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Evaluation of Crested Wheatgrass Introductions for Forage Yield and Quality

by
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TEACHING RESEARCH EXTENSION

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Evaluation of Crested Wheatgrass Introductions for Forage Yield and Quality

K. P. Vogel, P. E. Reece, and J. F. S. Lamb[1]

SUMMARY

Crested wheatgrass, *Agropyron cristatum* and *A. desertorum,* are among the most important cool-season forage grasses in the United States and Canada, particularly for reseeding arid range sites. Further improvement in this grass by breeding depends on identifying sources of genetic variability for forage yield and quality. Foreign introductions are an obvious source of genetic variation since crested wheatgrasses are introduced species.

In this study 38 accessions (PI lines) and 8 Nebraska experimental lines were evaluated for forage quality as measured by *in vitro* dry matter digestibility (IVDMD) and protein content and for forage yield. The cultivars 'Ruff' and 'Nordan' and two clonal lines were included as checks. The strains were evaluated at Lincoln and Alliance, NE., which differ markedly in climate.

There were large differences among strains evaluated for all traits including first- and second-cut forage yield, IVDMD, protein content, heading date, height and first year basal spread. The bulk (70% +) of the forage was harvested in the first cut. First-cut yields and IVDMD values were used to develop an index value (NI) which was used to rate strains for both forage yield and quality. The accessions, PI 369167, PI 369170, and PI 325180, had NI values as high as those of Ruff and Nordan. These five strains were the most promising germplasm identified in this study for improving the yield and forage quality of the crested wheatgrasses. The three superior accessions had mean IVDMD values 1 to 4 percentage points higher than that of Nordan which was the second highest yielding strain averaged over locations. Utilization of PI 369167, PI 369170, Ruff, and Nordan in a breeding program could result in crested wheatgrasses with improved forage yield and quality.

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INTRODUCTION

Crested wheatgrass is a genetic complex of several taxa of which the most important in North America are *Agropyron cristatum* (L.) Gaertn. spp. *pectinatum* (Bieb) Tzvel. and *A. desertorum* (Fisch. ex Link) Schult. (Asay and Dewey, 1983; Dewey, 1983). The widely grown cultivar 'Nordan' typifies the *A. desertorum* type while 'Fairway' typifies the *A. cristatum* spp. *pectinatum* type. Dewey (1983) described the current taxonomic classification and gave the botanical description of these grasses. Both the *A. cristatum* and *A. desertorum* types have the same genome but the former are usually diploids while the latter are tetraploids (Dewey, 1983). These grasses have been seeded into more than six million hectares of abandoned or depleted farm and rangeland in the Plains and Intermountain West of the United States and Canada because they have the ability to become established, persist, and be productive under arid rangeland conditions (Dewey and Asay, 1975; Rogler and Lorenz, 1983).

Crested wheatgrasses are native to Europe and Asia. All of the crested wheatgrasses in North America are the products of germplasm introduced after 1900 (Rogler and Lorenz, 1983; Dewey and Asay, 1975). More than 270 accessions (numbered lines or strains) were brought into the United States before 1971 (Dewey and Asay, 1975). Since that time, additional accessions have been introduced into the U.S. (Dewey and Plummer, 1980). Despite the large number of accessions that have been brought into the U.S., the germplasm base of the strains currently being used originated from less than a dozen introductions (Dewey and Asay, 1975). According to Hanson (1972) only two cultivars of *A. cristatum,* Fairway and 'Parkway' had been released in the U.S. and Canada up to 1972. The *A. cristatum* cultivar 'Ruff', which was listed as the experimental strain 'Nebraska 3576' by Hanson (1972), has since been released by the Nebraska Agricultural Experiment Station. Two *A. desertorum* cultivars, Nordan and 'Summit', have been released (Hanson, 1972). These strains were released primarily because of their seed and forage yields and their establishment capability.

Although the crested wheatgrasses are used primarily as forages, there has been only limited research on the genetic variability for forage yield and quality in the complex. Coulman and Knowles (1974) found significant differences in *in vitro* organic matter digestibility (IVOMD) among eight strains of crested wheatgrass which were primarily advanced lines. They also indicated that post-anthesis sampling gave the maximum differences among strains for *in vitro* dry matter digestibility (IVDMD). Junk and Austenson (1971) found differences in IVDMD among five crested wheatgrass strains grown in six locations in Saskatchewan or Alberta, Canada. Schaff *et. al.* (1962) reported that variation in forage yield among the strains studied was less than the variation in seed yield. Ranges in yields expressed as a percentage of the mean were 21% for forage yield and 71% for seed yield. Differences among experimental strains and released cultivars for forage yield have been reported in various experiment station bulletins and circulars.

The potential gain that can be made in a plant breeding program depends upon the available genetic variability for economic traits. Because crested wheatgrasses are not native species, plant introductions are a primary source of genetic diversity for their possible improvement. One objective of this study was to evaluate a set of crested wheatgrass accessions and experimental lines for forage yield and quality and to document the results. Another objective was to determine the relative magnitude of genotype and genotype x environment interaction effects on crested wheatgrass for the same traits; the results of this part of the study have been reported previously (Lamb *et al.,* 1984).

In summary, there were significant differences among strains for first-cut (harvest) forage yield, IVDMD, and protein (Lamb *et al.,* 1984). In the analyses over years and locations, strain x location interaction effects were significant only for first harvest forage yield and for this trait the interaction component was only 0.3 of the magnitude of the variance component for strains. Strain x year interaction effects were not significant for these traits. Forage yield and quality characteristics of a set of 50 crested wheatgrasses evaluated at Lincoln and Alliance, NE, are described in this bulletin.

MATERIALS AND METHODS

Procedures used in this study were described by Lamb *et al.* (1984). In brief, an array of 50 crested wheatgrasses representing the mix of germplasm available to breeders were evaluated. The 50 strains included 38 accessions (PI lines) obtained from the USDA Plant Introduction Station at Pullman, Washington, 8 Nebraska experimental strains, 2 check cultivars, Ruff and Nordan, and 2 clonal lines from 'Nebraska 10' (Table 1). The Nebraska experimental lines are predominately the products of the open-pollinated hybridization of Nebraska 10 with the plants selected from the synthesis of two Turkish accessions, PI 172691 and PI 180794 (Newell, 1966). The strains were evaluated at Lincoln and Alliance, Nebraska, which is located 540 km west of Lincoln. The climatic variables of the two locations are listed in Table 2. Seven accessions and one experimental strain were not included in the Alliance nursery because of insufficient seedlings.

Seedlings of the strains were started in a greenhouse in the winter of 1979 and transplanted into the field nurseries at Lincoln and Alliance in the spring of 1979. Plots were single rows of 10 plants with plants and rows spaced 1.1 m apart. The experimental design at both locations was a randomized complete block with four replicates. Nurseries were not harvested the establishment year. Weeds were controlled by hoeing, cultivation, and

Table 1. Descriptions and means from overall combined analysis for crested wheatgrass strains evaluated in the Lincoln and Alliance nurseries for 1980 and 1981.

				First cut means				
Strain	Origin	Species	Pedigree	Yield	Dry matter	IVDMD	Protein	Selection index (NI)
				g/plant	%	%	%	
PI 172690	Turkey	*A. cristatum*		177	50	50.8	10.5	1.06
PI 172691	“ ”	“		169	50	50.9	11.1	0.95
PI 173621‡	“ ”	“						
PI 203439	“ ”	“		120	51	47.6	10.1	-1.86
PI 203443	“ ”	“		130	50	48.9	10.3	-0.94
PI 206396	“ ”	“		111	48	49.0	10.8	-1.26
PI 229521	Iran	“		152	48	42.6	10.1	-4.00
PI 277352‡	“ ”	“						
PI 314596	USSR	“		197	48	50.5	11.1	1.29
PI 314597	“ ”	“		171	49	47.2	10.5	-1.06
PI 314602	“ ”	“		113	57	47.1	8.7	-2.28
PI 315066	“ ”	“		182	50	49.2	10.5	0.27
PI 325180	“ ”	“		252	49	50.5	11.1	2.39
PI 369167	“ ”	“		181	46	53.8	11.8	2.80
PI 369168	“ ”	“		170	47	50.4	10.5	0.70
PI 369169	“ ”	“		116	46	48.8	12.5	-1.27
PI 369170	“ ”	“		245	48	51.0	10.6	2.52
PI 273730	“ ”	“		164	47	50.1	11.0	0.41
PI 273731	“ ”	*A. desertorum*		189	50	47.1	10.2	-0.76
PI 277354	“ ”	“		210	51	46.0	10.0	-0.95
PI 283162‡	UK	“						
PI 284868‡	Denmark	“						
PI 314187‡	USSR	“						
PI 314603‡	“ ”	“						
PI 314604	“ ”	“		176	51	47.6	9.5	-0.74
PI 314927	“ ”	“		142	53	44.6	9.5	-3.09
PI 315068	“ ”	“				45.9	10.0	-1.54

Table 1. (Continued)

Strain	Origin	Species	Pedigree	First cut means: Yield	Dry matter	IVDMD	Protein	Selection index (NI)
				g/plant	%	%	%	
PI 316121	Australia	“		187	50	47.4	9.9	-0.63
PI 340059	Turkey	“		169	49	47.7	10.0	-0.82
PI 340060	“ ”	“		208	49	47.4	10.2	-0.21
PI 345584	USSR	“		168	51	47.5	10.3	-0.96
PI 370645	“ ”	“		244	51	48.0	10.8	0.84
PI 383538	Turkey	“		191	49	49.5	10.7	0.56
PI 383540	“ ”	“		172	48	48.8	10.4	-0.15
PI 401001‡	“ ”	“						
PI 401002	“ ”	“		164	51	47.0	9.7	-1.31
PI 401003	“ ”	“		209	50	50.0	11.4	1.25
PI 401004	“ ”	“		157	49	47.3	10.1	-1.29
NE #1			Syn-2((102Rx10a Syn-2) x (7x10a Syn-2))	183	49	49.2	9.7	0.46
NE #2‡			10a x Siberian Blue					
NE #3		“	Nebr. 10a	250	49	48.3	10.6	1.13
NE #4			Ne. (7x10a) Syn-3	216	50	50.4	10.4	1.62
NE #5			Ne. (1,2,3x10a) Syn-4	204	50	50.9	9.6	1.65
NE #6			Ne. (2 x 10b) Syn-4	204	50	48.8	9.8	0.49
NE #7			Ne. (7 x 102R) Syn-2	191	50	49.2	10.3	0.45
NE #8			(5 x 10a) Syn-2	191	50	49.0	10.0	0.34
Ruff		*A. cristatum*		243	48	51.0	10.7	2.49
Nordan		*A desertorum*		267	49	49.4	10.9	2.08
10b-1		“	clone of Nebr. 10	294	44	48.7	11.2	2.23
10b-2		“	clone of Nebr. 10	250	48	41.8	9.8	-2.48
Mean				188	49	48.5	10.4	
L.S.D. (0.05)				58	3	2.1	0.8	
C.V.%				26.4	4.6	6.5	3.8	

‡Strains not used in overall combined analysis of Lincoln and Alliance nurseries for 1980 and 1981.

Table 2. Climatic variables for Lincoln and Alliance, Nebraska, and the soils in the research fields.

Climatic variable[a]	Location	
	Lincoln	Alliance
Altitude	351 m	1226 m
Annual precipitation	740 mm	400 mm
Average annual'temperature	11 C	8 C
Growing season	160 days	120 days
Soils	Kennebac fine silty mixed soil (Cumulic Hapludoll)	Keith fine silty mixed soil Typic Argiustoll)

[a]National Oceanic and Atmospheric Administration (10).

by the use of herbicides. The nurseries were fertilized annually as described by Lamb *et al.* (1984).

Plants were harvested at a cutting height of 13 cm. First cuts or harvests were made after all plants in the nurseries had headed. This was the latter part of June at Lincoln and the first part of July at Alliance. Second cuts of forage were harvested after a heavy frost had ended the growing season—the last week of October in Alliance and the first week of November at Lincoln. A second cut was not harvested in 1980 at Alliance because of insufficient regrowth. Regrowth in 1981 was minimal at both locations and forage quality analyses were conducted only on 24 strains that yielded 230 g/plant or more in three of the four replications at each location.

Forage subsamples taken at time of harvest were used to determine dry matter, protein and IVDMD (Lamb *et al.,* 1984). The Kjeldahl procedure (A.O.A.C., 1960) was used to determine % N which was converted to crude protein by multiplying by 6.25. The Tilley and Terry (1963) procedure was used to determine IVDMD.

Heading date was the number of days between April 30 and the date when the majority of spikes had emerged from the boot of individual plants. Plant width was measured in April 1980 at Lincoln and in May 1980 at Alliance and represents first year basal spread of the plants. Plant height (height to the top of the spike) was measured for all plants in both years at Lincoln and in 1981 at Alliance. In 1980, only 10 strains which were harvested on an individual plant basis at Alliance were measured for plant height.

All results were expressed and analyzed as individual plant means per plot to simplify comparisons among strains and to compensate for missing plants.

Analyses of variance procedures were used to evaluate results at each location for each year, over years for a location, and over years and locations. The appropriate error mean square from each analysis was used to calculate LSD values for comparing the corresponding set of means.

The selection index developed by Roth (1971) for combining yield and IVDMD into a single index was also calculated for each strain. The index which we shall label the 'NI' value for Nebraska index is:

$$NI = \frac{\text{Yield} - \bar{X}\ (\text{yield})}{s(\text{yield})} + \frac{\text{IVDMD} - \bar{X}\ (\text{IVDMD})}{s(\text{IVDMD})}.$$

$\bar{X}$ is the mean and s is the square root of the error mean square in the F test for the appropriate trait.

RESULTS AND DISCUSSION

The traits in which we were primarily interested and for which we have two years' data for both locations were first-cut forage yield, IVDMD, and protein. The overall means of strains evaluated in this study for those traits were listed in Table 1. First- and second-cut means as well as heading date and plant height and width for the strains for the Lincoln and Alliance nurseries are listed in Tables 3 and 4, respectively. In the combined analyses over years and locations, there were significant differences among strains for these traits (Lamb *et al.,* 1984) (Table 1). Several introductions had yields or IVDMD values as high or higher than those of the released cultivars and experimental strains. There was also variation among strains evaluated for protein content but the range in variation was not as large as that for yield and IVDMD. We consider IVDMD to be a better measure of forage quality than protein content. Since there is more variation for IVDMD than for protein content, improving the forage quality of crested wheatgrass by breeding for IVDMD might be more likely to be successful than breeding for protein content. Breeding for IVDMD could also result in improved protein content since there was a low positive correlation between these traits (r = 0.36[2/] and 0.24 for Alliance and Lincoln, respectively). The correlation between first-cut yield and IVDMD was low and nonsignificant (r = 0.10 and -0.17 for Alliance and Lincoln, respectively) indicating that it should be possible to concurrently improve both first-cut yield and IVDMD in crested wheatgrass by breeding.

Index values are often used in plant breeding programs involving selection for two or more traits. The index (NI) used in this study weighs both first-cut forage yield and IVDMD equally. Strains with high positive NI values usually have both high yield and IVDMD values. The opposite is true for strains with negative NI values. Three introductions, PI 369167, PI

[2/]Significance at the 0.05 level of probability.

Table 3. Means and other statistics for traits of crested wheatgrass introductions and experimental strains evaluated at Lincoln, Nebraska, averaged over 1980 and 1981.

	Means												
	Plant				First cut					Second cut			
Strain	Heading date	Width a/	Height	Total yield	Yield	Dry matter	IVDMD	Protein	Selection Index (NI)	Yield	Dry matter	IVDMD	Protein
	days	cm	cm	g/plant	g/plant	%	%	%		g/plant	%	%	%
PI 172690	26	18	65	263	171	48	52.1	11.9	0.22	92	39	55.7	18.5
PI 172691	26	19	68	302	184	48	51.0	12.3	0.11	118	40	53.7	18.9
PI 173621	25	20	60	270	191	47	53.0	12.0	0.72	79	42	—	—
PI 203439	26	17	62	216	148	38	48.6	10.8	-1.00	68	38	—	—
PI 203443	26	16	66	221	165	49	51.5	11.0	-0.02	56	40	—	—
PI 206396	27	17	61	192	130	46	52.1	11.4	-0.34	61	41	—	—
PI 229521	22	19	63	239	164	47	42.9	10.9	-2.24	76	41	53.7	18.3
PI 277352	18	18	65	182	141	55	44.9	8.9	-2.04	41	45	—	—
PI 314596	22	19	66	326	229	48	51.1	12.6	0.75	88	40	—	—
PI 314597	24	20	63	285	177	48	48.2	11.7	-0.70	96	42	—	—
PI 314602	18	19	61	185	117	55	47.7	9.8	-1.65	68	42	57.9	18.9
PI 315066	22	23	69	324	188	48	51.2	12.2	0.22	136	48	44.9	15.8
PI 325180	29	25	58	484	313	46	51.7	12.8	2.06	172	46	44.8	16.1
PI 369167	30	20	50	256	189	44	55.7	13.9	1.39	67	42	51.3	17.4
PI 369168	23	22	65	235	154	44	51.8	12.3	-0.09	79	38	—	—
PI 369169	24	17	56	140	105	46	51.4	14.1	-0.87	37	41	—	—
PI 369170	28	23	64	406	296	46	51.9	12.8	1.88	110	42	51.1	17.8
PI 273730	25	20	62	272	196	47	51.7	12.6	0.46	82	41	—	—
PI 273731	23	22	66	285	198	49	47.8	11.7	-0.52	89	41	—	—
PI 277364	21	21	73	360	244	52	45.8	11.4	-0.40	110	40	—	—
PI 283162	24	21	68	180	149	48	48.2	11.3	-1.08	—	—	—	—
PI 284868	25	18	65	198	136	54	50.1	10.7	-0.78	—	—	—	—
PI 314187	22	23	67	277	182	52	46.5	10.7	-1.07	101	41	—	—
PI 314603	26	19	71	270	182	50	47.3	10.5	-0.87	84	41	—	—
PI 314604	25	20	70	280	208	50	49.4	10.3	0.03	66	46	—	—
PI 314927	19	18	62	226	150	52	46.1	10.3	-1.61	68	46	—	—
PI 315068	21	20	65	269	180	49	45.9	11.2	-1.25	89	43	47.2	17.3

Table 3. (Continued)

	Means												
	Plant				First cut					Second cut			
Strain	Heading date	Width a/	Height	Total yield	Yield	Dry matter	IVDMD	Protein	Selection Index (NI)	Yield	Dry matter	IVDMD	Protein
	days	cm	cm	g/plant	g/plant	%	%	%		g/plant	%	%	%
PI 316121	23	21	70	269	185	44	48.9	11.5	-0.41	84	49	—	—
PI 340059	27	19	63	264	166	47	48.6	10.9	-0.74	98	43	—	—
PI 340060	27	21	71	309	211	48	48.7	11.4	-0.11	98	40	54.1	18.1
PI 345584	22	21	66	300	175	52	49.0	11.9	-0.52	101	43	48.0	17.9
PI 370645	20	21	71	366	286	51	49.2	12.4	1.05	83	48	46.1	16.1
PI 383538	26	19	56	281	192	48	49.5	11.8	-0.16	89	40	54.4	18.5
PI 383540	24	17	68	216	165	48	50.3	11.6	-0.33	51	42	—	—
PI 401001	23	19	67	266	156	46	50.2	11.0	-0.48	110	41	—	—
PI 401002	25	17	68	256	179	50	49.4	10.8	-0.37	75	44	52.6	17.8
PI 401003	27	17	69	333	242	49	50.2	12.4	0.70	96	48	49.5	18.3
PI 401004	25	20	66	235	164	47	49.4	11.4	-0.57	74	44	47.9	17.4
NE #1	24	20	69	293	191	47	50.1	11.2	-0.02	91	44	—	—
NE #2	19	22	72	319	212	49	46.1	10.8	-0.76	104	41	—	—
NE #3	21	20	70	416	297	48	49.3	12.1	1.22	116	44	47.3	16.3
NE #4	24	21	72	350	234	48	51.4	11.4	0.90	115	37	54.1	19.0
NE #5	25	19	72	314	224	49	54.1	10.8	1.46	90	38	53.8	19.8
NE #6	23	19	71	303	191	49	50.7	11.1	0.13	112	37	52.2	19.3
NE #7	22	20	71	302	201	49	52.0	11.6	0.60	101	37	51.4	19.0
NE #8	24	20	75	320	209	48	51.0	11.0	0.46	110	39	53.5	19.2
Ruff	28	23	65	442	285	46	51.9	12.5	1.73	157	43	50.8	17.1
Nordan	22	25	73	428	310	48	50.4	12.3	1.68	116	44	46.8	16.3
10b-1	19	21	78	458	378	42	48.4	12.6	2.10	79	43	—	—
10b-2	17	15	76	321	324	45	44.7	10.7	0.42	38	52	—	—
Mean	24	20	66	293	202	48	49.6	11.6		90	42	52.5	17.8
L.S.D. (0.05)	5	3	8	110	85	5	4.5	1.3		55	NS	9.2	2.8
C.V. %	18.2	11.6	10.5	31.9	36.0	9.8	7.8	9.5		52.5	17.2	14.9	13.5

a/Measured in the spring of 1980 and represents first year basal spread.

Table 4. Means and other statistics for traits of crested wheatgrass introductions and experimental strains evaluated at Alliance, Nebraska, in 1980 and 1981.

	Means averaged over 1980 and 1981						1981 Means										
	First cut								First cut					Second cut			
Strain	Plant width[a]	Yield	Dry matter	IVDMD	Protein	Selection index (NI)	Heading date	Height	Total yield	Yield	Dry matter	IVDMD	Protein	Yield	Dry matter	IVDMD	Protein
	cm	g/plant	%	%	%		days	cm	g/plant	g/plant	%	%	%	g/plant	%	%	%
PI 172690	21	183	50	48.7	8.9	0.83	36	54	231	185	56	55.2	9.6	35	58	49.5	11.2
PI 172691	18	152	42	50.8	10.0	1.08	37	54	196	176	56	55.9	10.0	20	52	47.9	13.1
PI 203439	13	92	52	46.5	9.4	-1.80	34	46	120	107	56	51.2	9.6	13	59	—	—
PI 203443	15	95	51	46.3	9.7	-1.82	34	50	132	117	55	50.8	9.4	15	61	—	—
PI 206396	12	91	51	45.9	10.2	-2.05	35	48	126	108	55	49.9	10.2	18	63	—	—
PI 229521	16	140	48	42.3	9.2	-2.48	30	54	207	159	50	47.6	9.3	48	59	42.7	12.7
PI 314596	17	164	49	50.0	9.6	0.96	30	54	177	152	52	55.3	9.6	25	61	—	—
PI 314597	19	164	50	46.3	9.2	-0.46	31	58	222	192	55	49.5	8.8	31	57	—	—
PI 314602	16	110	58	46.6	7.6	-1.41	27	50	148	121	59	51.1	7.6	27	56	55.0	11.7
PI 315066	21	176	52	47.2	8.9	0.12	29	58	234	193	56	52.2	9.1	41	53	48.4	12.4
PI 325180	21	191	52	49.3	9.5	1.22	34	44	208	178	56	53.4	9.4	29	59	47.6	9.8
PI 369167	22	173	49	51.9	9.7	1.87	36	45	205	175	52	55.7	9.7	30	61	47.0	10.0
PI 369168	20	185	50	49.0	8.6	0.99	30	57	254	212	57	52.6	10.0	42	51	—	—
PI 369169	18	127	46	46.3	10.9	-1.19	29	56	168	138	50	50.1	12.1	30	54	—	—
PI 369170	22	194	51	50.0	8.5	1.55	35	51	206	184	54	53.8	8.5	22	59	48.8	10.1
PI 273730	17	132	48	48.5	9.4	-0.24	31	56	181	158	53	53.7	9.9	23	56	—	—
PI 273731	19	181	50	45.7	8.8	-0.36	31	66	273	215	54	51.1	8.4	58	56	—	—
PI 277354	20	175	51	46.2	8.6	-0.29	29	63	230	202	55	51.8	8.9	27	58	—	—
PI 314604	16	147	51	45.9	8.8	-0.95	32	65	207	177	53	47.9	8.8	31	56	—	—
PI 314927	17	135	54	43.2	8.6	-2.22	38	54	202	182	59	47.7	8.2	20	61	—	—
PI 315068	19	186	51	45.8	8.8	-0.22	32	57	271	229	54	50.8	9.0	42	55	52.4	11.6
PI 316121	17	189	51	45.9	8.4	-1.13	31	61	304	265	55	51.2	8.4	39	55	—	—
PI 340059	18	171	51	46.7	9.1	-0.17	33	58	240	194	54	51.4	9.7	46	50	—	—
PI 340060	20	204	50	46.2	9.0	0.28	32	62	250	214	54	52.5	9.5	36	51	48.6	13.1
PI 345584	17	162	51	46.0	8.7	-0.62	30	59	231	191	54	51.5	8.8	41	54	51.3	12.3

Table 4. (Continued)

Strain	Means averaged over 1980 and 1981								1981 Means								
	First cut									First cut				Second cut			
	Plant width[a]	Yield	Dry matter	IVDMD	Protein	Selection index (NI)	Heading date	Height	Total yield	Yield	Dry matter	IVDMD	Protein	Yield	Dry matter	IVDMD	Protein
	cm	g/plant	%	%	%		days	cm	g/plant	g/plant	%	%	%	g/plant	%	%	%
PI 370645	19	201	51	46.8	9.1	0.45	29	63	254	221	54	51.3	8.7	33	61	53.7	12.3
PI 383538	18	190	51	49.6	9.7	1.32	37	52	276	226	54	54.7	10.0	50	52	49.6	11.6
PI 383540	17	179	48	47.2	9.3	0.18	36	59	226	209	53	51.4	9.1	17	56	—	—
PI 401002	17	143	52	44.0	8.6	-1.76	32	55	200	180	56	48.4	8.6	19	51	53.6	12.5
PI 401003	18	176	51	49.9	10.3	1.16	34	57	228	188	53	54.1	9.9	40	50	56.7	14.0
PI 401004	17	150	51	45.2	8.7	-1.16	33	55	205	172	54	50.3	9.1	33	55	47.1	11.7
NE #1	18	176	50	48.2	8.3	0.50	31	62	240	206	56	52.2	8.6	34	54	—	—
NE #3	20	202	51	47.3	9.0	0.67	27	65	257	214	54	31.4	8.9	43	53	56.4	12.5
NE #4	18	197	52	49.5	9.3	1.41	33	62	278	230	55	55.2	9.8	48	52	53.5	13.4
NE #5	18	184	51	47.6	8.4	0.43	33	65	228	203	54	52.4	9.1	33	50	53.2	13.3
NE #6	20	217	51	46.8	8.5	0.77	32	63	289	233	55	52.2	8.8	56	49	56.1	13.5
NE #7	18	180	52	46.4	9.0	-0.11	31	61	245	204	55	50.9	9.5	41	52	53.8	12.8
NE #8	17	172	52	48.7	9.1	0.62	33	63	238	195	56	53.0	9.2	44	52	50.9	12.6
Ruff	20	203	51	50.0	8.8	1.72	33	55	247	204	55	53.9	8.8	43	58	48.9	9.5
Nordan	19	223	50	48.5	9.4	1.54	30	63	264	229	54	52.2	9.4	36	50	54.2	13.5
10b-1	16	210	46	49.1	9.9	1.52	31	66	290	247	50	52.7	9.4	42	55	—	—
10b-2	16	178	51	38.9	8.9	-3.04	23	61	240	217	54	43.2	8.1	24	59	—	—
Mean	18	170	51	47.2	9.1		32	57	225	191	54	51.8	9.2	34	55	51.1	12.1
L.S.D. (0.05)	2	60	3	3.0	1.4		2	4	52	44	3	3.1	0.9	17	6	6.1	1.6
C.V. %	11.6	22.9	5.5	5.4	13.2		5.8	6.5	19.6	19.6	5.1	5.2	8.0	43.9	9.1	10.2	10.9

[a]Measured in the spring of 1980 and represents first year basal spread.

369170, and PI 325180 had higher NI values than Nordan (Table 1). PI 369167 also had a higher NI value than Ruff. The NI values were not analyzed using analyses of variance procedures because they are non-parametric statistics. These three introductions, Nordan and Ruff, and the clonal line 10b-1 were the only strains in the study that had NI values greater than 2.0. PI 369167 had the highest IVDMD value of any strain in this study; Nordan and the clonal line 10b-1 had the highest forage yields (Table 1). Ruff, PI 369170, and PI 325180 had both high yields and high IVDMD values. Ruff, Nordan, PI 369167, PI 369170, and PI 325180 performed well at both locations indicating that they have broad adaptability (Tables 3 and 4).

There were significant differences among strains for second cut or regrowth forage yields and quality traits at both locations (Tables 3 and 4). The second-cut yields at Lincoln were higher than those at Alliance because of the higher precipitation and probably more representative of the regrowth potential of the strains evaluated. At both locations, the bulk of the forage was produced in the first cut. First- and second-cut forage yields were positively correlated (r = 0.33[3/] and 0.61[3/] for Lincoln and Alliance, respectively) in 1981, while first- and second-cut IVDMD values were not correlated at either location. Selection for first-cut forage yield and IVDMD could improve both first-cut forage yield and quality and second-cut yields.

There were significant differences among strains for first year width, height, and maturity by heading date. The correlations of these traits with the forage yield and quality traits are given by Lamb *et al.* (1984). Strains with the highest first-cut yields also had high second-cut yields and were taller but earlier in maturity than the low yielding strains. Plant width was positively correlated with first-year yields. Later maturing strains tended to be higher in IVDMD. Most of the differences among strains for IVDMD were probably due to factors other than maturity because most of the strains headed within the same week.

Although we have evaluated only a part of the accessions of crested wheatgrasses available for use by breeders, we have identified several accessions that are equal to, if not superior to, the released cultivars Ruff and Nordan for both first-cut forage yield and quality. Incorporation of these accessions in crested wheatgrass breeding programs by using procedures described by Asay and Dewey (1983) should result in the development of crested wheatgrasses with improved forage yield and quality. Further comprehensive evaluation of crested wheatgrass introductions could result in the identification of additional accessions with both high forage yield and quality characteristics.

[3/]Significance at the 0.5 level of probability.

LITERATURE CITED

1. Asay, K.H., and D. R. Dewey. 1983. Pooling the genetic resources of the crested wheatgrass complex. p. 124-127. *In* J. A. Smith and V. W. Hays (eds.) Proceedings of the XIV Int. Grassland Congress. Westview Press, Boulder, Colorado.
2. Association of Official Agricultural Chemists. 1960. Official methods of analyses of the A.O.A.C. 9th ed. Washington, DC.
3. Coulman, B. E., and R. P. Knowles. 1974. Variability for *in vitro* digestibility of crested wheatgrass. Can. J. Plant Sci. 54:651-657.
4. Dewey, D. R. 1983. Historical and current taxonomic perspectives of *Agropyron, Elymus,* and related genera. Crop Sci. 23:637-642.
5. Dewey, D. R., and K. H. Asay. 1975. The crested wheatgrasses of Iran. Crop Sci. 15:844-849.
6. Dewey, D. R., and A. P. Plummer. 1980. New collection of range plants from the Soviet Union. J. Range Management 33:89-94.
7. Hanson, A. A. 1972. Grass varieties in the United States. USDA Agricultural Handbook No. 170. Washington, DC.
8. Junk, R. J. G., and H. M. Austenson. 1971. Variability of grass quality as related to cultivar and location in western Canada. Can. J. Plant Sci. 51:309-315.
9. Lamb, J. F. S., K. P. Vogel, and P. E. Reece. 1984. Genotype and genotype x environment interaction effects on forage yield and quality of crested wheatgrasses. Crop Sci. (In Press).
10. National Oceanic and Atmospheric Administration. Climatological Data Annual Summaries 1979, 1980, 1981. Asheville, NC.
11. Newell, L. C. 1966. A gene bank for grasses. Farm, Ranch, and Home Quarterly, Nebr. Exp. Sta. Publ. QR 119:3-4.
12. Rogler, G. A., and R. J. Lorenz. 1983. Crested wheatgrass—early history in the United States. J. Range Management 36:91-93.
13. Roth, L. S., 1971. Development and application of selection criteria for improvement of corn forage. Ph.D. Diss., Univ. of Nebraska-Lincoln.
14. Schaff, H. M., G. A. Rogler, and R. J. Lorenz. 1962. Importance of variation in forage yield, seed yield, and seed weight to the improvement of crested wheatgrass. Crop Sci. 2:67-71.
15. Tilley, J. A., and R. A. Terry. 1963. A two stage technique of the *in vitro* digestion of forage crops. J. Brit. Grassland Soc. 18:104-111.

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