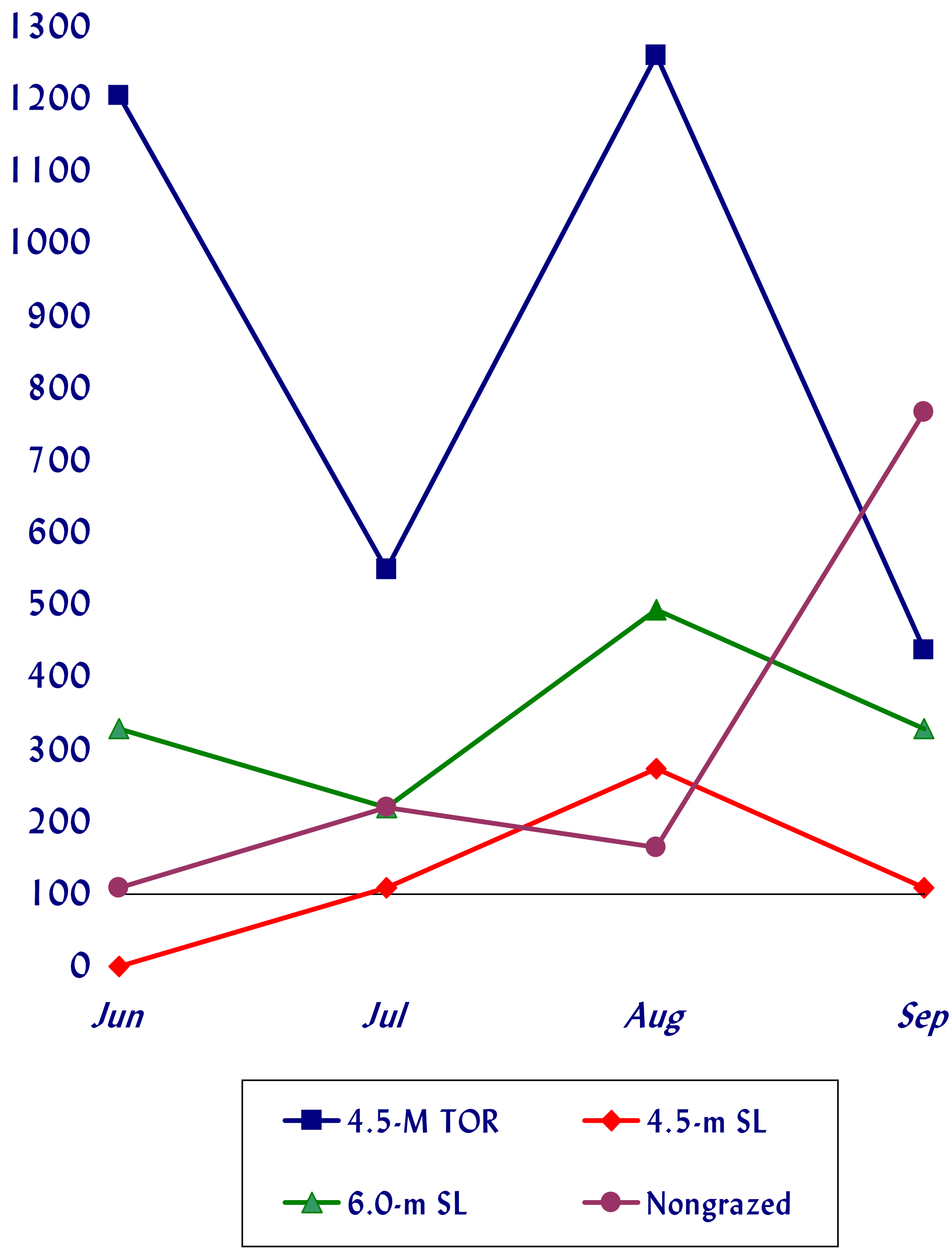

Figure 3. Secondary tiller density of western wheatgrass per square meter

Table 3. Rhizosphere volume (cm^3) per grass plant.

	June	July	August	September
4.5-m TOR	0.270a	0.491a	1.113a	1.192a
4.5-m SL	0.367ab	0.139b	0.511b	0.418b
6.0-m SL	0.629ab	0.369ab	0.327c	0.113c
Nongrazed	0.425b	1.032a	0.385abc	0.341bc

Means in the same column and followed by the same letter are not significantly different (P<0.05)

Table 4. Rhizosphere volume (cm^3) per cubic meter of soil.

	June	July	August	September
4.5-m TOR	3214.748a	3867.542a	7183.271a	6586.063a
4.5-m SL	1800.931a	642.209b	1963.017b	1802.973b
6.0-m SL	1695.208a	1087.083b	1128.077b	658.292c
Nongrazed	1725.236a	2804.612a	2391.966b	2438.473b

Means in the same column and followed by the same letter are not significantly different (P<0.05)

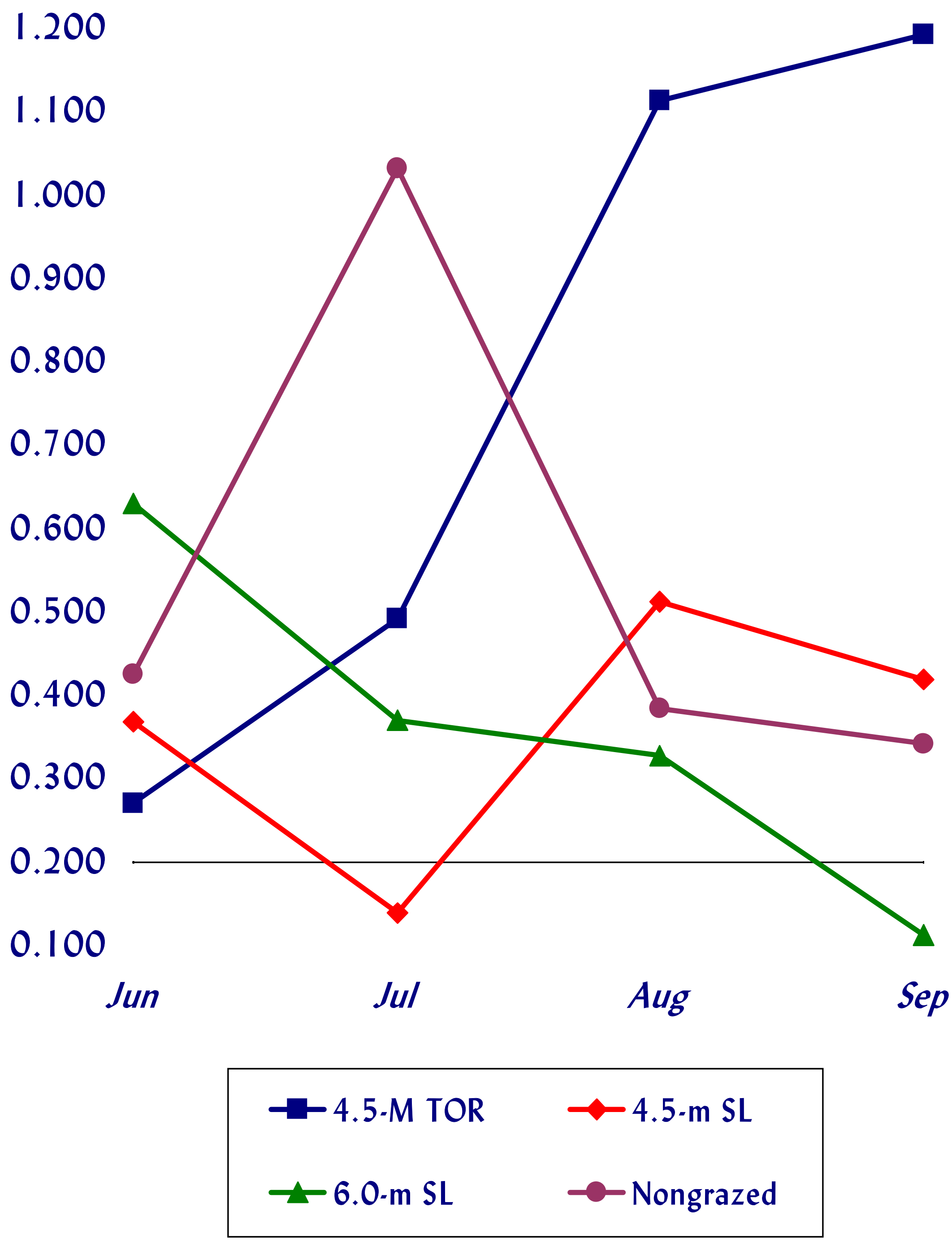

Figure 4. Rhizosphere volume (cm^3) per grass plant

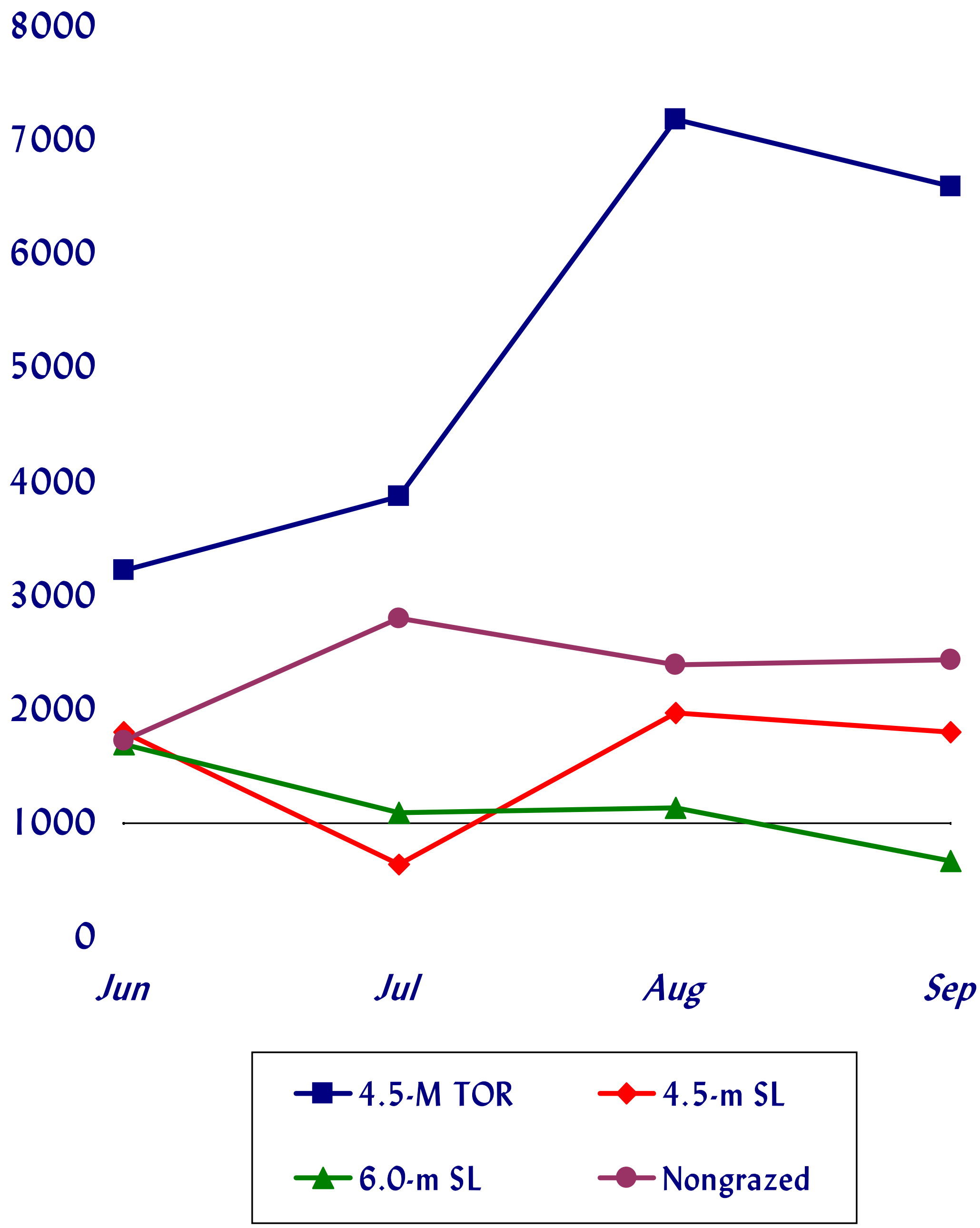

Figure 5. Rhizosphere volume (cm^3) per cubic meter of soil

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