PREDICTING GRASS STAND ADEQUACY FROM EARLY STAND PARAMETERS[1]

by

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Abstract. Early evaluation of grass stand establishment is important for making timely decisions on reseeding or proper management that will enhance the new grass stand. A field study with 5 species, 11 seeding dates per year, and 3 replications was conducted to determine which dates resulted in the best stands when direct seeded into wheat stubble using the same seeding techniques at each date. Seedings were made during the seeding years of 1987, 1988, and 1989. Stands were monitored for 5 years, 2 years after each seeding year. The number of grass seedlings m^{-2} was measured 45 days after emergence. This early stand parameter was correlated with the number of grass plants m^{-2}, number of grass stems m^{-2}, and grams of grass dry matter m^{-2} measured 2 years after the seeding year. The highest correlation coefficients ($P<0.01$) were between the number of grass seedlings m^{-2} 45 days after emergence and the number of grass stems m^{-2} 2 years after seeding for smooth bromegrass, western wheatgrass, crested wheatgrass, and sideoats grama·. Correlation coefficients were 0.69, 0.59, 0.71, and 0.41, respectively. The highest correlation coefficient (0.71, $P<0.01$) for blue grama was between the number of grass seedlings m^{-2} 45 days after emergence and the number of grass plants m^{-2} 2 years after seeding. Predictions of expected grass stems m^{-2} at 2 years after seeding and actual measured stems m^{-2} at 2 years were compared with a standard number of stems need for a successful stand. A decision on stand success made from the seedlings m^{-2} at 45 days after emergence was correct 100, 85, and 76% of the time for smooth bromegrass, western wheatgrass, and crested wheatgrass, respectively. For blue grama, prediction of stand success from the number of seedlings present 45 days after emergence was correct 79% of the time. Two year success estimates were not determined for sideoats grama because the relationship of seedlings m^{-2} and stems m^{-2} was only significant 1 out of 3 seeding years. Based on these results, a reasonable estimate of stand adequacy at 2 years after seeding may be predicted by the number of grass seedlings counted at 45 days after emergence.

Additional Key Words: seedlings m^{-2}, stems m^{-2}, plants m^{-2}, grams m^{-2}, regression equation, parameter correlations, smooth bromegrass, sideoats grama, western wheatgrass, blue grama, crested wheatgrass.

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Introduction

Monitoring changes occurring in vegetative communities has been recognized as the key to natural resource management (Bonham 1989). Changes occurring in grass stands are an indication that management changes may be needed to initiate and maintain productive stands. The relationship of early stand characteristics with productive and established stand characteristics is important to early determination of grass seeding success or failure. Early detection of seeding failures or marginal grass stands can result in timely decisions to reseed or apply proper management that will enhance the young grass stand. Vallentine (1979) indicated that monitoring new grass seedings should begin as soon as reliable data can be measured. Data evaluation indicating when monitoring of new grass stands should begin is scarce. Little information is available in the literature concerning the relationship of early grass stand parameters with the parameters that characterize an established and productive grass stand. Cook and Stubbendieck (1986) recommended that stand establishment measurements of perennial plants seeded in the semi-arid range should start near the end of the second growing season. According to their experience, only tentative data on new stand characteristics could be obtained during the first growing season. Ries and Svejcar (1991) reported data that suggest new stands of crested wheatgrass [*Agropyron desertorum* (Fisch. ex Link) Schult.] and blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.] could be considered established 21 days after emergence under the specific environmental conditions of their study. The purpose of this current paper is to characterize the relationships between grass stand parameters found during early and late stand development.

Study Area and Methods

This study was conducted at the USDA-ARS Northern Great Plains Research Laboratory, Mandan, North Dakota, to evaluate 11 seeding dates per year over 3 seeding years. The study was conducted on a Parshall fine sandy loam soil (coarse-loamy, mixed *Pachic Haploborolls*) on nearly level terrain. Monoculture grass seedings were made directly into spring wheat stubble with a double disk cone seeder with depth bands and packer wheels. Seedings were made August 15, September 4 and 24, October 9, November 1, April 1 and 21, May 9 and 26, June 10, and July 1 during the seeding years of 1987 (1986-87), 1988 (1987-88), and 1989 (1988-89). All species were seeded at 9 kg ha^{-1} pure live seeds at a depth of about 13 mm. Species studied included 3 cool-season grasses, smooth bromegrass [*Bromus inermis* Leyss., 'Lincoln'], western wheatgrass [*Agropyron smithii* Rydb., 'Rodan'; syn. = *Pascopyron smithii* (Rydb.) Löve], and crested wheatgrass, [*Agropyron desertorum* (Fisch. ex Link) Schult.) 'Nordan']. Two warm-season grasses were also evaluated; sideoats grama [*Bouteloua curtipendula* (Michx.) Torr., 'Pierre'], and blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex Steud., native collection].

Plots (3 m wide and 7.6 m long) were arranged in a randomized complete block design, split/split plot in time with 3 replications. Whole plots were years, with the first split species and the final split seeding date. Grass stands were sampled for seedling density (plants m^{-2}) 45 days after emergence was observed by counting the seedlings present on 5 randomly located 30.5 by 30.5 cm plots for each species and seeding date. The stands were sampled again during the growing season at near peak biomass accumulation (between July 1-15) 1 and 2 years after the seeding year. Measurements of grass plant density (plants m^{-2}), stem density (stems m^{-2}), and dry matter (grams m^{-2}) were taken by counting the number of grass plants and grass stems, and then clipping and oven drying (60°C for 48 h) grass plants sampled from 5 randomly located 30.5 by 30.5 cm plots for each species and seeding date.

Environmental conditions during the study were monitored by a weather station located on the study area following National Weather Bureau standards. Weather conditions measured included air temperature at 2 m above the soil, soil temperature at 16 mm-soil depth, precipitation, and free water evaporation from a Class A pan.

The grass species studied did not respond in the same manner to study conditions; therefore, correlation/regression analyses were conducted by species. Each seeding year included 11 seeding dates and 3 replications for a total of 33 observation. Since weather conditions and seedling response at each seeding date within each seeding year were different, an average function was developed by including data from all 3 years for a total of 99 observations. The number of grass seedlings m^{-2} counted at 45 days after emergence was correlated with the number of grass plants m^{-2}, number of grass stems m^{-2}, and grams of grass dry matter m^{-2} measured in each stand at near peak biomass accumulation 1 and 2 years after the seeding year.

Regression equations for the parameters with the highest correlation coefficients that were significant for all 3 seeding years were determined. The number of grass stems m^{-2} expected 2 years after the seeding year were predicted for smooth bromegrass, western wheatgrass, and crested wheatgrass by the regression equation developed for the relationship of the number of grass stems m^{-2} at 2 years (Y) with the number of grass seedlings m^{-2} at 45 days after emergence (X). The number of grass plants m^{-2} expected 2 years after seeding for blue grama were predicted by the regression equation for the relationship of the number of grass plants m^{-2} at 2 years (Y) with the number of grass seedlings at 45 days after emergence (X). A standard of 11 plants m^{-2} (Great Plains Council 1966) at 45 days after emergence was accepted as a measure of a successful grass seeding. The same regression equations were used to predict the expected number of stems m^{-2} or number of plants m^{-2} (blue grama) after 2 years that would be expected from a successful stand with 11 plants m^{-2} at 45 days after emergence. The predicted and actual measured stems m^{-2} or plants m^{-2} during the growing season 2 years after seeding were compared with the expected stems m^{-2} or plants m^{-2} for a successful stand. When either the actual or predicted values was less than the successful stand density, an error in estimating stand success from 45 days after emergence data occurred. Thirty-three stands minus the number of errors equalled the number of successful stands predicted from 45 days after emergence data. The number of successful stands predicted divided by 33 equalled the percent success.

The relationships of all combinations of average grass plants m^{-2} with grass stems m^{-2} with grams of grass dry matter m^{-2} measured 2 years after seeding were also quantified by correlation analysis. Relationships of all combinations of average grass plants m^{-2} with grass stems m^{-2} with grams of grass dry matter m^{-2} measured at 1 year and 2 years after seeding were also established by correlation analysis.

Results and Discussion

Weather during this 5 year study was variable among months as is common for the semi-arid area of the Northern Great Plains. Air temperatures for August through October were lower than long-term averages for the study area, while air temperatures for April through July were above the long-term average (Table 1). Mean soil temperatures at the 16 mm-soil depth were warmest during July with an average of 25.6 C (Table 1).

Soil temperatures for August and June were 23.2 and 23.7 C, respectively. During the months of August and May precipitation was highest at 60 and 61 mm, respectively. August precipitation was 10 mm higher than the long-term average, while the May precipitation was about equal to the long-term average. The greatest amount of free water evaporation during the study was observed during July and was only 6 mm more than the long-term average. April and June free water evaporation were also above the long-term average during this study (Table 2).

Table 1. Range, average (1986-91), and long-term average mean monthly air and soil temperatures (°C).

Month	Mean Air Temp. @ 2 m			Mean Soil Temp. @ 16 mm		
	Range	Avg.	LTA[1]	Range	Avg.	LTA[2]
Aug	18 to 22	19.7	20.4	20 to 27	23.2	--
Sep	11 to 16	13.9	14.0	12 to 18	16.1	--
Oct	5 to 7	6.5	7.8	7 to 9	7.6	--
Nov	-4 to 2	-1.1	-1.8	1 to 2	0.5	--
Apr	6 to 10	7.7	5.3	9 to 12	10.3	--
May	13 to 16	14.1	12.5	16 to 19	17.5	--
Jun	18 to 25	20.1	19.4	21 to 30	23.7	--
Jul	21 to 24	22.2	21.6	24 to 29	25.6	--

[1] LTA = long-term average--78 years (1914-1991).

[2] LTA not available.

Table 2. Range, average (1986-91), and long-term average monthly precipitation and free water evaporation (mm).

Month	Precipitation			Free Water Evaporation		
	Range	Avg.	LTA[1]	Range	Avg.	LTA[2]
Aug	38 to 99	60	50	115 to 231	182	203
Sep	1 to 108	38	40	80 to 154	126	130
Oct	0 to 6	4	21	--	--	--
Nov	0 to 71	18	11	--	--	--
Apr	0 to 58	22	39	112 to 174	139	106
May	20 to 88	61	57	131 to 185	158	173
Jun	4 to 112	52	89	186 to 282	213	195
Jul	21 to 95	44	57	164 to 287	238	232

[1] LTA = long-term average--78 years (1914-1991).
[2] LTA = long-term average--28 years (1964-1991).

The largest significant correlation coefficients ($P<0.01$) were for the number of seedlings m^{-2} 45 days after emergence and the number of stems m^{-2} 2 years after the seeding year for smooth bromegrass, western wheatgrass, crested wheatgrass, and sideoats grama. Coefficients were 0.69, 0.59, 0.71, and 0.41, respectively (Bold numbers in Table 3). Number of seedlings m^{-2} at 45 days after emergence was most highly correlated with the number of plants m^{-2} 2 years after seeding for blue grama ($r = 0.71$, $P<0.01$, Table 3). Correlation coefficients for these relationships for individual study years are shown in Table 4.

Table 3. Correlation coefficients (r) for seedlings m^{-2} at 45 days after emergence with grass stand parameters at 2 years after seeding for all 3 seeding years (n=99).

	Parameters		
Species	plants m^{-2}	stems m^{-2}	grams m^{-2}
Smooth bromegrass	0.54**	**0.69****	0.56**
Western wheatgrass	0.52**	**0.59****	0.47**
Crested wheatgrass	0.69**	**0.71****	0.41**
Sideoats grama	0.39**	**0.41****	0.20*
Blue grama	**0.71****	0.64**	0.36**

**P<0.01 -- Bold type indicates largest r value.
*P<0.05

Table 4. Correlation coefficients (r) for seedlings m^{-2} at 45 days after emergence with stems m^{-2} or plants m^{-2} (Bogr) at 2 years after seeding.

Species	1987	1988	1989	1987-89 Avg.
Smooth bromegrass	0.63**	0.69**	0.44*	0.69**
Western wheatgrass	0.75**	0.60**	0.40*	0.59**
Crested wheatgrass	0.75**	0.78**	0.59**	0.71**
Sideoats grama	0.30^{ns}	0.15^{ns}	0.54**	0.41**
Blue grama	0.62**	0.80**	0.68**	0.71**
# of observations	n=33	n=33	n=33	n=99

**P<0.01
*P<0.05

Most of the correlation coefficients were significant during each year except for sideoats grama where coefficients were nonsignificant during the 1987 and 1988 seeding years. Because of the insignificance of this relationship during some years, the regression equation was not used to predict stand parameters 2 years after seeding (Table 5). The equations used to predict future stand parameters for smooth bromegrass, western wheatgrass, crested wheatgrass, and blue grama are presented in Table 5.

Table 5. Regression equations quantifying the relationship of stems m^{-2} or plants m^{-2} at 2 years after seeding with seedlings m^{-2} present at 45 days after emergence (n=99)[1,2,3].

smooth bromegrass	
stems m^{-2} @ 2 yrs. = 270.43 + 4.11 (seedlings m^{-2} @ 45 days)	r^2 = 0.48**
western wheatgrass	
stems m^{-2} @ 2 yrs. = 374.49 + 7.27 (seedlings m^{-2} @ 45 days)	r^2 = 0.35**
crested wheatgrass	
stems m^{-2} @ 2 yrs. = 544.53 + 6.80 (seedlings m^{-2} @ 45 days)	r^2 = 0.50**
blue grama	
plants m^{-2} @ 2 yrs. = 5.10 + 0.18 (seedlings m^{-2} @ 45 days)	r^2 = 0.50**

[1] P>T = 0.0001 for intercept.
[2] P>T = 0.0001 for regression coefficient.
[3] P>F = 0.0001 for overall equation.
**P<0.01

These equations were used to predict the expected number of stems m^{-2} or plants m^{-2} (blue grama) 2 years after seeding from seedlings m^{-2} data measured 45 days after emergence. Correct predictions of stand success based on the number of stems m^{-2} were made 100, 85, and 76% of the time using the regression equations for smooth bromegrass, western wheatgrass, and crested wheatgrass, respectively. Correct predictions of stand success were made 79% of the time based on the number of plants m^{-2} expected for blue grama. Based on these results, a reasonable estimate of stand adequacy at 2 years after seeding may be predicted by the number of seedlings present 45 days after emergence.

There was also a highly significant relationship between the number of stems m^{-2} and grams dry matter m^{-2} 2 years after seeding (Table 6). For all species, a measure of stems m^{-2} strongly reflected grams dry matter m^{-2}. This suggests that a good estimate of grams of grass dry matter m^{-2} for a 2 yr old stand could be obtained from the counted number of stems m^{-2} rather than the clipping, oven drying, and weighing usually required when stand production is of interest.

Table 6. Correlation coefficients (r) for stems m^{-2} with grams dry matter m^{-2} at 2 years after seeding (n=99).	
Species	grams m^{-2}
smooth bromegrass	0.74**
western wheatgrass	0.92**
crested wheatgrass	0.78**
sideoats grama	0.74**
blue grama	0.78**

**P<0.01

The parameters of plants m^{-2}, stems m^{-2}, and grams dry matter m^{-2} measured 1 year after seeding were significantly correlated with the same parameter measured 2 years after seeding. The highest correlation coefficients were 0.77 and 0.73 for the number of stems m^{-2} (year 1 with year 2) for smooth bromegrass and western wheatgrass, respectively (Bold numbers in Table 7).

Table 7. Correlation coefficients (r) between grass stand parameters measured 1 year and 2 years after seeding (n=99).

	Species				
	Smooth bromegrass	Western wheatgrass	Crested wheatgrass	Sideoats grama	Blue grama
	plants m^{-2}				
Year 1	37	32	28	15	13
Year 2	25	49	29	13	11
r	0.59**	0.42**	**0.89****	**0.88****	**0.88****
	stems m^{-2}				
Year 1	268	277	488	286	343
Year 2	476	665	1040	356	610
r	**0.77****	**0.73****	0.80**	0.56**	0.87**
	grams m^{-2}				
Year 1	130	56	122	43	17
Year 2	299	204	351	118	74
r	0.63**	0.71**	0.47**	0.70**	0.78**

**P<0.01 -- Bold type indicates largest r value.

Correlation coefficients of 0.89, 0.88, and 0.88 were obtained for the number of plants m^{-2} (year 1 with year 2) for crested wheatgrass, sideoats grama, and blue grama, respectively (Bold numbers in Table 7). The number of stems m^{-2} was better related between year 1 and year 2 for the two rhizomatous species, while the number of plants m^{-2} was better related between year 1 and year 2 for the bunch-grass type species. This occurs because of the difficulty in identifying individual plants for rhizomatous species while counting the number of stems of rhizomatous species is readily repeatable. Similar information was reported by Cook and Stubbendieck (1986) and Bonham (1989). The significant correlations between year 1 and year 2 stand parameters support the concept that valid evaluation of grass stand success can be made 1 year after seeding when this period includes a winter dormant period (McWilliams 1955 and Cook and Stubbendieck 1986).

Summary

A good evaluation of stand parameters best used in evaluating grass stand success have been found from this study. Seedlings m^{-2} present 45 days after emergence were a reliable measure that correlated well with stems m^{-2} 2 years after seeding for smooth bromegrass, western wheatgrass, crested wheatgrass, and sideoats grama. Seedlings m^{-2} 45 days after emergence were better correlated with plants m^{-2}

than stems m^{-2} after 2 years for blue grama. A significant relationship between stems m^{-2} and grams dry matter m^{-2} 2 years after seeding was found. Data also showed that stand parameters 1 year after seeding were highly correlated with the same parameters 2 years after seeding, further suggesting that stand success can be evaluated 1 year after seeding when this year includes a dormant period. Stems m^{-2} 1 year and 2 years after seeding were more highly correlated for rhizomatous species; while, plants m^{-2} 1 year and 2 years after seeding were more highly correlated for bunchgrass species.

Results from this study are encouraging that good estimates of stand success may be made as early as 45 days after emergence. Estimates made in our study were quite successful and can be used along with good observations and judgment when evaluating stands as early as 45 days after grass seedling emergence. The r^2 for our study range from 0.35 to 0.50 for the relationship of seedlings m^{-2} 45 days after emergence with stems or plants m^{-2} 2 years after seeding. Except for sideoats grama, the relationship was significant in each seeding year. The goal now is to improve these r^2 numbers by adding secondary stand parameters that may further define the establishment level of the grass seedlings at 45 days after emergence. Addition of specific weather conditions may also increase these initial r^2 numbers. Both secondary stand parameters or weather conditions may improve the relationship of seedlings m^{-2} 45 days after emergence with the success of the stands 1 year or 2 years after seeding.

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