Phyllochron Development in Cool-Season Forage Grasses

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ABSTRACT
The purpose of this study was to evaluate the relationship between grass leaf insertion rate and accumulated growing degree-days, and determine the phyllochron for five perennial forage grass species and two cultivars of each species. Species field seeded in solid stands were crested wheatgrass [*Agropyron desertorum* (Fisch. ex. Link) Schult.], intermediate wheatgrass, [*Thinopyrum intermedium* Barkw. & Dewey:Syn:A. intermedium (Host) Brauv], western wheatgrass [*Pascopyrum smithii* (Rybd) L ve], green needlegrass (*Stipa viridula* Trin.), and smooth bromegrass (*Bromus inermis* Leyss). Species phyllochron differences ranged from 77 GDD for Mandan 404 smooth bromegrass to 114 GDD for Lodorm green needlegrass. Phyllochron differences were greater among species than cultivars within species which suggests a single equation is adequate for predicting species phyllochron for determining grazing readiness.

KEYWORDS
Growth staging, grass development, grazing, morphology, growing degree-days

INTRODUCTION
Proper pasture and range management begins when grazing starts in the spring. Grazing readiness or time to start grazing has generally been based on a calendar date, which does not account for the stage of plant development. Initiating grazing of cool-season grasses before development of at least three and a half leaves will reduce plant vigor and seasonal productivity. Reduced vigor of the grass stand reduces stand density, increases incidence of diseases and weed infestations, and can reduce productivity for several years. Since leaves on a grass plant develop in an orderly and predictable manner, development stage scales can be used to track grass development and for making decisions on when to begin grazing. Others have reported that rate of leaf insertion or the phyllochron is a function of air temperature or heat units expressed as growing degree-days (Bauer, *et al*., 1984; Frank et al., 1985; Robertson, 1968; and Wang, 1960). The objective of this study was to determine the relationship between accumulated growing degree-days (AGDD) and growth stage of five cool-season forage grasses for predicting the phyllochron.

METHODS
Seedings of 'Hycrest' and 'Nordan' crested wheatgrass, 'Manska' and 'Reliant' intermediate wheatgrass, 'Rodan' and 'Rosana' western wheatgrass, 'Lincoln' and Mandan 404 smooth bromegrass, and 'Lodorm' and South Dakota 93 green needlegrass were made in 3.6 X 6 m plots at 18 cm row spacing in 1992. There were two replicates in a randomized block design. The soil was a Parshall fine sandy loam (coarse-loamy mixed *Pachic Haploborolls*). The plots received 45 kg N ha^{-1} annually at fall dormancy and were rainfed. Plant growth stage was determined using the Haun scale (Haun, 1973). The Haun scale is a numerical expression of the number of leaves formed on a stem. Two reproductive plants from each of two replicates were staged at 2-3 day intervals from the beginning of spring greenup through Haun stage 4 in 1994, 1995, and 1996. The plots were clipped at 5-cm stubble height at maturity each year.

Growing degree-days (GDD) were calculated as GDD (°C) = (daily maximum air temperature + daily minimum air temperature/2) - base temperature of 0° C. Accumulation of GDD was started on 1 April each year. Data were subjected to linear regression analysis using SAS GLM procedures (SAS institute Inc., 1985) to determine the relationship between AGDD and Haun stage. The phyllochron or the GDD between successive Haun stages was calculated as the reciprocal of the regression slope.

RESULTS AND DISCUSSION
The relationship between Haun stage and AGDD for all five species and cultivars was linear with r^2 values ranging from 0.88-0.96 (Table 1). The regression equation intercepts were consistently low for all cultivars ranging from -0.237 for Lincoln smooth bromegrass to 0.186 for Manska intermediate wheatgrass. The low intercepts confirm that the 1 April starting date for accumulating GDD coincided closely to initiation of spring growth.

The strong linear relationship between Haun stage and AGDD corresponds to reports that temperature is the main environmental factor controlling plant development, especially the phyllochron (Frank, *et al.*, 1985, Klepper, 1982). The phyllochron showed less variation among cultivars than among species. Species phyllochron differences ranged from 77 GDD for Mandan 404 smooth bromegrass to 114 GDD for Lodorm green needlegrass. Among cultivars within a species, the largest phyllochron difference was 13 GDD between Manska and Reliant intermediate wheatgrass and the least was 2 GDD between Lodorm and South Dakota 93 green needlegrass. The small differences in the phyllochron between cultivars within each species suggests an equation for each species may be satisfactory for predicting growth stages for determining when to initiate spring grazing.

The ideal time to initiate grazing cool-season grasses is about Haun stage 3.5 (Frank, 1996). At Haun stage 3.5, grass development and regrowth conditions are generally favorable for continued phyllochron development, reducing the impact of leaf removal by grazing. The species in this study did not all develop the same number of leaves before inflorescence emergence. The wheatgrasses and smooth bromegrass cultivars developed 5-6 leaves and green needlegrass cultivars developed 4-5 leaves. Prior research has shown that the phyllochron of grasses increased as the number of leaves inserted on the stem increases (Frank, *et al*., 1985). Limiting the phyllochron calculation to those leaves needed to determine grazing initiation, as presented here, compared to plant development through inflorescence emergence should give more precision to determining the phyllochron for grazing.

In conclusion, a good linear relationship existed between grass leaf insertion as referenced to the Haun scale and AGDD. Phyllochron differences were larger among species than between cultivars within species. The phyllochron, based on AGDD, is proposed as a useful decision aid for determining grazing readiness of perennial forage grasses.

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Table 1
Linear regression analysis for Haun stage on accumulated growing degree-days and the phyllochron for cultivars of five cool-season grass species.

Species	Cultivars	n	Intercept	Slope	r^2	Phyllochron (GDD)
Crested wheatgrass	Hycrest	34	0.051	0.0099	0.92	101
	Nordan	33	-0.057	0.0106	0.96**	94
Intermediate wheatgrass	Manska	32	0.186	0.0102	0.88**	98
	Reliant	30	-0.126	0.0117	0.94**	85
Western wheatgrass	Rodan	38	-0.087	0.0092	0.90**	108
	Rosana	35	0.088	0.0106	0.94**	104
Smooth bromegrass	Lincoln	28	-0.237	0.0129	0.92**	78
	Mandan 404	27	-0.23	0.0130	0.90**	77
Green needlegrass	Lodorm	40	-0.199	0.0088	0.90**	114
	South Dakota 93	39	-0.197	0.0089	0.92**	112

**Significant at the 0.01 probability level.