



Effects of soil texture and salinity on the establishment and morphology of twelve range grasses
by Juanita J Lichthardt

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Biological Sciences

Montana State University

© Copyright by Juanita J Lichthardt (1986)

Abstract:

The performance and morphology of 12 grass species were observed on soils which differed in texture and soluble salt content. Grasses were grown on experimental plots built of nine subsoils which varied in texture from clay loam to sandy loam. Half of each experimental soil was salted with a mixture of NaCl and CaCl₂ to produce 18 treatment combinations of soil texture and salt level.

Stand performance was evaluated with a first-year measure of seedling density and second- and fourth-year measures of yield. Fine textures had a negative effect on seedling emergence of *Agropyron cristatum*, *A. inerme*, *Bouteloua gracilis*, and *Elymus junceus*. Salt had a negative effect on seedling emergence of *Agropyron cristatum*, *A. inerme*, *A. trachycaulum*, and *Bouteloua gracilis*. Second-year yield measures showed better yields of *Stipa viridula* on fine soils. Relatively low salinities produced significant second-year yield reductions of *Agropyron inerme*, *A. riparium*, *Bouteloua gracilis*, *Elymus angustus*, *E. junceus*, *Stipa viridula*, and *Triticum aestivum*. The effect of texture on yield had disappeared by the fourth growing season, but salt effects were still evident for *Agropyron inerme*, *A. riparium*, *A. smithii*, *Elymus angustus*, and *Stipa viridula*.

To determine the magnitude of plastic morphological responses of *Agropyron* ("Wheatgrass") species to soil texture and salinity, 21 different morphological characteristics were measured on randomly selected specimens of 7 representative species. Sixteen characters, both vegetative and reproductive, exhibited environmental plasticity, as indicated by significant variance components due to salt, texture, or their interaction. The most common responses seen were in the number of florets per spikelet, length of rachis internodes, and spikelet lengths. Most characters (67%) exhibited plasticity in fewer than 3 species. Because of this, variation in soil quality, in the range studied, is not expected to confuse identification of these species.

EFFECTS OF SOIL TEXTURE AND SALINITY ON THE
ESTABLISHMENT AND MORPHOLOGY OF
TWELVE RANGE GRASSES

by
Juanita J. Lichthardt

A thesis submitted in partial fulfillment
of the requirements for the degree

of
Master of Science
in
Biological Sciences

MONTANA STATE UNIVERSITY
Bozeman, Montana

September 1986

MAIN LIB.

N378

L617

cop. 2

ii

APPROVAL

of a thesis submitted by

Juanita J. Lichthardt

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

18 Sept 1986
Date

J. WEAVER
Chairperson, Graduate Committee

Approved for the Major Department

15 September, 1986
Date

Peter F. Brunard
Head, Major Department

Approved for the College of Graduate Studies

6 October 1986
Date

Henry L. Parsons
Graduate Dean

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made.

Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his/her absence, by the Director of Libraries when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature Juanita J. Luchthardt

Date 15 Sept 1986

TABLE OF CONTENTS

	Page
LIST OF TABLES.....	vi
LIST OF FIGURES.....	viii
GENERAL ABSTRACT.....	ix
GENERAL INTRODUCTION.....	1
PART I.....	3
ABSTRACT.....	4
INTRODUCTION.....	5
METHODS.....	9
RESULTS.....	18
Soil Texture Treatments.....	18
Salt Treatment.....	19
Soil Water.....	21
Seedling Density.....	21
Second-Year Yield.....	25
Fourth-Year Yield.....	30
DISCUSSION.....	35
Soil Effects on Plant Establishment.....	35
Soil Effects on Second-Year Yield.....	36
Soil Effects on Fourth-Year Yield.....	42
CONCLUSIONS.....	45
LITERATURE CITED.....	47
PART II.....	52
ABSTRACT.....	53
INTRODUCTION.....	54

TABLE OF CONTENTS---Continued

	Page
LITERATURE REVIEW.....	56
Environmental Plasticity and Taxonomy.....	56
Relationship of Morphology to Environmental Factors.....	57
METHODS.....	59
Overview.....	59
Growth Conditions.....	59
Collection of Specimens.....	59
Measurement of Grass Characters.....	60
Data Analysis.....	62
RESULTS.....	64
Detection of Plasticity in Grass Characters.....	64
Specific Effects of Texture and Salinity.....	67
DISCUSSION.....	75
Organs Responding Plastically.....	75
Response to Texture and Salinity.....	78
Implications for Species Identification.....	81
Detection of Plasticity.....	81
CONCLUSIONS.....	84
LITERATURE CITED.....	86
APPENDICES.....	90
Appendix A - Density and Biomass Data Supporting Part I, Establishment Study.....	91
Appendix B - Morphology Data Supporting Part II, Plant Variability Study.....	102

LIST OF TABLES

Table	Page
1. Monthly precipitation at the experimental site.....	10
2. Salinity of plots before and after salt application.....	12
3. Characteristics of surface (0-15 cm) soils in the experimental plots. November 1982.....	14
4. Sources and varieties used in the study and abbreviations of scientific names.....	15
5. Particle size fractions of nine soils used to create experimental plots, with corresponding mean particle diameters and standard deviations.....	19
6. Changes of soil salinity with time.....	20
7. Soil water potentials measured over 2 growing seasons.....	22
8. Variance components of seedling density.....	23
9. Seedling density on 3 textural types averaged over 2 salt treatments.....	24
10. Mean seedling densities (plants/m ²) on 2 salt treatments averaged over all soils; n=45.....	24
11. Variance components of 1983 yield data.....	26
12. Mean, second-year (1983) dry matter yield of 12 grass species.....	27
13. Variance components of 1983 yield data evaluated by a 4-factor mixed model ANOVA for all species combined.....	30
14. Variance components of fourth-year (1985) yield data.....	31
15. Mean, fourth-year (1985) dry matter yield of 11 grass species.....	33
16. Grass characters measured, and units used, for analysis of environmentally-induced morphologic variation in 7 species of <u>Agropyron</u>	61

LIST OF TABLES--Continued

	Page
17. The effect of soil texture on grass characters.....	65
18. The effect of soil salinity on grass characters.....	66
19. Summary of ANOVA analyses of grass morphological characteristics, grouped by character type.....	68
20. Treatment means of morphology data.....	69
21. Density of grass seedlings in the first growing season, 1982.....	92
22. Dry matter yield, of the grasses planted, in the second growing season, 1983.....	94
23. Dry matter yield in the fourth growing season, 1985.....	96
24. Measurements of morphological characteristics of 7 <u>Agropyron</u> species; characters 1-17.....	103
25. Measurements of morphological characteristics of 7 <u>Agropyron</u> species; characters 18-33.....	110
26. Key to index numbers, plot numbers, morphological characters, and missing data referred to in Tables 24, 25, and 27.....	117
27. Sample sizes for morphological measurements.....	119

LIST OF FIGURES

Figure	Page
1. Lay-out of experimental plots.....	11

GENERAL ABSTRACT

The performance and morphology of 12 grass species were observed on soils which differed in texture and soluble salt content. Grasses were grown on experimental plots built of nine subsoils which varied in texture from clay loam to sandy loam. Half of each experimental soil was salted with a mixture of NaCl and CaCl₂ to produce 18 treatment combinations of soil texture and salt level.

Stand performance was evaluated with a first-year measure of seedling density and second- and fourth-year measures of yield. Fine textures had a negative effect on seedling emergence of Agropyron cristatum, A. inerme, Bouteloua gracilis, and Elymus junceus. Salt had a negative effect on seedling emergence of Agropyron cristatum, A. inerme, A. trachycaulum, and Bouteloua gracilis. Second-year yield measures showed better yields of Stipa viridula on fine soils. Relatively low salinities produced significant second-year yield reductions of Agropyron inerme, A. riparium, Bouteloua gracilis, Elymus angustus, E. junceus, Stipa viridula, and Triticum aestivum. The effect of texture on yield had disappeared by the fourth growing season, but salt effects were still evident for Agropyron inerme, A. riparium, A. smithii, Elymus angustus, and Stipa viridula.

To determine the magnitude of plastic morphological responses of Agropyron ("Wheatgrass") species to soil texture and salinity, 21 different morphological characteristics were measured on randomly selected specimens of 7 representative species. Sixteen characters, both vegetative and reproductive, exhibited environmental plasticity, as indicated by significant variance components due to salt, texture, or their interaction. The most common responses seen were in the number of florets per spikelet, length of rachis internodes, and spikelet lengths. Most characters (67%) exhibited plasticity in fewer than 3 species. Because of this, variation in soil quality, in the range studied, is not expected to confuse identification of these species.

GENERAL INTRODUCTION

Coal strip-mining in southeastern Montana disturbs extensive land areas. State law mandates reclamation of these lands and the Montana Department of State Lands is charged with overseeing the reclamation process.

This project was supported by the Department of State Lands, with the objectives of improving both the reclamation process and the reclamation evaluation process. First, to improve the reclamation process it was desirable to know whether particular soil textures and salinities commonly appearing in Ft. Union subsoils were especially good or bad for the establishment of major range grasses used in revegetation. This question is addressed in Part I of this thesis. Second, the evaluation process was improved by asking whether variability in soil texture and/or salinity, like that appearing on reclaimed mine sites, would so modify plant phenotypes as to confuse the identification of species. Significant environmentally-induced variation could make it difficult to accurately identify species. Accurate identification of species is necessary to determine whether diversity requirements, set by State law, have been met. Part II of this thesis therefore determines the degree to which levels of texture and salinity commonly found in Ft. Union subsoils modify plant characters used to identify Agropyron species used in reclamation practice.

Both projects were simultaneously conducted in an experimental garden, with soils transported to a uniform climate. As a result of the projects being jointly undertaken, they are reviewed jointly here.

PART I

EFFECTS OF SOIL TEXTURE AND SALINITY
ON THE ESTABLISHMENT OF
TWELVE RANGE GRASSES

ABSTRACT

Performance of 12 grass species was observed, during the first 4 years of growth, on experimental plots built of soils which differed in texture and salt content. Nine subsoils varying in texture from clay to sandy loam were selected from the site of a coal strip-mine in south-eastern Montana and used to construct test plots. Half of each experimental soil was salted with a mixture of NaCl and CaCl₂ to produce 18 treatment combinations of soil texture and salt level.

Stand performance was evaluated with a first-year measure of seedling density, and second- and fourth-year measures of yield. Texture was primarily important during seedling emergence; density data indicated that fine textures had a negative effect on emergence of Agropyron cristatum, A. inerme, Bouteloua gracilis, and Elymus junceus, and little effect on establishment of 8 other species. Yield measures made at the end of the second growing season indicated little effect of soil texture on plant performance. Two exceptions were Agropyron inerme, which produced significantly better yields on loams, and Stipa viridula, which yielded best on fine soils.

Even though salts were rapidly leached through the soils, effects on both establishment and yield were observed. Seedling densities were reduced by salinity in A. cristatum, A. inerme, A. trachycaulum, and Bouteloua gracilis. Relatively low salinities produced significant second-year yield reductions of A. inerme, A. riparium, Bouteloua gracilis, Elymus angustus, E. junceus, Stipa viridula, and Triticum aestivum. Negative effects of salt on yield were still evident in fourth-year measurements.

Interactions in the analyses of variance, of both density and yield data, indicated significant effects of unidentified soil properties in addition to texture and salinity.

INTRODUCTION

By legal definition, successful revegetation of strip-mined lands requires the establishment of a diverse plant cover with production equal to or exceeding that observed prior to mining (USDA Office of Surface Mining 1979). To achieve such revegetation goals, reclamation engineers must know how soil properties will affect the success of plantings in the regional climate.

Many soil properties which affect plant growth are related to texture. Among these are water and nutrient holding capacity, porosity, infiltration rate, compactability, and salinity. Soil salinity in particular is often limiting to the establishment of vegetation in dry regions.

Because it influences plant growth, and because it is easily measured, soil texture has been used to characterize plant habitat (Gates et al. 1956, Ross and Hunter 1976), evaluate sites for plant establishment (Coile 1935, Heerwagen 1958, Heerwagen and Aandahl 1961), and to predict yield (Storie 1937, Medin 1960, Clary 1964). Guidelines have been established to rate the suitability of mine soils for plant growth based on texture and other properties (Shafer 1979). However, few studies have specifically measured the effect of soil texture on grass establishment (Kilcher and Lawrence 1970, Cox and Martin 1984).

Soil textural characteristics affect plant growth and production primarily through their effects on water availability (Fribourg et al. 1982), and indirectly through the effects of water on other plant growth

factors such as nutrient availability (Russell and McRuer 1927), and salinity (Richards 1969). Soil texture determines infiltration rates and permeability, and therefore water absorption (Black 1968). Soil texture is particularly important in arid regions because it determines the capacity of the soil to store absorbed water (McGinnies 1955, Clary 1964, Wollenhaupt et al. 1982). In general, loams provide the best combination of water holding capacity and permeability, and are associated with the highest forage production (Wilsie et al. 1944, Noller 1968). The relatively good infiltration and permeability associated with coarse soils sometimes offsets their low water holding and nutrient exchange capacity (Cox and Fisser 1978).

Besides texture, high levels of soluble salts also limit plant establishment and growth in semi-arid regions (Poljakoff-Mayber and Gale 1975, Smith 1978). Saline soils can severely limit the reclamation potential of proposed mine sites. When regulatory agencies choose topsoils and seed mixes they must make decisions based on existing knowledge of plant salinity tolerance. Current knowledge is largely based on observation of plants in greenhouse experiments, or on irrigated field plots in which water is not limiting. Results of these experiments are not directly applicable to field conditions where the effective salinity is dependent on the water content of the soil (Richards 1969). Field experiments are therefore needed to clarify the effects of soil salinity on plant growth under natural climatic regimes of arid and semiarid regions.

Grasses in the genus Agropyron ("Wheatgrasses") are generally considered salt tolerant (Dewey 1960). Research has related the use of

salt-tolerant Agropyron species to crop breeding programs (McGuire and Dvorak 1981), forage production (Forsberg 1953, Crowle 1970) and highway plantings (Hughes et al. 1975). The highest degrees of salt tolerance appear in introduced species of poor forage quality (Dewey 1960, Hunt 1965), while among native species, A. trachycaulum and A. smithii are the most tolerant (Dewey, 1960). Different levels of salinity tolerance can also appear among varieties of the same species (McGuire and Dvorak 1981).

The closely related genus Elymus ("Wildrye") has also been the subject of research on salinity tolerance. Introduced species E. junceus and E. angustus in particular have been recommended for forage production on saline soils in Canada: in field tests, their tolerance was comparable to that of A. trachycaulum (McElgunn and Lawrence 1973).

Various other dryland forage and crop species have shown some degree of salt tolerance. Yields of Bouteloua gracilis and Triticum aestivum for example, are reduced 50% by soil solution conductivities on the order of 12 and 10 mmhos/cm respectively (Richards 1969).

Application of test results to the selection of plants for revegetation cannot be straightforward, since salinity effects are dependent on the growth stage of the plant, the form of salt, and environmental conditions (Forsberg 1953, Choudhuri 1968, Moxley et al. 1978).

To experimentally determine the effects of soil texture and salinity on the establishment of grasses used in revegetation, the performance of 12 grass species was observed on 9 different soils, each with 2 levels of salinity. Soils were collected and field plots were established at a mine site in southeastern Montana. Field plots were

used to determine the responses of 7 Agropyron species: A. cristatum ("Crested Wheatgrass"), A. dasystachyum ("Thickspike Wheatgrass"), A. inerme ("Beardless Wheatgrass"), A. riparium ("Riparian Wheatgrass"), A. smithii ("Western Wheatgrass"), A. trachycaulum ("Slender Wheatgrass"), and A. trichophorum ("Pubescent Wheatgrass"; Barkworth and Dewey 1985). Five other species commonly included in range seedings were also tested: Bouteloua gracilis ("Blue Grama-Grass"), Elymus angustus ("Altai Wildrye"), E. junceus ("Russian Wildrye"), Stipa viridula ("Green Needlegrass"), and Triticum aestivum ("Spring Wheat"; Kilcher and Lawrence 1970, Hitchcock and Cronquist 1973). Plant performance on experimental soils was evaluated by measuring first-year seedling density, and second- and fourth-year maximum standing crops.

METHODS

The experiment was conducted at a site selected to represent Fort Union Formation surface coal mining, which will occur over extensive areas of southeastern Montana (USDI 1974). The site is located at the Spring Creek Coal Mine, 10 km north of Decker, in southeastern Montana. Elevation at the mine is 1050 m (3500 ft). Precipitation here averages 37 cm (14 in) annually, of which 45% falls between 1 April and 30 June (Table 1). Natural vegetation of the area is an open Ponderosa Pine woodland with semiarid grassland, and is included in Kuchler's Eastern Ponderosa Forest (Küchler 1964).

To examine the effects of soil texture on plant establishment, grasses were grown on different soils laid out in "pads", constructed on a site adjacent to the mine (Figure 1). Previous mining operations had created a level site with a compacted surface of gravel and porcelanite and without topsoil. Scrapers were used to collect nine diverse soils, haul them to the study site, and build nine, 27 X 4 m pads, approximately 0.5 m deep. Three soils were chosen in each of 3 textural categories: 1) coarse, sandy soils; 2) medium-textured loamy soils; and 3) fine, clay-rich soils. Each soil consisted of subsoil material taken from a previously undisturbed site. Pre-mine soil inventory data and soil maps were used to select the nine soils from those present on mine property.

Table 1. Monthly precipitation at the experimental site. Monthly totals (cm) for the 4 years of the study are given, with the mean, standard deviation, and range of monthly normals based on 20-year (1965-1985) precipitation records at Birney, Montana, located 40 km (25 mi) to the northeast of the experimental site.

	J	F	M	A	M	J	J	A	S	O	N	D	Total ¹
	cm												
Normal	Birney, MT												
Mean	1.96	1.50	2.03	3.71	6.02	7.21	2.82	2.11	3.07	2.74	1.78	2.03	36.98
SD	1.68	1.50	1.50	2.41	3.96	3.21	1.98	1.85	2.08	2.31	1.67	1.57	
Low	0.51	0.18	0.36	0.36	2.57	1.52	0.33	0.08	0	0	0.28	0.36	
High	8.33	6.60	6.20	7.72	19.58	13.06	6.07	7.42	7.59	6.15	4.72	3.05	
	Spring Creek Coal Mine												
1982	0.25	0.25	2.54	1.52	2.54	4.06	3.81	1.27	5.84	0.25	0.00	1.27	
1983	0.25	0.00	0.51	0.76	2.54	1.78	1.78	1.52	1.78	0.51	1.27	0.51	
1984	0.25	0.05	1.52	2.79	2.03	7.62	1.52	1.02	2.54	0	1.52	1.52	
1985	0.25	0.25	1.02	2.29	1.52	4.06	3.56	3.05	2.03	0.51	1.78	0.51	

¹Total for water year (Sept.-Aug.); 1982 not given because data is not available for Sept.-Dec. 1981.

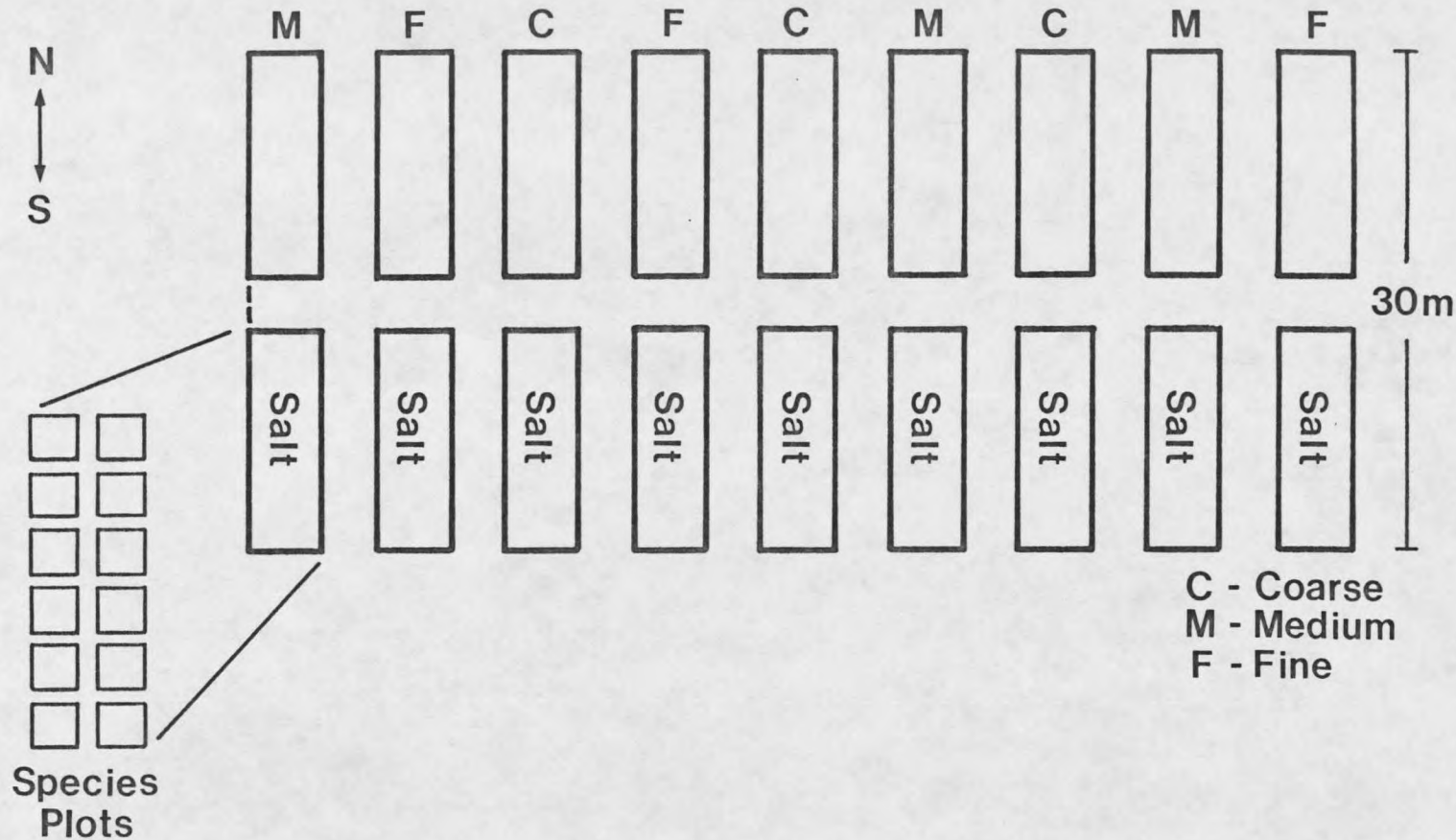


Figure 1. Lay-out of experimental plots. Plots consisted of 9 soil pads, approximately 4 X 27 m, separated by truck-width paths. Each plot in the lower half of the diagram was salt treated (see text). Each of the 18 treatment combinations of texture and salinity was subdivided into twelve, 1.5 X 1.5 m plots, in each of which the responses of an individual grass species were observed.

All soils were initially low in salts (Table 2) so, to determine the effect of moderate salinity, half of each soil pad was salt-treated with a 4:1 mixture of CaCl_2 and NaCl (meq CaCl_2 : meq NaCl). This mixture of salts was used to avoid either excessive aggregation or dispersion. Salt was applied to the pads in amounts expected to produce electrical conductivities of 5 mmhos/cm, expressed as the conductivity of the saturation extract (EC_e). Amounts of salt added varied from 150 to 743 g/m^2 depending on the original conductivity of the soil (Table 2). Salt was hand broadcast and incorporated to a depth of 30 cm with a chisel plow. In this manner, 18 treatment combinations of texture and salinity were produced.

Table 2. Salinity¹ of plots before and after salt application. Electrical conductivities were measured at the end of the first growing season (Nov. 1982).

Texture	Rep.	Conductivity of unsalted plot	Amount of salt applied ²	Conductivity obtained
		mmhos/cm	g/m^2	mmhos/cm
Fine	1)	2.1	732	6.1
	2)	3.0	743	7.0
	3)	2.8	743	10.0
Medium	1)	0.8	377	4.1
	2)	0.9	377	5.2
	3)	0.9	377	6.4
Coarse	1)	2.4	150	4.1
	2)	1.9	205	3.6
	3)	1.0	205	4.3

¹mmhos/cm of a saturated paste extract.

²Salt was applied as a 1:4 mixture of NaCl to CaCl_2 (measured in milliequivalents) to prevent soil dispersion. The salt applied was therefore 20% NaCl by weight.

Plots were fertilized differentially with ammonium nitrate and ortho-phosphate to create a nearly uniform level of fertility (Table 3). Amounts of fertilizer added were based on pre-treatment soil analyses. This approach seemed valid since none of the soils contained significant amounts of organic matter which might release nutrients through decomposition.

Twelve species were planted in subplots on each pad. To maximize the genetic purity of the species grown, "breeder" or "foundation" seed was obtained for Agropyron dasystachyum, A. inerme, A. riparium, A. smithii, A. trachycaulum, A. trichophorum, Elymus angustus, and E. junceus. This seed was supplied by Soil Conservation Service Plant Material Centers at Bridger, Montana; Pullman, Washington; and Aberdeen, Idaho (Table 4). Because breeder quality seed was unavailable for Agropyron cristatum, Bouteloua gracilis, and Stipa viridula, less pure, locally adapted types were acquired from commercial centers (Table 4).

The soil pads were seeded in May of 1982 and, due to that summer's drought, again in November of 1982. Each soil pad, representing a texture-salinity combination, was divided into twelve, 1.5 X 1.5 m species plots separated by walkways (Figure 1). A single species was assigned randomly to each plot and seed was hand-broadcast. The surface was raked before seeding, and was raked and lightly packed afterwards to provide good contact. A seeding rate of 1080 pure live seed/m² (100 PLS/ft²) was used; this corresponds to 25 kg/ha (22 lbs/A) PLS for a species such as A. cristatum. In order to insure stand establishment the following year, all plots were reseeded in November, 1982 at half the original rate, or 540 PLS/m² (50 PLS/ft²).

Table 3. Characteristics¹ of surface (0-15 cm) soils in the experimental plots, November, 1982.

Treat- ment #	Texture				Nutrients									
	Sand	Silt	Clay	Class	PAWC	Sat.	OM	CEC	EC	SAR	pH	N	P	K
	%				%	%	%	me/100g	mmhos			ppm		
Coarse														
1)	51	31	18	1	10.9	32.6	1.8	22.2	2.5	1.1	7.8	28.8	1.4	102.2
2)	52	29	19	s1	11.0	32.9	1.7	21.3	1.9	1.4	8.0	27.6	3.8	102.8
3)	63	27	10	s1	12.5	34.8	2.0	25.2	1.0	1.0	7.8	12.8	1.8	212.0
Coarse with Salt														
1)	46	34	20	1	-	33.8	1.9	21.6	4.1	1.8	7.7	36.4	1.4	108.8
2)	53	27	20	scl	-	32.4	1.9	23.5	3.6	2.3	7.8	35.6	3.8	111.2
3)	51	36	13	1	-	36.6	2.3	25.4	4.3	1.8	7.6	15.2	1.4	184.0
Medium														
1)	39	41	20	1	12.0	35.5	2.4	21.5	0.8	1.1	8.0	12.8	1.8	89.0
2)	38	46	16	1	16.8	37.8	2.7	29.7	0.9	1.1	7.8	16.4	0.7	200.0
3)	36	48	16	1	15.8	38.8	2.6	31.2	0.9	0.7	7.8	18.8	2.0	204.0
Medium with Salt														
1)	34	45	21	1	-	35.7	2.3	21.9	4.1	4.7	7.8	23.6	1.1	94.6
2)	31	53	16	sil	-	39.8	2.5	31.1	5.2	2.4	7.5	14.0	0.9	152.0
3)	40	43	17	1	-	52.8	2.9	30.5	6.4	2.3	7.4	25.6	2.0	232.0
Fine														
1)	19	51	30	sic1	16.0	52.9	0.6	25.2	2.1	11.6	8.4	22.4	0.7	86.2
2)	18	50	32	sic1	16.9	52.7	1.2	27.7	3.0	12.8	8.3	26.0	2.0	92.4
3)	20	40	40	c	14.2	51.7	1.3	23.4	2.8	14.5	8.2	32.8	1.4	72.0
Fine with Salt														
1)	16	51	33	sic1	-	47.7	1.8	22.3	6.1	13.2	7.9	24.8	1.4	74.6
2)	19	49	32	sic1	-	51.2	0.9	25.6	7.0	13.0	7.9	20.4	3.6	79.6
3)	23	40	37	cl	-	47.3	1.0	25.8	10.0	18.2	7.9	23.6	1.6	70.0

¹Soil texture (% sand, silt, or clay); texture class (USDA 1962); plant available water capacity (by weight, 15 bar-0.33 bar, %); % water at saturation; % organic matter; cation exchange capacity (meq/100g); electrical conductivity of the saturation extract (mmhos/cm); SAR = $\text{Na}^+ / \sqrt{(\text{Ca}^{++} + \text{Mg}^{++})/2}$; soil pH; NO₃-nitrogen; Olsen phosphorus, and AB-DTPA extractable potassium (ppm); - = data not available.

Table 4. Sources and varieties used in the study and abbreviations of scientific names.

Species	Abrev.	Variety	Source ¹
<u>Agropyron cristatum</u> (L.) Gaertn.	AGCR	Parkway	Bridger
<u>A. dasystachyum</u> (Hook) Scribn.	AGDA	Critana	Bridger
<u>A. inerme</u> (Scribn. and Smith) Rydb.	AGIN	Whitmar	Pullman
<u>A. riparium</u> Scribn. and Smith	AGRI	Sodar	Aberdeen
<u>A. smithii</u> Rydb.	AGSM	Rosana	Bridger
<u>A. trachycaulum</u> (Link) Malte.	AGTRA	Primar	Pullman
<u>A. trichophorum</u> (Link) Richt.	AGTRI	Luna	Bridger
<u>Elymus angustus</u> Trin.	ELAN	Prairieland	Bridger
<u>E. junceus</u> Fisch.	ELJU	Vinall	Bridger
<u>Bouteloua gracilis</u> (HBK) Lag. ex Steud.	BOGR	locally collected	Shelby
<u>Stipa viridula</u> Trin.	STVI	Lodorm	Bridger
<u>Triticum aestivum</u> L.	TRAE	Cheyenne/spring	Belgrade

¹Soil Conservation Service Plant Materials Centers at Bridger, MT, Aberdeen, ID, and Pullman, WA; Peavey Co., Belgrade, MT, and Big Sky Wholesale Seeds, Shelby, MT.

Precipitation and soil water were monitored during the first 2 years of the experiment. Soil moisture tension was measured with gypsum blocks (Taylor et al. 1961), buried at a depth of 25 cm in all plots of A. smithii, A. cristatum, Bouteloua gracilis, Stipa viridula, Elymus junceus and Triticum aestivum. Precipitation was monitored at an on-site weather station with a cumulative rain gauge for the duration of the experiment. The plots were never irrigated.

Soils were characterized by samples taken in November 1982 (Table 3). Twenty-four soil cores, 2 from each species plot, were taken from the top 15 cm and combined, to provide one composite sample for each treatment combination. Samples were analyzed by the NERCO (Northern Energy Resource Co.) environmental laboratory in Sheridan, Wyoming. Mechanical analysis (Day 1965) was used to determine texture. Plant available water holding capacity was determined, with a pressure membrane apparatus, as the difference between 1/3 bar and 15 bar water content (Richards 1965, 1969). Organic matter was measured colorimetrically after dichromate oxidation (Graham 1959). Cation exchange capacity was determined by the sodium acetate method (Richards 1969). Soil pH was measured on a saturated paste (Richards 1969). Sodium adsorption ratio (SAR) was determined on the saturated paste extract (Richards 1969). Nitrate-nitrogen was measured by the chromotropic acid method (Sims and Jackson 1971). Phosphorus was measured after extraction with sodium bicarbonate (Olson et al. 1954). Potassium and micronutrients were extracted in AB-DTPA and determined directly by atomic absorption (Soltanpour and Schwab 1977). In order to

monitor salt levels, electrical conductivity was measured in November 1982, June 1983, and November 1983.

To index germination and emergence, seedling density was recorded twice during the first growing season. Rooted plants were counted in five, 2 X 2 dm quadrats within each species plot. Counts were made on 7 July, and again on 24 August. To normalize for parametric analysis density data were transformed to $(x + 0.5)^{1/2}$ as suggested by Bartlett (1947).

As an index of establishment and performance, yield was measured after the second (1983) and fourth (1985) growing seasons. Both harvests were made late in August. In the first harvest, five 2 X 5 dm frames were clipped, at 5 cm height, in each species planting. In 1985, three 3 X 6 dm (1 X 2 ft) frames were used to reduce variance. Samples were weighed after being oven-dried to constant weight.

Density and yield data were subjected to a 3-factor, nested factorial analysis of variance (ANOVA). Fixed treatments, "salt" and "texture", were crossed, with 3 random soils nested within each texture. Data were analyzed using Bio-medical Computer Programs (BMDP, Dixon 1981).

RESULTS

Soil Texture Treatments

Soil texture treatments are referred to as coarse (sandy loam and loam), medium (loam), and fine (clay loam and silty clay loam). Results of soil analyses confirm that the soils used represent three textural types ranging from moderately coarse to moderately fine (Soil Survey Staff 1962, Table 3). One soil which is technically a loam was grouped with coarse soils due to similarity of its sand content with that of sandy loams. Textural differences were quantified by calculating a mean particle diameter for each soil, using the revised textural triangle of Shirazi and Boersma (1984). In this system texture is designated by a mean particle size, which takes into account sand, silt, and clay particle size fractions, and a standard deviation indicating uniformity of texture. Mean particle diameters support the grouping of these soils into 3 textural categories, and indicate a larger range in particle size among coarse soils than among fine (Table 5).

Most other soil characteristics were sufficiently similar to allow differences in plant performance to be attributed to texture and/or salinity (Table 3). A possible exception was the relatively high sodium content of the fine soils, which approached values at which soil physical properties are affected (Richards 1969). None of the nutrient levels measured were low enough to limit plant growth markedly. Differences in end-of-season nitrate content between salted and unsalted

plots may have been due to greater plant growth and nitrogen consumption on unsalted plots.

Table 5. Particle size fractions of nine soils used to create experimental plots, with corresponding mean particle diameters¹ and standard deviations (S.D.). Soils are arranged in order of decreasing mean particle size².

Soil	Class	Sand	Silt	Clay	Particle Diameter ¹	
					Geometric Mean	S.D. of the G.M.
					mm	
Coarse						
3	s1	57	32	11	.170	10.73
2	s1	52	28	20	.092	15.63
1	1	49	32	19	.085	15.38
Medium						
3	1	38	46	16	.062	7.24
1	1	36	44	20	.059	13.71
2	1	34	50	16	.054	8.25
Fine						
1	sic1	17	51	32	.020	11.18
2	sic1	18	50	32	.020	11.18
3	c1	22	40	38	.015	13.11

¹Geometric mean particle diameter from the revised soil triangle of Shirazi and Boersma (1984).

²Sand fraction = 0.05-2.0 mm; silt = .002-.05 mm; clay = <.002 mm.

Salt Treatment

Untreated soils were initially low in salinity as indicated by electrical conductivities in the 0.8 to 3.0 mmho range (Table 2). Experimental addition of salts resulted in an increased but variable salt content at the end of the first growing season (Table 6). All but one of the salt-treated plots had conductivities greater than 4 mmhos/cm, the salt level used to define "saline" soils (Richards 1969).

On medium and coarse soils conductivities ranged from 3.6 to 6.4 mmhos/cm. Higher values (6-10 mmhos) for fine textured soils were due, in part, to higher initial salinity levels than anticipated.

Table 6. Changes of soil salinity with time. Electrical conductivity of the saturation extract in the top 15 cm of salt-treated (s) and control (ns) plots on 3 sampling dates.

Texture	Nov 1982		June 1983 ¹		Nov 1983	
	ns	s	ns	s	ns	s
Coarse			mmhos/cm			
1)	2.4	4.1	-	3.0	1.0	1.0
2)	1.9	3.6	-	1.9	1.2	1.3
3)	1.0	4.3	-	1.2	0.4	0.5
Medium						
1)	0.8	4.1	-	1.4	0.5	1.0
2)	0.8	5.2	-	2.7	0.4	1.9
3)	0.9	6.4	-	3.7	0.5	2.1
Fine						
1)	2.1	6.1	-	3.2	1.1	2.1
2)	3.0	7.0	-	6.1	1.9	3.7
3)	2.8	10.0	-	6.6	1.2	4.2

¹No data available for unsalted plots (-).

Due to leaching, the salinity of all soils decreased during the experiment (Table 6). Salt treated, coarse soils had the same conductivities as their unsalted counterparts by the end of the second growing season, and both were lower than they had been at the start of the experiment. Medium and fine textured soils retained salts longer, but the salinity of salt-treated plots had still dropped markedly by the end of the second growing season. Salinity of untreated plots dropped to a lesser degree.

Soil Water

While the first growing season (1982) had only slightly sub-normal precipitation, the second growing season (1983) was exceptionally dry (Table 1). Total 1983 precipitation of 16.5 cm (5 in) at the Spring Creek Mine site was less than half the 20 year average measured at Birney, Montana, 40 km (25 mi) to the northeast (Table 1). The largest total for any month was 2.5 cm, and no more than 1 cm was ever received in a 24-hr period.

In 1982, monthly soil water measurements never indicated tensions in excess of permanent wilting point (15 bars, Table 7). In 1983 however, most soils reached wilting point in July and remained dry through October. Measurements of soil water availability paralleled differences in precipitation and plant yield between the two years.

Seedling Density

For 8 of the 12 species tested, analysis of variance (ANOVA) showed no significant effect of either salt or texture on late summer seedling density (August, Table 8). The remaining 4 species responded to salt (Agropyron trachycaulum), or to both salt and texture (A. cristatum, A. inerme, Bouteloua gracilis). Much of the variance in establishment occurred among soils within textural groups, and it was highly significant in 4 cases. This indicates that, for at least 5 species, germination and/or emergence was affected to a greater degree by some soil property or properties other than texture.

Comparison of plant density means among textures (Table 9) and between salinity treatments (Table 10) illustrates the nature of

Table 7. Soil water potentials measured over 2 growing seasons. Each entry is the mean of 5 gypsum block readings (negative bars).

Treat- ment	Date								
	1982				1983				
	11 JUL	27 JUL	24 AUG	24 SEPT	8 APR	11 JUN	18 JUL	25 AUG	4 NOV
Coarse	- bars								
1)	-	4	8	0	0	5	>20	>20	>20
2)	-	6	7	0	0	10	>20	>20	>20
3)	0	1	3	0	0	1	>20	>20	>20
Coarse with salt									
1)	-	3	4	0	0	2	>20	>20	>20
2)	-	2	5	0	0	3	>20	>20	>20
3)	0	1	3	0	0	3	>20	>20	>20
Medium									
1)	2	2	5	1	1	1	>20	>20	>20
2)	1	2	8	0	0	10	>20	>20	>20
3)	0	1	7	0	0	7	>20	>20	>20
Medium with salt									
1)	0	1	3	0	0	3	>20	>20	>20
2)	0	1	2	0	0	1	>20	>20	>20
3)	0	0	3	0	0	5	>20	>20	>20
Fine									
1)	-	0	0	0	0	2	>20	>20	>20
2)	-	0	1	0	0	5	>20	>20	>20
3)	0	0	1	1	0	4	>20	>20	>20
Fine with salt									
1)	-	0	0	0	0	0	7	>20	>20
2)	-	0	0	0	0	0	6	>20	>20
3)	1	1	1	2	0	0	3	>20	>20

treatment effects. Although some species did not show significant responses to texture or salinity, two consistent trends appear across all species. First, mean seedling densities for coarse, medium, and fine textured soils, averaged across salt treatments, indicate fewer

Table 8. Variance components of seedling density. Mean squares, F-statistics and significance levels are given.¹ Seedling counts were given a $(x+0.5)^{1/2}$ transformation prior to analysis.

Species	Among Textures		Between Salt Treatments		Among Soils within Texture		Interactions ²				Error
	MS	F	MS	F	MS	F	T X S		S X Soil		
							MS	F	MS	F	
AGDA	8.74	19.22 **	2.46	9.69	.45	.83	1.35	5.31 *	.25	.47	.54
AGDA	38.04	4.60	24.64	4.92	8.27	4.81 **	.36	.07	.25	.47	.54
AGIN	29.62	10.51 *	11.53	10.10 *	2.82	1.83	1.63	1.43	1.14	.74	1.54
AGRI	18.58	5.04	6.06	2.61	3.69	2.22	5.08	2.19	2.32	1.40	1.66
AGSM	.65	.87	5.73	3.85	.76	.74	2.29	1.54	1.49	1.46	1.66
AGTRA	6.72	.79	7.63	7.67 *	8.56	5.17 **	2.23	2.24	1.00	.60	1.65
AGTRI	8.58	2.02	6.39	2.74	4.24	3.72 **	.81	.35	2.33	2.04	1.14
BOGR	11.35	6.00 *	8.90	9.36 *	1.89	2.64 *	.80	.85	.95	1.33	.72
ELAN	1.42	.69	.92	.93	1.66	4.79 **	.44	.44	.99	2.85 *	.35
ELJU	24.55	4.81	8.25	2.56	5.10	2.92 *	3.24	1.01	3.22	1.84	1.75
STVI	2.09	5.13	2.73	1.27	.41	.59	.24	.11	2.14	3.08 **	.70
TRAE	.22	.32	.19	.34	.68	1.83	.21	.37	.56	1.50	.37

¹Mean square deviation (MS), F-statistic (F), and significance: * = $p < 0.05$, ** = $p < 0.01$.

²Interaction between texture and salinity (TXS) and between salinity and soils within textures (S X Soil).

Table 9. Seedling density on 3 textural types averaged over 2 salt treatments. Mean density (plants/m²); n=30.

Species	Textural Group		
	Coarse	Medium	Fine
	plants/m ²		
<u>Agropyron cristatum</u>	101 a	90 a	27 b
<u>A. dasystachyum</u>	689	477	227
<u>A. inerme</u>	414 a	408 a	138 b
<u>A. riparium</u>	541	484	253
<u>A. smithii</u>	83	105	78
<u>A. trachycaulum</u>	334	276	185
<u>A. trichophorum</u>	265	326	163
<u>Bouteloua gracilis</u>	107 ab	118 a	28 b
<u>Elymus angustus</u>	63	46	36
<u>E. junceus</u>	296	313	110
<u>Stipa viridula</u>	77 a	61 ab	38 b
<u>Triticum aestivum</u>	43	53	42

¹Means in the same row, followed by different letters are significantly different (p<0.05); Tukey method of multiple comparisons.

Table 10. Mean seedling densities (plants/m²) on 2 salt treatments averaged over all soils; n=45.

Species	No salt	Salt	Comparison ¹
	plants/m ²		
<u>Agropyron cristatum</u>	82	55	*
<u>A. dasystachyum</u>	559	340	
<u>A. inerme</u>	369	243	*
<u>A. riparium</u>	469	363	
<u>A. smithii</u>	113	66	
<u>A. trachycaulum</u>	311	216	*
<u>A. trichophorum</u>	290	207	
<u>Bouteloua gracilis</u>	108	53	*
<u>Elymus angustus</u>	55	41	
<u>E. junceus</u>	296	200	
<u>Stipa viridula</u>	71	45	
<u>Triticum aestivum</u>	48	3	

¹An * indicates a significant difference between salt treatments (p<0.05); Method of Least Significant Difference (LSD).

plants emerging on fine soils for every species (Table 9). This effect was significant only for Agropyron cristatum, A. inerme, Bouteloua gracilis, and Stipa viridula ($p < 0.05$). There was never a significant difference in seedling density between coarse and medium soils, although densities were higher on coarse soils for eight of the twelve species. Second, overall mean density was lower on salt-treated soils for every species (Table 10). This effect was only significant for Agropyron cristatum, A. inerme, A. trachycaulum, and Bouteloua gracilis ($p < 0.05$).

Grasses established in the absence of weeds the first year. Those weeds present, consisting almost exclusively of Salsola kali and Kochia scoparia, were restricted to the sides of soil pads. Flat, smooth surfaces produced by the seeding method may have discouraged weed growth. In the second growing season annual weeds invaded those plots that had sparse grass cover.

Second-Year Yield

Because treatment response was expected to vary among species, yield data were first analyzed individually by species in order to simplify interpretation of the results. For 11 of the 12 species tested, no differences in yield could be attributed to soil texture in the range moderately-coarse to moderately-fine (Table 11). The exception was Agropyron inerme, for which yield was significantly greater on medium-textured soils than on coarse ($p < 0.01$, Table 12). For 6 of the twelve species, variance in yield due to soils within texture was significant, and highly significant in several cases, as was previously demonstrated with the density data. This result indicates important

Table 11. Variance components of 1983 yield data. Mean square deviations, F-statistics and significance tests are given for a 2-factor ANOVA, soils nested within textures¹; n=5.

Species	Among Textures		Between Salt Treatments		Among Soils within Texture		Interactions ²				Error	
							T X S		S X Soil			
	MS	F	MS	F	MS	F	MS	F	MS	F	MS	
AGCR	1063.7	2.23	570.5	2.72	477.1	3.42 **	689.3	3.29	209.6	1.50	139.6	
AGDA	8.0	0.09	398.2	3.92	86.1	1.76	175.1	1.72	101.6	2.07	49.0	
AGIN	259.5	9.76 *	437.8	27.97	26.6	1.87	59.2	3.78	15.6	1.10	14.2	
AGRI	16.6	0.25	1396.3	47.67 **	66.5	2.48 *	148.5	5.07	29.3	1.09	26.3	
AGSM	157.9	1.28	215.0	4.98	123.3	5.11 **	58.8	1.36	43.2	1.79	24.1	26
AGTRA	244.4	1.13	38.3	0.07	216.1	2.80 *	560.5	1.09	514.4	6.67 **	77.1	
AGTRI	156.4	0.70	15.7	0.07	224.7	1.98	40.1	0.19	210.3	1.85	113.6	
BOGR	4.6	0.90	26.5	6.42 *	5.1	4.62 **	3.4	0.19	4.1	3.75	1.1	
ELAN	24.8	.92	206.1	6.46 *	27.0	1.33	56.7	1.78	31.9	1.58	20.2	
ELJU	10.5	0.20	86.4	7.97 *	53.9	4.13 **	6.5	0.60	10.8	0.83	13.1	
STVI	56.1	5.05	205.5	16.43 **	11.1	1.92	79.8	6.38 *	12.5	2.16	5.8	
TRAE	73.5	2.92	494.2	7.02 *	25.1	1.00	11.9	0.17	70.4	2.81 *	25.1	

¹Mean square deviation (MS), F-value (F), and significance: * = p<0.05, ** = p<0.01.

²Interaction between texture and salinity (T X S) and between salinity and soils within textures (S X Soil).

Table 12. Mean, second-year (1983) dry matter yield of 12 grass species. Yields are shown for each species on coarse (c), medium (m), and fine (f) textured soils and on unsalted (ns) or salted (s) conditions.

Species	Texture	Salt Level		ave	Comparisons ¹	
		ns	s		Texture	Salt
g/m ²						
AGCR	c	145	205	175		
	m	220	120	170		
	f	125	14	70		*
	ave	163	113	-		
AGDA	c	90	104	97		
	m	122	53	88		
	f	125	54	90		
	ave	112	70	-		
AGIN	c	41	24	33	A	
	m	109	66	88	B	*
	f	78	6	42	AB	*
	ave	76	32	-		**
AGRI	c	110	33	72		*
	m	90	54	72		
	f	147	22	85		*
	ave	116	36	-		**
AGSM	c	23	24	23		
	m	61	18	40		
	f	94	43	69		
	ave	59	28	-		
AGTRA	c	96	157	127		
	m	175	183	179		
	f	226	118	172		
	ave	166	153	-		
AGTRI	c	120	140	130		
	m	161	184	173		
	f	176	158	167		
	ave	152	161	-		

Table 12--Continued

Species	Texture	Salt Level		ave	Comparisons ¹	
		ns	s		Texture	Salt
g/m ²						
BOGR	c	9	4	7		
	m	21	3	12		*
	f	9	0	4		
	ave	13	2	-		*
ELAN	c	31	17	24		
	m	36	20	28		
	f	72	10	41		*
	ave	46	16	-		*
ELJU	c	66	51	54		
	m	54	41	47		
	f	71	41	52		*
	ave	64	44	-		*
STVI	c	19	7	13	A	
	m	22	11	16	A	
	f	72	4	38	B	*
	ave	38	7	-		**
TRAE	c	101	40	70		
	m	86	49	67		
	f	63	21	42		
	ave	83	37	-		*

¹Factor level means for texture were compared using the Studentized Range; factor level means for salt were compared using Student's t; p<0.05 (*), p<0.01 (**).

differences among soils, in one or more of the textural groups, that were apparently independent of texture, but influenced both plant production and density.

By the beginning of the second growing season (1983), salt-treated plots had decreased in salinity by as much as 70%, exhibiting conductivities between 1.2 to 6.6 mmhos/cm (Table 6). Nevertheless, dry matter yield was markedly lower on salt treated plots for most species, and this effect occurred across all textural groups (Table 12). Overall yield was significantly less on salt-treated plots for: A. inerme, A. riparium, Bouteloua gracilis, Elymus angustus, E. junceus, Stipa viridula, and Triticum aestivum. Even for those species not significantly affected by salt, yields were always lower on salt treated plots when averaged across all textures (Table 12).

A combined ANOVA on yield data, in which species were considered as a third factor, along with texture and salinity, showed three effects. First, there was an interaction between salt and texture in which salt reduced yield most on fine soils ($p=0.02$, Table 13). Secondly, individual species differed as to the soil type on which each performed best, as indicated by significant interactions between species and texture, and between species and soils, in the combined ANOVA (Table 13). Third, even the combined data show no differences among species in response to salinity, which would be indicated by an interaction between species and salinity.

Table 13. Variance components of 1983 yield data evaluated by a 4-factor mixed model ANOVA for all species combined.¹

Source of Variation:		df	MS	F	p
1)	Species	11	7.57	34.17	.000
2)	Soil Texture	2	1.38	2.31	.180
3)	Salt Treatment	1	19.19	43.36	.001
4)	Soils within Texture				
Interactions:					
	1 X 2	22	.46	2.09	.011
	1 X 3	11	.28	1.51	.150
	2 X 3	2	3.38	7.63	.022
	1 X 4	66	.22	2.54	.000
	3 X 4	6	.44	5.06	.000
	1 X 2 X 3	22	.17	.94	.546
	1 X 3 X 4	66	.18	2.11	.000
Error		864	.09		

¹Raw data were transformed by $\log(x+1)$ to equalize variances among species.

Fourth-Year Yield

Analysis of 1985 yield data, representing 4-year-old stands, produced results similar to those obtained for second-year yield (Table 14). First, the second-year texture effect on Agropyron inerme disappeared, so there was no significant texture effect for any species. Second, there was still a significant variance component due to salinity for Agropyron inerme, A. riparium, Elymus angustus, and Stipa viridula. No difference was detected for Bouteloua gracilis or Elymus junceus, which had shown lower yields on saline soils in 1983. Only Agropyron smithii showed a yield reduction due to salt that had not been significant in the 1983 data. In the case of A. smithii the effect of salt was dependent on texture, as evidenced by a texture X salt interaction.

Table 14. Variance components of fourth-year (1985) yield data. Mean square deviations, F-statistics, and significance levels are given for a 2-factor ANOVA, soils nested within textures¹; n=3.

Species	Among Textures		Between Salt Treatments		Among Soils within Texture		Interactions ²					
							T X S		S X Soil		Error	
	MS	F	MS	F	MS	F	MS	F	MS	F	MS	
AGCR	2850.6	2.15	4099.6	3.60	1325.0	3.78 **	2989.8	2.62	1140.1	3.25 **	350.4	
AGDA	1946.1	3.64	2985.1	4.17	534.1	1.01	1374.9	1.92	716.7	1.36	527.1	
AGIN	2146.3	2.71	2913.4	18.28 **	793.1	6.96 **	499.1	3.13	159.4	1.40	114.0	
AGRI	441.9	1.84	3288.6	11.30 *	240.1	0.84	861.1	2.96	291.1	1.02	285.3	
AGSM	1126.6	4.26	2055.5	8.92 *	263.6	2.14	1372.6	5.95 *	230.6	1.87	123.3	
AGTRA	3296.5	1.89	11.9	0.01	1741.4	6.10 **	516.2	0.57	905.9	3.17 **	285.6	
AGTRI	5413.8	2.54	91.4	0.15	2130.2	3.07 *	224.0	0.37	600.7	0.86	694.6	
BOGR	69.6	1.03	110.6	1.78	67.3	3.14 *	1.0	0.02	67.2	3.13 *	21.5	
ELAN	1694.8	1.86	7019.2	8.16 *	912.3	1.17	1950.8	2.27	860.5	1.10	782.8	
ELJU	188.1	1.69	0.4	0.00	111.0	0.67	30.2	0.13	238.6	1.44	165.5	
STVI	2481.1	5.26	5246.3	12.95 *	471.8	1.11	222.1	0.55	405.2	0.96	423.8	

¹Mean square deviation (MS), F-statistic (F), and significance (* = p<0.05, ** = p<0.01).

²Interactions between texture and salinity (T X S) and between salinity and soils within textures (S X Soil).

Treatment means indicate especially large yield decrements on saline soils within the fine soils group (Table 15). Yields of Agropyron trachycaulum, A. trichophorum, and Elymus junceus were little affected by salt, as indicated by particularly low mean squares due to salt. As in the second-year (1983) analysis there is a large variance component due to soils within textures which is significant for 5 out of 11 species. No 1985 data were available for Triticum since it was not planted in the third and fourth years.

Table 15. Mean, fourth-year (1985) dry matter yield of 11 grass species. Yields are shown for each species on coarse (c), medium (m), and fine (f) textured soils and for unsalted (ns) or salted (s) conditions.

Species	Soil Texture	Salt Level		ave	Salt Comparison ¹
		ns	s		
		g/m ²			
AGCR	c	183	240	212	
	m	337	171	254	
	f	205	70	138	
	ave	242	160	-	
AGDA	c	207	190	199	
	m	368	204	286	
	f	219	192	206	
	ave	265	195	-	
AGIN	c	58	41	50	
	m	188	116	152	
	f	157	41	99	
	ave	134	66	-	**
AGRI	c	128	79	104	
	m	129	105	117	
	f	222	75	148	
	ave	160	86	-	*
AGSM	c	51	66	104	
	m	121	79	100	
	f	206	59	99	
	ave	126	68	-	*
AGTRA	c	54	103	79	
	m	192	141	167	
	f	208	196	202	
	ave	151	147	-	
AGTRI	c	165	214	190	
	m	341	327	334	
	f	197	198	197	
	ave	234	246	-	

Table 15--Continued

Species	Soil Texture	Salt Level		ave	Salt Comparison ¹
		ns	s		
g/m ²					
BOGR	c	26	15	21	
	m	34	20	27	
	f	17	1	9	
	ave	26	12	-	
ELAN	c	195	45	120	
	m	186	191	189	
	f	293	118	206	
	ave	225	118	-	*
ELJU	c	73	86	80	
	m	110	104	107	
	f	109	99	104	
	ave	97	96	-	
STVI	c	71	16	44	
	m	185	66	126	
	f	199	97	148	
	ave	152	60	-	*

¹Factor level means for salt treatments were compared using Student's t; $p < 0.05$ (*) or 0.01 (**); no significant differences were detected among soil textures.

DISCUSSION

Soil Effects on Plant Establishment

Low seedling densities, observed on fine-textured soils for every species (Table 9), may have resulted from crust strength or low permeability on these soils. Crust strength of dry, fine soils is commonly greater than that of coarse soils, and can impede emergence. While crusting was observed, differences in crust strength could not be detected with a penetrometer. Kilcher and Lawrence (1970) measured emergence rates that were similar on soils with clay contents of 23 to 40%, but higher on those with only 7% clay. Results here indicate a similar trend, with coarse soils showing the highest establishment rates for 8 out of 12 species (Table 9). The seedbed preparation used, in which plot surfaces were packed with a roller after seeding, may have contributed to crusting of fine-textured soils.

The tendency of fine-textured soils to minimize penetration of light summer rains (Weaver 1985), may have simultaneously contributed to poor establishment in two ways. Low infiltration and permeability would have reduced water availability, and would have been accompanied by increased salt retention relative to coarser soils. If increased salt retention was a factor in seedling establishment this should have been indicated by an interaction between salt and texture in the ANOVA, but this interaction only appeared for Agropyron cristatum (Table 8). The high sodium content of the fine soils probably contributed to poor

physical properties, potentially affecting both crust strength and water movement.

In field plantings, the effect of fine soils might be ameliorated by mulching or irrigation, as either would simultaneously reduce crusting and increase water supply.

The salt treatment was intended to test for the effect of increased osmotic stress on germination and emergence, the stages most susceptible to salinity (McElgunn and Lawrence 1973). Salt was added as a mixture of both calcium (flocculating) and sodium (dispersing) salts to minimize dispersion, which could cause crusting (Russell 1973). Therefore, the consistently lower, overall mean densities observed on salted plots were probably due to osmotic stress, which may be twice as great at wilting point as at field capacity (Richards 1969). Increasing water tensions were recorded through July and August, and help to explain the negative effect of relatively low salt levels on establishment of 4 species (Table 7). Of the four species negatively affected by salinity (Agropyron cristatum, A. inerme, A. trachycaulum, and Bouteloua gracilis), A. trachycaulum is noteworthy because it is considered the most salt-tolerant of those considered here (Forsberg 1953, McElgunn and Lawrence 1973).

Soil Effects on Second-Year Yield

Yield is a more useful measure of plant performance than density for at least 3 reasons. First, it integrates both plant number and plant size. Second, production of vigorous above-ground vegetative growth is usually accompanied by production of fertile seed, which

further ensures stand success, and third, it relates directly to forage production and erosion control - important concerns in revegetation practice. Second-year yield data document the capacity of Agropyron species, once established, to quickly produce biomass and ground cover. Some of the plots with the lowest seedling densities produced the highest second-year yields.

That a species is better adapted for one soil texture than another is suggested by agronomists in recommending species for plantings on different soils (Vallentine 1980, Long 1981), as well as by ecologists studying plant distribution (Hanson and Whitman 1938, Marks 1950, Kleiner and Harper 1977). The overall analysis of second-year yield data supports this view by indicating a significant species X texture interaction (Table 13). Yields were lowest on fine soils for Agropyron cristatum, Bouteloua gracilis, Elymus junceus, and Triticum aestivum. Conversely, yields were lowest on coarse soils for Agropyron smithii, A. trachycaulum, A. trichophorum, and Stipa viridula. However, performance differences among textural groups were statistically significant for only 1 of the twelve species. Only Agropyron inerme showed a statistically significant response to texture, in which yields were better on medium, than on coarse-textured soils (Table 12).

For plants yielding best on coarse soils -- A. cristatum, Bouteloua gracilis, Elymus junceus, and Triticum aestivum -- benefits of the relatively high available water holding capacity of fine soils in this range (Table 3) may have been offset by reduced infiltration rate and permeability. Coarse soils have the advantage of being able to trap water readily and protect it from evaporation (Cox and Fisser 1978).

Since precipitation during the first 2 years of the experiment may not have been sufficient to fill even the coarse soil pads (i.e., water storage capacity was not limiting), plants with established root systems might have had some advantage on coarse soils. In fact, the highest yields of 4 species -- Agropyron inerme, A. trachycaulum, A. trichophorum, and Bouteloua gracilis -- were obtained on medium-textured soils expected to combine favorable water movement and storage characteristics.

Although the experiment considered a relatively narrow range of soil textures, the textures were representative of cover soils available at the mine site, and probably typical of Fort Union Formation soils throughout southeastern Montana. Based on texture alone, these soils are considered fair to good for use in reclamation (Shafer 1979). However, other factors being equal, there seems to be little difference in the suitability of textures within the sandy loam to clay loam range for grass establishment, and soil properties other than texture may have greater effects. The trends observed are therefore probably insufficient to warrant the time and expense of selecting different species for specific topsoils. The use of extreme textures such as "sands" or "clays" might elicit differentiating responses, but in an experiment the use of such extremes would make it difficult to hold other soil variables constant.

Differences in plant performance relative to soil texture may have been obscured by effects of soils within textures (Mean Square, Soils within Texture, Table 11). Even though many important physical and chemical soil variables were measured and found to be comparable

(Table 3), the analysis indicated important yield differences among soils within textural groups. This variance within texture was not due to a particular textural group, although the fine soils group most often showed the highest variance. Differences among soils, which affected yield, could be related to an untested soil variable such as coarse fragment content, or to variables which are difficult to quantify, such as microtopography or soil organisms. They might also be due to an interaction of factors which, when considered separately, do not appear to be significant.

The detrimental effect of salinity on second-year yields of 7 grasses (Table 11) is especially notable when considering 1) the small number of species that responded to salt during establishment, 2) the steady decrease in salinity that occurred over the course of the experiment, and 3) the reported tolerance of some of the affected species. Plants are said to be most sensitive to salt stress during germination and emergence (McElgunn and Lawrence 1973). Here however, salt effects were more pronounced in second-year yield than in seedling densities, which index the seedling establishment phase. Dry soil conditions, prevalent during the second growing season (Table 7), may have contributed to the impact of salt on established plants by concentrating salt and compounding the drought stress effectively imposed by lower soil osmotic potentials. It is also likely that salt, which had leached out of the top 15 cm of soil, was still present within the rootzone.

Species differed in their responses to saline conditions. The 4 species that did not show a significant second-year yield reduction under saline conditions -- Agropyron dasystachyum, A. smithii, A.

trachycaulum, and A. trichophorum are recognized for their relatively high salt tolerance (Dewey 1960, Hughes 1975, Moxley et al. 1978). Although Elymus junceus and E. angustus are also considered good species for use on irrigated, saline sites (Forsberg 1953, McElgunn and Lawrence 1973), their yields were significantly reduced under the dry, slightly saline conditions imposed by this experiment. Soil salts also reduced yields for Agropyron riparium; this conflicts with Dewey's (1960) finding, using the same varieties, that A. riparium was comparable to A. trachycaulum in salt tolerance. In field trials Dewey (1960) found A. inerme to be the most salt-sensitive of 25 strains of Agropyron; here it was also among the most sensitive of the twelve species, with a yield reduction less than that of A. riparium, but comparable to that of Stipa viridula. In this experiment the closely related species Agropyron riparium and A. dasystachyum reacted differently to the salt treatments. Such between-species variability is expected, since even varieties of the same species commonly show different levels of salinity tolerance (McGuire and Dvorak 1981). Results obtained here differ from previously published findings primarily in the reduction of yields of Agropyron riparium, Elymus angustus, and E. junceus by low salt levels. This difference probably resulted from the absence of supplementary water in this experiment. In revegetation practice species that are adapted to dry, saline sites will be the most useful.

While some generalizations can be made on the basis of the ANOVA, results give little indication of relative salt tolerances among the 6 salt-affected species. Confidence intervals for the sample means are too wide to detect differences between species pairs. Even the overall

analysis does not indicate a significant interaction between salt and species, although it does show an effect due to salt (Table 13). A large number of significant interactions detract from the ability of the test to detect differential responses of species to salt. All of the interactions involving soils within texture are highly significant, differences between individual soils once again providing the overwhelming source of variation. This variability of soils within textures also affected the impact of added salts on yield (Salt X Soil, Table 13). As a result it may also be responsible to some degree for the absence of a salt effect in the analysis of some individual species (e.g., A. dasystachyum, Bouteloua gracilis, and Triticum aestivum).

To conclude that there are no differences among the salt-affected species (Agropyron cristatum, A. inerme, A. riparium, Bouteloua gracilis, Elymus angustus, E. junceus, Stipa viridula, and Triticum aestivum) with respect to salt tolerance would contradict the voluminous literature to the contrary. Failure of the analysis to detect differences among these species in their response to salt may be due to the relatively low stress applied, or to the large variability inherent in the experiment resulting from 1) interactions among plants, soils, and soil salts, 2) the complex physical nature of soils, and 3) difficulty of controlling experimental variables in the field.

Since 4 more tolerant species were not affected (Agropyron dasystachyum, A. smithii, A. trachycaulum, and A. trichophorum), a heavier salt application may have been used to rank them. This would have probably eliminated all establishment of species which had low yields on salted plots, e.g., Stipa viridula, Elymus

angustus, Bouteloua gracilis, and Agropyron inerme (Table 12). Such high salt applications would therefore have been incompatible with the morphology study (Part II), because plants were required from every treatment combination. It was therefore necessary to use relatively light salt treatments.

Salt reduced grass yields more on fine than on coarse or medium soils. While this interaction was usually not significant in single species analyses (Table 11), it is significant in the overall analysis (Table 13), and is reflected in the treatment means (Table 12). Since this response was recorded in the second season, after some leaching had occurred, it was probably due to lower salinities on coarse than on fine soils. The greater water holding capacity of the fine soils may have to some extent mitigated the effect of their high salt content by decreasing its concentration. The interaction may otherwise have been evident in the individual analyses.

Soil Effects on Fourth-Year Yield

Because second-year yield is not a reliable predictor of long-term stand production (White and Wight 1984), additional measurements should be made after an equilibrium condition has been reached. Fourth-year yield data give a better indication of stand success, but may not yet reflect the long-term performance of these species.

No effects of texture on establishment were evident for any species after 4 years (Table 14). This suggests that second-year effects were residual effects of poor seedling establishment.

Differences in yield between soils with similar textures did persist into the fourth year (Table 14). This effect once again

overwhelmed variance components due to texture alone, which were not significant for any species. Because this variance component due to individual soils is a random effect, it cannot be attributed to any specific soil characteristic. The use, in this study, of 3 random soils in each textural category prevented differences in yield among soils from being mistakenly attributed to texture.

In spite of the fact that no salt was added after the initial treatment (1982) and that it is known to have leached rapidly, the salt effect was almost as evident in fourth, as in second-year yield measurements (Table 14). After 2 years, stands of Agropyron inerme, A. riparium, Elymus angustus, and Stipa viridula still exhibited a clear yield decrement on salt-treated soils. Yield of Agropyron smithii showed a large variance component due to salinity in 1983, and this is even more clearly expressed in the 1985 data, where it is significant at the 5% level. Only Elymus junceus and Bouteloua gracilis no longer showed the initial, negative salt effects. It is doubtful that stands of Bouteloua recovered fully from the salt stress, because the mean square due to salt was still high in the 1985 analysis. However, the effect of salt was not consistent within textural groups (Salt X Soil, Table 14), resulting in the lower F-value obtained in 1985.

While only 5 of the 11 species showed a significant negative response to salt in fourth-year (1985) yield, most species continued to show lower mean yields on salted plots (Table 15). A. trachycaulum and A. trichophorum are exceptional in the similarity of their fourth-year yields on salted and unsalted treatments. This similarity is consistent with their reported salinity tolerances. Sample means for 1985 yield

(Table 15) indicate similar increases on salted and unsalted plots since 1983 (Table 12). Even if relative production, due to vegetative plant growth, was similar between salted and unsalted soils, from the second to the fourth year, any initial yield decrement due to fewer numbers of plants on salted soils might persist.

CONCLUSIONS

Establishment of 12 grass species was observed on 18 soils differing in texture and salinity. Measures of seedling density and second- and fourth-year yield were used to compare grass performance on these soils in a semi-arid climate characteristic of eastern Montana and adjacent Wyoming. My observations suggest the following conclusions:

- 1) Given the same climatic conditions, grasses differed as to the soil type on which they established best. However, textural properties in the range studied were of relatively little importance in determining fourth-year yield, and therefore probably do not warrant site-specific species selection.
- 2) Low seedling densities are to be expected on soils containing more than 30% clay, in the absence of management input.
- 3) Soil texture effects, probably caused by establishment rates, persisted into the second year, but disappeared by the fourth year.
- 4) Under conditions of low precipitation, an increase in initial electrical conductivity on the order of 4 mmhos/cm (EC_e), caused by soluble salts, reduced second-year yield of even tolerant forage grasses, and this effect remained into the fourth year, even though salt leached from topsoils.
- 5) To determine long-term effects of specific salinities in field experiments, plots would have to be resalted at least annually.

However, a failure to resalt yields data more relevant to reclamation management, at least in cases where topsoils are applied to well-drained sites subject to leaching.

LITERATURE CITED

LITERATURE CITED

- Barkworth, M. E., and D. R. Dewey. 1985. Genomically based genera in the perennial Triticeae of North America: identification and membership. *Amer. J. Bot.* 72: 767-776.
- Bartlett, M. S. 1947. The use of transformations. *Biometrics* 3: 39-52.
- Black, C. A. 1968. *Soil Plant Relationships*. Wiley and Sons. 792 pp.
- Choudhuri, G. N. 1968. Effect of soil salinity on germination and survival of some steppe plants in Washington. *Ecology* 49: 465-471.
- Clary, W. P. 1964. A method for predicting potential herbage yield on the Beaver Creek pilot watersheds. *Amer. Soc. of Agron. Spec. Pub.* No. 5: 244-250.
- Coile, T. S. 1935. Relation of site index for shortleaf pine to certain physical properties of the soil. *J. Forestry* 33:726-730.
- Cox, J. R. and H. G. Fisser. 1978. The effects of water stress on phenology and carbohydrate storage in the shortgrass prairie. In Goodin, J. and D. Northington (eds.), *Arid Land Plant Resources*. Texas Tech. Univ., Lubbock, TX. 724 pp.
- _____, and M. H. Martin. 1984. Effects of planting depth and soil texture on the emergence of four love-grasses. *J. Range Manage.* 37: 204.
- Crowle, W. L. 1970. Revenue slender wheatgrass. *Can. J. Plant Sci.* 50: 748-749.
- Day, P. R. 1965. Particle size fractionation and particle size analysis. In Black, C. A. (ed.), *Methods of Soil Analysis, Agronomy* no. 9, part 1. p 545.
- Dewey, D. R. 1960. Salt tolerance of twenty-five strains of Agropyron. *Agron. J.* 52: 631-635.
- Dixon, W. J. 1979. *Biomedical Computer Programs*. University of California Press, Berkeley, CA.
- Forsberg, D. E. 1953. The response of various forage crops to saline soils. *Can. J. Agric. Sci.* 33: 542-549.

- Fribourg, H. A., R. J. Carlisle, and V. H. Reich. 1982. Yields of warm- and cool-season forages on adjacent soils. *Agron. J.* 74: 663.
- Gates, D. H., L. A. Stoddart, and C. W. Cook. 1956. Soil as a factor influencing plant distribution on salt deserts of Utah. *Ecol. Monographs* 26: 155-175.
- Graham, E. R. 1959. An explanation of the theory and methods of soil testing. *University of Missouri Ag. Exp. Sta. Bull.* 734, p 17.
- Hanson, H. C. and W. Whitman. 1938. Characteristics of major grassland types in western North Dakota. *Ecol. Monog.* 8: 57-114.
- Heerwagen, A. 1958. Management as related to range sites in the central plains of eastern Colorado. *J. Range Mgmt.* 11: 5-9.
- _____, and A. R. Aandahl. 1961. Utility of soil classification units in characterizing native grassland communities in the southern plains. *J. Range Mgmt.* 14: 207-213.
- Hitchcock, C. L. and A. Cronquist. 1973. *Flora of the Pacific Northwest.* Univ. of Washington Press, Seattle, Washington. 730 pp.
- Hughes, T. D., J. D. Butler, and G. D. Sanks. 1975. Salt tolerance and suitability of various grasses for saline roadsides. *J. Environ. Qual.* 4: 65-68.
- Hunt, O. J. 1965. Salt tolerance in intermediate wheatgrass. *Crop Sci.* 5: 407-409.
- Kilcher, M. R. and T. Lawrence. 1970. Emergence of Altai wild ryegrass and other grasses as influenced by depth of seeding and soil type. *Can. J. Plant Sci.* 50: 475-479.
- Kleiner, E. F. and K. T. Harper. 1977. Occurrence of four major perennial grasses in relation to edaphic factors in a pristine community. *J. of Range Mgmt.* 30: 286-289.
- Küchler, A. W. 1964. *Potential Natural Vegetation of the Conterminous United States.* Amer. Geogr. Soc. Spec. Publ. #36. NY.
- Long, S. G. 1981. Characteristics of plants used in western reclamation. ERT Inc., Ft. Collins, Colorado. 148 pp.
- Marks, J. B. 1950. Vegetation and soil relations in the lower Colorado Desert. *Ecology* 31: 176-193.
- McElgunn, J. D. and T. Lawrence. 1973. Salinity tolerance of Altai wild rye grass and other forage grasses. *Can. J. Plant Sci.* 53: 303-307.

- McGinnies, W. G. 1955. The United States and Canada. In Plant Ecology: Reviews of Research. UNESCO Pub. on Arid Zone Research No. 6: 250-286.
- McGuire, P.E. and J. Dvorak. 1981. High salt tolerance in wheatgrasses. Crop Sci. 21: 702-705.
- Medin, D. E. 1960. Physical site factors influencing annual production of true mountain mahogany, Cercocarpus montanus. Ecol. 41: 454-460.
- Moxley, M. G., W. A. Berg, and E. M. Barran. 1978. Salt tolerance of 5 species of wheatgrass during seedling growth. J. Range Mgmt. 31: 54-55.
- Noller, G. L. 1968. The relationships of forage production to precipitating cover and soils in North Central Wyoming. PhD. Dissertation. University of Wyoming, Laramie.
- Olsen, S. R., C. V. Cole, F. S. Watanabe, and L. A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Cir. 939: 1-19.
- Poljakoff-Mayber, A. and J. Gale. 1975. Plants in Saline Environments Springer-Verlag, New York. 213 pp.
- Richards, L. A. 1965. Physical condition of water in the soil. In C. A. Black (ed.). Methods of Soil Analysis. Agronomy series #9. Amer. Soc. of Agronomy. Madison, Wisconsin. 770 pp.
- _____. 1969. Diagnosis and improvement of saline and alkali soils. USDA Agric. Hndbk. 60. 160 pp.
- Ross, R. L. and H. E. Hunter. 1976. Climax vegetation of Montana based on soils and climate. USDA-SCS. 64 pp.
- Russell, E. W. 1973. Soil Conditions and Plant Growth. Longman, London. 849 pp.
- Russell, J. C. and W. G. McRuer. 1927. The relation of organic matter and nitrogen content to series and type in virgin grassland soils. Soil Sci. 24: 421-452.
- Shafer, W. M. 1979. Guides for estimating cover-soil quality and mine soil capability for use in coal stripmine reclamation in the western U. S. Reclam. Rev. 2: 67-74.
- Shirazi, M. A. and L. Boersma. 1984. A unifying quantitative analysis of soil texture. Soil Sci. Soc. Am. J. 48: 142-147.

- Sims, J. R. and G. D. Jackson. 1971. Rapid analysis of soil nitrate with chromotropic acid. *Soil Sci. Soc. Amer. Proc.* 35:603-606.
- Smith, C. M. 1978. Salty soils and saline seep. Montana State Univ. Cooperative Extension Service. Cir. 1166. 10 pp.
- Soil Survey Staff. 1962. Soil survey manual. Agric. Hndbk. 18. USDA, U.S. Government Printing Office, Washington, D.C. 503 pp.
- Soltanpour, P. N. and A. P. Schwab. 1977. A new soil test for simultaneous extraction of macro and micro-nutrients in alkaline soils. *Commun. in Soil Sciences and Plant Analysis* 8:195-207.
- Storie, R. E. 1937. An index for rating the agricultural value of soils. *Calif. Agric. Exp. Stat. Bull.* No. 556. 48 pp.
- Taylor, S., D. Evans and W. Kemper. 1961. Evaluating soil water. Utah State U. Ag. Exp. Sta. Bull. 426. Logan, UT. 67 pp.
- USDA-OSM. 1979. Surface coal mining and reclamation operations. Permanent regulatory program, part II. *Fed. Reg.* 44(50): 15311-15463.
- USDI, Bureau of Mines. 1974. Most Probable Development Forecast. Northern Great Plains Resource Council (Map).
- Vallentine, J. F. 1980. Range development and improvements. Brigham Young University Press, Provo, Utah. 545 pp.
- Weaver, T. 1985. Summer showers: their sizes and interception by surface soils. *American Midland Naturalist* (in press).
- White, L. M. and J. R. Wight. 1984. Forage yield and quality of dryland grasses and legumes. *J. of Range Mgmt.* 37: 233-236.
- Wilsie, C. P., C. A. Black, and A. R. Aandahl. 1944. Hemp production experiments: cultural practices and soil requirements. *Iowa Agric. Exp Stat. Bull.*, p. 63.
- Wollenhaupt, N. C., E. C. Doll and J. L. Richardson. 1982. A technique for estimating plant available moisture capacity from soil texture. *Proc. No. Dak. Acad. of Science* Vol. 36: 53.

PART II

EFFECTS OF SOIL TEXTURE AND SALINITY

ON THE MORPHOLOGY OF SEVEN

SPECIES OF AGROPYRON

ABSTRACT

To determine the magnitude of plastic morphological responses of Agropyron ("Wheatgrass") species to soil properties, morphological characteristics were compared, for 7 representative species, among plants grown in 18 soils differing in texture and salt level. Nine soils, ranging in texture from sandy loams (coarse) to clay loams (fine), were used to construct texture test plots at a coal strip-mine site in southeastern Montana. Effects of salinity were tested by incorporating salt into the soil on half of each soil texture test plot. Agropyron cristatum, A. dasystachyum, A. inerme, A. riparium, A. smithii, A. trachycaulum, and A. trichophorum were grown on each of the different soils. Plastic responses to soil quality were detected by measuring 21 different morphological characters on randomly selected specimens. Characters were compared among soil textures and between salt treatments with an analysis of variance (ANOVA). A few vegetative and reproductive characters exhibited environmental plasticity. This was indicated by significant variance components due to salt, texture, or their interaction. The plant characters exhibiting plasticity varied among species. The most common responses seen were in the number of florets per spikelet, spikelet length, and rachis internode length. A response in these characters was detected in 6, 5, and 4 species respectively, of the 7 studied. While most characters (67%) exhibited plasticity in fewer than 3 species, only 3 characters showed no response to treatments in any species. In the ranges studied, salinity and texture appeared to have equal potential for inducing plastic responses in any given character. Since observed phenotypic plasticity was slight, relative to morphological differences used by taxonomists to separate these species, normal variation in soil quality is not expected to confuse species identification.

INTRODUCTION

Many of the 17 species of Agropyron occurring in the northern great plains (Hitchcock 1950) are important to range reclamation practice, and to range management in general, because they establish easily and produce large amounts of good-quality forage. Correct identification of these plants is essential to evaluation of stand composition for both management and research purposes. For example, reclaimed land can be released from bond only after certain diversity and productivity standards have been met (USDA-OSM 1979).

Identification proves difficult when morphologic variation within a taxon is high relative to that among related taxa. High within-taxon variance may be the result of genetic diversity in the taxon and/or environmentally-induced variation (Bradshaw 1965). First, the high genetic diversity of Agropyron is recognized (Baum 1979) and may be due to inherent variability as well as interspecific hybridization. Second, to the extent that it occurs, environmentally-induced variation in identifying characters may contribute to difficulty in species identification. Field ecologists have speculated that variation in soil texture and salinity on sites seeded to Agropyron species may induce morphologic variation, thereby significantly compounding identification problems.

The objectives of this project were to determine: 1) whether variation in soil texture-salinity levels such as those commonly found on reclaimed lands will induce morphologic variation, 2) what characters

are most variable, and 3) whether or not some species are more plastic than others. To test for effects of soil quality on plant morphology, 21 characters were measured on plants experimentally grown in 18 soil treatments differing in texture and salinity.

LITERATURE REVIEW

Environmental Plasticity and Taxonomy

The interaction between environment and genotype in the determination of plant phenotype has long been recognized as an important aspect of plant adaptation (Harper 1967, Gray 1985). Plants respond to environmental variation through the modification of morphological characters, and especially in vegetative organs (Stebbins 1950). The potential for variation in a given character in response to environmental influences is referred to as its plasticity (Bradshaw 1965). Since it is genetically controlled, the degree of plasticity in a given character may vary among related species, varieties, and even populations (Stebbins 1950, Harrison 1960, Chinnappa and Morton 1984).

The environmentally plastic component of plant phenotype can obscure morphological differences used to distinguish species (Stebbins 1950). For this reason, taxonomists need information on the relative plasticity of plant characters used in identification. The more information available on the phenotypic plasticity of a species, within a practical range of environmental variation, the more realistic will be the classification (Bell 1967), and the more sound the resulting determinations. The value of a taxonomic character increases with increases in its stability relative to environmental factors. Davis (1983) demonstrated the importance of character plasticity to species relationships in taxonomically difficult groups. In a study of variation in

Puccinellia (Poaceae), using different levels of drought and salt stress, he found variation in 8 characters was attributable in a larger extent to environment than to genotype.

Research involving a variety of applications and a diversity of plant species has demonstrated response to environment by virtually all vegetative organs and, to a lesser extent, in reproductive organs as well. Leaves vary in size (LaRoche 1978, Cain and Harvey 1983), shape (Cook and Johnson 1968, Chinnappa and Morton 1984), pubescence (Bell 1967), and lobing (Talbert and Holch 1957). Stems commonly exhibit plasticity with respect to height and number produced (Knight and Hollowell 1959, Kilcher and Lawrence 1970), and modifications in diameter and growth form have also been observed (Wallace 1981, Davis 1983). Floral characters are usually less plastic than vegetative characters, and consequently more valuable to taxonomists (Stebbins 1950). While environmental factors may even influence flower size and color (Mayer and Lord 1983, Schlichting and Levin 1984), examples are rare. Plasticity in floral characters is usually expressed in reproductive vigor, e.g., the number of inflorescences produced, the number of flowers per inflorescence, and the number of seeds produced (Marshall and Jain 1968, Hickman 1975, Turkington 1983).

Relationship of Morphology to Environmental Factors

Controlled experiments have demonstrated environmental modification of plant characters by edaphic factors including soil texture, pH, fertility, and salinity (Turri11 1940, Cain and Harvey 1983, Schlichting and Levin 1984), as well as to water regime, air temperature,

photoperiod, competition, and herbivory (Baskin and Baskin 1975, Quinn and Hodgkinson 1983, Schlichting and Levin 1984).

Soil texture effects have been of perennial interest. Early common garden experiments used soils of different textures to determine the contribution of soil properties to variation among plant populations (Marsden-Jones and Turrill 1938). Soil texture is still used in studies of plant variation; Wu and Jain (1978) attributed to soil texture and precipitation over 75% of the geographic variation in 5 morphological characters of Bromus rubens (Poaceae). The effect of soil texture on plant growth has usually been attributed to its effects on the penetration, storage, availability, and evaporation of water. Different water regimes, under the same soil texture conditions, have been shown to affect plant morphology (Schlichting and Levin 1984).

Soil salinity may have ionic or osmotic effects on plant growth (Fitter and Hay 1981). Morphological modifications associated with water stress occur along salinity gradients, since soluble salts effectively increase soil water tension in plants that do not accumulate salt. Plastic responses to salinity have been demonstrated in economically important grass characters including height, seed weight, and tiller number (Marshall and Jain 1968, Wu and Jain 1978, Cain and Harvey 1983). However, much less research concerns salt effects on taxonomic characters such as panicle length, and the sizes and shapes of floral bracts (Davis 1983).

METHODS

Overview

To determine the effects of soil quality on Agropyron morphology, characteristics of plants grown on 18 soils varying in texture and salinity were compared. Seven representative Agropyron species -- of the 17 occurring in the region -- were planted on each soil. Plastic responses were evaluated by measuring 21 characters, ranging from those expected to be relatively stable to those expected to be environmentally plastic. Soil treatments included three examples each of three soil types (fine, loam, and coarse), each salted to two levels (control and saline).

Growth Conditions

The nine soils studied, the salting of half of each plot to produce 18 soil treatments, and the field lay-out of the experiment, are described by Lichthardt (1986).

Seven of 12 species plots on each of the 18 soils were planted to Agropyron species. The species studied, seeding methods used, and plant performance in terms of density and yield, are described by Lichthardt (1986).

Collection of Specimens

In August of the second growing season, when the plants were well established and seed heads were ripe, 180 specimens of each species were

collected, ten from each treatment combination of soil texture and salinity. Plants were selected along a transect placed across the center of each individual species plot, parallel to the north and south boundaries of the plots. Ten fixed points were specified on the transect at 1 dm intervals. At each point the closest individual with a mature inflorescence was collected and pressed in the field. No specimens were collected within 0.2 m of a plot boundary. Fewer than 10 specimens were obtained from several sparsely vegetated plots, and in 6 species plots no fruiting material was available (see Appendix B, Table 27).

Measurement of Grass Characters

To determine morphological responses, 21 characters pertaining to the spikelet, inflorescence, and vegetative organs were measured. A spectrum of characters was selected, ranging from stable reproductive characters, commonly used to separate the species in taxonomic keys, to relatively plastic vegetative characters rarely used in identification (Table 16).

Measurements were made on well-defined parts, and with appropriate precision. Relatively coarse characters -- culm, rachis, and leaf blade lengths -- were measured directly with a ruler. Finer features of the spikelet, and leaf widths, were measured using a dissecting microscope fitted with an optical micrometer with a 0.01 mm grid. Spikelet features were measured on the the first glume and first floret of the middle spikelet, or of the spikelet just above the middle node of the rachis. Leaf blade indument and rhizome abundance were qualitatively scored (Table 16).

Table 16. Grass characters measured, and units used, for analysis of environmentally-induced morphologic variation in 7 species of Agropyron.

Vegetative Characters

1. Culm height (to nearest mm).
2. Height to the spathe leaf node (to nearest mm).
3. Length of the uppermost internode (to nearest mm).
4. Leaf sheath length (to nearest mm).
5. Leaf blade length (to nearest mm).
6. Maximum width of leaf blade (mm).
7. Indument of the upper (adaxial) surface of the leaf blade. Seven simple states ranked as follows, 1-glabrous, 3-scabrate, 5-scabrous, 7-puberulent, 9-pubescent, 10-pilose, 12-hispid (and intermediates between these), and 7 compound states in which 2 of the previous types are exhibited simultaneously: 13-hispid and scabrous, 14-hispid and puberulent, 15-pilose and puberulent, 16-pilose and pubescent, 17-pilose and scabrous, 18-pubescent and puberulent, and 19-pubescent and scabrous.
8. Length of the ligule (mm).
9. Length of the longest auricle (mm).
10. Rhizome abundance (5 states relative to the size of the plant: barely in evidence, several and well developed, abundant and well developed, and intermediates between these).

Reproductive Characters

11. Inflorescence length (to nearest mm).
 12. Rachis length (to nearest mm).
 13. Length of the central rachis internode (mm).
 14. Length of the central spikelet (mm).
 15. Number of spikelets (count).
 16. Number of florets on the central spikelet (count).
 17. Glume length (mm).
 18. Width of glume (mm).
 19. Length of the lemma of the first floret (mm).
 20. Length of the awn of the glume (mm).
 21. Length of the awn of the lemma (mm).
-

Two sets of plants were measured. First, of the 10 specimens pressed from each treatment plot, 3 random individuals were used in measuring 20 characters (2-21, Table 16). These provided 3 replicate measurements per species and treatment combination. The tallest culm on the specimen was always chosen for measurement. To be included, this culm was required to have an inflorescence which had completely emerged from the boot. The order of measurement was systematically varied such that no species or treatment was measured as a block. Second, because it was expected to be highly variable, culm height was measured, on a set of 10 plants, in the field.

Data Analysis

All variates were transformed before analysis. Both ranks and metric variates were transformed by taking their natural logs ($\log_e$). This was done to obtain estimates of variance which could be compared among the various characters, regardless of the units of measurement, i.e., to measure the intrinsic variability of a character (Lewontin 1966). Counts of florets and spikelets were transformed by $x^{1/2}$ as suggested by Bartlett (1947), to approximate a normal distribution required by the statistical analysis used.

A 2-way, mixed model ANOVA was used, for each character, to estimate variance components due to texture and salinity, and test for their significance. Analyses were performed using Biomedical Computer Programs BMDP-3V, which uses the Maximum Likelihood (ML) method of analyzing unbalanced data with both random (soil) and fixed (salt, texture) effects (Jennrich and Sampson 1981). The Maximum Likelihood procedure

produces results identical to the more conventional Method of Least Squares when cell sizes are equal.

RESULTS

Detection of Plasticity in Grass Characters

Results of tests for the effects of texture (Table 17) and salinity (Table 18) on plant characters are presented as values of p , the probability of obtaining a larger chi-square value when testing a unimodal population for the effect of a given treatment. Chi-squares for treatment effects were obtained by re-estimating the parameters of the model with one effect set to zero, and comparing the result with that obtained from the complete model. The p -values indicate, in standard notation, the alpha level at which the effect of a treatment is considered significant. Only p -values are presented because neither conventional mean squares nor F -values are produced in the Maximum Likelihood (ML) method utilized by Biomedical Computer Programs' BMDP-3V (Jennrich and Sampson 1981).

A statistically significant ($p < 0.05$) response to soil texture was detected, in at least 1 species, for 3 vegetative characters (culm height, length of culm internode, and rhizome abundance) and 4 reproductive characters (length of rachis internode, spikelet length; floret number, and lemma awn length, Table 17).

A statistically significant response to salinity ($p < 0.05$) was detected, in at least 1 species, for 3 vegetative (internode length, leaf blade length, and ligule length), and 5 reproductive characters (inflorescence length, spikelet number, floret number, spikelet length and lemma length, Table 18).

Table 17. The effect of soil texture on grass characters. Tabled values summarize significance tests by giving the probability (p) of obtaining a larger chi-square when testing for an effect due to texture¹.

Character	Species						
	AGCR	AGDA	AGIN	AGRI	AGSM	AGTRA	AGTRI
p							
<u>Vegetative</u>							
1. Culm height	0.544	0.214	0.045**	0.710	0.083*	0.003**	0.305
2. Ht to spathe leaf node	0.456	0.550	0.132	0.493	0.449	0.951	0.539
3. Length of internode	0.106	0.550	0.020**	0.153	0.348	0.415	0.774
4. Leaf sheath length	0.252	0.608	0.532	0.532	0.400	0.557	0.303
5. Leaf blade length	0.994	0.561	0.067*	0.648	0.177	0.085*	0.171
6. Leaf blade width	0.832	0.809	0.127	0.452	0.360	0.288	0.284
7. Leaf blade indument	0.106	0.998	0.141	0.696	0.524	0.343	0.475
8. Ligule length	0.900	0.193	0.724	0.230	0.496	0.233	0.100
9. Auricle length	0.269	0.579	0.373	0.779	0.943	0.573	0.470
10. Rhizomes	NA	0.038**	NA	0.803	0.825	NA	NA
<u>Reproductive</u>							
11. Inflorescence length	0.152	0.298	0.691	0.308	0.058*	0.595	0.863
12. Rachis length	0.890	0.098*	0.831	0.179	0.291	0.426	0.183
13. Rachis internode length	0.027**	0.063*	0.594	0.727	0.261	0.933	0.810
14. Spikelet length	0.006**	0.922	0.040**	0.131	0.710	0.542	0.439
15. Spikelet number	0.716	0.174	0.937	0.378	0.372	0.476	0.184
16. Floret number	0.001**	0.024**	0.004**	0.157	0.458	0.891	0.020**
17. Glume length	0.188	0.961	0.663	0.257	1.000	0.949	0.624
18. Glume width	0.360	0.540	0.780	0.335	0.500	0.238	0.450
19. Lemma length	0.358	0.800	0.808	0.402	0.125	0.870	0.991
20. Glume awn length	0.097*	0.398	0.641	0.720	0.933	0.243	0.500
21. Lemma awn length	0.507	0.105	0.257	0.921	0.246	0.036**	0.968

¹Significant at the 10% (*) or 5% (**) level. NA = not applicable to this species.

Table 18. The effect of soil salinity on grass characters. Tabled values summarize significance tests by giving the probability (p) of obtaining a larger chi-square when testing for the presence of an effect due to salinity¹.

Character	Species						
	AGCR	AGDA	AGIN	AGRI	AGSM	AGTRA	AGTRI
P							
<u>Vegetative</u>							
1. Culm height	0.176	0.167	0.792	0.925	0.289	0.299	0.448
2. Height to spathe lf. node	0.188	0.370	0.525	0.144	0.134	0.839	0.495
3. Length of internode	0.046**	0.370	0.451	0.016**	0.131	0.838	0.178
4. Leaf sheath length	0.976	0.241	0.539	0.206	0.179	0.513	0.626
5. Leaf blade length	0.007**	0.407	0.228	0.670	0.406	0.956	0.215
6. Leaf blade width	0.260	0.561	0.883	0.232	0.183	0.979	0.970
7. Leaf blade indument	0.439	0.700	0.791	0.443	0.510	0.068*	0.147
8. Ligule length	0.789	0.122	0.011**	0.842	0.086*	0.456	0.612
9. Auricle length	0.489	0.961	0.222	0.346	0.703	0.548	0.937
10. Rhizomes	NA	0.317	NA	0.419	0.421	NA	NA
<u>Reproductive</u>							
11. Inflorescence length	0.040**	0.298	0.368	0.303	0.163	0.136	0.747
12. Rachis length	0.634	0.098*	0.395	0.172	0.855	0.402	0.868
13. Rachis internode length	0.400	0.063*	0.788	0.554	0.523	0.353	0.611
14. Spikelet length	0.010**	0.922	0.111	0.106	0.021**	0.486	0.091*
15. Spikelet number	0.852	0.174	0.177	0.012**	0.345	0.312	0.865
16. Floret number	0.012**	0.024**	0.003**	0.885	0.021**	0.204	0.030**
17. Glume length	0.665	0.961	0.096*	0.097*	0.060*	0.643	0.099*
18. Glume width	0.154	0.540	0.232	0.547	0.216	0.055	0.811
19. Lemma length	0.037**	0.800	0.084*	0.143	0.293	0.501	0.036**
20. Glume awn length	0.389	0.398	0.598	0.695	0.437	0.972	0.572
21. Lemma awn length	0.093*	0.105	0.617	0.878	0.529	0.257	0.252

¹Significant at the 10% (*) or 5% (**) level. NA = not applicable to this species.

The number of florets per spikelet was the only character affected by both texture and salinity in as many as four species (Agropyron cristatum, A. dasystachyum, A. inerme, and A. trichophorum). Spikelet length was affected by both texture and salinity for A. cristatum.

For 11 characters, statistically significant responses to soil treatments were demonstrated by only 1 or 2 species (Table 19). Culm height, internode length, leaf blade length, and lemma length each responded in 3 species. Rachis internode length responded in 4 species and spikelet length in five. In floret number, 6 of 7 species exhibited a response. Rachis length, leaf width, leaf blade indument, and auricle length never responded to variation in either soil texture or salinity.

The species demonstrating plasticity varied from character to character. Agropyron cristatum exhibited plasticity in 43% of the characters measured - more than any other species. At the other extreme, only 14% of the characters measured varied plastically in A. smithii.

Specific Effects of Texture and Salinity

The specific effects of soil treatments were determined by comparing treatment means for each character (Table 20). Comparisons among treatment means showed where the greater expression of a character occurred in terms of size (e.g. leaf length), numbers (e.g. floret number) or rank (e.g. leaf indument). These comparisons show the direction of the significant plastic responses previously mentioned, and indicate trends which support actual directional response in characters as opposed to random variation. The following effects, summarized.

Table 19. Summary of ANOVA analyses of grass morphological characteristics, grouped by character type. Entries refer to species in which a significant treatment response was indicated at a 5% (10%) significance level¹.

Character Type	Character	Factor		
		Texture	Salinity	TXS ²
Integer	Spikelet number	-	4	-(3)
	Floret number	1,2,3,7	1,2,3,5,7	1,2,6(4,7)
Qualitative	Indument	-	-(6)	-
	Rhizome abundance	2	-	-(5)
Vegetative	Culm height	3,6(5)	-	4(1)
	Size			
	Height to spathe node	-	-	1
	Internode length	3	1,4	4
	Leaf sheath length	-	-	1,7
	Leaf blade length	-(3,6)	1	1,2,7
	Leaf blade length	-	-	-(1)
	Ligule length	-	3(5)	-(6)
	Auricle length	-	-	4
Inflores- cence size	Inflorescence length	-(5)	1	1
	Rachis length	-(2)	-(2)	-(4)
	Rachis internode	1(2)	-(2)	2,5,7(6)
	Spikelet length	1,3	1,5(7)	1,6,7
Spikelet Size	Glume length	-	-	6,7(5)
	Glume width	-	-	6,(2)
	Lemma length	-	1,7(3)	1,3,7
	Glume awn length	-(1)	-	4
	Lemma awn length	6	-(1)	-(7)

¹Species codes in the body of the table are: 1-Agropyron cristatum, 2-A. dasystachyum, 3-A. inerme, 4-A. riparium, 5-A. smithii, 6-A. trachycaulum, 7-A. trichophorum.

²Texture X salinity interaction.

Table 20. Treatment means of morphology data. Tabled values are means for coarse (C), medium (M), and fine (F) soil textures, and on salted (s) and unsalted (ns) conditions; n=9.

	Species													
	AGCR		AGDA		AGIN		AGRI		AGSM		AGTRA		AGTRI	
	ns	s	ns	s	ns	s	ns	s	ns	s	ns	s	ns	s
1) Culm Height (cm)														
C	33.1	32.2	34.0	35.4	38.6	36.1	37.8	35.6	38.0	41.7	30.8	32.4	44.3	48.0
M	31.4	38.2	35.7	39.9	40.8	39.6	33.0	37.6	47.0	43.8	34.9	34.3	50.2	49.2
F	35.2	34.5	38.0	37.8	39.7	42.5	36.5	34.0	43.0	48.4	38.2	43.0	44.5	46.5
2) Height to Spathe Leaf Node (cm)														
C	16.3	23.5	12.9	12.9	13.0	13.4	15.5	11.2	23.2	15.4	15.9	17.7	25.0	28.7
M	22.6	19.8	13.3	14.1	19.6	15.4	13.2	15.3	18.2	18.5	17.1	16.2	27.2	25.2
F	18.4	18.9	16.1	13.5	15.2	16.5	16.8	13.2	20.7	19.9	17.3	16.9	23.6	25.8
3) Internode Length (cm)														
C	8.2	12.6	9.3	8.4	8.1	7.9	10.0	7.5	12.9	9.0	6.8	7.4	14.5	12.9
M	11.3	11.3	9.6	9.7	12.5	10.8	9.5	10.3	12.4	11.9	7.2	6.5	14.8	13.0
F	8.6	9.1	10.7	9.2	10.0	10.4	11.5	8.4	10.8	10.3	8.0	7.8	14.1	14.6
4) Leaf Sheath Length (cm)														
C	4.7	5.9	5.3	4.7	6.6	6.9	5.6	4.4	7.8	6.3	8.0	8.2	8.9	7.6
M	5.3	5.6	5.1	4.8	6.6	6.6	4.6	5.2	7.2	7.8	7.5	8.2	7.4	8.2
F	5.1	4.0	5.4	5.3	6.0	6.7	5.8	5.0	7.2	6.3	7.3	7.6	7.9	8.9
5) Leaf Blade Length (cm)														
C	7.1	9.8	4.7	4.8	8.3	7.5	4.2	3.7	7.3	8.0	9.7	9.9	11.8	10.2
M	7.4	9.4	5.2	4.5	7.8	8.9	4.9	4.4	9.0	9.7	8.7	8.9	9.9	11.6
F	8.6	7.8	3.7	5.2	6.4	7.2	5.7	4.7	8.2	7.7	8.5	8.5	9.0	10.9
6) Leaf Blade Width (mm)														
C	5.29	6.29	2.99	2.87	2.53	2.31	2.63	2.43	3.93	4.25	5.39	5.11	7.05	6.45
M	5.39	6.45	2.81	3.02	2.06	2.21	2.77	2.74	4.30	4.39	4.52	5.08	6.07	6.07
F	5.89	5.29	2.74	2.90	2.09	2.04	2.98	2.68	3.68	4.21	4.73	4.55	5.98	6.69
7) Leaf Blade Indument ¹														
C	10.8	9.8	4.9	7.6	14.7	16.4	6.4	6.3	3.0	3.7	2.3	2.1	13.7	11.5
M	10.7	10.0	6.1	5.2	15.9	14.3	5.0	6.6	4.2	3.8	2.1	1.9	13.3	11.6
F	11.8	12.0	5.4	4.9	16.7	17.4	4.6	5.1	3.4	3.8	2.3	1.8	10.9	11.1
8) Ligule Length (mm)														
C	0.41	0.47	0.34	0.39	0.41	0.22	0.45	0.15	0.53	0.54	0.93	0.79	0.54	0.51
M	0.41	0.45	0.41	0.43	0.41	0.47	0.45	0.49	0.42	0.48	0.85	0.79	0.45	0.45
F	0.45	0.38	0.34	0.39	0.34	0.48	0.43	0.45	0.39	0.54	0.72	0.81	0.45	0.45
9) Auricle Length (mm)														
C	0.27	0.19	0.64	0.49	0.15	0.22	0.60	0.30	0.77	0.73	0.43	0.31	0.64	0.58
M	0.30	0.41	0.74	0.68	0.15	0.22	0.68	0.47	0.73	0.61	0.46	0.34	0.73	1.04
F	0.19	0.36	0.53	0.70	0.09	0.15	0.41	0.62	0.74	0.67	0.41	0.50	0.93	0.53
10) Rhizome Abundance														
C	-	-	0.34	0.89	-	-	1.12	2.01	1.76	3.34	-	-	-	-
M	-	-	1.01	0.88	-	-	1.89	1.51	1.61	3.01	-	-	-	-
F	-	-	1.56	2.23	-	-	1.78	1.88	2.89	1.84	-	-	-	-
11) Inflorescence Length (cm)														
C	17.6	23.2	26.9	21.5	28.5	24.3	25.5	21.2	18.9	23.1	28.4	28.9	33.6	30.3
M	19.7	25.3	26.5	25.8	26.9	33.8	25.1	28.1	29.6	28.9	27.4	28.1	28.5	31.7
F	20.9	18.0	23.6	23.4	27.7	28.9	28.0	23.2	25.9	28.8	27.1	33.6	30.4	33.4
12) Rachis Length (cm)														
C	3.47	4.26	6.33	4.35	6.83	5.81	5.24	3.94	6.00	5.91	11.80	11.77	10.92	9.46
M	3.19	4.09	5.81	4.88	5.48	7.19	5.25	5.99	6.49	7.04	10.95	11.02	7.66	8.64
F	4.29	3.26	5.29	5.49	5.87	6.43	6.08	4.68	6.22	6.06	10.11	11.29	8.33	9.75

Table 20--Continued

	AGCR		AGDA		AGIN		AGRI		AGSM		AGTRA		AGTRI	
	ns	s	ns	s	ns	s	ns	s	ns	s	ns	s	ns	s
13) Length of Rachis Internode (mm)														
C	1.09	1.06	6.13	4.67	11.17	9.74	5.82	5.89	5.47	6.45	5.92	4.86	10.09	8.62
M	1.19	1.25	5.95	5.48	10.58	10.55	5.70	6.76	8.36	6.21	5.45	4.98	9.03	9.03
F	1.26	1.73	5.92	6.38	8.97	10.86	6.26	5.73	6.20	6.59	5.01	5.57	8.09	10.12
14) Spikelet Length (mm)														
C	9.9	11.7	12.2	10.9	13.3	13.1	13.3	11.7	15.0	18.3	13.0	12.0	14.0	12.6
M	9.6	11.8	11.7	12.7	12.0	13.1	12.1	12.4	17.0	18.1	12.3	12.5	12.6	13.7
F	13.0	11.6	13.0	13.6	13.6	15.3	14.8	12.7	16.6	18.8	11.4	12.7	12.4	16.0
15) Spikelet Number														
C	27.1	31.9	10.2	7.9	5.7	5.3	9.0	6.6	10.0	9.2	20.1	21.2	11.2	11.2
M	26.0	30.0	8.7	8.7	4.6	6.4	8.9	8.9	7.6	9.8	18.7	19.4	9.3	9.9
F	28.3	22.4	8.9	8.0	5.3	5.4	9.6	7.2	9.4	9.6	18.0	19.1	10.4	9.4
16) Floret Number														
C	4.9	6.6	4.7	4.3	3.9	4.3	5.0	4.7	4.8	7.2	5.1	4.2	5.3	5.2
M	5.3	7.0	4.4	5.1	3.8	5.0	4.2	5.1	6.0	6.7	4.4	5.0	4.7	5.0
F	8.7	7.3	5.0	6.6	4.9	5.6	5.8	5.0	6.6	7.2	4.1	5.1	5.0	6.6
17) Glume Length (mm)														
C	5.9	6.2	5.2	4.6	6.8	6.4	5.3	5.1	8.8	9.7	10.3	8.6	7.0	6.5
M	5.4	5.9	5.0	5.3	6.3	7.4	5.7	5.5	6.2	10.5	9.4	9.5	6.2	7.0
F	6.2	5.7	5.2	5.3	6.1	6.9	6.3	5.3	10.2	10.0	8.8	10.0	6.1	6.9
18) Glume Width (mm)														
C	1.3	1.4	1.1	1.0	1.4	1.4	1.1	1.0	1.7	1.8	1.8	1.7	2.2	2.2
M	1.2	1.3	1.1	1.2	1.4	1.6	1.1	1.1	1.7	1.8	1.7	1.9	2.2	2.2
F	1.4	1.4	1.0	1.1	1.4	1.5	1.2	1.1	1.8	1.9	1.7	1.9	2.2	2.4
19) Lemma Length (mm)														
C	7.81	8.56	8.48	7.88	9.78	9.05	9.12	8.47	10.96	11.54	10.26	10.16	9.32	8.84
M	7.67	8.45	7.99	8.41	9.01	9.84	9.38	8.83	12.09	11.86	10.13	10.04	8.82	9.34
F	8.57	8.22	8.55	8.38	8.76	9.82	9.99	8.99	11.74	12.37	9.95	10.53	8.59	9.68
20) Glume Awn Length (mm)														
C	2.4	2.4	0.4	0.4	-	-	-	0.4	0.9	0.8	0.6	0.6	-	-
M	2.0	2.0	-	0.3	-	0.2	0.9	0.5	1.6	1.0	0.5	0.4	-	-
F	2.6	2.0	0.4	0.4	-	-	0.5	0.4	1.1	1.2	0.5	0.6	-	-
21) Lemma Awn Length (mm)														
C	2.2	2.6	0.4	0.7	-	-	1.3	0.8	1.1	1.0	1.2	1.0	-	0.5
M	2.2	2.5	0.7	0.6	0.5	0.5	1.5	1.0	1.2	1.1	0.7	1.0	0.6	0.7
F	2.2	2.2	-	0.6	0.4	0.5	1.6	1.5	1.5	1.3	1.1	0.9	0.7	0.7

¹Values refer to numbered states of Table 16.

character-by-character, were significant, based on treatment means and results of the ANOVA.

1. Culm Height. In Agropyron inerme and A. trachycaulum, culm height was affected by soil texture; plants of both species were shorter on coarse soils than on fine. Culm height was never affected by the salt treatment. An interaction between salt and texture was detected in A. riparium, which did not suggest any biological interpretation.
2. Height to the Spathe Leaf Node. No individual effects of texture or salinity were detected. An interaction between texture and salt was detected for A. cristatum for which no biological interpretation could be given.
3. Length of Culm Internode. In A. inerme the shortest culm internodes were found on coarse soils; this trend parallels the significant trend in total height. A. cristatum had longest internodes on salted soils, while A. riparium internodes were shortest on salted soils. There was a significant interaction between texture and salinity in the expression of this character for A. riparium, in which the reduction of internode length by salinity was especially pronounced on fine soils.
4. Leaf Sheath Length. No significant response was detected for either texture or salinity alone. A significant interaction was detected for both A. cristatum and A. trichophorum for which no biological interpretation could be given.
5. Leaf Blade Length. Texture alone had no effect on leaf blade length. In A. cristatum blade lengths were longer on salted

soils and a significant interaction indicated that they were longest on coarse, salted soils and shortest on coarse, unsalted soils. Significant interactions were also detected for A. dasystachyum and A. trichophorum, but these suggested no biological interpretation.

6. Leaf Blade Width. No significant treatment response was detected in any species.
7. Indument of Leaf Blade. No significant treatment response was detected in any species.
8. Ligule Length. No texture effects were indicated. A salt effect was indicated for A. inerme in which plants had longer ligules on salted than on unsalted soils. There were no significant interactions.
9. Auricle Length. No individual effects of texture or salt alone were indicated. An interaction was present in A. riparium which did not suggest a biological interpretation.
10. Rhizome Abundance. Rhizomes were more abundant on fine textured soils for A. dasystachyum. This effect was not observed in the other species with rhizomes, A. riparium and A. smithii. No salinity or interaction effects were observed.
11. Inflorescence Length. No texture effects were indicated. Inflorescence length in A. cristatum was increased by salinity on coarse and medium-textured soils, but not on fine textured soils, resulting in significant salt and interaction effects.
12. Rachis Length. No significant treatment response was detected in any species.

13. Length of Rachis Internode. This character, indicating degree of spikelet imbrication, responded to texture in A. cristatum, and lengths were greatest on fine soils. No response to salt was detected. Interactions were indicated for A. dasystachyum, A. smithii, and A. trichophorum which could not be interpreted biologically.
14. Spikelet Length. In A. inerme and A. cristatum spikelet lengths were greatest on fine-textured soils. In A. cristatum and A. smithii spikelet lengths were greatest on salted soils. Interactions between salt and texture for A. cristatum, A. trachycaulum and A. trichophorum could not be interpreted biologically.
15. Spikelet Number. No effects of texture were observed. In A. riparium more spikelets were produced per inflorescence on non-saline soils. No interaction effects were observed.
16. Floret Number. Six of the seven species responded to environmental variation with changes in the number of florets per spikelet. The nature of this response was consistent among the affected species: there were more florets per spikelet on both fine soils and salted soils for A. cristatum, A. dasystachyum, A. inerme, and A. trichophorum. In A. smithii, floret number responded to salt alone, with an increase on saline soils. A salt X texture interaction affected floret number in A. cristatum, and A. dasystachyum, in which plants on fine, salted soils had the most florets. Interaction effects for A. trachycaulum could not be biologically interpreted.

17. Glume Length. No effect of texture or salt alone was detected. Interactions were detected in A. trachycaulum and A. trichophorum which could not be biologically interpreted.
18. Glume Width. No individual effects of texture or salt were detected. An interaction was significant for A. trachycaulum in which glume widths were greatest on fine and medium, saline soils.
19. Lemma Length. Lemma length did not respond to texture in any species. For A. cristatum and A. trichophorum, lemmas were longer on plants growing in salted soils. This effect of salt seemed to be limited to coarse and medium textures for A. cristatum, to medium and fine textures for A. trichophorum, and to fine textures for A. inerme, resulting in significant interactions for these 3 species.
20. Glume Awn Length. No response to texture or salt was detected in any species. An interaction was significant for A. riparium in which glume awns were particularly long on medium-textured, nonsaline soils.
21. Lemma Awn Length. Lemma awns were shorter on plants of A. trachycaulum grown on medium-textured soils. No effect of salt and no interactions were detected.

DISCUSSION

Organs Responding Plastically

Every species studied exhibited some plastic response, although a limited number of characters were affected. Species exhibited plastic responses to texture, salinity, or their interaction ($p < 5\%$) in three (Agropyron smithii) to an average of six, to nine (A. cristatum) of 21 characters. Their number and identities are given in Table 19.

This study showed little consistency among species as to the specific characters responding to texture/ salinity stress. The characters most frequently affected were floret number, spikelet length, and rachis internode length, varying significantly in 6, 5, and 4 species respectively. Of the remaining characters, 4 varied in 3 species, two varied in 2 species, 9 varied in 1 species, and 3 characters showed no variation due to treatments. Because it is dependent on genotype, plasticity of a given character may be expected to vary, as these did, among closely related species. Even ecotypes may differ in the nature of their morphological response to variation in environment (LaRoche 1978).

Data show little difference in plasticity among plant part types, but give some support to the hypothesis that plasticity declines from integer characters, through vegetative and inflorescence size characters and hairiness, to the size of reproductive and floral parts (Bradshaw 1965, Harper 1977). For integer characters (spikelet and floret number)

31% of the 42 species-treatment-character combinations were statistically significant, but these were usually responses in floret number (12/13) and rarely spikelet number (1/13, Table 19). The corresponding figures for qualitative characters (pubescence and rhizome abundance), sizes of vegetative parts (e.g., culm length), inflorescence sizes (e.g., rachis length), and sizes of spikelet parts (glume or lemma length) were 2%, 10%, 15%, and 9% respectively.

Concerning integer characters, Harper (1977) offers the hypothesis that numbers of reproductive or vegetative units (e.g., tillers, phytomers, leaves, flowers, seeds, and inflorescences) comprise the most plastic character class. The observation that plants responded most frequently in numbers of florets in the middle spikelet supports this hypothesis. The only other integer character studied (spikelet number) provides negative support for this hypothesis since it only showed significant variation in A. riparium.

With respect to the sizes of organs, data show no clear differences in plasticity among vegetative, inflorescence, and spikelet parts. Vegetative size characters responded to texture, salt, or their interaction in 10% of the species-treatment-character combinations, inflorescence size characters in 15%, and spikelet parts in 9% (Table 19). If all inflorescence and spikelet characters are pooled, half of the characters representing sizes of reproductive parts showed a plastic response, in at least one species, and half also of the vegetative size characters varied significantly.

Characters of the spikelet are expected to be very stable with respect to environmental influences. However, treatment responses were

found for lemma length and lemma awn length (Table 19). Lemma length responded to salt in both A. cristatum and A. trichophorum, even though the same two species showed no response in such presumably plastic characters as culm height. Lemma awn length varied with texture in A. trachycaulum. In addition to these individual effects of texture and salt, interactions were detected for all spikelet characters other than lemma awn length. Spikelet length, which varied in 5 species, was considered an inflorescence character because of its dependence on both floret number and the sizes of floret parts. Responses in spikelet number might well reflect the variation in floret number previously mentioned.

Detection of plasticity may depend on the complexity of the character as well as the magnitude of the response. Characters which are developmentally simple may exhibit less inherent variation, making it easier to detect a response in these, than in more complex characters. For example, the length of the uppermost internode contributes to total height and height to the spathe leaf node, but, while a response was detected for 3 species in the simple internode length, the complex height to the spathe leaf node never responded to treatments, and the still more complex total height only responded in 2 species. Spikelet length, which is dependent on both the size and number of florets, did show a plastic response, but far less consistently than did the simple floret number.

Plasticity is also said to be difficult to detect for ranked characters such as leaf indument and rhizome abundance (Davis 1983). This could be due to the relative inaccuracy of measurement arising when

continuous variation is recorded in a few discrete character states. The absence of variation in pubescence, for example, could be due to a real absence of plasticity, or a failure to detect variation that did occur. Increased leaf pubescence has been attributed to water stress (Talbert and Holch 1957, Bell 1967), and might therefore have been expected to respond to soil texture or salinity. Despite these expectations, no response in leaf indument was detected among the varieties of Agropyron studied here, and leaf indument was usually characteristic for a given species (Table 20).

Response to Texture and Salinity

Texture and salt affected similar kinds of characters and affected them with similar frequencies. In no case did the number of species affected in a character differ significantly between texture and salinity, i.e., there there was no evidence that plasticity of any character was specific to either texture or salinity. Both texture and salinity affected reproductive as well as vegetative characters; both factors also elicited the same pronounced response from floret number. Stresses induced by texture and salinity seem to have been of similar magnitude since, at the 5% (10%) level, plastic responses to texture were detected 12 (19) times for different species-character combinations, and responses to salt were detected in 14 (23) different species-character combinations (Table 19).

General effects of texture might be indicated best by characters which represent important components of plant biomass and, as such, reflect plant vigor. Characters which exhibited a significant treatment

effect (e.g., culm height, rhizome number, length of rachis internode, spikelet length, and floret number), tended to increase in size (or number) on fine textured soils (Table 20). Such increases may indicate a more favorable water balance on fine than on coarse soils. Only 2 characters countered this generalization; lemma awn lengths were significantly greater on coarse soils and leaf blades were especially long on salted, coarse soils.

Salinity effects might be due to effects on water availability or specific ion effects, both of which are expected to affect plant vigor (Fitter and Hay 1981). The primary effect of soluble salts is to decrease water availability by decreasing the osmotic potential of the soil solution, and plant vigor should decrease concurrently. However, sizes and numbers of affected parts generally increased on saline soils. For example, observed increases in spikelet length on saline soils for A. cristatum, A. inerme, and A. smithii parallel concurrent increases in floret number on these soils. Spikelet number did show the expected result since it decreased on saline soils in A. riparium. In contrast to trends observed here, available literature demonstrates a stunting of growth by salt, with the possible exception of halophytes, but salt concentrations used are usually higher than those used here (Poljakoff-Mayber and Gale 1975):

Since direct salinity effects are expected to be negative, any observed positive responses might be attributed to some indirect effect. If salt stress reduced plant densities on salted plots it might have caused relaxation of water stress. Dewey (1960) found some evidence of enhancement in the growth of Agropyrons (A. trichophorum) by moderate

salt levels like those used here, and attributed this effect to low plant densities. Research on morphologic response to plant density shows that plants commonly respond to density stress in the production of fewer seeds relative to total dry matter (Harper 1977). For A. smithii and A. inerme therefore, increased floret number and spikelet size on saline soils could conceivably be due to a relaxation of water stress allowed by the lower plant densities observed on these soils (Lichthardt 1986, Table 10). However, not all species support this density hypothesis for salt enhancement. While densities of A. cristatum and A. dasystachyum, measured in 1983, were not significantly lower on coarse, saline soils, plants on these soils had longer culm internodes, leaves, inflorescences, spikelets and lemmas (A. cristatum), and more florets per spikelet (A. cristatum and A. dasystachyum), than their counterparts on coarse, unsalted soils.

The most numerous treatment effects were those due to the interaction of texture and salinity (Table 19). These effects cannot be generalized, since texture and salinity interacted in different ways. The nature of some interactions, detected only for A. cristatum, was that a salt effect was expressed on coarse and medium-textured soils but not on fine (leaf blade length, inflorescence length, Table 20). More often, salt effects were expressed exclusively on fine soils (e.g. spikelet length, A. trichophorum; lemma length, A. trichophorum; floret number, A. cristatum and A. dasystachyum). Interaction effects were considered evidence for plasticity in a given character because they could result from effects by a particular treatment combination of

texture and salt level, and because they limit the detection of responses to texture and salinity individually.

Implications for Species Identification

Results indicate no plastic responses that would detract from identification of the species studied. Except in the case of A. cristatum, fewer than 7 characters showed a response in any given species. Most characters were stable within the range of treatments tested. Proportions of characters unaffected by treatments ranged from 86% in A. smithii, to 57% in A. cristatum, with an average of 71%. Characters which showed the strongest tendency towards plasticity were floret number and spikelet length, which are unimportant to species identification in Agropyron, and rachis internode length, which could be important. A. cristatum exhibited the most plasticity, but is also the most morphologically distinct of all species studied, and certainly so in characters of the inflorescence.

While observed changes in morphology were of little importance to species identification, they do illustrate responses of both vegetative and reproductive characters to edaphic factors which vary on a local scale. It is quite possible that observed differences would increase in number and degree if more severe salinity and texture treatments were imposed.

Detection of Plasticity

The fact that some reportedly plastic features did not respond to variation in soil quality must indicate that: 1) soil treatments were not severe enough to affect plant vigor, 2) sample sizes were too small

to detect differences, or 3) the characters are less plastic than expected.

First, yield data showed that plant biomass was affected by soil treatments in 6 of 7 Agropyron species, and therefore that plant vigor was affected (Lichthardt 1986, Table 11). Since the morphology analysis showed relatively few plastic changes in the sizes of plant parts, these production differences must be primarily due to differences in numbers of tillers or numbers of plants, rather than plastic changes in the sizes of plant parts.

Second, the sample size chosen was based on that used in similar published research (Davis 1983). Adequacy of this sample size is supported by the fact that slight changes in morphology were detected, in at least one species, for most characters (Table 19). Responses were detected in stable characters which displayed little inherent variation, as well as highly variable characters.

Third, assuming then that stress was induced by at least some of the soil treatments, and sample sizes were adequate, a lack of response in any given character reflects low plasticity in that character, for that species. Some characters proved to be more plastic (rachis internode, lemma length), and others less plastic (height, height to spathe leaf node, leaf length) than expected.

The detection of slight plastic changes in morphology was facilitated by the use of a common garden, to minimize extraneous environmental variation, and by planting certified seed, to minimize genotypic variance. Plants grown from certified seed likely exhibit less variability than is normally found in natural populations, or in commercially

grown varieties open to hybridization. Detection of plasticity would have been still more difficult under natural conditions, since plastic variation would have been confounded with more intraspecific genetic variability.

CONCLUSIONS

- 1) My results show only occasional and slight variation in the presumably stable sizes of spikelet parts among levels of salinity and texture studied. Variation in characters such as leaf indument and leaf length were less environmentally plastic than was predicted. Even characters noted for their plasticity, like plant height, were little affected by variation normally found in Fort Union soils.
- 2) The characters which respond to environmental influence differ among Agropyron species.
- 3) In the range studied, soil texture and salinity are equally likely to elicit a morphological response. Most texture effects were associated with soils containing more than 30% clay. Salinity effects were induced by salt levels which were initially 3.6 to 10 mmhos/cm and fell to 0.5 to 4.2 mmhos/cm.
- 4) Results of this study indicate no loss of morphologic distinction among Agropyron species due to environmentally-induced variation. For example, in the representative species studied, taxonomically important characters (leaf pubescence, spikelet size, degree of imbrication of spikelets, and presence of rhizomes) are very stable within species. The extreme range and overlap of variation reported by workers on revegetated mine sites must therefore be due to the same genetic factors which have prohibited a satisfactory classification of this group. Given the well documented problems associated

with the taxonomy of Agropyron it is likely that the impacts of genetic variability and hybridization out-weigh environmental effects in causing the variable morphology of these species.

- 5) While more variability might have been detected by using more extreme soils, different characters, or larger sample sizes, my conclusions are relevant to the needs of field taxonomists and ecologists, at least in Fort Union soils of southeastern Montana, the Dakotas and Wyoming, and probably on other soils of the Northern High Plains.

LITERATURE CITED

LITERATURE CITED

- Bartlett, M. S. 1947. The use of transformations. *Biometrics* 3: 39-52.
- Baskin, J. M. and C. C. Baskin. 1975. Observations on the ecology of the cedar glade endemic Viola egglestonii. *Amer. Midl. Nat.* 93: 320-329.
- Baum, B. R. 1979. The generic problem in the Triticeae: Numerical taxonomy and related concepts. In Estes, J. R. et al. (eds.), *Grasses and Grasslands: Systematics and Ecology*. Univ. of Oklahoma Press, Norman.
- Bell, C. R. 1967. *Plant Variation and Classification*. Wadsworth, Belmont, Calif. 135 pp.
- Bradshaw, A. D. 1965. Evolutionary significance of phenotypic plasticity in plants. *Adv. Genet.* 13: 115-155.
- Cain, D. J. and H. T. Harvey. 1983. Evidence of salinity-induced ecophenic variation in cordgrass (Spartina foliosa Trin.). *Madrono* 30: 50-62.
- Chinnappa, C. C., and J. K. Morton. 1984. Studies on the Stellaria longipes complex (Caryophyllaceae) - biosystematics. *Syst. Bot.* 9: 60-73.
- Cook, S. A. and M. P. Johnson. 1968. Adaptation to heterogeneous environments. I. Variation in heterophylly in Ranunculus flammula L. *Evolution* 22: 496-516.
- Davis, J. 1983. Phenotypic plasticity and the selection of taxonomic characters in Puccinellia (Poaceae). *Systematic Botany* 8: 341-353.
- Dewey, D. R. 1960. Salt tolerance of twenty-five strains of Agropyron. *Agron. J.* 52: 631-635.
- Fitter, A. H. and R. K. M. Hay. 1981. *Environmental Physiology of Plants*. Academic Press. 355 pp.
- Gray, A. J. 1985. Adaptation in perennial coastal plants - with particular reference to heritable variation in Puccinellia maritima and Ammophila arenaria. *Vegetatio* 61: 179-188.

- Harper, J. L. 1967. A Darwinian approach to plant ecology. *J. Ecol.* 55: 247-270.
- _____. 1977. Population Biology of Plants. Associated Press. 892 pp.
- Harrison, J. H. 1960. New concepts in Flowering Plant Taxonomy. Harvard Univ. Press, Cambridge, Mass. 135 pp.
- Hickman, J. C. 1975. Environmental unpredictability and plastic energy allocation strategies in the annual Polygonum cascaden (Polygonaceae). *J. Ecol.* 63: 689-701.
- Hitchcock, A. S. 1950. Manual of the Grasses of the United States (rev. A. Chase). USDA Misc. Publ. No. 200. 1051 pp.
- Jennrich, R. and P. Sampson. 1981. General mixed model analysis of variance. In W. J. Dixon (ed.) Biomedical Computer Programs. Univ. of California Press, Berkeley, Ca. p. 62.
- Kilcher, M. R. and T. Lawrence. 1970. Emergence of Altai wild ryegrass and other grasses as influenced by depth of seeding and soil type. *Can. J. Plant Sci.* 50: 475-479.
- Knight, W. E. and E. A. Hollowell. 1959. The effect of stand density on physiological and morphological characteristics of crimson clover. *Agron. J.* 51: 73-76.
- LaRoche, G. 1978. An experimental study of population differences in leaf morphology of Aquilegia canadensis L. *Amer. Midl. Nat.* 100: 341.
- Lewontin, R. C. 1966. On the measurement of relative variability. *Syst. Zool.* 15: 141-142.
- Lichthardt, J. 1986. Effects of Soil Texture and Salinity on the Establishment and Morphology of Twelve Grass Species. M.S. thesis, Montana State University, Bozeman.
- Marsden-Jones, E. M. and W. B. Turrill. 1938. Fifth report on the transplant experiments of the British Ecological Society. *J. Ecol.* 26: 359-389.
- Marshall, D. R. and S. K. Jain. 1968. Phenotypic plasticity of Avena fatua and A. barbata. *Am. Nat.* 102: 457-467.
- Mayer, A. M. and E. M. Lord. 1983. Comparative flower development in the cleistogamous species Viola odorata. I. A growth rate study. *Amer. J. Bot.* 70: 1548-1555.

- Poljakoff-Mayber, A. and J. Gale. 1975. Plants in Saline Environments. Springer-Verlag, New York. 213 pp.
- Quinn, J. A. and K. C. Hodgkinson. 1983. Population variability in Danthonia caespitosa (Gramineae) in responses to increasing density under 3 temperature regimes. Amer. J. Bot. 70: 1425-1431.
- Schlichting, C. D. and D. A. Levin. 1984. Phenotypic plasticity of annual phlox: tests of some hypotheses. Amer. J. Bot. 71: 252-260.
- Stebbins, G. L. 1950. Variation and Evolution in Plants. Columbia Univ. Press, New York. 643 pp.
- Talbert, C. M. and A. E. Holch. 1957. A study of the lobing of sun and shade leaves. Ecology 38: 655-658.
- Turkington, R. 1983. Plasticity in growth and patterns of dry matter distribution of two genotypes of Trifolium repens grown in different environments of neighbors. Can. J. Bot. 61: 2186-2194.
- Turrill, W. B. 1940. Experimental and synthetic plant taxonomy. In J. Huxley (ed.), The New Systematics.
- USDA-OSM. 1979. Surface coal mining and reclamation operations. Permanent regulatory program, part II. Fed. Reg. 44(50): 15311-15463.
- Wallace, L. L. 1981. Growth, morphology, and gas exchange of mycorrhizal and non-mycorrhizal Panicum coloratum L. a C₄ grass species, under different clipping and fertilization regimes. Oecologia 49: 272-278.
- Wu, K. K. and S. K. Jain. 1978. Genetic and plastic responses in geographic differentiation of Bromus rubens populations. Can. J. Bot. 56: 873-879.

APPENDICES

APPENDIX A
DENSITY AND BIOMASS DATA SUPPORTING PART I,
ESTABLISHMENT STUDY

Table 21. Density of grass seedlings in the first growing season, 1983. Entries are the numbers of seedlings per 2 X 5 dm frame. Five frames were counted in each species plot.

Treatment ¹	Frame #					Frame #					Frame #					Frame #								
	Index	1	2	3	4	5	Index	1	2	3	4	5	Index	1	2	3	4	5	Index	1	2	3	4	5
Coarse ns1	1111	8	4	2	0	3	2111	47	22	5	22	11	3111	15	3	14	6	10	4111	19	29	41	21	32
s1	1121	9	3	1	3	3	2121	16	13	4	32	33	3121	28	1	7	20	13	4121	20	8	47	8	53
Medium ns1	1211	2	4	15	2	2	2211	58	10	40	14	21	3211	19	44	21	8	22	4211	6	5	17	25	14
s1	1221	4	1	0	3	0	2221	18	6	5	25	11	3221	16	3	10	25	10	4221	11	16	15	27	32
Fine ns1	1311	0	0	3	0	1	2311	8	7	0	0	0	3311	0	8	8	13	23	4311	23	4	6	10	2
s1	1321	0	0	0	0	0	2321	3	15	3	1	5	3321	0	10	0	3	1	4321	8	9	14	10	3
Coarse ns2	1112	3	5	1	2	1	2112	33	25	32	50	37	3112	32	4	4	31	19	4112	12	15	27	7	18
s2	1122	7	15	0	1	6	2122	32	4	11	10	14	3122	24	20	9	10	25	4122	4	4	16	13	16
Medium ns2	1212	6	5	8	5	6	2212	18	76	15	7	38	3212	19	36	11	14	7	4212	51	65	14	7	19
s2	1222	2	3	1	1	5	2222	13	7	28	5	3	3222	0	5	13	15	17	4222	22	11	25	32	14
Fine ns2	1312	2	3	0	10	0	2312	21	16	38	27	11	3312	10	2	11	2	3	4312	28	18	15	27	17
s2	1322	0	0	1	4	0	2322	2	7	22	8	10	3322	3	6	6	5	2	4322	2	13	6	0	12
Coarse ns3	1113	11	12	2	1	4	2113	35	38	52	48	41	3113	38	29	50	26	9	4113	18	22	23	22	50
s3	1123	3	3	11	0	4	2123	60	46	39	25	52	3123	13	7	14	44	19	4123	21	3	54	41	40
Medium ns3	1213	5	0	6	4	7	2213	31	16	12	22	20	3213	24	18	24	38	12	4213	25	16	13	15	13
s3	1223	2	4	1	0	6	2223	53	32	5	11	21	3223	8	8	15	38	26	4223	24	8	33	16	21
Fine ns3	1313	1	0	0	0	2	2313	15	26	27	18	18	3313	12	16	4	10	8	4313	39	8	16	9	21
s3	1323	0	0	0	0	0	2323	8	2	4	3	1	3323	3	0	9	0	5	4323	7	0	7	16	2
Coarse ns1	5111	0	1	3	10	3	6111	4	4	14	5	23	7111	11	10	2	8	5	8111	1	0	35	12	17
s1	5121	1	1	4	0	7	6121	6	4	2	4	3	7121	27	10	4	7	3	8121	4	3	2	3	3
Medium ns1	5211	15	0	10	1	8	6211	8	10	4	14	38	7211	3	8	8	7	11	8211	5	4	5	1	14
s1	5221	1	2	1	13	2	6221	1	4	13	7	5	7221	3	8	5	12	17	8221	0	1	0	3	0
Fine ns1	5311	1	2	2	7	3	6311	38	1	2	13	8	7311	3	3	11	14	0	8311	0	0	0	0	2
s1	5321	2	1	2	0	1	6321	2	6	2	10	3	7321	17	2	8	0	1	8321	0	1	0	0	0
Coarse ns2	5112	5	2	6	0	5	6112	6	4	1	9	16	7112	24	8	5	14	6	8112	3	2	1	2	0
s2	5122	1	0	0	0	0	6122	12	10	15	15	5	7122	6	15	4	4	2	8122	1	0	3	4	2

Table 21--Continued

Medium	ns2	5212	10	2	2	10	2	6612	13	9	12	6	14	7212	39	33	16	49	6	8212	20	6	4	9	8
	s2	5222	7	1	0	16	1	6222	10	5	9	15	8	7222	5	11	3	15	10	8222	0	0	4	12	5
Fine	ns2	5312	3	5	0	5	16	6312	10	12	11	10	26	7312	10	9	4	12	4	8312	1	0	1	1	0
	s2	5322	13	0	0	1	2	6322	0	7	6	9	6	7322	1	6	2	1	0	8322	0	1	0	0	0
Coarse	ns3	5113	1	3	1	11	1	6113	15	52	12	40	33	7113	14	26	14	13	15	8113	3	13	9	2	1
	s3	5123	4	1	4	10	5	6123	7	31	19	79	31	7123	25	25	8	19	5	8123	8	3	4	5	4
Medium	ns3	5213	0	2	0	3	7	6213	9	5	27	31	8	7213	6	18	26	19	4	8213	2	3	8	4	20
	s3	5223	13	3	4	4	2	6223	41	2	7	16	9	7223	25	11	13	25	11	8223	6	2	8	4	1
Fine	ns3	5313	5	19	18	2	3	6313	0	7	12	24	10	7313	13	17	11	24	8	8313	3	4	9	0	5
	s3	5323	0	0	0	1	0	6323	3	6	0	1	12	7323	21	4	8	9	1	8323	0	0	0	0	1
Coarse	ns1	9111	3	0	5	0	5	10111	4	17	8	9	9	11111	26	5	8	0	7	12111	0	0	0	4	1
	s1	9121	0	9	0	1	1	10121	22	20	12	4	30	11121	0	0	0	0	0	12121	0	0	0	0	0
Medium	ns1	9211	1	6	0	0	0	10211	4	11	31	11	10	11211	2	1	1	6	3	12211	1	0	3	2	0
	s1	9221	1	0	0	0	1	10221	3	3	1	2	2	11221	1	10	1	0	0	12221	1	0	0	3	1
Fine	ns1	9311	0	0	2	0	0	10311	26	14	7	1	10	11311	2	0	0	0	0	12311	0	1	2	8	2
	s1	9321	1	0	0	0	0	10321	0	2	1	0	1	11321	0	0	8	0	0	12321	0	1	0	0	0
Coarse	ns2	9112	2	0	1	1	0	10112	33	10	14	4	11	11112	2	5	1	2	6	12112	0	1	1	3	4
	s2	9122	2	5	4	6	1	10122	8	25	1	5	10	11122	2	3	0	13	2	12122	3	2	0	6	2
Medium	ns2	9212	0	0	0	0	1	10212	6	9	1	20	8	11212	0	2	0	2	2	12212	5	1	3	0	2
	s2	9222	0	1	1	0	3	10222	5	13	10	13	48	11222	3	0	0	2	3	12222	2	2	1	2	0
Fine	ns2	9312	1	3	3	6	3	10312	4	12	14	5	3	11312	6	1	5	4	0	12312	6	0	4	1	0
	s2	9322	0	2	1	1	2	10322	9	6	1	5	3	11322	0	0	0	1	0	12322	2	0	4	0	1
Coarse	ns3	9113	10	5	1	3	1	10113	19	61	11	32	3	11113	6	1	0	1	0	12113	0	3	0	5	0
	s3	9123	1	2	2	0	6	10123	7	17	27	15	21	11123	4	16	1	0	4	12123	0	6	4	2	2
Medium	ns3	9213	11	15	3	4	3	10213	14	32	42	3	39	11213	2	4	1	11	2	12213	5	8	1	3	1
	s3	9223	1	3	1	2	1	10223	62	16	7	29	3	11223	3	5	0	0	5	12223	2	0	4	2	2
Fine	ns3	9313	1	1	4	1	0	10313	3	6	6	5	5	11313	9	3	1	0	3	12313	0	1	1	0	1
	s3	9323	1	0	1	0	2	10323	1	0	0	0	2	11323	0	0	0	0	4	12323	2	0	0	6	5

¹s=salted; ns=not salted; numbers 1-3 refer to replicate textures.

²First digit refers to species (1-Agropyron cristatum, 2-A. dasystachyum, 3-A. inerme, 4-A. riparium, 5-A. smithii, 6-A. trachycaulum, 7-A. trichophorum).

Table 22. Dry matter yield, of the grasses planted, in the second growing season, 1983. Entries are grams of dry matter measured in five, 2 X 5 dm clip frames.

Species ¹	Treatment ²	1	2	3	4	5	Species	1	2	3	4	5	
1	Coarse	ns1	78	161	178	131	260	2	174	124	78	190	64
1		ns2	217	272	120	120	141	2	81	116	41	70	43
1		ns3	22	87	70	165	153	2	72	78	58	63	104
1		s1	71	106	166	454	622	2	4	42	30	94	62
1		s2	86	272	226	225	379	2	326	215	328	75	26
1		s3	77	65	34	145	149	2	134	84	64	40	38
1	Medium	ns1	186	44	23	83	170	2	302	71	130	133	79
1		ns2	474	758	50	12	387	2	152	63	69	199	161
1		ns3	193	349	45	88	325	2	215	96	45	51	69
1	Fine	s1	23	53	82	02	95	2	141	84	43	31	28
1		s2	20	55	107	165	240	2	127	23	33	89	67
1		s3	376	162	242	164	13	2	16	33	13	7	54
1		ns1	00	130	125	56	232	2	392	24	187	1	62
1		ns2	458	234	234	81	100	2	113	149	203	156	64
1		ns3	89	20	01	29	88	2	126	125	65	91	112
1		s1	68	03	00	01	00	2	37	8	76	8	44
1		s2	76	02	00	55	00	2	274	77	103	12	94
1		s3	00	00	00	00	00	2	15	10	18	41	0
3	Coarse	ns1	04	06	41	33	14	4	303	71	84	58	127
3		ns2	31	50	58	56	45	4	220	105	103	63	103
3		ns3	57	35	64	54	66	4	124	104	45	83	54
3		s1	54	47	14	20	10	4	09	22	22	28	27
3		s2	14	26	13	34	20	4	25	05	82	56	48
3		s3	38	20	09	10	32	4	32	65	21	30	20
3	Medium	ns1	29	178	60	68	199	4	82	72	35	83	44
3		ns2	44	90	122	59	77	4	96	126	107	149	180
3		ns3	06	147	183	106	64	4	124	04	71	110	63
3	Fine	s1	68	100	181	00	28	4	11	21	22	10	74
3		s2	97	23	02	35	02	4	39	69	26	89	78
3		s3	58	62	29	71	137	4	157	90	17	42	73
3		ns1	06	151	134	46	39	4	105	49	169	29	300
3		ns2	08	28	75	68	07	4	291	228	136	191	182
3		ns3	31	84	96	103	101	4	248	77	77	66	52
3		s1	08	00	00	20	05	4	20	39	22	19	15
3		s2	00	08	02	05	01	4	35	114	02	42	05
3		s3	13	21	00	00	00	4	07	18	00	00	00
5	Coarse	ns1	55	00	00	48	20	6	05	200	72	12	150
5		ns2	19	14	22	08	30	6	175	82	57	08	29
5		ns3	24	38	20	42	04	6	66	132	156	77	106
5		s1	07	98	32	31	50	6	14	48	02	177	142
5		s2	00	18	37	00	00	6	121	336	161	228	110
5		s3	19	04	12	26	25	6	116	120	182	273	326
5	Medium	ns1	68	49	90	55	40	6	216	190	196	106	244
5		ns2	30	144	90	85	259	6	279	268	219	303	194
5		ns3	04	00	00	00	00	6	36	107	77	45	146
5	Fine	s1	06	28	08	05	05	6	26	39	41	38	02
5		s2	37	05	10	16	05	6	101	24	194	243	337
5		s3	14	104	20	15	00	6	252	320	423	453	256
5		ns1	112	07	152	22	17	6	77	80	286	381	407
5		ns2	159	178	92	129	206	6	475	230	256	201	316
5		ns3	55	30	23	166	68	6	191	187	81	167	61
5		s1	00	27	15	06	54	6	80	50	199	180	152
5		s2	289	244	05	06	00	6	24	00	45	324	180
5		s3	00	00	00	00	00	6	36	88	190	226	00

Table 22--Continued

Species ¹	Treatment ²	1	2	3	4	5	Species	1	2	3	4	5
7	Coarse ns1	26	69	22	59	54	8	04	07	02	52	58
7	ns2	113	50	204	116	170	8	01	00	00	00	02
7	ns3	148	150	314	190	121	8	04	07	05	02	00
7	s1	43	33	118	14	288	8	09	00	05	11	20
7	s2	80	56	84	136	218	8	01	00	00	02	01
7	s3	339	333	139	86	137	8	03	00	02	01	01
7	Medium ns1	206	217	285	240	178	8	28	52	23	43	30
7	ns2	119	117	129	218	257	8	27	22	12	15	17
7	ns3	139	85	45	88	88	8	06	06	31	05	01
7	s1	258	103	62	47	288	8	01	00	02	00	00
7	s2	40	233	98	135	251	8	00	00	06	09	01
7	s3	232	141	87	346	442	8	10	04	00	04	05
7	Fine ns1	271	08	61	59	354	8	00	00	00	00	00
7	ns2	256	280	285	139	117	8	00	02	00	03	00
7	ns3	169	186	236	137	79	8	00	20	26	70	11
7	s1	382	406	06	367	00	8	00	00	00	00	02
7	s2	327	182	385	45	00	8	00	00	00	00	00
7	s3	07	38	218	00	00	8	00	00	00	00	00
9	Coarse ns1	45	62	38	03	00	10	110	82	64	112	88
9	ns2	46	05	33	19	106	10	103	98	36	98	30
9	ns3	06	00	67	19	00	10	33	26	50	27	36
9	s1	94	09	08	03	15	10	53	46	85	35	34
9	s2	00	65	16	48	00	10	40	100	49	31	30
9	s3	01	00	00	00	00	10	106	58	21	27	19
9	Medium ns1	00	00	00	126	40	10	20	45	50	28	82
9	ns2	04	08	12	04	33	10	65	29	37	68	36
9	ns3	100	93	53	61	00	10	127	56	54	20	92
9	s1	76	00	36	06	00	10	03	52	44	05	81
9	s2	47	23	00	00	63	10	18	39	58	49	20
9	s3	43	06	02	00	00	10	44	34	76	33	54
9	Fine ns1	292	37	247	00	00	10	59	66	10	196	66
9	ns2	120	114	99	48	27	10	109	222	30	110	53
9	ns3	60	14	25	00	00	10	28	53	16	32	19
9	s1	00	00	00	00	00	10	04	35	33	00	40
9	s2	18	12	85	00	00	10	156	25	131	70	33
9	s3	39	00	00	00	00	10	00	00	22	10	56
11	Coarse ns1	24	13	28	41	00	12	112	30	24	85	73
11	ns2	53	10	08	41	00	12	49	289	39	199	49
11	ns3	10	06	41	12	00	12	63	51	43	56	136
11	s1	01	00	00	00	00	12	18	06	40	40	55
11	s2	08	13	02	00	00	12	12	102	00	00	01
11	s3	31	34	02	08	00	12	38	42	33	89	120
11	Medium ns1	18	18	25	48	00	12	62	76	31	115	71
11	ns2	01	35	15	17	01	12	126	89	55	228	74
11	ns3	19	19	10	66	34	12	97	179	74	08	10
11	s1	21	06	11	28	0	12	123	83	39	49	70
11	s2	53	03	00	00	00	12	31	73	28	16	28
11	s3	19	04	27	00	00	12	14	76	21	22	60
11	Fine ns1	22	36	24	109	00	12	02	07	00	07	26
11	ns2	16	55	106	47	122	12	04	50	116	59	93
11	ns3	97	183	144	34	87	12	83	30	136	154	177
11	s1	34	00	00	00	00	12	49	02	10	19	06
11	s2	00	00	00	00	00	12	27	122	20	48	12
11	s3	30	00	00	00	00	12	00	00	00	00	00

¹See text, Table 4, or Appendix Table 21.²s=salted; ns=not salted; numbers 1-3 refer to replicate soil textures.

Table 23. Dry matter yield in the fourth growing season, 1985. Tabled values are the weights of samples clipped from 4, 3 X 6 dm frames (I-IV) in each 1.5 X 1.5 m species plot. The herbage clipped was divided into the planted species (PS), other grasses (OG), Kochia scoparium (KOSC), Salsola kali (SAKA), and other forbs (OF).

Plot Index ¹		Dry Biomass (g/plot)																			
		I					II					III					IV				
		Plant- ed sp.	Other Gr.	KOSC	SAKA	Other Forb	PS	OG	KOSC	SAKA	OF	PS	OG	KOSC	SAKA	OF	PS	OG	KOSC	SAKA	OF
1111	C11	101.1	00.0	00.0	00.0	00.0	67.2	0.0	0.0	0.0	0.0	22.0	0.0	10.0	0.0	0.0	46.8	0.0	1.3	20.7	0.0
1112	C21	20.0	0.0	0.0	19.6	0.0	3.9	0.0	22.9	21.7	0.0	11.4	0.0	5.6	9.9	0.0	16.6	0.0	11.0	0.0	0.0
1113	C31	51.3	0.0	0.0	0.0	0.0	22.5	0.0	0.0	0.0	0.0	17.1	0.0	0.0	0.0	0.0	27.3	0.0	0.0	0.0	0.0
1121	C12	28.6	0.0	6.0	0.6	0.0	41.5	0.0	0.1	0.0	0.0	30.1	0.0	5.6	0.0	0.2	71.2	0.0	18.0	0.0	0.4
1122	C22	55.9					40.6					62.2					75.7				
1123	C32	10.0					56.8			11.7		24.5					35.7			1.3	
1211	M11	35.2					55.1					34.3					37.9				
1212	M21	76.6					67.7					59.3					58.8				
1213	M31	74.1					103.7					52.6					93.1				
1221	M12	24.8					38.6					24.5					56.7				
1222	M22	8.6					9.6					0.0					21.1				
1223	M32	38.2					38.1					93.0					26.0				
1311	F11	31.0					26.1					75.5					79.6				
1312	F21	18.5					30.6					33.3					52.5				
1313	F31	30.5					52.4		4.0			5.5		0.1			19.8			5.4	
1321	F12	0.7	2.7				46.1					25.7					18.5				
1322	F22	18.9					1.0		1.0			3.6					38.1				
1323	F32	0.3			6.7		0.3		8.5			0.0		3.7			2.4		14.0		
2111	C11	78.8					63.1					46.6					48.0				
2112	C21	15.1		6.0	2.8	5.9	11.3		16.4	13.9		9.8		20.3	9.6		31.8		0.1	0.3	
2113	C31	50.4					41.9					34.1					29.8				
2121	C12	12.4		20.3			12.9		1.6			3.3		0.9	9.0		94.5				
2122	C22	47.7					15.4					21.1		8.6			37.3				
2123	C32	44.6					49.0					41.2					42.5				
2211	M11	56.5					75.5					30.6					110.5				
2212	M21	94.9					25.1					60.7					78.9				
2213	M31	73.8					54.6					62.2					94.4				
2221	M12	69.8					42.5					56.0					44.8				
2222	M22	31.5		0.2	2.5		39.0					11.7			0.4		76.0			0.4	

Table 23--Continued

	Plant- ed sp.	Other Gr.	KOSC	Other SAKA	Forb	PS	OG	KOSC	SAKA	OF	PS	OG	KOSC	SAKA	OF	PS	OG	KOSC	SAKA	OF
2223 M32	35.7					12.1					22.2					12.5				
2311 F11	68.4					15.0					29.0					11.4		0.8		
2312 F21	76.9					24.0					30.6					28.7				
2313 F31	61.7					31.6					42.8					67.2				
2321 F12	23.2					49.3		2.6			1.2		5.3			73.9				
2322 F22	22.3					76.7					24.0					45.2				
2323 F32	60.5			2.4		15.9					14.8					19.4		0.6		
3111 C11		49.0						30.0	2.3		0.3		34.0					33.4		
3112 C21		22.4	6.9			2.9		20.5			1.6			4.7		1.4		18.0		
3113 C31	29.5					35.9					20.9					37.5				
3121 C12		40.2						37.1					36.7			0.4		42.8		
3122 C22		33.6	16.4					47.0	0.5				81.6	10.5				49.0	0.3	
3123 C32	28.0					5.5					26.2					30.7				
3211 M11	49.7					25.7					21.8			9.8		50.7				
3212 M21	44.5					22.6					33.6					33.2				
3213 M31	58.6					12.5		0.1			16.2			0.1		48.8				
3221 M12		0.5	12.1	6		18.9		3.8			32.0					18.4				
3222 M22	28.0					19.0					8.8		0.1			9.1		0.9		
3223 M32	21.0				8.1	27.1					29.9					44.5				
3311 F11	19.6					25.9					46.4					41.9				
3312 F21	15.4					4.5					31.4			1.7		6.8				
3313 F31	28.9					31.7					57.3					38.3		0.1		
3321 F12	7.6		4.3			4.5			3.0		13.7			1.2		17.2				
3322 F22	8.0		8.5					4.1	2.5		1.7		2.8			12.5				
3323 F32	22.1							1.7			3.1					0.1		2.3		
4111 C11	65.8					23.6					25.2					30.1				
4112 C21	6.4	0.6	31.0			28.3		7.0			0.4		13.9	29.3		2.9		24.2	14.2	
4113 C31	31.3					25.4					20.7					23.5				
4121 C12	7.0		3.5	0.1		9.4		10.6	9.0				24.7	15.3		1.9		24.6	7.5	
4122 C22	3.5	29.7	2.7			19.6					17.4		8.1	6.5		29.2				
4123 C32	14.3					20.5					15.4					37.5				
4211 M11	6.1					13.3					15.6					52.7				
4212 M21	27.8					19.9					25.3					32.9				
4213 M31	38.2					7.4					27.4					20.8				
4221 M12	12.7					19.0					4.2					19.7				
4222 M22	12.4					18.1		0.1			18.7					37.0				
4223 M32	5.3					17.8					20.4					48.6				
4311 F11	105.3					4.0					25.4					67.6				
4312 F21	38.2					21.2					23.8					69.3				
4313 F31	19.9					46.9					23.2					48.0				
4321 F12	3.3					20.3			2.6		12.4					45.8		1.4		

Table 23--Continued

	Plant- ed sp.	Other Gr.	KOSC	SAKA	Other Forb	PS	OG	KOSC	SAKA	OF	PS	OG	KOSC	SAKA	OF	PS	OG	KOSC	SAKA	OF
4322 F22	20.4					18.9					10.4					2.6				
4323 F32	2.4					10.7					14.8					5.6			11.3	
5111 C11	21.0				0.1	1.4		19.1			1.5		13.7			9.8		2.5		
5112 C21	1.3	34.8				0.0		29.3			0.1		44.3			14.2		9.9		
5113 C31	22.6					12.2					10.5					19.7		0.1	0.1	
5121 C12	4.3	8.0	7.6			15.3		6.0	1.0		10.6		2.2			8.8		23.5	12.2	
5122 C22	9.9	18.7				1.9		16.1	2.5		15.8		17.5			4.4		14.2	12.8	
5123 C32	21.8					15.1					20.7					18.7				
5211 M11	35.0					24.8					18.8					28.9				
5212 M21	33.0					19.4					24.5				0.1	50.8				
5213 M31	9.2	0.1	1.9			6.9		0.4	5.1		11.2		0.1			5.8		7.2	2.9	
5221 M12	16.2			2.3		21.1			1.5		6.4		4.6	6.1		7.1				
5222 M22	5.2			4.5		7.9		0.7			27.6		0.2			9.5		5.1		
5223 M32	7.7	0.4	7.0			13.7		1.6	0.1		27.9					25.1		0.1		
5311 F11	33.0					31.0					67.6					26.7				
5312 F21	27.9					27.1					42.4					56.3				
5313 F31	63.4					41.9					11.9					27.8				
5321 F12	9.2					51.0					13.2					17.5				
5322 F22	19.9					1.3		3.0			17.7			1.7		1.1		2.7		
5323 F32	0.1	2.8						4.4			0.7		0.1			0.5		2.3		
6111 C11		39.2						33.0			14.9		13.7	9.3		2.6		36.6		
6112 C21		28.7						10.7	10.2				20.6					23.9		
6113 C31	17.7					19.6					24.7					41.3				
6121 C12		5.3	0.2					7.0		1.0			17.8					34.7		
6122 C22		15.1	45.4					22.7	20.4				13.0	21.7	2.2	16.2			26.7	
6123 C32	41.2					57.5					35.9					79.0				
6211 M11	27.6			0.1		58.9					37.3					51.5				
6212 M21	65.2					35.8					26.6					36.6				
6213 M31	3.6	6.5	33.2			23.3		1.9	47.0		23.8		0.2	7.5		35.8		2.3	0.1	
6221 M12		11.4	12.5			4.1		1.2	6.7		0.4		7.4	6.2		1.8		9.0	8.2	
6222 M22	37.4	0.5	7.0			25.3		1.4	1.7		30.4		1.7	2.6		54.0				
6223 M32	22.8	4.2	2.9			60.1		3.3	0.3		6.9		15.1			71.1				
6312 F21	20.3					50.5					43.5					39.2				
6313 F31	1.1					30.8					51.8					32.3				
6321 F12	21.0					13.4			0.9		67.4					51.6			1.6	
6322 F22	40.9					80.8					13.8					63.7				
6323 F32	27.1					12.9					41.6					0.9		3.5	0.3	
7111 C11	0.4	26.6				4.6		37.7			3.7		40.5		5.0	15.9		22.6	3.5	
7112 C21	5.5	38.3	2.4			19.1		3.9	8.8		7.5		19.1	1.6		14.7		40.1	0.8	
7113 C31	74.8					59.0				0.3	101.2				0.3	60.4				
7121 C12	12.4	24.3	39.4			4.8		24.2	4.0		84.4		0.1					40.6	5.0	

Table 23---Continued

	Plant- ed sp.	Other Gr.	KOSC	Other SAKA Forb	PS	OG	KOSC	SAKA	OF	PS	OG	KOSC	SAKA	OF	PS	OG	KOSC	SAKA	OF
7122 C22	25.7		0.4	44.0	53.0					30.5		9.0	0.7		46.3		22.4	2.1	
7123 C32	43.8				36.8					36.2					102.3				
7211 M11	58.8				54.6					74.3					42.6			3.3	
7212 M21	88.1				40.1					29.3					124.7				
7213 M31	101.8				39.5					32.2					71.6			0.5	
7221 M12	34.5				26.8			1.3		67.0					77.0				
7222 M22	112.1				79.3					36.3					92.2				
7223 M32	75.0				27.2		1.2			18.9		0.8			80.2				
7311 F11	42.4				15.0					26.2					79.8				
7312 F21	45.1				32.3					34.7					40.7				
7313 F31	37.4				21.3					6.1					39.9				
7321 F12	44.8				21.3					59.3					0.6				
7322 F22	16.7	0.1			44.4					51.3					19.2				
7323 F32	31.6				1.4			1.2		60.8			1.2		89.0				1.2
8111 C11		26.0			0.2		41.7			5.2	0.6	7.6	1.1		1.5		25.4		
8112 C21	5.2	54.6					30.4				3.0	30.0	2.4		0.2	0.6	33.2		
8113 C31	15.4	0.1	0.1		5.4			5.0		24.8					0.2			3.7	
8121 C12	16.9	25.0	0.8			22.3	15.2				16.5	10.4			4.2		22.6	0.5	
8122 C22	0.1	36.3					39.3				51.4	0.9					26.8		
8123 C32	4.0	0.1	0.3	11.0	3.3		2.7	4.5		3.9	0.1				0.3	1.0	5.8	3.3	
8211 M11	19.3			0.5	10.5		3.4	8.4		13.0	0.2		6.4		13.0			3.6	
8212 M21		20.1	1.3				2.6	6.3			20.7					12.6			
8213 M31		0.6	11.5	27.3	16.2		0.7			1.9	4.0				2.0	7.3	1.4		
8221 M12	2.7	0.1	1.8	8.5	8.4	0.1	2.1	5.6					29.0		3.0	0.1	0.1	15.0	
8222 M22	14.4				0.2		12.3			0.1		19.4			0.4		10.7	0.8	
8223 M32	0.9	9.0			4.4		5.1	6.0		8.2		2.6			0.7		3.5		
8311 F11			3.9	4.6	1.8					0.1	2.4	0.1	5.7		3.4			2.2	
8312 F21	0.1		0.6		0.3		5.7			2.2		4.8			1.2		6.0		
8313 F31	4.4		3.2		16.2		1.6			3.1		6.2			4.0		0.1		
8321 F12			9.2				10.6					10.2			0.9		4.5	0.4	
8322 F22	0.7		2.1				13.2			0.1		1.5			0.1		1.1		
8323 F32		0.1	2.5	4.2	0.1		11.1				3.2	2.7					10.5		
9111 C11	38.6		0.6		6.3		10.3	1.5		2.4		5.3	5.0		9.0		6.5	10.1	
9112 C21	3.3		9.1	0.1	62.7		2.1			19.5		8.7			80.4				
9113 C31	59.2				22.2		0.5	9.0		51.1				6.0	78.8		0.1	0.5	
9121 C12	12.5		1.7		4.7				1.2			9.1			4.1		2.3		
9122 C22	22.7		6.8	4.5	4.4		37.3	10.6		7.8		4.5			4.5		13.6	6.7	
9123 C32	19.0		0.1				0.1	3.9		1.9		0.7	5.0		17.5			3.1	
9211 M11	8.6			0.5			1.8			86.7					28.0				
9212 M21	37.8				0.1	22.1				36.5					31.0				
9213 M31	21.5					36.5				11.6					92.4				

Table 23--Continued

		Plant- ed sp.	Other Gr.	KOSC	Other SAKA Forb	PS	OG	KOSC	SAKA	OF	PS	OG	KOSC	SAKA	OF	PS	OG	KOSC	SAKA	OF
9221 M12	138.4					67.5					55.0								1.7	
9222 M22	17.2					18.6					25.3					34.8		0.1		
9223 M32	9.3		1.1					5.4			42.2					15.4		0.4		
9311 F11	45.4					121.4					32.4					50.3				
9312 F21	90.6					16.5					84.8					38.3				
9313 F31	44.5					69.0					6.7					51.0				
9321 F12	2.1		0.2			52.9					24.0					2.7				
9322 F22	13.0					77.8					16.3					25.3				
9323 F32	8.9		0.1			9.6		8.3			30.8							2.8		
10111 C11	10.9					16.7					1.6					30.2				
10112 C21	26.5					16.4					5.4					25.9				
10113 C31	7.3					2.8					18.3					00.0				
10121 C12	8.5					6.7			0.6		2.6					5.4				
10122 C22	4.9					5.1					10.1					45.3				
10123 C32	11.1					9.6					12.5					69.2				
10211 M11	14.5					7.2					23.3					39.2				
10212 M21	13.0					19.7					23.8					20.9				
10213 M31	19.6					28.1					5.0					30.0				
10221 M12	33.0					11.4					24.8					44.8				
10222 M22	13.9			0.9		16.6					12.4					24.1				
10223 M32	13.7					9.5					13.7					13.1				
10311 F11	11.5					19.4					13.9					31.5				
10312 F21	15.7					26.6					4.9					45.5				
10313 F31	10.6					21.3					7.3					33.5				
10321 F12	29.3					21.1					41.4					11.6		0.1		
10322 F22	10.3					3.9					9.1					21.7				
10323 F32	18.1			7.1		3.6					18.3					32.3			14.0	
11111 C11	31.9					6.8			5.2		17.4					1.6			3.8	
11112 C21	32.1		0.1					7.9			0.1		1.3	25.5				20.0		17.3
11113 C31	19.1		0.2	0.3		0.1		2.2	5.7		33.0					16.8			4.7	
11121 C12			31.9					27.0	0.7		0.1		43.8	3.7		1.9		42.9	1.5	
11122 C22			34.6					45.4	1.3				29.7			0.3			8.7	
11123 C32	10.5			2.2		2.7		0.6	0.5		18.9					1.2		5.2	6.5	
11211 M11	20.9					97.0			4.4		40.0					9.5			3.1	
11212 M21	48.0				1.0	14.3		0.6	5.2		10.6		0.1			62.2				
11213 M31	49.1					4.5		1.0	0.1		23.5		0.1	0.2		31.1		0.7	0.1	
11221 M12	21.2					51.0			3.5		17.6			4.6		1.4		0.2	8.0	
11222 M22	11.5		6.7	2.6		1.7					5.4		0.1	3.0		5.7		0.2	6.2	
11223 M32	15.3		5.0	0.4		0.6		10.0	1.7		13.2		3.0			2.0		20.3		
11311 F11	28.2					36.1					24.5					3.9				
11312 F21	46.2					24.5					38.5					19.4				

Table 23--Continued

	Plant- ed sp.	Other Gr.	KOSC	SAKA	Other Forb	PS	OG	KOSC	SAKA	OF	PS	OG	KOSC	SAKA	OF	PS	OG	KOSC	SAKA	OF
11313 F31	56.8					53.3					39.0					72.5				
11321 F12	14.7		2.9	0.1		1.7		4.6			5.2			8.0		104.5				
11322 F22			0.4			1.2		3.0			0.2		4.9	0.1		12.4			6.9	
11323 F32	0.1		4.7			2.5		2.9			65.8					7.4			8.6	
12111 C11			15.4	1.2				18.1					22.1					20.1	2.6	
12112 C21			32.6					26.5					34.6					11.8		
12113 C31		5.3	0.4				0.8	3.8	19.7			1.2		2.6			0.1	0.4	8.0	
12121 C12			33.9					31.4					49.5					41.1	4.8	
12122 C22			28.3	1.8				22.8	5.0				20.7	2.0				25.5	3.0	
12123 C32		0.9		10.6			0.6	0.1	9.7			0.1	0.8	7.0			1.0	2.8	4.7	
12211 M11			6.3	6.9	6.9		0.3	10.8	11.6			4.0	5.1	9.0			4.6	11.3		
12212 M21		6.8	0.1				5.9	6.7					3.9	45.3				16.6	12.1	
12213 M31		0.4	8.4	20.8				10.8	50.5			0.5	12.9	6.9				14.1	19.0	
12221 M12		4.0	14.3	13.8			5.7	8.4	8.2			1.7	14.3	10.2			1.5	32.0	0.9	
12222 M22		0.2		2.7			0.1	13.3				1.2	3.4	6.9			2.1	6.9		
12223 M32		6.9	3.7				6.8		1.5			4.5	0.6				7.1		1.1	
12311 F11			11.7					14.4				0.1	13.3					10.7		
12312 F21			14.4					7.8				0.1	15.2				0.1	6.4		
12313 F31		0.1	11.5				2.6	7.7				15.6	3.1				0.1		0.9	
12321 F12		0.1	2.3				0.3		3.7			0.2	6.7				0.1	8.7		
12322 F22		0.1	6.7					10.2	0.4			1.5	10.4					9.6		
12323 F32			7.0	0.4			6.0	8.4				0.1	14.0					5.3	2.4	

¹Plot index includes the species (1-12), texture (1=coarse, 2=medium, 3=fine), salt treatment (1=unsalted, 2=salted), and the rep (1-3).

APPENDIX B
MORPHOLOGY DATA SUPPORTING PART II,
PLANT VARIABILITY STUDY

Table 24. Measurements of morphological characteristics of 7 Agropyron species; characters 1-17. A key to species, treatments, characters, and missing data (-8, -9) appears in Table 26.

Index Plot	Character																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
11111 C11	3.7	26	14.2	7.4	4.4	16.3	3	4	12	9.9	5	19	5	1	1	14	0
11112 C11	3.8	28	18.0	8.6	5.1	20.7	3	5	8	10.0	6	20	7	1	1	11	0
11113 C11	4.9	37	26.4	11.7	5.6	20.3	3	5	8	9.5	6	21	8	1	1	12	0
11121 C21	3.2	30	11.6	5.7	5.0	13.1	3	4	6	6.3	3	21	6	1	1	11	0
11122 C21	4.6	35	19.8	6.1	5.2	11.3	3	3	8	11.7	6	25	7	1	1	13	0
11123 C21	4.4	33	14.6	6.1	5.9	15.0	3	4	7	11.0	5	24	7	1	1	15	0
11131 C31	1.6	11	16.0	9.5	3.0	12.1	3	3	7	10.0	4	20	7	1	1	13	0
11132 C31	2.5	23	19.3	8.4	3.9	15.0	3	3	8	9.8	4	20	7	1	1	12	0
11133 C31	2.5	21	18.6	10.2	3.9	22.6	4	4	8	10.5	5	20	7	1	1	11	0
11211 C12	6.0	35	26.3	12.8	6.4	24.4	3	7	7	11.0	8	22	7	4	1	14	0
11212 C12	4.8	36	20.8	11.9	6.9	27.2	4	3	8	11.0	6	22	6	2	1	13	0
11213 C12	3.3	26	18.1	9.0	5.1	21.3	4	3	7	10.8	7	21	6	1	1	13	0
11221 C22	6.0	46	30.0	16.6	7.7	27.9	3	4	8	12.9	7	23	7	1	1	13	0
11222 C22	4.9	41	27.1	15.9	6.3	25.5	3	2	8	12.0	5	23	10	1	1	16	0
11223 C22	4.1	36	22.2	11.7	6.0	19.4	3	3	8	12.6	7	21	8	1	1	9	0
11231 C32	5.0	38	27.6	12.7	6.2	22.8	3	3	8	13.1	7	25	7	2	1	14	0
11232 C32	2.2	14	19.4	13.5	5.1	27.6	4	5	8	10.3	6	20	7	1	1	11	0
11233 C32	2.0	15	17.0	9.4	3.2	15.2	3	4	7	11.7	6	22	7	2	1	10	0
12141 M11	1.8	19	18.8	12.7	4.2	23.6	3	5	10	8.7	5	19	5	1	1	15	0
12142 M11	5.5	27	28.2	12.5	6.4	22.7	3	6	8	8.6	6	18	6	1	1	6	0
12143 M11	3.3	31	22.8	10.1	4.9	14.5	3	3	7	12.0	7	23	7	1	1	11	0
12151 M21	1.8	13	15.4	7.7	3.9	16.0	3	3	7	8.4	4	13	4	1	1	9	0
12152 M21	3.0	27	15.4	6.0	4.9	19.1	4	3	7	8.6	5	18	4	1	1	11	0
12153 M21	4.0	38	19.9	13.8	7.9	30.6	4	3	7	9.0	5	22	8	1	1	11	0
12161 M31	4.5	40	20.9	14.4	5.6	28.4	3	5	12	11.9	6	20	7	1	1	8	0
12162 M31	3.2	24	-8	14.1	6.0	28.6	4	7	8	9.9	5	21	8	1	1	12	0
12163 M31	1.6	15	15.8	10.4	4.0	19.5	3	3	8	9.6	5	21	7	2	1	11	0
12241 M12	2.3	16	19.9	8.8	4.2	17.0	3	3	7	12.8	7	23	7	1	1	14	0
12242 M12	2.8	17	18.0	8.5	3.9	14.4	3	6	8	11.1	6	20	6	1	1	12	0
12243 M12	4.0	29	30.8	10.4	5.0	17.9	3	5	7	12.4	8	23	8	2	1	11	0
12251 M22	3.9	30	26.9	13.7	5.6	25.6	3	2	8	10.0	6	17	6	1	1	6	0
12252 M22	3.4	29	25.6	7.5	4.9	12.9	2	7	8	11.3	7	19	5	1	1	9	0
12253 M22	3.4	28	30.3	9.1	6.5	15.8	3	4	7	13.0	5	24	8	1	1	12	0
12261 M32	6.3	45	24.8	18.4	7.5	33.0	3	3	6	12.1	7	22	8	2	1	15	0
12262 M32	3.7	30	21.1	9.8	4.4	15.0	2	3	7	10.6	8	17	6	2	1	6	0
12263 M32	7.0	46	30.0	15.2	8.5	26.8	3	7	8	13.0	9	24	9	1	1	12	0
13171 F11	3.9	20	17.0	10.1	3.9	23.5	3	4	18	11.6	7	22	5	2	1	25	0
13172 F11	5.9	35	27.7	12.2	5.3	20.2	3	5	8	12.8	9	23	7	1	1	12	0
13173 F11	6.0	39	28.2	8.9	5.0	14.4	3	4	8	13.8	10	22	7	1	1	15	1
13181 F21	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
13182 F21	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
13183 F21	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
13191 F31	2.2	25	14.8	8.6	5.0	20.0	3	4	7	11.0	7	19	7	2	1	10	0
13192 F31	3.5	27	17.6	10.2	4.8	21.4	3	4	7	13.0	10	22	8	2	1	9	0
13193 F31	4.2	24	20.2	1.7	6.8	10.7	3	6	5	15.8	9	24	9	2	1	10	0
13271 F12	3.0	21	18.0	9.8	4.8	18.7	3	7	8	10.6	6	17	-8	1	1	11	0
13272 F12	4.2	25	23.7	8.7	4.2	17.2	3	6	8	11.3	7	23	8	1	1	14	0
13273 F12	1.3	11	12.1	7.4	2.3	14.9	3	4	7	10.0	7	16	6	1	1	9	0
13281 F22	3.7	26	18.5	9.4	3.8	18.8	4	5	12	11.0	6	22	7	1	1	15	0
13282 F22	3.8	26	18.3	9.1	3.9	17.3	3	10	9	11.1	7	18	7	2	1	7	0
13283 F22	3.5	22	22.3	12.2	4.9	25.6	4	7	13	13.9	9	22	9	1	1	7	0
13291 F32	3.3	26	13.2	6.9	3.8	19.4	4	4	7	13.1	9	25	7	2	1	12	0
13292 F32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
13293 F32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
21111 C11	8.5	12	33.4	14.9	8.1	18.0	2	25	5	15.2	6	23	6	1	0	-9	-9
21112 C11	11.2	14	42.3	9.0	5.9	10.2	2	28	5	13.8	5	23	6	1	2	2	-9

Table 24--Continued

Index Plot	Character																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
21113 C11	3.9	7	22.4	8.9	4.8	13.3	3	25	5	10.3	4	16	6	1	0	-9	-9
21121 C21	5.7	8	19.6	8.2	4.5	10.8	2	20	5	10.8	4	7	4	1	2	2	-9
21122 C21	7.9	15	24.1	8.5	4.7	13.0	3	17	5	12.8	5	23	6	1	2	3	-9
21123 C21	5.6	10	24.0	6.5	4.4	9.4	2	18	5	10.8	4	18	5	1	0	-9	-9
21131 C31	6.3	12	34.3	14.4	7.6	22.6	2	23	5	12.8	5	20	6	1	0	-9	-9
21132 C31	4.0	8	19.7	6.5	4.1	9.5	2	20	6	12.5	5	19	6	1	2	1	-9
21133 C31	3.8	6	22.0	6.5	3.5	9.1	2	21	4	11.2	4	17	6	1	0	-9	-9
21211 C12	3.6	6	22.5	7.8	3.3	9.7	2	17	5	12.0	4	18	5	1	2	1	-9
21212 C12	3.9	8	12.0	5.4	4.5	9.4	2	15	4	9.8	4	18	5	1	2	2	-9
21213 C12	4.1	10	27.7	8.3	4.6	10.9	2	14	7	9.6	4	14	6	1	0	-9	-9
21221 C22	6.0	12	23.9	9.5	5.5	16.0	3	16	5	11.8	5	18	5	2	0	-9	-9
21222 C22	5.9	9	26.2	12.3	5.8	18.6	3	22	5	12.8	5	19	5	1	2	2	-9
21223 C22	4.2	7	16.3	6.9	5.0	10.9	2	16	6	8.8	3	14	5	1	0	-9	-9
21231 C32	4.7	7	23.1	8.4	4.0	15.4	3	8	3	10.2	4	13	5	2	0	-9	-9
21232 C32	3.9	7	23.7	9.2	5.1	13.4	2	19	5	12.6	5	17	5	1	0	-9	-9
21233 C32	2.8	5	18.0	7.7	4.2	11.4	2	23	6	10.5	5	18	5	1	2	3	-9
22141 M11	3.4	5	17.0	7.8	3.5	10.0	2	17	4	8.1	4	15	6	1	0	-9	-9
22142 M11	3.6	7	17.8	6.3	3.7	8.6	2	14	5	7.5	3	14	5	1	0	-9	-9
22143 M11	9.4	14	32.6	10.3	6.4	15.7	2	24	4	11.5	4	20	5	1	0	-9	-9
22151 M21	6.1	9	30.8	9.8	6.8	15.2	3	23	5	12.9	5	18	6	1	0	-9	-9
22152 M21	4.0	6	27.9	11.3	4.4	14.9	3	20	5	11.3	5	18	6	1	0	-9	-9
22153 M21	7.5	10	38.0	11.0	5.4	13.7	2	22	4	14.9	6	20	7	1	0	-9	-9
22161 M31	7.8	11	37.4	15.3	6.5	18.6	2	25	5	15.7	5	22	6	1	0	-9	-9
22162 M31	4.4	5	18.9	6.3	3.9	8.0	2	28	3	11.0	3	15	6	1	2	1	-9
22163 M31	6.0	11	18.2	7.9	5.3	15.1	3	18	3	12.2	5	20	5	1	0	-9	-9
22241 M12	5.3	10	26.7	7.4	3.2	8.1	1	18	5	16.0	6	21	6	2	0	-9	-9
22242 M12	3.5	7	22.6	8.5	3.3	10.4	2	17	5	10.1	5	17	5	1	2	2	-9
22243 M12	4.8	8	26.7	12.9	5.7	20.7	3	22	5	12.4	5	20	5	1	2	2	-9
22251 M22	5.3	10	30.3	14.1	6.4	23.6	3	16	5	12.8	5	19	6	1	2	2	-9
22252 M22	3.7	7	21.6	8.0	3.3	9.2	2	20	5	10.8	5	14	6	1	0	-9	-9
22253 M22	5.6	11	22.8	10.3	7.1	18.0	3	17	5	12.7	5	19	6	1	0	-9	-9
22261 M32	5.6	8	31.1	12.1	5.7	16.8	2	28	5	14.7	5	21	7	1	0	-9	-9
22262 M32	4.0	6	26.0	8.0	4.7	12.7	3	22	5	12.7	5	19	6	1	2	1	-9
22263 M32	6.1	11	24.0	6.2	3.3	7.3	2	16	7	11.8	5	21	8	1	2	1	-9
23171 F11	5.2	8	25.9	10.7	6.0	14.5	2	24	5	15.0	5	17	5	1	0	-9	-9
23172 F11	4.6	7	16.0	13.6	4.9	18.5	3	17	5	13.3	3	16	5	1	2	1	-9
23173 F11	3.6	6	26.1	9.1	4.4	12.7	2	22	7	10.9	3	22	6	1	2	2	-9
23181 F21	7.7	13	29.8	10.5	4.9	14.9	2	19	7	13.8	6	19	6	1	0	-9	-9
23182 F21	5.0	8	21.6	11.9	6.7	20.2	3	23	5	13.3	6	24	4	1	2	3	-9
23183 F21	9.9	17	37.1	14.3	7.5	20.7	2	20	5	15.1	6	20	7	1	0	-9	-9
23191 F31	4.5	8	17.9	8.4	5.1	16.3	3	20	5	11.3	5	16	4	2	0	-9	-9
23192 F31	3.0	7	20.2	8.5	4.1	13.6	3	18	5	10.7	4	16	5	1	0	-9	-9
23193 F31	4.1	6	18.1	8.8	4.7	13.8	2	27	7	13.6	7	18	7	2	0	-9	-9
23271 F12	5.0	9	21.9	7.8	3.9	7.8	1	19	6	13.1	7	21	7	1	2	2	0
23272 F12	4.7	8	20.0	6.1	3.4	8.4	2	23	4	13.2	6	17	6	1	0	-9	-9
23273 F12	7.7	8	37.2	18.4	8.3	28.4	3	34	5	15.5	8	20	6	1	0	-9	-9
23281 F22	4.1	8	16.7	10.7	6.5	20.6	4	15	4	13.1	6	20	6	1	2	2	-9
23282 F22	6.1	7	16.5	7.5	6.5	11.7	2	19	6	13.9	7	20	5	1	0	-9	-9
23283 F22	6.9	10	31.5	7.5	5.2	10.6	2	24	6	14.5	7	20	6	1	0	-9	-9
23291 F32	5.0	8	20.3	10.6	5.6	16.9	3	19	5	8.2	-8	18	7	1	0	-9	-9
23292 F32	3.0	5	20.7	6.0	3.3	7.2	1	24	5	12.3	6	15	5	1	0	-9	-9
23293 F32	6.9	9	26.0	8.5	4.5	10.1	1	28	5	18.4	6	19	6	1	0	-9	-9
31111 C11	9.1	4	27.4	4.5	7.0	5.8	1	56	5	13.1	3	24	6	2	0	-9	-9
31112 C11	8.7	7	36.2	7.6	6.3	9.2	2	52	5	13.9	3	27	8	2	0	-9	-9
31113 C11	10.8	8	36.7	7.6	7.3	11.6	2	48	3	14.2	4	27	8	2	0	-9	-9
31121 C21	4.9	5	20.0	8.4	6.9	16.1	3	35	4	12.0	4	23	7	2	0	-9	-9
31122 C21	4.9	7	18.9	7.8	4.6	10.3	2	29	3	12.9	4	22	8	2	0	-9	-9

Table 24--Continued

Index Plot		Character																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
31123	C21	6.0	7	21.3	8.5	7.2	22.3	4	28	3	13.0	5	25	8	1	2	1	-9
31131	C31	4.3	3	26.1	9.3	7.1	14.4	3	39	5	10.0	3	14	5	5	0	-9	-9
31132	C31	5.9	5	33.9	10.4	6.4	15.1	3	38	3	15.7	5	29	9	2	0	-9	-9
31133	C31	6.8	5	36.2	8.7	6.9	11.7	2	34	3	14.7	4	28	9	2	0	-9	-9
31211	C12	7.3	6	27.2	7.3	5.6	10.7	2	34	4	12.1	5	20	6	2	0	-9	-9
31212	C12	3.6	6	20.8	9.4	6.8	15.3	3	24	5	12.6	4	24	7	2	0	-9	-9
31213	C12	4.7	6	19.1	9.4	12.6	21.9	4	34	5	11.7	4	22	7	1	1	2	-9
31221	C22	4.6	5	11.9	6.0	6.5	16.3	4	28	4	11.6	3	20	7	2	0	-9	-9
31222	C22	6.5	6	31.0	8.0	6.3	12.0	2	37	4	14.9	5	28	8	2	0	-9	-9
31223	C22	6.4	5	23.7	8.0	7.0	13.8	3	36	4	13.9	4	27	7	2	0	-9	-9
31231	C32	4.1	3	22.4	8.5	5.1	11.0	2	47	1	13.1	4	19	7	2	0	-9	-9
31232	C32	9.8	7	38.5	4.6	-8	5.2	1	41	5	15.5	6	29	8	2	0	-9	-9
31233	C32	5.2	4	24.4	10.1	5.2	14.3	2	32	3	12.8	4	17	7	5	0	-9	-9
32141	M11	3.5	4	4.5	21.5	7.9	40.2	4	51	1	10.9	4	24	6	2	0	-9	-9
32142	M11	10.3	9	39.5	12.4	7.6	16.0	2	42	4	13.8	4	21	8	2	0	-9	-9
32143	M11	4.7	5	31.9	9.4	5.6	18.0	2	-8	1	11.8	3	24	7	1	0	-9	-9
32151	M21	5.6	5	25.2	10.0	6.8	14.4	3	28	3	13.0	4	23	7	1	0	-9	-9
32152	M21	6.5	4	28.0	13.8	7.6	21.7	3	45	1	12.8	4	22	7	2	0	-9	-9
32153	M21	5.0	4	29.6	13.9	7.2	20.7	3	36	3	11.1	4	22	7	2	0	-9	-9
32161	M31	3.0	3	25.9	11.7	5.2	14.9	2	37	2	11.1	3	22	6	2	0	-9	-9
32162	M31	4.7	3	24.5	7.9	5.2	14.1	3	32	5	12.1	4	20	7	2	0	-9	-9
32163	M31	6.0	4	32.8	12.1	6.5	16.0	2	31	1	11.8	4	23	9	2	0	-9	-9
32241	M12	5.9	6	33.7	10.5	6.7	16.3	3	39	3	12.6	3	28	9	2	0	-9	-9
32242	M12	5.0	6	26.9	7.8	4.7	10.5	2	37	3	15.6	6	19	6	2	0	-9	-9
32243	M12	11.5	9	47.7	8.4	6.2	9.6	2	47	4	16.0	7	34	11	4	0	-9	-9
32251	M22	5.3	4	26.3	11.2	7.2	17.2	3	28	3	14.0	5	28	8	1	2	1	-9
32252	M22	5.4	6	31.8	12.2	6.9	19.3	3	24	3	11.2	4	22	7	2	0	-9	-9
32253	M22	8.0	7	31.1	15.0	7.7	23.3	3	38	3	15.0	5	28	8	2	0	-9	-9
32261	M32	7.7	7	36.9	6.5	5.3	7.8	2	40	4	9.1	-8	29	8	2	0	-9	-9
32262	M32	7.4	5	33.4	14.6	7.7	19.1	2	51	4	13.2	5	21	9	2	0	-9	-9
32263	M32	8.5	8	36.0	11.0	7.4	15.4	2	35	3	10.9	-8	28	7	2	2	1	-9
33171	F11	13.2	8	50.5	13.4	9.3	17.2	2	-8	2	18.1	5	32	8	2	2	4	-9
33172	F11	3.3	4	16.5	8.0	3.8	14.0	3	25	3	10.7	4	17	6	2	0	-9	-9
33173	F11	5.6	6	31.3	11.6	7.9	17.4	2	30	5	15.9	6	24	9	2	0	-9	-9
33181	F21	6.4	5	30.7	8.8	4.6	10.5	2	35	4	15.6	6	23	8	2	0	-9	-9
33182	F21	4.0	2	10.4	13.2	6.5	23.4	3	20	2	9.2	3	16	6	5	0	-9	-9
33183	F21	5.2	6	26.8	11.3	6.0	15.6	2	36	2	14.6	6	21	7	2	0	-9	-9
33191	F31	5.0	5	29.4	7.7	5.6	13.6	3	40	3	14.2	5	21	7	5	0	-9	-9
33192	F31	6.7	6	33.8	9.7	6.3	14.8	3	45	3	13.3	5	25	8	2	0	-9	-9
33193	F31	3.4	6	19.5	6.0	3.9	10.5	3	25	5	11.1	4	18	6	2	0	-9	-9
33271	F12	9.1	6	38.4	9.5	6.4	13.0	2	45	3	18.6	7	25	6	2	0	-9	-9
33272	F12	6.1	6	27.1	11.8	7.2	18.3	3	41	2	16.4	6	24	9	2	0	-9	-9
33273	F12	2.9	3	21.4	7.1	4.6	13.7	3	20	2	12.7	4	22	7	2	0	-9	-9
33281	F22	5.2	5	28.0	13.4	7.2	22.7	3	35	3	15.5	7	28	9	1	2	2	-9
33282	F22	6.1	6	25.8	10.5	7.8	17.7	3	43	4	16.2	6	24	6	2	0	-9	-9
33283	F22	8.1	7	30.1	15.3	11.3	24.6	3	45	4	16.0	6	28	8	1	0	-9	-9
33291	F32	10.2	7	37.6	4.0	4.2	4.6	1	49	4	14.2	5	25	9	2	0	-9	-9
33292	F32	3.7	3	22.6	11.3	5.1	17.1	3	32	1	12.7	4	21	8	1	0	-9	-9
33293	F32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
41111	C11	7.7	11	33.5	8.0	5.7	10.5	2	23	5	14.2	4	22	6	1	0	-9	-9
41112	C11	5.7	8	27.6	11.7	5.8	16.2	-8	23	5	12.1	5	14	4	2	0	-9	-9
41113	C11	6.4	12	26.5	10.5	6.0	17.0	3	17	5	11.6	6	18	5	1	0	-9	-9
41121	C21	4.5	7	22.3	9.0	4.6	12.3	2	25	5	17.4	6	19	6	1	0	-9	-9
41122	C21	4.0	10	15.5	9.3	5.7	18.4	3	11	5	10.2	4	15	4	1	0	-9	-9
41123	C21	7.1	12	30.5	11.1	9.4	20.3	3	19	5	15.2	6	23	6	1	0	-9	-9
41131	C31	3.3	6	22.3	10.0	4.7	16.7	4	23	5	12.0	5	17	6	1	2	2	-9
41132	C31	2.8	5	24.4	14.4	5.6	20.4	3	23	5	12.9	5	19	7	1	0	-9	-9

Table 24--Continued

Index	Plot	Character																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
41133	C31	5.6	10	27.2	5.7	3.3	07.3	2	23	6	14.4	4	22	7	1	0	-9	-9
41211	C12	2.2	4	5.9	6.0	3.4	14.4	3	22	4	9.3	4	15	4	1	2	2	-9
41212	C12	4.0	6	23.9	8.6	4.4	10.8	2	20	4	11.2	5	14	6	1	0	-9	-9
41213	C12	4.2	7	23.7	8.6	5.0	12.4	2	21	6	14.0	4	21	5	2	0	-9	-9
41221	C22	5.9	9	26.6	9.4	7.3	17.9	3	23	5	12.8	6	28	7	1	2	3	-9
41222	C22	4.3	6	28.2	9.4	4.3	12.0	2	30	5	14.6	5	19	5	1	2	1	-9
41223	C22	3.6	7	19.0	6.6	3.9	8.6	2	18	5	11.6	5	15	5	1	0	-9	-9
41231	C32	4.9	8	24.5	8.6	4.9	11.1	2	21	5	13.1	6	21	7	1	2	3	-9
41232	C32	3.1	6	16.6	3.1	2.1	3.9	2	15	5	8.0	3	13	5	1	0	-9	-9
41233	C32	3.2	6	22.8	6.8	3.9	9.5	2	19	6	10.9	4	17	4	1	2	2	-9
42141	M11	5.5	7	22.6	7.8	3.8	9.1	2	23	5	8.0	3	22	5	1	0	-9	-9
42142	M11	5.1	8	29.2	8.5	3.8	9.6	2	20	6	17.2	5	26	5	1	1	6	0
42143	M11	4.4	10	19.6	7.5	3.7	10.1	2	18	13	9.6	3	18	5	1	0	-9	-9
42151	M21	10.7	16	40.9	15.0	7.1	18.0	2	21	5	14.8	5	23	7	1	2	3	0
42152	M21	4.4	7	24.1	9.7	4.4	11.6	2	21	5	13.0	6	17	5	2	0	-9	-9
42153	M21	2.4	6	10.1	7.0	3.8	13.4	3	13	5	9.5	3	18	6	1	0	-9	-9
42161	M31	3.6	7	24.3	11.3	4.2	17.7	2	21	5	11.5	4	18	5	1	0	-9	-9
42162	M31	6.4	9	25.6	11.5	5.7	18.5	3	26	5	13.3	5	21	6	1	0	-9	-9
42163	M31	4.7	10	29.8	7.2	-8	11.1	2	20	5	12.1	4	20	6	1	0	-9	-9
42241	M12	5.8	9	30.9	9.5	5.0	14.0	2	23	5	13.0	6	20	6	1	2	3	-9
42242	M12	8.4	12	36.4	9.7	4.8	12.0	2	24	5	13.3	6	23	7	1	2	2	-9
42243	M12	6.1	10	29.7	8.7	4.2	10.1	2	25	5	14.6	6	29	7	2	2	2	-9
42251	M22	5.8	10	23.3	8.5	5.6	15.2	3	21	3	11.8	5	15	6	2	0	-9	-9
42252	M22	6.9	10	30.0	6.9	4.0	8.2	2	23	5	11.9	5	15	6	1	0	-9	-9
42253	M22	7.8	11	33.4	16.5	9.1	23.5	3	26	3	13.8	6	17	5	1	0	-9	-9
42261	M32	3.8	5	22.3	11.1	4.3	19.4	3	16	2	10.9	4	16	5	1	0	-9	-9
42262	M32	6.4	8	28.4	12.5	5.5	20.1	2	26	5	12.0	4	23	6	1	2	4	-9
42263	M32	2.9	5	18.8	9.4	3.8	15.1	3	33	5	10.2	4	19	5	1	2	1	-9
43171	F11	4.2	7	25.9	12.8	7.1	23.2	4	23	5	14.2	7	18	5	1	2	1	-9
43172	F11	9.7	9	38.7	12.7	6.4	15.8	2	39	5	20.9	8	30	7	1	2	3	-9
43173	F11	7.5	10	37.7	14.2	9.1	22.4	3	25	5	15.9	7	30	8	1	0	-9	-9
43181	F21	6.5	11	27.8	10.3	4.9	13.3	2	17	5	11.3	5	19	5	1	0	-9	-9
43182	F21	5.2	10	16.0	9.0	3.8	10.9	2	16	4	11.1	5	20	6	1	1	5	0
43183	F21	4.5	11	21.9	6.0	4.1	9.0	2	14	4	13.0	5	22	7	1	0	-9	-9
43191	F31	8.4	13	34.3	10.1	5.3	11.9	2	23	5	12.9	4	21	7	1	2	3	-9
43192	F31	5.1	8	29.1	14.8	5.5	24.4	3	25	6	19.6	5	21	4	1	2	3	-9
43193	F31	3.6	7	20.5	13.7	6.3	20.0	3	19	5	14.0	6	21	7	1	2	1	-9
43271	F12	3.4	6	20.1	8.9	4.0	13.1	2	16	4	11.0	4	19	6	1	2	1	-9
43272	F12	3.4	4	20.2	7.2	3.6	10.5	3	16	5	10.6	4	12	5	1	0	-9	-9
43273	F12	4.5	8	20.6	6.2	4.0	8.8	2	19	5	12.0	5	15	7	1	0	-9	-9
43281	F22	5.2	8	27.7	8.6	5.6	13.2	3	24	5	14.1	7	23	6	2	0	-9	-9
43282	F22	5.7	7	22.7	9.3	7.3	18.3	3	29	5	14.5	5	24	6	2	0	-9	-9
43283	F22	7.2	10	27.0	10.0	6.8	17.2	3	26	5	13.6	5	22	6	2	0	-9	-9
43291	F32	5.3	7	28.3	11.2	5.8	15.3	2	18	3	14.3	5	20	5	1	2	3	-9
43292	F32	2.3	5	19.1	7.3	3.1	11.6	2	19	5	12.1	5	17	5	1	0	-9	-9
43293	F32	5.1	10	23.4	7.1	5.0	10.8	2	17	5	11.7	5	17	5	1	0	-9	-9
51111	C11	5.7	10	27.9	11.0	6.0	15.2	2	21	5	16.0	5	32	10	1	2	3	-9
51112	C11	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
51113	C11	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
51121	C21	6.6	11	7.6	21.7	11.6	39.3	3	21	6	16.2	6	31	9	1	2	7	-9
51122	C21	4.3	6	12.3	9.1	7.3	21.5	4	18	6	14.1	4	30	7	2	2	6	-9
51123	C21	7.4	13	27.7	9.7	6.1	16.8	3	18	6	13.8	4	32	10	1	2	3	-9
51131	C31	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
51132	C31	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
51133	C31	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
51211	C12	4.6	8	21.2	8.1	4.7	11.5	2	22	5	19.6	9	33	10	2	0	-9	-9
51212	C12	3.7	6	15.6	5.0	6.7	13.0	3	17	7	17.8	6	32	10	2	2	2	-9

Table 24--Continued

Index	Plot	Character																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
51213	C12	9.0	12	31.9	7.8	5.9	9.6	2	29	5	19.8	8	41	10	1	2	4	-9
51221	C22	6.1	11	24.0	13.3	7.9	27.4	4	19	5	18.8	8	32	10	1	2	3	-9
51222	C22	6.8	8	24.4	12.1	6.5	18.5	2	28	5	18.1	7	31	8	2	2	4	-9
51223	C22	5.2	10	21.3	7.9	6.0	12.5	3	23	6	15.9	5	39	9	1	2	7	-9
51231	C32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
51232	C32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
51233	C32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
52141	M11	5.8	7	29.6	11.2	7.0	16.3	2	32	5	18.5	8	40	10	2	2	7	-9
52142	M11	5.2	6	19.5	9.4	5.5	10.5	2	37	3	13.5	5	22	7	1	0	-9	-9
52143	M11	5.8	8	26.2	13.3	6.8	19.0	2	29	5	20.8	10	38	10	1	0	-9	-9
52151	M21	7.2	11	31.2	13.0	8.2	18.1	1	26	3	19.0	4	12	9	1	2	6	-9
52152	M21	5.5	9	27.8	13.8	7.2	25.5	2	30	3	11.0	5	10	9	1	1	8	0
52153	M21	9.4	4	43.5	13.9	8.4	19.8	1	25	3	19.0	4	11	9	1	1	13	0
52161	M31	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
52162	M31	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
52163	M31	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
52241	M12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
52242	M12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
52243	M12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
52251	M22	5.6	7	26.7	6.8	6.6	14.3	3	24	6	16.9	6	38	9	1	2	9	-9
52252	M22	8.3	11	34.9	15.3	9.1	23.9	2	29	6	24.9	8	47	12	1	2	6	-9
52253	M22	6.5	10	27.7	12.0	6.3	22.1	3	8	5	14.4	6	30	10	1	2	2	-9
52261	M32	6.0	8	27.5	13.7	7.5	8.4	2	26	5	16.8	7	40	9	1	2	3	-9
52262	M32	6.9	11	21.9	9.4	7.6	14.9	2	21	5	15.6	6	28	8	1	1	6	0
52263	M32	8.9	12	34.4	14.3	9.5	27.3	3	25	5	19.9	7	42	8	2	2	6	0
53171	F11	7.7	10	39.8	17.4	9.1	24.7	2	27	7	20.3	8	43	10	2	2	7	-9
53172	F11	7.0	9	28.4	8.7	6.5	17.8	3	24	5	18.0	7	38	11	1	0	-9	-9
53173	F11	8.7	12	35.4	13.1	8.8	22.8	3	27	5	15.8	5	41	11	2	2	4	-9
53181	F21	4.5	9	18.4	9.7	6.4	20.8	3	19	6	15.1	5	34	8	2	2	5	-9
53182	F21	5.4	11	20.1	12.6	8.4	23.2	4	15	7	15.6	6	37	9	1	1	9	0
53183	F21	6.5	8	28.0	12.1	8.9	21.0	3	23	5	16.0	7	33	9	2	2	4	-9
53191	F31	4.3	8	16.7	5.2	6.0	22.6	4	18	5	15.8	7	34	8	1	2	4	-9
53192	F31	5.5	9	20.5	9.0	5.7	19.3	3	22	5	17.1	8	32	9	1	2	7	-9
53193	F31	6.3	9	26.1	9.1	5.2	13.6	3	24	5	16.1	6	35	9	1	2	7	-9
53271	F12	4.6	9	25.7	11.9	6.1	21.2	3	18	5	13.1	5	30	10	2	2	2	-9
53272	F12	6.5	10	36.1	11.7	5.9	20.4	4	21	5	24.8	11	39	10	2	2	4	-9
53273	F12	7.0	12	34.3	12.1	6.7	19.3	3	21	6	21.2	9	33	9	2	0	-9	-9
53281	F22	6.7	9	22.5	9.0	6.9	22.0	3	27	5	19.7	8	36	11	1	2	8	-9
53282	F22	5.2	8	27.9	7.4	6.0	20.5	3	25	5	17.4	5	37	9	1	2	11	-9
53283	F22	6.3	9	26.0	9.4	6.3	16.2	3	29	5	16.3	5	39	11	1	0	-9	-9
53291	F32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
53292	F32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
53293	F32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
61111	C11	15.4	28	38.6	9.6	12.2	21.2	3	17	5	13.0	5	38	10	1	2	3	-9
61112	C11	12.3	26	18.4	7.2	8.6	21.9	4	15	4	12.4	5	30	9	1	0	-9	-9
61113	C11	9.9	20	17.0	6.8	7.3	15.7	3	16	5	11.0	5	30	9	1	2	2	-9
61121	C21	14.9	26	37.6	10.7	9.7	19.7	3	32	4	15.6	7	47	7	2	1	7	0
61122	C21	12.9	20	23.3	4.6	7.3	13.0	4	20	5	13.2	5	41	11	1	2	3	-9
61123	C21	11.2	18	24.3	1.5	7.0	9.9	3	22	5	13.0	5	37	10	1	0	-9	-9
61131	C31	8.4	12	32.0	7.9	6.7	16.1	3	26	5	12.7	4	34	11	1	2	3	-9
61132	C31	11.0	15	34.3	8.6	7.4	16.5	3	23	5	14.8	6	38	7	2	2	1	0
61133	C31	10.2	16	30.4	4.0	5.8	8.6	3	19	5	11.1	4	37	10	1	2	4	-9
61211	C12	13.3	22	31.9	7.5	9.4	14.2	3	17	5	12.1	4	34	7	1	0	-9	-9
61212	C12	12.6	22	18.6	2.9	7.3	8.2	3	16	5	9.8	3	28	8	1	0	-9	-9
61213	C12	15.1	26	33.9	8.2	8.6	15.9	3	18	5	11.4	4	33	9	1	0	-9	-9
61221	C22	11.9	25	31.0	9.0	8.7	23.3	4	15	5	13.5	5	35	9	1	2	3	-9
61222	C22	11.7	18	25.8	6.1	8.7	17.3	4	19	5	13.4	5	38	10	1	2	4	0

Table 24--Continued

Index	Plot	Character																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
61223	C22	10.9	24	27.1	7.4	8.6	22.9	4	15	5	11.3	4	31	9	1	2	2	-9
61231	C32	8.9	18	28.4	8.1	7.9	19.6	3	16	5	11.8	4	30	8	1	2	6	-9
61232	C32	11.0	19	26.2	6.9	6.8	15.2	3	19	5	11.6	4	31	10	1	0	-9	-9
61233	C32	10.5	17	37.0	10.7	7.7	22.4	4	21	5	12.7	5	15	9	1	2	2	-9
62141	M11	10.9	20	24.8	6.1	7.6	15.2	3	18	5	13.4	5	34	9	2	2	1	-9
62142	M11	10.6	20	28.1	7.2	7.4	14.2	3	16	5	11.5	5	30	9	1	0	-9	-9
62143	M11	15.6	24	33.1	6.9	10.1	20.8	4	20	5	12.2	5	30	8	2	0	-9	-9
62151	M21	8.5	18	20.4	5.8	7.4	16.7	4	16	4	12.0	4	34	9	1	2	5	0
62152	M21	7.1	13	20.8	7.0	5.9	15.3	3	18	4	10.6	4	27	8	1	0	-9	-9
62153	M21	10.5	18	28.4	7.6	8.3	17.3	4	21	5	11.9	4	34	8	1	2	1	-9
62161	M31	10.0	17	27.1	7.8	7.1	16.9	4	19	5	12.6	5	37	10	1	2	3	-9
62162	M31	12.0	16	30.6	8.0	7.4	16.1	3	27	5	13.7	4	40	9	1	2	2	-9
62163	M31	13.3	22	33.2	8.2	6.4	21.1	3	20	5	12.9	4	36	10	1	0	-9	-9
62241	M12	10.1	16	23.2	4.2	6.6	12.6	4	21	5	13.7	6	37	9	2	2	1	-9
62242	M12	11.2	21	24.1	4.1	6.8	9.9	3	15	5	12.1	4	32	9	1	2	2	-9
62243	M12	7.7	12	23.9	3.0	5.4	8.9	3	22	5	13.9	6	36	11	1	0	-9	-9
62251	M22	11.3	20	30.3	6.8	7.4	17.8	4	18	4	12.0	5	34	9	1	0	-9	-9
62252	M22	11.9	21	30.2	8.4	9.1	21.3	4	15	4	12.3	5	36	10	1	2	3	-9
62253	M22	8.5	17	27.0	5.3	5.0	10.4	3	18	5	11.3	4	30	10	1	0	-9	-9
62261	M32	11.0	21	27.7	7.8	9.1	16.4	3	14	5	11.7	4	31	9	1	2	2	-9
62262	M32	14.2	24	33.6	9.5	10.6	20.3	3	18	6	13.2	5	34	11	1	0	-9	-9
62263	M32	13.2	23	32.5	9.5	13.8	28.5	4	19	5	12.0	6	34	11	1	0	-9	-9
63171	F11	11.8	19	31.6	8.9	8.1	22.1	4	18	5	12.9	5	37	10	1	0	-9	-9
63172	F11	9.2	14	24.4	9.6	5.6	14.6	3	24	4	11.1	4	30	9	1	2	1	-9
63173	F11	13.9	21	36.4	7.3	9.4	14.2	3	23	5	12.7	5	35	10	1	2	2	-9
63181	F21	9.8	20	27.4	7.1	7.9	19.1	4	14	5	10.8	4	29	9	2	0	-9	-9
63182	F21	7.9	19	22.5	6.6	6.3	17.5	4	14	6	10.3	4	28	8	1	2	4	-9
63183	F21	7.0	12	18.0	6.5	5.2	11.4	3	18	5	10.8	3	30	8	1	0	-9	-9
63191	F31	9.0	18	22.8	7.9	6.7	17.7	3	12	5	9.9	3	26	9	1	0	-9	-9
63192	F31	10.9	19	31.8	9.8	7.6	18.0	3	20	5	11.8	4	35	9	1	2	4	0
63193	F31	11.4	20	29.0	8.1	8.9	21.1	4	18	5	11.9	5	32	9	1	0	-9	-9
63271	F12	12.7	20	40.6	3.3	7.1	9.7	3	23	5	13.1	5	34	9	2	0	-9	-9
63272	F12	9.8	17	28.2	6.9	5.8	13.3	3	20	5	12.0	5	35	9	1	2	2	-9
63273	F12	11.0	21	36.2	9.6	7.3	17.5	3	16	5	11.8	5	29	9	1	0	-9	-9
63281	F22	13.2	22	41.4	10.8	9.9	23.4	4	22	5	13.8	5	43	11	1	1	7	0
63282	F22	13.4	22	42.7	10.9	8.7	21.6	3	19	5	12.2	5	34	11	1	2	2	-9
63283	F22	9.8	18	34.0	9.8	8.9	22.4	4	18	6	14.1	6	39	10	1	1	4	-9
63291	F32	11.0	15	34.1	6.5	6.3	12.1	2	24	5	12.5	5	38	11	1	0	-9	-9
63292	F32	8.6	15	21.6	5.0	6.3	11.0	3	19	4	11.8	5	33	11	2	2	2	-9
63293	F32	12.1	22	23.3	7.6	7.7	21.0	4	18	5	12.9	5	38	10	1	2	3	-9
71111	C11	9.0	11	36.8	12.5	8.4	18.5	3	29	6	16.1	7	21	12	5	0	-9	-9
71112	C11	11.9	10	27.7	12.8	8.5	28.1	4	46	6	14.3	5	27	12	2	0	-9	-9
71113	C11	8.5	12	17.9	10.3	8.5	15.5	2	28	7	12.0	5	23	11	2	0	-9	-9
71121	C21	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
71122	C21	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
71123	C21	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
71131	C31	10.1	11	35.6	15.2	8.5	28.2	3	34	4	12.3	4	26	10	2	0	-9	-9
71132	C31	14.4	12	43.3	17.4	9.6	28.2	2	44	5	15.9	6	27	12	2	0	-9	-9
71133	C31	11.6	11	40.3	18.8	10.1	31.7	3	35	5	13.2	5	27	12	2	0	-9	-9
71211	C12	4.5	6	14.7	10.3	5.6	26.2	3	28	1	10.3	4	21	6	2	0	-9	-9
71212	C12	10.5	12	32.9	12.7	8.1	30.5	3	31	7	12.9	6	21	12	4	0	-9	-9
71213	C12	7.1	11	25.9	12.3	6.0	22.1	3	24	5	10.1	4	22	9	2	0	-9	-9
71221	C22	11.3	16	24.8	11.1	8.9	32.4	4	24	5	13.0	5	25	15	3	0	-9	-9
71222	C22	11.9	11	32.9	11.5	7.7	20.2	2	40	5	14.7	6	23	8	2	0	-9	-9
71223	C22	8.5	9	38.6	14.8	8.5	28.7	4	36	5	13.4	6	26	14	2	0	-9	-9
71231	C32	10.3	13	33.7	12.6	6.6	37.7	3	29	5	12.3	5	24	13	5	0	-9	-9
71232	C32	12.0	13	36.6	15.5	8.9	29.2	3	32	7	12.7	5	24	12	2	0	-9	-9

Table 24--Continued

Index	Plot	Character																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
71233	C32	9.0	10	32.7	15.4	8.2	30.8	3	33	7	13.7	6	24	13	1	2	1	-9
72141	M11	7.9	11	26.7	14.4	6.7	29.3	3	28	5	11.1	3	20	10	3	0	-9	-9
72142	M11	10.2	9	37.9	15.8	6.9	22.8	2	39	7	15.2	6	24	8	2	0	-9	-9
72143	M11	6.8	7	27.7	16.9	6.4	28.4	3	39	5	15.2	6	26	14	4	0	-9	-9
72151	M21	7.7	11	28.8	17.0	7.8	26.6	2	27	6	12.8	5	25	11	3	0	-9	-9
72152	M21	4.8	7	18.2	10.5	6.8	23.7	3	29	6	11.0	4	22	10	2	0	-9	-9
72153	M21	7.2	7	30.2	13.7	5.8	18.7	2	41	5	13.0	5	20	13	2	0	-9	-9
72161	M31	10.1	14	36.7	14.3	10.4	31.0	3	26	4	14.0	6	23	13	4	0	-9	-9
72162	M31	10.5	13	32.0	16.7	9.0	31.4	3	30	5	11.4	4	23	13	4	0	-9	-9
72163	M31	3.7	5	18.3	13.8	6.3	33.3	3	31	1	10.0	3	16	11	5	0	-9	-9
72241	M12	10.0	12	32.5	16.3	8.9	26.2	2	29	4	14.5	5	27	12	1	0	-9	-9
72242	M12	9.0	10	31.5	10.4	7.6	22.1	4	31	6	13.6	5	22	14	2	0	-9	-9
72243	M12	8.3	9	29.3	11.6	9.1	26.8	3	35	6	14.9	5	27	13	2	0	-9	-9
72251	M22	10.1	10	38.2	16.3	8.4	24.4	2	39	5	14.4	6	23	7	2	0	-9	-9
72252	M22	7.6	7	40.5	15.5	7.3	24.3	3	39	7	14.2	4	29	10	2	0	-9	-9
72253	M22	9.0	11	36.7	16.4	9.7	32.0	3	32	4	15.0	6	27	15	2	0	-9	-9
72261	M32	7.8	11	22.1	8.7	5.7	20.7	4	24	4	11.2	4	21	11	4	0	-9	-9
72262	M32	8.3	10	30.9	11.8	7.5	21.2	3	28	5	11.7	5	23	10	1	0	-9	-9
72263	M32	7.6	9	23.4	10.4	9.2	29.3	4	33	7	14.0	5	27	11	2	0	-9	-9
73171	F11	13.8	15	41.7	16.0	10.5	27.5	3	14	5	14.9	6	26	11	2	0	-9	-9
73172	F11	9.6	12	28.1	12.1	8.2	26.0	3	30	5	12.2	5	21	11	5	0	-9	-9
73173	F11	7.3	7	28.9	14.9	6.0	13.1	3	40	6	13.9	5	21	11	3	0	-9	-9
73181	F21	8.4	12	30.9	13.1	8.8	18.8	2	26	4	11.1	5	21	13	2	0	-9	-9
73182	F21	4.4	6	25.0	14.2	6.8	25.2	3	29	6	10.5	3	21	11	2	0	-9	-9
73183	F21	8.7	12	36.7	14.8	8.0	20.8	2	28	5	13.5	6	29	12	2	2	3	-9
73191	F31	9.5	14	34.4	14.6	9.6	31.3	3	23	5	12.1	5	20	12	5	0	-9	-9
73192	F31	6.2	7	25.3	14.1	6.2	23.0	3	38	7	11.2	5	18	11	5	0	-9	-9
73193	F31	7.0	9	22.7	12.8	6.7	26.7	4	32	7	12.0	5	18	11	3	0	-9	-9
73271	F12	9.3	10	31.3	11.8	7.3	21.8	3	33	6	12.1	5	21	12	3	0	-9	-9
73272	F12	11.1	13	36.3	16.8	9.4	33.3	4	31	6	15.4	6	27	12	2	0	-9	-9
73273	F12	1.7	3	18.5	10.9	8.0	21.2	3	27	6	13.0	6	19	11	5	0	-9	-9
73281	F22	13.3	10	46.8	17.4	11.1	9.5	2	47	5	21.2	8	31	12	2	0	-9	-9
73282	F22	10.3	10	28.0	11.4	8.8	23.7	3	37	6	14.4	6	27	14	1	0	-9	-9
73283	F22	18.7	12	52.9	15.9	10.9	29.3	3	53	6	21.4	9	32	13	2	0	-9	-9
73291	F32	9.3	9	35.8	18.4	9.5	38.9	4	39	5	16.1	7	21	13	4	0	-9	-9
73292	F32	6.4	8	31.8	16.8	8.2	32.2	3	28	6	14.1	6	22	13	6	0	-9	-9
73293	F32	7.6	10	19.1	11.8	6.8	22.7	3	30	6	15.9	6	21	13	2	0	-9	-9

Table 25. Measurements of morphological characteristics of 7 Agropyron species; characters 18-33. A key to species, treatments, characters, and missing data (-8, -9) appears in Table 26.

Index	Plot	Characters															
		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
11111	C11	3	4	1	8	0	7.6	1	5	1	19	8.6	10	1	5	1	-9
11112	C11	3	1	1	9	0	8.1	1	5	1	17	8.2	10	1	1	3	-9
11113	C11	4	3	1	7	0	7.6	2	1	1	22	8.0	9	1	-9	3	-9
11121	C21	4	3	1	8	0	6.9	2	2	1	20	5.7	10	5	0	3	-9
11122	C21	3	2	1	6	0	8.1	1	1	1	21	6.7	19	1	2	2	-9
11123	C21	3	5	1	7	0	8.3	1	5	1	22	7.3	9	7	-9	1	-9
11131	C31	3	2	1	6	0	7.4	1	5	1	16	5.2	10	13	2	2	-9
11132	C31	2	2	1	10	2	8.0	1	8	1	14	5.9	10	1	-8	2	-9
11133	C31	3	1	1	9	0	8.2	1	8	1	19	8.5	10	1	1	2	-9
11211	C12	4	1	1	9	0	8.3	1	5	1	26	12.4	10	1	-9	2	-9
11212	C12	2	2	1	9	0	7.8	1	7	1	23	9.2	9	1	1	3	-9
11213	C12	3	2	1	7	0	7.7	1	5	1	20	9.0	10	6	-8	3	-9
11221	C22	3	3	1	11	0	8.6	1	5	1	29	13.2	10	1	1	3	-9
11222	C22	4	1	1	12	0	9.6	1	1	1	26	10.0	9	1	2	2	-9
11223	C22	3	4	1	9	0	8.9	1	1	1	22	10.3	10	1	2	3	-9
11231	C32	4	4	1	10	0	8.9	1	5	1	25	10.9	10	1	-9	2	-9
11232	C32	2	1	1	8	0	8.3	1	5	1	16	7.6	10	6	1	2	-9
11233	C32	3	2	1	8	0	8.9	1	5	1	15	5.7	10	8	1	2	-9
12141	M11	2	2	1	10	0	7.4	1	1	1	17	7.2	10	5	1	2	-9
12142	M11	1	1	1	4	0	6.6	1	5	1	23	7.4	10	1	3	2	-9
12143	M11	4	4	1	8	0	7.9	2	5	7	20	-8	10	1	-8	2	-9
12151	M21	1	2	1	9	2	7.0	1	5	1	13	6.5	10	1	2	1	-9
12152	M21	2	3	1	6	2	7.2	1	4	1	20	6.5	10	5	2	2	-9
12153	M21	3	3	1	9	0	8.5	2	1	1	20	7.2	10	1	1	3	-9
12161	M31	2	2	1	11	0	8.8	1	5	1	22	9.7	16	1	-9	3	-9
12162	M31	2	2	1	6	0	7.9	3	5	1	23	7.3	10	1	-8	2	-9
12163	M31	4	6	1	8	0	7.7	1	5	1	15	7.4	10	1	2	2	-9
12241	M12	2	2	1	10	0	8.2	1	5	1	18	9.0	10	1	2	3	-9
12242	M12	3	2	1	10	0	8.2	1	6	1	16	7.7	10	1	4	1	-9
12243	M12	3	1	1	10	0	8.9	1	1	1	22	9.7	10	1	3	3	-9
12251	M22	1	1	1	8	0	7.6	1	5	1	26	10.0	10	1	2	2	-9
12252	M22	3	1	1	7	0	8.2	1	5	1	22	9.2	10	1	-9	2	-9
12253	M22	3	5	1	9	0	9.4	2	5	1	-8	-8	-8	-8	-8	2	-9
12261	M32	4	2	1	10	0	9.2	1	1	1	27	11.3	10	1	-8	3	-9
12262	M32	3	2	1	7	0	7.2	1	7	1	22	9.0	10	1	3	2	-9
12263	M32	4	1	1	10	0	9.1	1	1	1	31	-8	10	1	1	3	-9
13171	F11	5	5	1	9	0	8.4	4	1	1	16	8.6	10	2	2	2	-9
13172	F11	2	4	1	8	0	8.1	3	1	1	24	9.9	10	1	2	3	-9
13173	F11	3	2	1	8	0	8.2	3	1	1	24	7.5	9	1	-9	2	-9
13181	F21	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
13182	F21	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
13183	F21	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
13191	F31	3	5	1	6	0	8.0	1	5	1	19	7.9	10	11	1	2	-9
13192	F31	3	1	1	7	0	8.5	1	5	1	22	8.7	16	2	1	3	-9
13193	F31	4	5	1	9	0	10.2	3	7	1	21	8.8	16	1	-9	2	-9
13271	F12	1	3	1	8	2	7.9	1	2	1	19	7.1	10	2	-9	1	-9
13272	F12	4	3	1	8	0	8.5	1	6	1	22	10.2	10	1	4	2	-9
13273	F12	3	3	1	5	0	6.8	2	5	1	12	5.2	19	13	-9	1	-9
13281	F22	4	1	1	11	0	8.9	1	5	1	16	6.9	10	1	2	3	-9
13282	F22	2	1	1	9	0	7.7	1	19	1	22	8.1	16	1	4	3	-9
13283	F22	3	5	1	5	0	9.0	3	1	1	26	10.2	10	1	-9	2	-9
13291	F32	3	2	1	9	0	8.7	1	5	1	15	7.2	9	1	3	2	-9
13292	F32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
13293	F32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
21111	C11	3	2	0	-9	-9	9.3	5	5	1	11	4.5	6	1	5	2	-9
21112	C11	3	3	2	2	-9	9.9	5	6	1	12	8.6	6	5	3	2	-9

Table 25--Continued

Index	Plot	Characters															
		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
21113	C11	3	2	0	-9	-9	7.3	3	5	1	9	3.7	6	1	2	3	-9
21121	C21	3	1	2	1	-9	7.9	5	5	1	12	4.3	1	1	-9	1	-9
21122	C21	3	5	0	-9	-9	8.9	1	7	1	12	3.5	5	1	4	2	-9
21123	C21	3	3	0	-9	-9	8.0	3	8	1	11	3.7	6	1	6	2	1
21131	C31	3	1	0	-9	-9	8.1	1	1	1	10	5.0	6	1	2	1	2
21132	C31	4	7	0	-9	-9	8.1	9	7	1	9	3.0	5	1	5	1	-9
21133	C31	4	5	0	-9	-9	8.8	7	8	1	10	6.0	3	1	3	2	-9
21211	C12	3	1	2	3	0	9.1	5	6	1	9	3.5	19	1	1	2	-9
21212	C12	4	5	2	1	-9	7.1	4	1	1	9	3.4	5	1	3	2	-9
21213	C12	4	1	0	-9	-9	6.9	3	1	1	12	4.9	5	1	4	1	2
21221	C22	3	5	1	4	0	8.6	6	4	1	8	3.8	6	1	1	2	1
21222	C22	3	5	2	3	-9	9.0	7	1	1	15	3.8	19	1	-9	2	-9
21223	C22	3	1	0	-9	-9	7.2	1	1	1	12	7.9	2	1	5	2	1
21231	C32	3	1	0	-9	-9	7.1	1	5	1	7	4.1	6	1	2	2	-9
21232	C32	2	5	0	-9	-9	8.2	6	5	1	10	5.6	4	1	2	2	2
21233	C32	3	2	2	1	-9	7.7	1	8	1	10	6.1	2	1	5	3	2
22141	M11	3	4	0	-9	-9	6.6	1	6	1	8	3.3	2	1	5	2	-9
22142	M11	3	1	0	-9	-9	6.5	5	8	1	10	4.4	5	1	4	2	-9
22143	M11	3	3	0	-9	-9	8.9	3	8	1	10	6.6	5	1	2	2	-9
22151	M21	3	1	0	-9	-9	9.1	1	1	1	9	4.7	5	1	-9	1	1
22152	M21	3	2	2	1	-9	8.4	3	5	1	10	5.4	20	1	4	3	2
22153	M21	4	2	0	-9	-9	8.7	1	8	1	12	5.0	2	1	7	2	3
22161	M31	4	5	0	-9	-9	6.4	1	5	1	14	7.3	5	1	4	3	2
22162	M31	2	1	1	4	0	8.6	5	5	1	8	5.0	5	1	6	2	-9
22163	M31	3	3	2	2	-9	8.7	3	5	1	9	4.6	6	1	3	2	1
22241	M12	3	5	2	1	-9	8.8	6	5	1	11	4.0	3	1	4	2	-9
22242	M12	3	5	0	-9	-9	7.1	7	5	1	9	4.1	6	1	3	2	-9
22243	M12	3	1	2	3	-9	8.8	1	8	1	9	3.7	5	1	3	2	2
22251	M22	3	2	0	-9	-9	8.0	2	5	1	13	5.6	6	6	5	3	-8
22252	M22	3	1	2	2	-9	8.0	3	14	1	9	2.7	6	1	2	2	2
22253	M22	3	5	0	-9	-9	8.3	6	7	1	10	2.9	5	1	3	2	-9
22261	M32	3	3	1	3	0	9.5	1	5	1	11	5.6	4	1	4	2	3
22262	M32	4	5	2	1	-9	8.6	7	5	1	10	4.9	6	1	-9	2	-9
22263	M32	3	3	2	2	-9	8.5	4	5	1	15	6.9	6	1	8	3	-9
23171	F11	2	1	0	-9	-9	8.0	2	5	1	9	2.8	6	1	2	2	2
23172	F11	3	5	1	19	1	13.0	5	1	1	8	2.4	5	1	-9	2	3
23173	F11	3	5	0	-9	-9	8.7	7	5	1	8	3.3	6	1	1	2	1
23181	F21	5	5	0	-9	-9	7.8	7	1	1	15	4.9	6	1	3	2	2
23182	F21	3	1	0	-9	-9	7.9	1	4	1	10	3.4	6	1	3	3	1
23183	F21	4	1	0	-9	-9	9.0	1	7	1	12	4.1	6	1	-8	1	1
23191	F31	3	2	0	-9	-9	6.5	1	5	1	9	4.2	5	1	6	1	-9
23192	F31	3	5	0	-9	-9	7.7	7	5	1	8	3.3	6	1	4	1	3
23193	F31	3	2	0	-9	-9	8.3	7	8	1	9	5.0	3	1	3	2	1
23271	F12	3	6	0	-9	-9	8.1	7	5	1	12	6.1	5	5	3	1	5
23272	F12	3	4	0	-9	-9	7.9	7	1	1	8	4.5	4	1	6	2	3
23273	F12	4	2	0	-9	-9	9.0	5	8	1	11	4.4	5	1	2	2	2
23281	F22	3	5	2	2	-9	8.7	5	7	1	9	2.9	2	1	3	2	-9
23282	F22	3	7	2	2	-9	9.0	8	8	1	11	8.7	5	1	5	2	5
23283	F22	3	1	0	-9	-9	8.3	7	7	1	11	6.3	7	1	5	2	2
23291	F32	4	4	2	-8	-9	8.1	5	1	1	11	4.0	5	1	3	2	-9
23292	F32	-8	3	2	2	-9	6.9	1	1	1	8	3.7	6	1	2	2	1
23293	F32	3	4	0	-9	-9	9.4	1	5	1	12	6.2	5	1	4	3	2
31111	C11	4	1	0	-9	-9	9.9	1	5	1	7	9.5	10	1	2	3	-9
31112	C11	4	1	0	-9	-9	10.8	1	5	1	13	7.3	17	1	1	2	-9
31113	C11	5	1	2	3	-9	10.6	1	1	1	14	9.9	16	1	-8	2	-9
31121	C21	4	1	0	-9	-9	9.8	1	1	1	7	6.9	16	1	-9	2	-9
31122	C21	5	1	0	-9	-9	8.8	1	5	1	10	7.6	19	1	-9	2	-9
31123	C21	3	2	0	-9	-9	9.8	1	5	1	9	9.1	8	1	1	2	-9
31131	C31	4	1	0	-9	-9	8.4	1	1	1	6	8.0	8	1	-9	2	-9
31132	C31	4	1	0	-9	-9	10.1	1	1	1	7	8.6	19	1	2	2	-9

Table 25--Continued

Index	Plot	Characters															
		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
31133	C31	5	1	0	-9	-9	9.8	1	1	1	8	7.7	19	1	-9	2	-9
31211	C12	4	1	0	-9	-9	8.2	1	5	1	12	7.0	17	1	1	2	-9
31212	C12	4	2	0	-9	-9	8.3	1	1	1	7	8.0	17	1	1	-9	-9
31213	C12	3	3	0	-9	-9	8.3	1	5	1	7	8.7	19	2	1	2	-9
31221	C22	3	1	2	1	-9	9.8	1	1	1	6	7.9	19	1	1	3	-9
31222	C22	3	1	0	-9	-9	9.4	1	1	1	9	6.7	16	3	2	2	-9
31223	C22	4	1	0	-9	-9	10.3	1	1	1	8	8.5	17	1	1	3	-9
31231	C32	4	1	0	-9	-9	8.7	1	1	1	8	7.2	16	3	-9	2	-9
31232	C32	5	1	0	-9	-9	10.4	1	1	1	7	5.1	10	1	1	2	-9
31233	C32	4	1	0	-9	-9	8.0	1	1	1	10	8.7	17	1	2	3	-9
32141	M11	3	1	1	2	0	8.8	1	1	1	4	2.1	17	1	2	1	-9
32142	M11	4	1	0	-9	-9	9.1	1	1	1	9	11.2	17	1	2	4	-9
32143	M11	3	1	2	2	-9	9.4	1	1	1	9	7.7	17	1	1	2	-9
32151	M21	4	1	0	-9	-9	9.9	1	1	1	6	8.2	16	1	-9	1	-9
32152	M21	5	1	0	-9	-9	9.7	1	1	1	10	9.7	19	1	-9	3	-9
32153	M21	3	1	0	-9	-9	8.3	3	2	1	7	9.4	8	1	1	1	-9
32161	M31	4	1	2	1	-9	8.7	1	7	1	8	6.3	16	1	-9	2	-9
32162	M31	5	1	0	-9	-9	8.9	1	5	1	7	6.4	16	1	1	2	-9
32163	M31	5	1	0	-9	-9	8.2	1	1	1	6	9.5	17	1	-9	3	-9
32241	M12	4	1	2	2	-9	10.4	1	1	1	7	9.6	17	1	-9	3	-9
32242	M12	4	1	0	-9	-9	8.7	1	1	1	6	7.0	17	1	0	2	-9
32243	M12	6	1	0	-9	-9	11.1	1	5	1	11	8.4	8	1	3	2	-9
32251	M22	5	1	2	2	-9	9.8	1	5	1	7	11.2	16	1	3	3	-9
32252	M22	5	1	2	1	-9	8.7	1	1	1	8	7.7	19	1	-9	2	-9
32253	M22	5	1	0	-9	-9	10.2	1	1	1	8	9.3	19	1	-9	1	-9
32261	M32	6	1	0	-9	-9	9.7	1	1	1	8	8.1	8	1	3	3	-9
32262	M32	5	3	0	-9	-9	9.9	1	8	1	7	8.8	17	1	-9	3	-9
32263	M32	6	1	0	-9	-9	10.0	1	6	1	9	9.8	8	1	1	3	-9
33171	F11	4	1	0	-9	-9	10.3	1	1	1	11	9.9	16	1	2	3	-9
33172	F11	4	3	0	-9	-9	7.7	1	1	1	7	4.9	17	1	-9	2	-9
33173	F11	4	1	2	2	-9	9.8	1	2	1	7	7.8	17	1	-9	1	-9
33181	F21	4	1	0	-9	-9	9.2	1	1	1	12	4.9	16	1	-9	2	-9
33182	F21	5	1	0	-9	-9	7.3	1	1	1	5	6.2	17	1	-9	2	-9
33183	F21	4	1	0	-9	-9	8.4	1	3	1	7	5.6	16	1	1	2	-9
33191	F31	4	1	0	-9	-9	9.8	1	1	1	6	5.8	16	1	-9	2	-9
33192	F31	4	1	2	1	-9	8.9	1	1	1	6	7.5	16	1	1	1	-9
33193	F31	3	2	0	-9	-9	7.4	1	5	1	6	4.6	19	1	0	1	-9
33271	F12	5	1	2	1	-9	9.4	1	1	1	8	8.8	17	1	1	3	-9
33272	F12	5	2	0	-9	-9	9.9	1	1	1	7	6.6	17	1	-9	2	-9
33273	F12	5	1	0	-9	-9	8.6	1	1	1	6	6.1	16	1	1	2	-9
33281	F22	4	1	2	3	-9	10.6	1	5	1	7	7.5	19	1	1	3	-9
33282	F22	5	1	2	1	-9	10.6	1	1	1	8	6.5	19	1	-9	2	-9
33283	F22	5	1	0	-9	-9	10.6	1	5	1	8	8.3	16	1	-9	3	-9
33291	F32	6	1	0	-9	-9	9.1	1	1	1	8	6.0	19	1	3	3	-9
33292	F32	5	1	2	2	-9	9.7	1	1	1	6	7.8	16	1	-9	2	-9
33293	F32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
41111	C11	3	1	2	2	-9	10.1	1	3	1	10	5.1	6	1	2	3	-9
41112	C11	2	1	0	-9	-9	7.1	1	1	1	8	3.7	2	1	2	2	1
41113	C11	3	4	2	1	-9	8.1	5	7	1	10	4.8	19	1	2	2	3
41121	C21	3	1	1	15	1	12.4	1	1	1	9	4.2	1	1	3	2	1
41122	C21	3	1	2	1	-9	7.0	3	8	1	9	2.6	6	1	3	2	-9
41123	C21	3	3	0	-9	-9	10.1	4	1	1	-8	-8	-8	-8	4	3	2
41131	C31	3	3	1	3	0	8.4	6	1	1	9	3.6	6	1	3	2	3
41132	C31	3	5	0	-9	-9	9.0	5	8	1	9	5.2	6	1	3	3	-9
41133	C31	3	3	1	5	0	9.8	5	3	1	11	4.4	5	1	6	2	-9
41211	C12	3	3	2	3	-9	7.4	3	1	1	6	-9	1	1	-9	-9	-9
41212	C12	3	1	0	-9	-9	7.9	3	6	1	9	4.0	7	3	1	2	1
41213	C12	4	6	1	8	0	10.7	7	1	1	9	5.6	2	1	2	2	3
41221	C22	3	1	2	1	-9	10.2	3	5	1	13	10.5	5	1	2	3	2
41222	C22	3	3	0	-9	-9	8.8	6	5	1	9	5.9	5	2	3	2	2

Table 25--Continued

Index	Plot	Characters															
		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
41223	C22	3	5	2	2	-9	8.1	20	5	1	8	3.5	6	1	2	2	2
41231	C32	3	5	2	3	-9	9.0	7	5	1	9	4.9	20	1	2	2	5
41232	C32	3	6	2	1	-9	6.2	8	5	1	7	3.4	6	1	1	1	3
41233	C32	3	5	2	2	-9	7.9	5	1	1	8	4.2	5	1	1	2	-9
42141	M11	3	4	2	1	-9	7.6	4	5	1	9	5.7	6	1	5	3	2
42142	M11	3	1	1	27	1	16.4	5	1	1	9	5.7	5	1	3	2	6
42143	M11	3	5	2	1	-9	7.9	5	8	1	9	4.1	6	1	5	2	-9
42151	M21	3	1	1	5	0	10.7	5	6	1	14	8.7	3	1	1	3	-9
42152	M21	3	2	2	1	-9	8.8	3	8	1	10	5.3	6	3	3	3	1
42153	M21	3	3	2	1	-9	7.1	1	7	1	6	2.0	5	1	1	2	2
42161	M31	3	3	2	2	-9	8.4	6	5	1	11	3.4	5	1	4	2	3
42162	M31	3	2	0	-9	-9	9.2	5	1	1	9	4.1	7	1	3	2	2
42163	M31	5	1	0	-9	-9	8.3	1	5	1	12	5.0	2	1	7	2	1
42241	M12	3	5	2	2	-9	8.8	8	6	1	15	4.5	19	1	6	2	-9
42242	M12	3	5	1	4	0	10.9	5	5	1	9	6.4	5	5	3	3	3
42243	M12	5	2	1	4	0	10.2	1	5	1	12	5.1	6	1	6	3	2
42251	M22	3	3	0	-9	-9	7.5	1	2	1	10	4.5	5	1	2	2	-8
42252	M22	3	3	2	2	-9	8.0	5	1	1	7	2.3	6	1	1	2	2
42253	M22	3	1	0	-9	-9	8.3	1	8	1	12	4.6	6	1	2	3	3
42261	M32	3	1	1	8	0	8.7	2	1	1	7	3.4	4	1	1	2	1
42262	M32	3	3	2	2	-9	8.8	5	1	1	9	4.5	5	1	1	3	1
42263	M32	3	4	0	-9	-9	8.2	5	5	1	7	4.1	3	1	-9	3	-9
43171	F11	4	4	2	2	-9	8.9	7	1	1	11	6.7	1	1	-9	2	2
43172	F11	3	3	2	2	-9	11.6	3	1	1	13	6.9	5	1	3	3	1
43173	F11	3	2	2	2	-9	10.6	1	11	1	14	7.8	3	1	7	3	4
43181	F21	4	2	2	2	-9	8.9	1	1	1	9	4.2	6	1	-9	2	4
43182	F21	4	1	1	7	0	9.2	1	1	1	-8	-8	5	1	3	2	3
43183	F21	4	5	0	-9	-9	9.1	5	5	1	8	-8	6	1	-9	2	-9
43191	F31	3	5	2	1	-9	8.7	1	1	1	10	4.3	4	2	2	2	-9
43192	F31	3	7	1	24	2	14.7	7	6	1	11	4.8	8	1	2	2	-9
43193	F31	4	3	0	-9	-9	8.2	3	5	1	9	5.0	3	1	2	2	2
43271	F12	3	5	0	-9	-9	8.0	2	1	1	14	3.2	6	1	2	2	3
43272	F12	3	1	0	-9	-9	7.1	1	1	1	9	3.6	5	1	2	2	-9
43273	F12	3	1	0	-9	-9	7.7	3	8	1	10	4.2	6	1	5	2	2
43281	F22	3	3	0	-9	-9	8.2	3	5	1	10	6.7	6	1	8	3	2
43282	F22	4	1	2	4	-9	10.3	1	1	1	10	6.2	2	1	1	3	3
43283	F22	5	3	2	1	-9	10.0	5	6	1	11	8.1	3	1	4	3	-9
43291	F32	3	1	1	9	1	10.8	5	1	1	8	4.2	8	1	2	2	-8
43292	F32	3	3	1	4	0	8.7	5	1	1	5	2.4	5	1	3	2	2
43293	F32	3	3	1	9	0	10.1	3	1	1	9	3.4	5	1	2	2	3
51111	C11	3	3	1	5	0	12.1	2	8	2	16	8.7	3	1	7	4	1
51112	C11	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
51113	C11	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
51121	C21	4	5	2	2	-9	10.8	5	1	1	16	4.6	5	1	1	3	2
51122	C21	3	1	1	6	0	10.6	1	7	1	10	6.1	1	1	1	1	-9
51123	C21	4	5	2	2	-9	10.3	5	5	6	14	9.6	3	1	7	3	4
51131	C31	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
51132	C31	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
51133	C31	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
51211	C12	4	1	2	2	-9	10.9	1	5	1	13	6.0	2	1	4	2	5
51212	C12	4	6	1	5	0	10.6	5	5	1	14	7.5	2	1	3	3	4
51213	C12	4	5	2	2	-9	13.0	7	1	1	18	10.4	5	1	7	4	5
51221	C22	3	2	2	3	-9	11.1	1	1	1	18	8.7	5	1	2	3	-9
51222	C22	3	2	2	3	-9	11.0	2	5	1	15	7.4	3	1	2	3	2
51223	C22	4	3	1	7	0	12.6	2	1	1	13	8.0	5	1	5	2	4
51231	C32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
51232	C32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
51233	C32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
52141	M11	4	4	2	3	-9	11.9	1	9	1	16	9.6	9	1	4	2	1
52142	M11	3	2	0	-9	-9	9.3	3	-8	1	12	6.6	5	1	4	2	-8

Table 25--Continued

Index Plot	Characters																
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	
52143 M11	3	3	1	4	0	12.3	2	5	1	15	7.9	3	1	5	3	-9	
52151 M21	3	3	1	6	0	14.0	1	1	1	17	11.0	3	2	5	2	-9	
52152 M21	4	3	2	3	-9	12.0	1	1	1	13	6.1	3	1	3	2	2	
52153 M21	4	1	1	5	0	13.0	1	2	1	19	12.7	2	1	2	2	5	
52161 M31	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	
52162 M31	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	
52163 M31	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	
52241 M12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	
52242 M12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	
52243 M12	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	
52251 M22	4	2	2	6	0	11.8	1	1	1	11	10.7	5	1	4	3	1	
52252 M22	6	2	2	3	-9	13.3	1	1	8	18	11.5	4	1	1	3	5	
52253 M22	4	1	2	3	-9	10.3	1	5	1	15	7.6	4	1	2	2	5	
52261 M32	5	3	2	5	-9	12.0	1	1	1	13	7.4	5	1	4	1	-9	
52262 M32	4	1	2	3	0	11.0	1	6	1	21	10.8	2	1	4	4	2	
52263 M32	5	2	2	3	-9	12.7	3	1	1	16	10.1	3	1	4	2	5	
53171 F11	7	5	1	4	-9	11.5	4	1	1	16	8.8	4	1	2	2	4	
53172 F11	4	5	2	4	-9	13.0	1	6	1	12	8.8	3	1	4	2	2	
53173 F11	5	1	2	4	-9	12.1	1	5	1	16	10.3	3	1	5	1	2	
53181 F21	3	3	1	4	0	11.9	1	6	1	12	5.7	5	1	3	2	3	
53182 F21	4	7	1	4	0	11.4	7	8	1	15	10.4	4	1	5	2	3	
53183 F21	5	1	2	3	-9	11.3	1	1	1	14	13.2	2	1	6	2	3	
53191 F31	5	3	1	7	0	10.4	1	5	1	10	4.1	4	1	2	3	4	
53192 F31	4	3	1	8	0	11.7	1	1	1	10	4.9	3	1	4	2	1	
53193 F31	5	1	1	9	0	12.3	1	5	1	13	7.2	3	1	4	2	4	
53271 F12	4	4	2	3	-9	10.9	1	5	1	12	6.0	4	1	2	2	-9	
53272 F12	4	1	1	5	0	12.7	1	1	1	20	8.2	1	1	6	3	1	
53273 F12	4	3	2	2	-9	11.8	2	8	1	13	8.2	4	1	3	3	1	
53281 F22	4	1	1	5	0	12.8	1	5	1	16	7.2	5	2	4	3	1	
53282 F22	3	2	1	6	0	13.0	1	3	1	15	9.2	4	1	3	3	3	
53283 F22	4	3	1	6	0	13.0	1	1	1	14	7.5	5	1	3	3	5	
53291 F32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	
53292 F32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	
53293 F32	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	
61111 C11	6	1	1	3	0	11.0	1	1	1	25	10.7	2	1	2	4	-9	
61112 C11	6	5	2	3	-9	9.8	1	1	1	21	9.5	2	1	1	4	-9	
61113 C11	4	1	1	10	0	3.0	2	1	1	19	9.9	2	1	3	6	-9	
61121 C21	5	1	2	4	-9	12.6	1	1	1	25	12.3	2	1	4	4	-9	
61122 C21	5	5	1	5	0	11.7	1	5	1	17	9.5	2	1	-9	6	-9	
61123 C21	5	2	2	3	-9	10.6	2	1	1	16	8.2	3	1	3	6	-9	
61131 C31	4	2	1	4	0	11.2	1	1	1	15	8.8	4	1	3	4	-9	
61132 C31	5	2	2	2	-9	12.0	2	1	1	16	10.3	2	2	2	5	-9	
61133 C31	3	2	2	3	-9	10.4	3	1	1	19	8.1	2	1	-8	5	-9	
61211 C12	5	2	2	2	-9	9.9	1	6	1	19	12.3	2	1	2	4	-9	
61212 C12	5	4	1	3	0	9.6	1	1	1	22	9.7	2	1	2	5	-9	
61213 C12	4	3	1	4	0	10.9	3	1	1	19	11.4	2	1	-8	4	-9	
61221 C22	4	2	2	3	0	10.4	1	1	1	19	10.4	2	1	-9	4	-9	
61222 C22	4	2	2	3	-9	10.6	1	1	1	21	11.0	2	1	2	5	-9	
61223 C22	4	3	1	4	0	9.6	4	1	1	20	9.1	3	1	-9	3	-9	
61231 C32	5	1	1	5	0	9.9	1	5	1	16	8.1	1	1	3	3	-9	
61232 C32	5	3	1	4	0	9.9	1	6	1	14	8.5	3	1	3	5	-9	
61233 C32	5	3	1	4	0	10.6	3	1	1	14	8.8	2	1	1	4	-9	
62141 M11	3	3	2	2	-9	10.5	1	5	1	16	8.4	2	1	2	5	-9	
62142 M11	4	3	0	-9	-9	9.2	1	1	1	17	9.2	1	1	-9	4	-9	
62143 M11	4	1	2	2	-9	10.0	3	3	1	19	8.9	1	1	-8	4	-9	
62151 M21	6	3	1	3	0	10.8	1	1	1	14	7.5	1	1	3	4	-9	
62152 M21	3	2	1	4	1	9.4	4	1	1	14	6.9	3	1	3	3	-9	
62153 M21	5	2	2	1	-9	9.8	2	1	1	16	10.3	3	1	4	4	-9	
62161 M31	4	2	2	1	-9	9.8	2	1	1	14	9.2	3	1	2	3	-9	
62162 M31	3	2	2	3	-9	11.2	1	1	1	15	8.9	2	2	2	6	-9	

Table 25--Continued

Index Plot	Characters															
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
62163 M31	4	3	2	3	-9	10.4	5	1	1	20	8.7	3	1	3	7	-9
62241 M12	5	3	1	6	0	11.5	1	1	1	9	10.7	2	1	1	4	-9
62242 M12	5	3	1	4	0	10.1	1	1	1	17	10.2	3	1	1	3	-9
62243 M12	3	5	2	3	-9	10.5	1	1	1	17	6.6	1	1	2	4	-9
62251 M22	3	3	2	3	-9	9.8	1	5	1	19	8.4	3	1	2	5	-9
62252 M22	5	1	0	-9	-9	9.5	1	1	1	19	10.8	1	1	-9	3	-9
62253 M22	3	5	0	-9	-9	9.3	5	1	1	17	3.0	2	1	-8	4	-9
62261 M32	5	2	1	4	0	9.9	1	1	1	19	11.0	3	1	4	4	-9
62262 M32	6	4	1	2	-9	9.8	2	1	1	25	11.0	1	1	2	5	-9
62263 M32	5	1	2	2	-9	9.9	3	1	1	21	8.0	1	1	2	5	-9
63171 F11	5	4	1	6	0	11.1	1	1	1	18	8.6	3	1	4	3	-9
63172 F11	4	3	1	4	0	10.0	3	1	1	14	7.2	2	1	2	4	-9
63173 F11	4	5	2	3	-9	10.5	1	1	1	18	13.0	2	1	2	4	-9
63181 F21	5	2	2	3	-9	9.4	2	1	1	16	7.5	2	1	3	3	-9
63182 F21	3	2	1	5	0	9.5	1	1	1	15	6.1	2	1	3	4	-9
63183 F21	3	4	1	3	0	9.8	3	3	1	16	7.2	3	1	2	4	-9
63191 F31	3	2	2	2	-9	8.7	2	1	1	18	8.0	2	1	1	4	-9
63192 F31	5	1	1	6	0	10.6	4	1	1	19	9.4	2	1	2	3	-9
63193 F31	4	4	1	4	0	9.9	3	1	1	18	9.2	3	1	-9	5	-9
63271 F12	3	3	2	1	0	10.9	2	1	1	14	6.7	2	1	2	4	-9
63272 F12	5	2	2	2	-9	10.0	1	1	1	15	5.9	1	1	3	5	-9
63273 F12	3	3	0	-9	-9	9.1	1	2	1	14	8.7	2	1	2	3	-9
63281 F22	6	1	1	5	0	11.8	1	1	1	19	11.1	1	1	2	4	-9
63282 F22	6	3	0	-9	-9	9.5	1	1	1	18	9.4	1	1	-8	4	-9
63283 F22	4	3	2	3	-9	10.9	2	1	1	18	8.7	2	1	1	5	-9
63291 F32	4	1	1	5	0	10.9	1	1	1	16	10.0	3	1	4	4	-9
63292 F32	5	3	2	3	-9	9.9	2	1	1	16	7.1	2	1	3	5	-9
63293 F32	5	3	2	3	-9	11.7	1	1	1	16	8.6	2	1	4	4	-9
71111 C11	5	7	0	-9	-9	8.9	6	4	3	29	12.2	14	1	6	3	-9
71112 C11	7	6	0	-9	-9	9.2	7	1	3	21	8.8	12	5	2	2	-9
71113 C11	5	5	0	-9	-9	8.2	1	5	13	26	12.8	16	7	5	3	-9
71121 C21	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
71122 C21	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
71123 C21	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8
71131 C31	5	6	0	-9	-9	9.7	7	1	2	22	10.8	13	1	4	2	-9
71132 C31	5	6	0	-9	-9	10.2	6	1	2	27	14.4	14	13	3	4	-9
71133 C31	7	1	2	1	-9	9.7	1	1	2	26	11.9	13	1	-9	3	-9
71211 C12	5	1	2	2	0	8.8	1	1	2	17	8.6	6	1	1	3	-9
71212 C12	6	7	2	2	-9	8.6	7	1	2	24	10.3	10	12	-9	3	-9
71213 C12	5	6	0	-9	-9	8.1	6	1	3	17	9.3	13	13	4	2	-9
71221 C22	6	3	2	2	-9	9.0	1	1	1	30	11.1	13	1	-9	3	-9
71222 C22	7	7	2	1	-9	8.6	6	8	2	24	8.6	6	1	5	3	-9
71223 C22	5	1	0	-9	-9	8.7	1	1	2	25	14.1	14	13	3	2	-9
71231 C32	5	1	2	2	-9	9.1	1	13	2	20	9.8	14	1	8	3	-9
71232 C32	7	7	0	-9	-9	9.2	7	1	2	21	10.6	13	13	3	3	-9
71233 C32	5	4	2	2	-9	9.4	2	1	3	29	9.5	14	13	-8	2	-9
72141 M11	6	7	0	-9	-9	8.0	7	1	2	19	8.8	14	1	8	3	-9
72142 M11	5	3	0	-9	-9	8.9	1	3	3	24	11.0	16	13	-8	2	-9
72143 M11	5	1	2	2	-9	9.8	1	1	2	21	7.4	16	13	5	2	-9
72151 M21	5	7	0	-9	-9	8.4	7	2	2	22	11.8	14	13	1	3	-9
72152 M21	5	7	2	3	-9	9.8	7	5	3	21	10.0	13	13	4	3	-9
72153 M21	7	7	0	-9	-9	9.0	7	5	2	25	9.9	10	10	5	2	-9
72161 M31	5	1	0	-9	-9	8.7	1	1	3	25	11.5	10	13	-9	2	-9
72162 M31	6	1	2	1	-9	8.6	1	1	3	23	10.1	10	1	-8	2	-9
72163 M31	3	1	0	-9	-9	8.1	1	5	1	15	8.2	17	5	-8	2	-9
72241 M12	6	1	0	-9	-9	10.0	1	1	3	22	12.0	13	1	6	3	-9
72242 M12	6	5	0	-9	-9	9.0	1	1	3	13	8.4	13	14	6	3	-9

Table 25--Continued

Index	Plot	Characters															
		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
72243	M12	5	6	0	-9	-9	9.8	5	1	2	24	10.5	14	13	-8	1	-9
72251	M22	7	2	0	-9	-9	8.4	1	3	2	24	10.7	14	13	6	2	-9
72252	M22	5	7	0	-9	-9	10.1	7	5	3	23	13.3	13	13	7	3	-9
72253	M22	5	2	0	-9	-9	9.3	1	1	1	24	11.7	1	1	-8	3	-9
72261	M32	5	1	0	-9	-9	8.1	1	1	2	23	9.7	13	1	2	1	-9
72262	M32	5	5	2	2	-9	8.9	6	1	3	19	15.5	10	1	5	2	-9
72263	M32	6	6	2	3	-9	10.4	7	1	2	23	12.1	13	13	6	3	-9
73171	F11	5	3	0	-9	-9	9.4	1	1	2	28	12.8	14	1	5	3	-9
73172	F11	5	2	0	-9	-9	8.1	1	5	2	20	8.5	13	1	1	2	-9
73173	F11	5	2	0	-9	-9	8.9	1	1	3	16	6.2	14	13	-9	2	-9
73181	F21	6	1	2	1	-9	8.3	1	1	1	24	9.5	6	1	9	3	-9
73182	F21	6	7	2	2	-9	8.6	7	1	2	20	9.2	10	1	1	2	-9
73183	F21	5	6	1	4	0	10.1	6	13	2	27	8.4	6	13	12	2	-9
73191	F31	5	1	0	-9	-9	8.2	1	1	1	20	10.6	10	1	7	2	-9
73192	F31	5	1	0	-9	-9	7.6	1	1	3	18	8.2	13	1	3	3	-9
73193	F31	5	7	0	-9	-9	8.1	7	3	3	19	7.4	12	1	6	2	-9
73271	F12	5	7	0	-9	-9	9.0	1	1	2	23	10.9	14	1	-9	2	-9
73272	F12	5	2	0	-9	-9	9.6	2	1	1	23	6.4	14	1	2	2	-9
73273	F12	5	1	0	-9	-9	8.6	1	1	3	19	10.2	14	13	-8	2	-9
73281	F22	6	3	0	-9	-9	11.1	1	1	3	28	12.3	6	13	4	3	-9
73282	F22	6	5	2	2	-9	9.7	1	1	3	25	10.5	11	1	5	2	-9
73283	F22	5	2	2	3	-9	11.3	1	1	3	31	16.8	13	1	4	3	-9
73291	F32	5	7	0	-9	-9	8.8	7	1	2	25	9.3	13	1	2	2	-9
73292	F32	7	4	0	-9	-9	9.9	1	1	1	19	12.4	1	1	3	3	-9
73293	F32	5	1	0	-9	-9	9.1	1	1	3	22	9.3	14	13	2	2	-9

Table 26. Key to index numbers, plot numbers, morphological characters, and missing data referred to in Tables 24, 25, and 27.

Index: Each plant has a unique index code consisting of 5 numbers which indicate (in order); 1) Species: 1-Agropyron cristatum, 2-A. dasystachyum, 3-A. inerme, 4-A. riparium, 5-A. smithii, 6-A. trachycaulum, 7-A. trichophorum, 2) Texture treatment (1-coarse, 2-medium, 3-fine), 3) Salt treatment (1-no salt added, 2-salt added), 4) Soil number for 3 representative soils in each textural treatment (coarse 1-3, medium 4-6, fine 7-9), and 5) Plant number (1-3).

Plot: A 3-character label which indicates only the texture (C-coarse, M-medium, F-fine), salt (1 or 2), and the soil number within that texture (1-3).

Characters: (1-33)

1. Length of rachis (cm).
2. Number of spikelets (count).
3. Inflorescence length; from spathe leaf node to tip of rachis (cm).
4. Length of culm internode; uppermost internode, terminating at the spathe leaf node (cm).
5. Leaf sheath length; measured on the leaf just below the spathe leaf (cm).
6. Height to the spathe leaf node; from the base of the culm (cm).
7. Number of elongated internodes (count).
8. Length of rachis internode; measured on the middle internode of the rachis (count of .28 mm grid squares).
9. Rachis indument (ranked: 1-glabrous 3-scabrate 5-scabrous 7-hispid 8-pubescent 9-pilose).
10. Length of spikelet; measured on the middle spikelet of the rachis, or the spikelet just below the central internode (mm).
11. Number of florets; of the spikelet in #10 (count).
12. Glume length; of the first glume of the spikelet in #10 (count of .28 mm grid squares).
13. Glume width (count of .19 mm grid squares).
14. Shape of apex of glume (ranked, 1- acuminate 2-acute 3-obtuse 4-cuspidate 5-rounded 6-truncate).
15. Presence of glume awn (0-unawned, 1-awned, 2-awn-tipped).
16. Length of awn of glume (count of .19 mm grid squares).
17. Divergence of glume awn (0-not divergent 1-divergent 2-slightly divergent).
18. No. of nerves in glume (count).

Table 26--Continued

-
19. Indument on nerves of glume (rank, 1-glabrous or papillate 3-scabrate 5-scabrous 7-hispid 8-pubescent 9-pilose).

Characters 20-24 were measured on the lowermost floret on the spikelet in #10.

20. Presence of lemma awn (0-unawned 1-awned 2-awn-tipped).
 21. Length of lemma awn (count of .28 mm grid squares).
 22. Divergence of lemma awn (0-not divergent 1-divergent 2-slightly divergent).
 23. Lemma length (mm).
 24. Indument of lemma (rank, same as for glumes, #19).
 25. Indument of sheath bases (ranked, 1-glabrous 3-scabrate 5-scabrous 7-hispid 8-pubescent 9-pilose).
 26. Indument of throat (1-glabrous, 2-hispid or pilose, 3-hirsute or ciliate).
 27. Leaf blade width; measured on the leaf just beneath the spathe leaf (count of .28 mm grid squares).
 28. Leaf blade length, of the leaf in #27 (cm).
 29. Indument of upper surface of leaf blade (rank, 1-glabrous 3-scabrate 5-scabrous 6-puberulent 8-pubescent 10-pilose 11-pubescent to hispid 12-pilose to hispid 13-hispid 14-hispid and scabrous 15-hispid and puberulent 16-pilose and puberulent 17-pilose and pubescent 18-pilose and scabrous 19-pubescent and puberulent 20-pubescent and scabrous).
 30. Indument on undersurface of leaf blade (ranked as in #29).
 31. Length of longest auricle (count of .19 mm grid squares).
 32. Length of ligule (count of .19 mm grid squares).
 33. Rhizome abundance (ranked, relative to the size of the plant: 1-barely in evidence 3-several, well-developed 5-abundant and well-developed).

Missing Data:

In all cases -8=missing and -9=not applicable

Table 27. Sample sizes for morphological measurements. Each entry is the number of plants on which characters were measured in the treatment given.

<u>Treatment</u>		<u>Species</u>						
		AGCR	AGDA	AGIN	AGRI	AGSM	AGTRA	AGTRI
Coarse	1, ns	3	3	3	3	1	3	3
	2, ns	3	3	3	3	3	3	0
	3, ns	3	3	3	3	0	3	3
	1, s	3	3	3	3	3	3	3
	2, s	3	3	3	3	3	3	3
	3, s	3	3	3	3	0	3	3
Medium	1, ns	3	3	3	3	3	3	3
	2, ns	3	3	3	3	3	3	3
	3, ns	3	3	3	3	0	3	3
	1, s	3	3	3	3	0	3	3
	2, s	3	3	3	3	3	3	3
	3, s	3	3	3	3	3	3	3
Fine	1, ns	3	3	3	3	3	3	3
	2, ns	0	3	3	3	3	3	3
	3, ns	3	3	3	3	3	3	3
	1, s	3	3	3	3	3	3	3
	2, s	3	3	3	3	3	3	3
	3, s	1	3	2	3	0	3	3

MONTANA STATE UNIVERSITY LIBRARIES
stks N378.L617 RL
Effects of soil texture and salinity on

3 1762 00514481 9

Main
N378
L617
con.2