Identification of intermediate wheatgrass (Agropyron intermedium [Host] Beauv.) and pubescent wheatgrass (Agropyron trichophorum [Link] Richt.) based on fourteen morphological characteristics of the seed head

by Louis Willard Harper

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Agronomy

Montana State University

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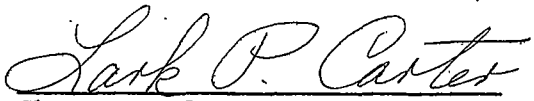

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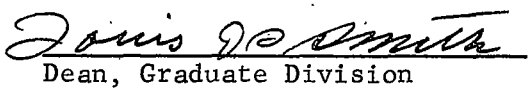

Dean, Graduate Division

MONTANA STATE COLLEGE
Bozeman, Montana

June, 1964

ACKNOWLEDGMENT

The author wishes to express sincere thanks to Dr. L. P. Carter for his advice, constructive criticism, and encouragement throughout the course of this study.

Special thanks to Mr. Dan Niffenegger for his help and advice and for materials used in this study.

The author also wishes to thank Mr. R. F. Eslick and Dr. Glenn Ingram for their assistance with the statistical analysis, and to thank Mr. Jim Johnson for his drawing of a wheatgrass spike.

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ABSTRACT

A study was initiated to determine means of distinguishing between intermediate wheatgrass (Agropyron intermedium (Host.) Beauv.) and pubescent wheatgrass (Agropyron trichophorum (Link) Richt.). Morphological characteristics of the plant spikes were studied. Presence or absence of awns, pubescence, and ergot were recorded. Stems were checked to see if they were hollow or solid. Number of florets per spikelet, number of spikelets per head, glume shape, length of spikelet, internode length and spike length were also measured. In analysis of variance significant differences between intermediate wheatgrass and pubescent wheatgrass were obtained for the following characteristics: number of spikelets per head, percent ergot, glume shape, internode length, rate of occurrance of pubescent-type heads, and degree of pubescence on the rachis and glume. Spike length was significantly different between intermediate wheatgrass and pubescent wheatgrass when adjusted by covariance to a constant number of spikelets per head.

INTRODUCTION

The identification of intermediate wheatgrass and pubescent wheatgrass seeds creates a problem for the experienced seed analyst as well as the beginner. Since intermediate wheatgrass and pubescent wheatgrass are listed as two distinct species in the Federal Seed Act, it is mandatory that they be separated when found in seed samples.

Intermediate wheatgrass and pubescent wheatgrass are noted for their late maturity. Their growth continues for two or three weeks longer than most other grasses grown in the same region of adaptation. The large seeds produce robust, somewhat coarse plants remarkably free from disease (4)(21).

Intermediate wheatgrass is a mild sod former. It is easy to establish, has excellent seedling vigor, and gives a dense leafy growth the first year. Its root system is fibrous, vigorous and produces short rhizomes. The stems are strong and are resistant to lodging. Smith states that although the plants have a low percentage of self-fertility, intermediate wheatgrass is a good seed producer (18). This implies that a high percentage of cross fertilization occurs.

Pubescent wheatgrass is also a mild sod former and produces short rhizomes. It is similar to intermediate wheatgrass in growth habits, seasonal development, and cultural requirements. It differs from intermediate wheatgrass in being reported as better adapted to low fertility soils, alkaline soils, low rainfall areas, and high elevations. Seedling vigor is good and it is easy to establish. It has a low percentage of self-fertilization.

Seeds of pubescent wheatgrass and intermediate wheatgrass are very similar in appearance. With presently available seed keys and descriptions, it is difficult to separate and identify seeds of the two species.

The purpose of this study was to provide ground work for further investigation of intermediate wheatgrass (Agropyron intermedium) and pubescent wheatgrass (Agropyron trichophorum). The ultimate goal is to devise a probability table or a numerical rating key based on seed, seedling, mature plant and/or spike characteristics that could be used to distinguish intermediate wheatgrass from pubescent wheatgrass.

A second purpose of this study was to investigate the premise that intermediate wheatgrass and pubescent wheatgrass are two different species, and to determine if species differentiation is justifiable.

REVIEW OF LITERATURE

Morphological characteristics of the grasses have been studied by many workers (1)(2)(3)(5)(6)(8)(9)(10)(13)(14). It is the opinion of some authors that many of the Agropyrons have been incorrectly named and identified (16)(19). Peto (16) reports that this may be due to the wide range of variability existing within the species and also the large number of intergrading types that occur between these species. Sometimes this variability is not reported and in other cases the intermediate types have been classified as distinct species. Peto further reports that evidence of hybridity has been found in many native and introduced species of Agropyron. This hybridization is not restricted to species of the same chromosome number, but it can occur between species with different chromosome numbers.

The taxonomic status of A. intermedium, A. trichophorum, and A. elongatum, according to Musil (11) (12), is not very clear. Particularly indeterminable are those species passing under the name A. intermedium. Indications are that European specimens of A. trichophorum were considered by early botanists as a variety of A. intermedium. The National Grass Herbarium considers these to be distinct species.

Musil (11) in examining seed lots of Ree Wheatgrass found that these seed lots contained two distinct types of seeds, suggesting a mixture of species or the possible presence of hybrids. The predominating type was A. intermedium. The other type comprising 15 to 35 percent of the bulk seed was intermediate in character between A. intermedium and A. trichophorum.

Nevski (14) divides the tribe Hordeae into eight genera and two subgenera. He places the true wheatgrasses in the genus Agropyron subgenus Elytrigia (Desv). The following is a brief general description of the true wheatgrass as described by Nevski.

> "Spikes always straight, with solitary spikelets. Spikelets 3-11 flowered, entirely sessile, awnless, or less commonly awned; awns short and straight, less commonly long and reflexed. Glumes lanceolate, linear lanceolate or oblong, nerves (3) 6-11, closely spaced, smooth (only the midnerve sometimes scaberulous in the upper part), less commonly glumes softly hirsute; lemma lanceolate, with 5 nerves converging or almost converging in the upper part, glabrous, or less commonly hirsute at the base, with a shallow cross furrow and shortened small glabrous callus. Lodicules cilate on the margins are hirsute in the upper part. Florets often sterile. Ripe spikelets sometimes drop off entire with glumes. Anthers long (5.6) 4-7 (8) mm, longer than half the palea. Caryopsis oblong, hirsute, in the upper part, with a deep groove inside. Plants perennial, with long creeping rhizomes or densely caespitose, with or without short stolons. Blade convolute, less commonly flat, hirsute, scabrous on the upper surface, usually smooth glaucescent or glaucous on the lower surface."

Nevski's botanical description of Agropyron intermedium and Agropyron trichophorum are listed in Table I. As shown in Table I the main feature for distinguishing the two species is by the pubescence.

Swallen (19) reports that due to the increased interest in grass and grasslands a number of species have been introduced from Russia and Siberia to the United States. Some of these plant introductions have remained unidentified and others have been incorrectly named. Intermediate wheatgrass and pubescent wheatgrass were introduced in the United States during the late 1920's and early 1930's. Other introductions of these two species have been made from time to time since the original introductions.

Table I. Nevski's Botanical description of intermediate wheatgrass (Agropyron intermedium) and pubescent wheatgrass (Agropyron trichophorum). 1/

Plant Characteristics:	Agropyron intermedium	Agropyron trichophorum
Life cycle	Perennial	Perennial
Culms	60-100 cm Glabrous, smooth	60-100 cm Glabrous
Leaf characteristics:		
Sheaths	Ciliate on margins	Lower leaves hirsute (Less commonly glabrous) Ciliate on margins
Blades	Flat .3-.7 cm wide	Flat .3-.7 cm wide
Upper surface	Long-hirsute (hairs sparce) or glabrous, scabrous	Villous and scabrous
Lower surface	Smooth or scabrous only in upper half	Sharply scabrous and sometimes hirsute
Spike characteristics:		
Spikes	Straight, fairly rare 10-20 cm long	Fairly rare 10-20 cm long
Rachis	Scabrous on 2 main angles	More or less hirsute
Spikelets	1-1.6 cm long 3-5 (6) flowered	Densely hirsute .9-1.8 cm long (3) 4-7 flowered
Glumes	Oblong or oblong-lanceolate, obtuse at apex somewhat obliquely truncate .5-.8 cm long, 2-3 mm wide shorter at lower florets 5-7 nerved; smooth glabrous	Oblong-lanceolate obtuse or obtuse-acuminate, obliquely truncate but not so broad as A. intermedium. Hirsute slightly unequal .5-.9 cm long 2-2.5 mm wide 5-7 nerved
Lemma	Broad-lanceolate .8-1 cm long somewhat obtuse glabrous	Hirsute with large white hairs in upper part of margins glabrous in lower part of back (.7) .8-1.2 cm long somewhat obtuse

Table I. Continued

Characteristic	Agropyron intermedium	Agropyron trichophorum
Palea	Almost equal to lemma	Slightly shorter than lemma long-ciliate on keels
Anther	5-6.5 mm long	Up to 8 mm long

Glossary

Acuminate- Tapering gradually at the end, or apex; taper-pointed.

Ciliate- Hair fringed; provided with eyelashlike hairs on the edge.

Glabrous- Devoid of hairs or pubescence.

Hirsute- Hairy with rather coarse, stiffish, straight, beardlike hairs.

Keel- A grass glume or lemma when more or less compressed and boat-like, with its midrib projecting.

Lanceolate- Lance shaped; several times longer than broad and tapering from the relatively narrow base to the apex.

Oblique- Unequal sided; slanting.

Oblong- About two to four times longer than broad, and with the sides, though gently rounded, approximately parallel.

Obtuse- Blunt or rounded at the tip; not sharply pointed.

Scabrous- Rough or harsh to the touch.

Truncate- Squared at the tip; terminating abrubtly as if cut off crosswise.

Villous- Shaggy; beset with long, soft weak hairs.

1/ Nevski, S. A. Description of Agropyron species. In Komarov: Flora U.S.S.R., (English translation by Vera Turin, 1940). 1934.

Hanson (5) reports ten varieties of intermediate wheatgrass. Of these varieties, nine have as their origin the plant introduction number of P.I.98568. A wide range of variability occurs between these nine varieties. They range from awnless to awned; pubescent to glabrous; green to blue-green color; and some varieties exhibit all of the before-mentioned characteristics within their population. Amur is another variety of intermediate wheatgrass listed by Hanson. It was received as P.I. 131532 under the name Agropyron amurense. Four varieties of pubescent wheatgrass are listed by Hanson (5). Here again a wide range of plant characteristics exist. They are green to blue-green in color, and many plants intergrade taxonomically and appear to be closely related to intermediate wheatgrass.

Niffenegger and Davis (15) reported the rate of occurrence of pubescent-type seeds in pubescent wheatgrass and intermediate wheatgrass. They found marked differences in the percentage of pubescent-type seeds in different samples of the two species Table II. Although the average percent of pubescent-type seeds was higher for pubescent wheatgrass than for intermediate wheatgrass, the variation among samples of the same species was quite high.

Table II. The occurrence of pubescent-type seeds in commercial seed lots of pubescent wheatgrass and intermediate wheatgrass.

Percentage classes of pubescent-type seeds present per sample	Kind of seed	
	Intermediate Wheatgrass	Pubescent Wheatgrass
% by number	% of Samples 1/	% of Samples 2/
0	9	0
1-10	70	0
11-20	13	0
21-30	8	7
31-70	0	7
71-80	0	14
81-90	0	51
91-99	0	21
100	0	0

1/ 67 Samples examined
2/ 14 Samples examined

Lawrence (10) determined the correlations between seventeen plant characteristics. His results suggest that linkage relationships are few. Forage and seed yields were positively correlated, indicating that selection for one will not likely reduce the other. The data suggest that rated values as indicators of yield might be justified, and that non-agronomic characteristics, foliage color and leaf pubescence, could be useful as variety identification markers.

Cytological Investigations

Several workers have been interested in the chromosome number of the wheatgrasses as an aid in identifying the various species within the genus Agropyron (6)(7)(9)(16)(18)(20).

The number of chromosomes in intermediate wheatgrass is generally reported to be 42. Hartung (7) reported observing 42 and 43 chromosomes in some intermediate wheatgrass material. Hanson (6) cites Khiznak who observed 28 chromosomes in intermediate wheatgrass. Hanson and Hartung (6)(7) reported that pubescent wheatgrass has a chromosome number of 42.

The cytological investigations show promise as an aid in identifying and classifying various species.

Inter-Specific Hybridization

Information concerning the inter-specific hybridization occurring between plants of intermediate wheatgrass and pubescent wheatgrass is limited. However, these wheatgrasses have been used quite extensively in a program which is directed toward the development of a perennial wheat.

Valvilov (20) points out that cytological work conducted by Vakar indicated some species of Agropyron are related more readily to the genus Triticum than to the genus Agropyron.

Musil (11) and Peto (16) give the impression that inter-specific hybridization is regularly occurring among these grasses. This in part could account for the wide variations among the wheatgrass species. Chromosomal variations as well as taxonomic intergradation between species could be partly due to inter-specific hybridization.

MATERIALS AND METHODS

The Montana Grain Inspection Laboratory, Bozeman, Montana, received 169 lots of intermediate wheatgrass and 11 lots of pubescent wheatgrass seed samples for germination and purity analysis from July, 1959 to July, 1961. The seeds were planted to determine if these seed samples were being identified correctly.

Two hundred rows of intermediate wheatgrass and ten rows of pubescent wheatgrass were planted in 20 foot rows in the spring of 1961. Each row represented a different seed lot. Approximately twelve seeds were planted per foot. Since wheatgrass does not produce seed the first year, little experimentally, was done in 1961 except for an occasional cultivation to curb the growth of weeds.

Late in the summer of 1962 the seed heads were harvested by hand. To prevent an excess of bulk, but still get a uniform representation of head types, 125-150 seed heads were gathered from each row. All pubescent wheatgrass rows were harvested. Due to the lack of available storage space only 37 rows of intermediate wheatgrass were harvested. Within these 37 rows, however, all of the various types and characteristics of intermediate wheatgrass appeared to be represented.

The seed heads were labeled and stored. One hundred heads were selected at random from the bulk portion of heads harvested for each row. Each selected head was examined individually under a seven power binocular microscope. Observable characteristics were recorded on a chart similar to the one in Table III.

Table III. Data collection sheet for intermediate wheatgrass and pubescent wheatgrass on plant head characteristics.

Row No._____

1. Pubescent or Non pubescent (100 heads examined)
   Yes_____ No_____
2. Awns present on florets, must be at least 1 mm long (100 heads examined)
   Pubescent Heads Yes_____ No_____
   Non pubescent Heads Yes_____ No_____
3. Stems hollow or solid (100 heads examined)

Hollow	Solid	
		Pubescent
		Non pubescent

4. Ergot present (100 heads examined)

Yes	No	
		Pubescent
		Non pubescent

10 Heads will be observed for each of the following characteristics

5. Average number of florets per spikelet-Start with 5th spikelet from the bottom-Count 4 spikelets per head.

	5	6	7	8	9	10	11	12	13	14	15
Pubescent											
Non pubescent											

6. Number of spikelets per head

	14	15	16	17	18	19	20	21	22	23
Pubescent										
Non pubescent										

7. Shape of the glumes and scores assigned

	1	2	3	4	5	6	7	8	9
Pubescent									
Non pubescent									

8. Length of spikelet-Measure 5th spikelet from the bottom-record in mm
   Pubescent
   Non pubescent
9. Length of internode-Measure 5th internode from bottom-record in mm
   Pubescent
   Non pubescent
10. Length of spike-Record length in mm
    Pubescent
    Non pubescent
11. If pubescent heads are present, degree of pubescence

Light	Moderate	Heavy

12. Location of pubescence- Yes or No (Head divided into thirds)

	Top 1/3	Middle 1/3	Bottom 1/3
Lemma			
Rachis			
Glume			

The data were processed at the Data Processing Center, Montana State College, Bozeman, Montana. The values for each observed characteristic were averaged for each row. This information was then punched on cards, one card for each row. For analytical purposes, each species was considered to have been made up of three populations.

Pubescent wheatgrass

Population A. Pubescent-type heads from rows containing only pubescent-type heads.

Population B. Pubescent-type heads from rows containing both pubescent-type and glabrous heads.

Population C. Glabrous heads from rows containing both pubescent-type and glabrous heads.

Intermediate wheatgrass

Population D. Glabrous heads from rows containing only glabrous heads.

Population E. Glabrous heads from rows containing both glabrous and pubescent-type heads.

Population F. Pubescent-type heads from rows containing both glabrous and pubescent-type heads.

An analysis of variance was made to determine if significant differences existed between species or among population means for the different characteristics.

An analysis of covariance was made to adjust the values for number of florets per spikelet, spikelet length, and spike length to the number of spikelets per head. The number of spikelets per head was considered the predetermining factor as to the number and size of each of the other characteristics. A sketch of a grass spike illustrating the plant parts which were observed is shown in Figure 1.

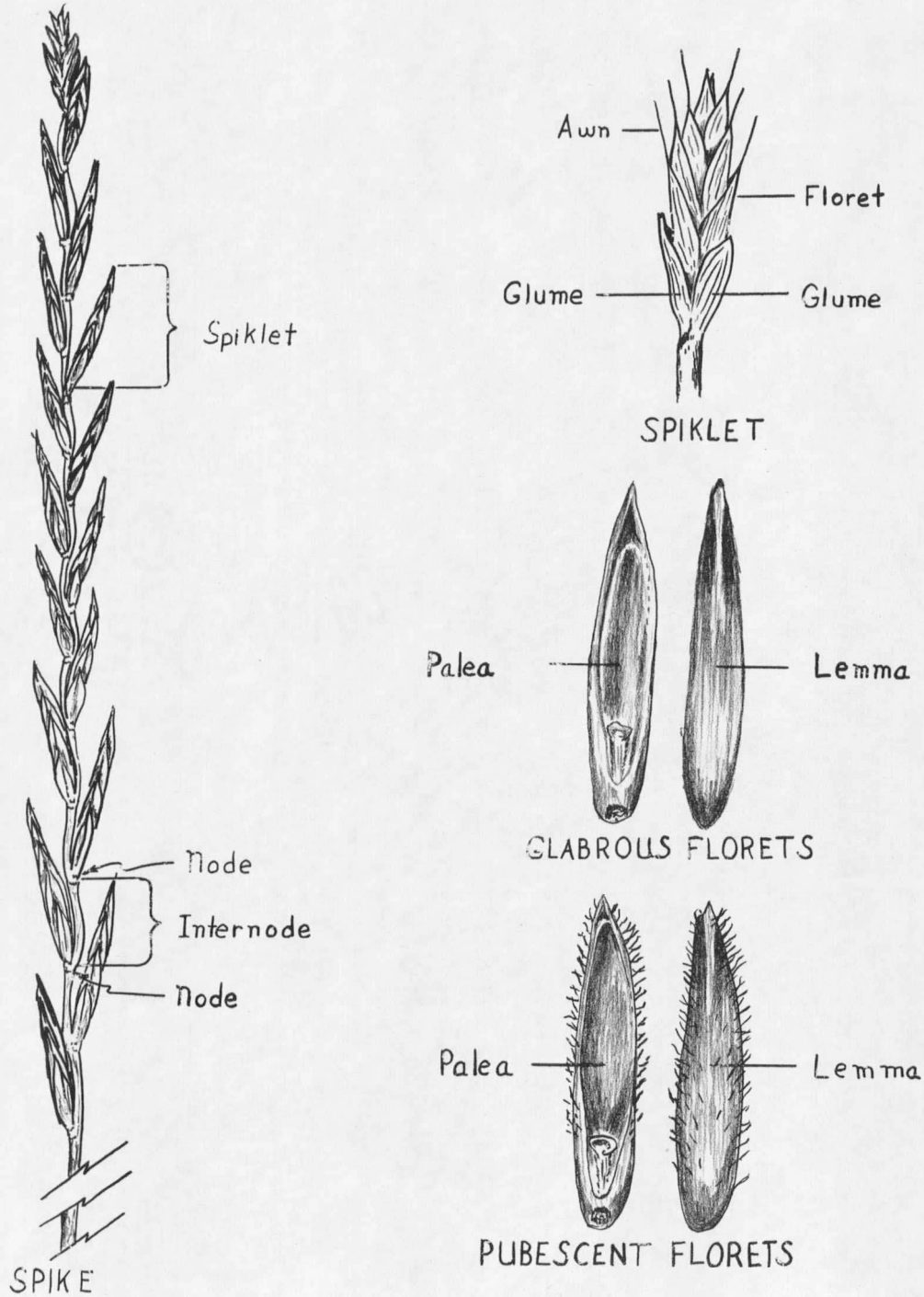

Fig. 1. Sketch of a grass spike illustrating the plant parts which were observed.

RESULTS AND DISCUSSION

Differences Between Species

Mean values for the nine characteristics measured among the six populations are given in Table IV.

The mean number of spikelets per head was significantly lower for pubescent wheatgrass than for intermediate wheatgrass. This indicates that the number of spikelets per head may be a useful characteristic for distinguishing the two species (Table IV). Mean values of the three pubescent wheatgrass populations were all lower than the lowest intermediate wheatgrass population value.

Ergot infected pubescent wheatgrass to a much greater extent than intermediate wheatgrass (Table IV). The amount of ergot averaged 50.44% for pubescent wheatgrass heads but only 1.95% for intermediate wheatgrass heads. From these results it appears that one method of distinguishing the two species would be to check for presence or absence of ergot in the seed head. A possible cause for pubescent wheatgrass having a higher infection percentage could have been due to the trapping of particles of water by the plant hairs enabling the ergot spores to grow more easily. This theory can be discounted, however, because the glabrous population from pubescent wheatgrass had a very high infection percentage also. Another possible cause could be that the flowers of pubescent wheatgrass remain open for a longer period of time enabling the spores to get into the flowers causing the infection. This could be related to pollen

Table IV. Average values for nine characteristics observed between pubescent wheatgrass and intermediate wheatgrass.

Species and Population 1/	Number of Rows	Mean No. of Spikelets per head	% Ergot	Glume Score 2/	Mean Internode Length	Mean Spike Length	% Awns	% Hollow Stems	Mean No. Florets per Spikelet	Mean Spikelet Length
Pubescent Wheatgrass										
Population A	1	16.30	68.00	6.70	14.50	228.00	38.00	33.00	7.20	18.00
Population B	9	17.08	50.66	5.42	14.15	224.00	21.66	67.22	7.35	18.03
Population C	9	18.50	50.22	5.44	12.05	211.22	7.33	49.77	7.41	18.40
Species Mean		17.79 **	50.44 **	5.43 **	13.10 **	217.61	14.50	58.50	7.38	18.22
Intermediate Wheatgrass										
Population D	17	19.96	2.17	3.64	11.13	212.47	39.05	63.41	7.24	18.72
Population E	20	20.55	0.95	3.05	11.11	214.70	19.25	59.75	7.51	18.91
Population F	20	19.70	2.95	3.55	11.28	206.65	30.15	46.80	7.10	17.92
Species Mean		20.12	1.95	3.30	11.20	210.69	24.90	53.27	7.31	18.41

1/ Population A. Pubescent-type heads from rows containing only pubescent-type heads
Population B. Pubescent-type heads from rows containing both pubescent-type and glabrous heads
Population C. Glabrous heads from rows containing both pubescent-type and glabrous heads
Population D. Glabrous heads from rows containing only glabrous heads
Population E. Glabrous heads from rows containing both glabrous and pubescent-type heads
Population F. Pubescent-type heads from rows containing both glabrous and pubescent-type heads

2/ High score indicates bluntness. Low score indicates pointedness.

* Significant at 5% level. Applies to comparison of species only.

** Significant at 1% level. Applies to comparison of species only.

availability and time of flowering. One other possible cause for high ergot infection percentage on pubescent wheatgrass could be due to growing location. The rows of pubescent wheatgrass were grown some distance from all but one of the rows of intermediate wheatgrass. The previous cropping for either plot is not known, but it is possible that the pubescent wheatgrass was grown in soil containing a large number of ergot sclerotia. The fact that the single row of intermediate wheatgrass growing in the pubescent wheatgrass area had no ergot, however, supports the conclusion that pubescent wheatgrass was more susceptible to the disease.

Glume shape has long been used as a characteristic in distinguishing different species of grasses. The glume shape is used in nearly all keys in the identification of grasses. If pubescent wheatgrass and intermediate wheatgrass are two distinct species, this could be one of the areas where significant differences might occur. A highly significant difference between species was noted for glume index score. To determine the glume index score, values of one through nine were assigned to the various glume shapes (Table III) which were found. The most pointed were given a value of one and the most blunt or rounded were given a value of nine. In-between variations were scored accordingly. The lowest values given in Table IV are for the populations of intermediate wheatgrass. The highest values are for the pubescent wheatgrass populations. It appears that glume shape may be a valuable aid in the identification of these two species. Intermediate wheatgrass tends to have more pointed glumes.

The mean internode length was longer in pubescent wheatgrass than in intermediate wheatgrass. The glabrous population of pubescent wheatgrass (Population C) had the shortest mean internode length of any of the pubescent wheatgrass populations, while the pubescent-type population of intermediate wheatgrass (Population F) had the longest mean internode length of the intermediate wheatgrass populations (Table III). Although variability was present within the populations of these two species, the variability did not overlap between the species, if one considers population averages only. Identification could be aided by using the mean internode length as a characteristic. Twelve mm. might be used as a breaking point. Any spike with an internode length longer than 12 mm. is more likely to be pubescent wheatgrass than intermediate wheatgrass. In intermediate wheatgrass, the mean internode length is more likely to be less than 12 mm.

The analysis of variance did not reveal any significant differences between species in mean spike length, percent awns, percent hollow stems, mean number of florets per spikelet, or mean spikelet length.

The validity of the quantitative measurements such as spikelets per head, florets per spikelet, spike length and internode length may be questioned due to different growing locations. Unmeasured factors, such as fertility may have contributed to the results. However, the results of the covariance analysis (described in a later section of this thesis) indicate that the differences between the species were real.

Differences Among Populations

Differences among glabrous populations (C, D, E) and among pubescent-type populations (A, B, F) were tested for significance. Results of these analyses are summarized in Table V.

Differences among pubescent-type populations were significant for mean number of spikelets per head, percent ergot, glume score, and mean internode length (Table V). These are the same four characteristics which were found to be significantly different between species (Table IV). It can be seen from Table V that differences among pubescent-type population means for these four characteristics can be accounted for as species differences. For all four characteristics, the high and low values among glabrous and among pubescent-type population means represent different species.

The same situation exists for the comparison of glabrous populations (Table V). Again the high and low values represent different species. In the case of the glabrous populations, however, mean number of spikelets per head and mean internode differences failed to reach significance.

A highly significant difference among the glabrous populations was found for the awned characteristic. Differences in percent awns were variable among pubescent-type populations but were not significant. According to Hanson (5), awnedness is a characteristic for which some intermediate wheatgrass and pubescent wheatgrass varieties have been selected. From the data in Table V it appears that Population C represents a different pubescent wheatgrass variety or varieties than Populations A or B.

Table V. Average values of nine characteristics observed within pubescent-type and glabrous populations of intermediate wheatgrass and pubescent wheatgrass.

Population 1/	Number of Rows	Mean No. of Spikelets per head	% Ergot	Glume Score 2/	Mean Internode Length	Mean Spike Length	% Awns	% Hollow Stems	Mean No. Florets per Spikelet	Mean Spikelet Length
Pubescent-type		*	**	*	**					
Population A	1	16.30	68.00	6.70	14.50	228.00	38.00	33.00	7.20	18.00
Population B	9	17.08	50.66	5.42	14.15	224.00	21.66	67.22	7.35	18.03
Population F	20	19.70	2.95	3.55	11.28	206.65	30.15	46.80	7.10	17.92
Glabrous			**	*			**			
Population C	9	18.50	50.22	5.44	12.05	211.22	7.33	49.77	7.41	18.40
Population D	17	19.96	2.17	3.64	11.13	212.47	39.05	63.41	7.24	18.72
Population E	20	20.55	00.95	3.05	11.11	214.70	19.25	59.75	7.51	18.91

1/ Population A. Heads from pubescent wheatgrass rows containing only pubescent-type heads.
Population B. Heads from pubescent wheatgrass rows containing both pubescent-type and glabrous heads.
Population F. Heads from intermediate wheatgrass rows containing both glabrous and pubescent-type heads.
Population C. Heads from pubescent wheatgrass rows containing both pubescent-type and glabrous heads.
Population D. Heads from intermediate wheatgrass rows containing only glabrous heads.
Population E. Heads from intermediate wheatgrass rows containing both glabrous and pubescent-type heads.

2/ High score indicates bluntness. Low scores indicate pointedness.

* Denotes significance at 5% level between high and low values.
** Denotes significance at 1% level between high and low values.

Correlation of Certain Plant Characteristics with Number of Spikelets per Head

The number of spikelets per head was hypothesized as being the measured characteristic which most affected florets per spikelet, spikelet length, internode length, and spike length. Regression analyses were made to test this hypothesis. As shown in Table VI florets per spikelet and spike length were correlated with spikelets per head. Spikelet length and internode length were not. This analysis indicates that with each additional spikelet, the spike acquires .0834 additional florets per spikelet and an added length of 7.652 mm. The relationship between spikelet length and spikelets per head approached significance, indicating that heads with more spikelets may tend to have spikelets slightly greater in length.

Table VI. Correlation coefficients, regression coefficients and F values for number of spikelets per head (X) with the factors (Y_1, Y_2, Y_3, Y_4) as determined by analysis of 71 paired values.

	Y_1 Florets per Spikelet	Y_2 Spikelet Length	Y_3 Internode Length	Y_4 Spike Length
Correlation Coefficient (r)	.793**	.668**	.056	.641**
Regression Coefficient (byx)	.0834	.1355	.0126	7.652
F value	4.6316*	3.2225	.0219	48.2042**

* Significant at the 5% level
** Significant at the 1% level

Use of Covariance for Adjusting Mean Values of 3 Plant Characteristics

Spikelets per head was an uncontrollable, but measurable, characteristic which was related to spike length, florets per spikelet, and possibly spikelet length (Table VI). An analysis of covariance was used to adjust mean values of these three characteristics to the mean number of spikelets per head and to test adjusted species differences for significance. Species differences for florets per spikelet and spikelet length were widened by the adjustment, but still showed no significance (Table VII). Spike length differences, however, were significant following adjustment. This indicates that spike length may be a useful characteristic for distinguishing pubescent wheatgrass and intermediate wheatgrass, provided that spikes containing a set number of spikelets per head are measured. It is suggested that this number be between 17 and 21.

The results of the analysis of covariance provide evidence that the differences shown in Tables IV and V were true species differences. If growing location had been the sole cause of the differences, one would expect to find no significant differences between species following adjustment of mean values to a constant number of spikelets per head. Since a significant difference did exist after adjustment, it is reasonable to conclude that the species did differ.

Table VII. Mean values of four characteristics adjusted for mean number of spikelets per head by analysis of covariance.

Characteristic	Adjusted or non-adjusted1/	Species		Mean Difference Between Species
		Pubescent Wheatgrass	Intermediate Wheatgrass	
Spike Length in mm	Non-adjusted	217.611	210.675	6.936
	Adjusted	231.002	206.929	24.073**
Number of Florets per Spikelet	Non-adjusted	7.383	7.307	.076
	Adjusted	7.532	7.237	.295
Spikelet Length in mm	Non-adjusted	18.216	18.415	-.199
	Adjusted	18.478	18.418	.060

1/ Pubescent wheatgrass and intermediate wheatgrass means were adjusted to 17.7157 and 20.0771 spikelets per head respectively.

** Significant at 1% level

Rate of Occurrence and Degree of Pubescence on Seed Heads

Intermediate wheatgrass and pubescent wheatgrass were observed for the rate of occurrence of pubescent-type heads. The method of scoring for degree of pubescence was: light pubescence= 1; moderate pubescence = 2; heavy pubescence = 3. The highest possible score was 15 (5 plants x score of 3 = 15).

Rate of occurrence of pubescent-type heads was greater for pubescent wheatgrass than for intermediate wheatgrass (Table VIII). The species averages of 65.20% for pubescent wheatgrass and 10.73% for intermediate wheatgrass compare fairly well with corresponding averages of 79.1% and 6.1% reported by Niffenegger and Davis (15) for pubescent-type seeds in commercial seed samples. They reported ranges of pubescent-type seeds of

30-95% in pubescent wheatgrass and 0-26% in intermediate wheatgrass seed samples. It would appear from the analyses of seed samples (15) and from the analyses of head samples (Table VIII) that rate of occurrence of pubescence, by itself, is not a reliable characteristic for distinguishing intermediate wheatgrass and pubescent wheatgrass.

Degree of pubescence was greater in pubescent wheatgrass than in intermediate wheatgrass (Table VIII). Population A and B of pubescent wheatgrass showed no difference in the degree of pubescence. Although this characteristic appears to be a valid one for distinguishing the two species, experience in using it is necessary before it can be used with confidence.

Table VIII. Rate of occurrence and degree of pubescence of pubescent-type heads in rows of pubescent wheatgrass and intermediate wheatgrass.

Population 1/	No. of Rows	Average rate of occurrence of pubescent-type heads		Scores for degree of pubescence of pubescent-type heads 2/
		%	Range	
Population A	1	100.00	--	10.00
Population B	9	61.33	20-98	10.33
Population F	20	19.85	1-68	7.90
Combined average for all pubescent wheatgrass populations	10	65.20	20-100	---
Combined average for intermediate wheatgrass population	37	10.73	0-68	---

1/ Population A. Pubescent wheatgrass containing only pubescent-type heads.
Population B. Pubescent wheatgrass containing both pubescent-type and glabrous heads.
Population F. Intermediate wheatgrass containing both glabrous and pubescent-type heads.

2/ Score for degree of pubescence derived as follows: light pubescence = 1; moderate pubescence = 2; heavy pubescence = 3. A maximum score of 15 is possible (3 x 5 spikes = 15).

Extent of Pubescence on Various Plant Parts

For deriving lemma, rachis, and glume scores, the spikes were divided into thirds. Since it appeared that the spike was pubescent on the lower third more frequently than on the upper two thirds, scoring values for location on the spike were assigned as follows: bottom third = 1; middle third = 2; and top third = 3.

Five heads of each test row were examined for location of pubescence on the lemma, rachis, and glumes. The highest possible score was 30 for any given row:

Bottom third--1 x 5 spikes	= 5
Middle third--2 x 5 spikes	= 10
Top third --3 x 5 spikes	= 15
Maximum Total	30

The maximum score would indicate that the spike part in question was pubescent on all portions of the spike and all heads observed.

The lemma score was 30 (the maximum) for all three pubescent-type populations (Table IX). All lemmas were pubescent if pubescence was found anywhere on the spike.

Occurrence of pubescence on the rachis and/or the glumes may be useful for distinguishing between the two species. Scores for the rachis and glumes of pubescent wheatgrass were significantly higher than similar scores for intermediate wheatgrass (Table IX). This means that the pubescence is spread over a greater portion of the pubescent wheatgrass spike than on the intermediate wheatgrass spike. From the data in Table IX, it would appear that heads producing rachis or glume pubescence scores of

over 15 are probably pubescent wheatgrass. Intermediate wheatgrass would be expected to produce average rachis or glume scores below 15.

Table IX. Scores indicating extent of pubescence on three plant parts of pubescent wheatgrass and intermediate wheatgrass.

Population	No. of heads examined	Lemma Score 1/	Rachis Score 1/	Glume Score 1/
Population A. Pubescent wheatgrass rows containing pubescent-type heads	5	30	18.00	18.00
Population B. Pubescent wheatgrass rows containing both pubescent-type and glabrous heads	45	30	20.22 **	22.00 *
Population F. Intermediate wheatgrass rows containing both glabrous and pubescent-type heads	100	30	6.85	12.15

1/ Maximum score possible was 30. Maximum score indicates that pubescence occurred on all plant parts observed regardless of location on the spike. Degree of pubescence (light, medium, or heavy) is not expressed in these scores.

** Significance at the 1% level. Applies to comparison between Population B and Population F.

* Significance at the 5% level. Applies to comparison between Population B and Population F.

A summary of the plant head characteristics which are significantly different between plants of intermediate wheatgrass and pubescent wheatgrass are shown in Table X.

Table X. Summary of plant head characteristics differing significantly between plants of pubescent wheatgrass and intermediate wheatgrass.

Characteristic	Pubescent Wheatgrass	Intermediate Wheatgrass
Spikelets per head	17.79**	20.13
% Ergot	50.44**	1.95
Glume Score 1/	5.43**	3.31
Internode Length in mm.	13.11**	11.20
Spike length in mm. (Adjusted by Covariance)	231.00**	206.93
Rate of occurrence of pubescent-type heads	65.20**	10.73
Rachis score for extent of pubescence 2/	20.00**	6.9
Glume score for extent of pubescence 2/	21.60*	12.2

1/ Glume score derived by assigning values of one through nine to the glume shape. The most pointed were given a value of one, while the most blunt or rounded were given a value of nine.

2/ Rachis and glume scores were derived by assigning various values. The location of the pubescence determined what the score would be. The spike was divided into thirds: the lower third was given a value of 1; the middle third was given a value of 2; and the top third was given a value of 3. A maximum of 30 was possible.

** Significant at the 1% level

* Significant at the 5% level

SUMMARY

Mature spikes of pubescent wheatgrass and intermediate wheatgrass were analyzed for fourteen different spike characteristics. There was a significant difference between the species on four characteristics.

Intermediate wheatgrass had a larger mean number of spikelets per head than did pubescent wheatgrass.

Ergot attacked pubescent wheatgrass more frequently than intermediate wheatgrass.

The glume was more pointed in intermediate wheatgrass than in pubescent wheatgrass.

Pubescent wheatgrass had a longer mean internode length than intermediate wheatgrass.

No significant differences between species were found for the percent of awns, percent of hollow stems, mean number of florets per spikelet, mean spikelet length and mean spike length.

Data from three populations which contained pubescent-type plants were analyzed statistically. Pubescent-type plants from two different pubescent wheatgrass populations showed significant differences for percent pubescent plants, rachis score and glume score when compared with pubescent-type intermediate wheatgrass plants.

The means for number of florets per spikelet, spikelet length, internode length and spike length were adjusted to the mean number of spikelets per head. Adjustment by covariance revealed a significant species difference for mean spike length. Mean spike length had not

shown up as a significant value in the non-adjusted analysis of variance.

Based on the data from this experiment it can be said that intermediate wheatgrass and pubescent wheatgrass are quite similar morphologically. They differ significantly, however, for several characteristics. These differences may or may not represent species differences.

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