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Morphological variability in some synthetic hexaploid wheats derived from *Triticum turgidum* × *T. tauschii*

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ABSTRACT

A morphological study of 50 synthetic hexaploid (SH) wheats ($2n=6x=42$) derived from *Triticum turgidum* ($2n=4x=28$) × *T. tauschii* ($2n=2x=14$) crosses was undertaken to establish descriptors for subsequent use in wheat breeding. Thirtyfive qualitative and quantitative traits of seedlings, leaves, culms, glumes, inflorescences, spikes and grains for each entry were recorded and compared. Data on quantitative traits subjected to complete linkage cluster analysis resulted in classifying the SH materials into three distinct phenotypic groups. Substantial variation existed within the materials tested. Our observations demonstrate that from relatively simple taxonomic descriptors, classifications can be developed for utilizing the synthetic hexaploid wheat germplasm.

Key words: Cluster analysis, Interspecific hybrids, *Aegilops squarrosa*, *Triticum aestivum*, Wheat descriptors.

INTRODUCTION

Goatgrass [*Triticum tauschii* (Coss.) Schmal; formerly *Aegilops squarrosa* L.] constitutes a relatively untapped germplasm pool for broadening the genetic base of common hexaploid wheat. This diploid species, the donor of the D-genome in *Triticum aestivum* L., is widely distributed in the vast area east of Caucasus, namely Iran, Afghanistan, Pakistan and the neighboring regions of Turkey, USSR and China (Gill *et al.*, 1985; Gill *et al.*, 1986).

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Germplasm evaluation of this species has shown levels of cold hardiness (Limin and Fowler, 1981), rust and powdery mildew resistance (Gill *et al.*, 1985; Gill *et al.*, 1986; Kerber, 1984, Kerber and Dyck, 1978; Pasquini, 1980; Raupp *et al.*, 1983), and insect resistance (Gill *et al.*, 1985; Gill *et al.*, 1986; Harvey *et al.*, 1980; Hatchett and Gill, 1981, 1984). Moreover, wheat germplasm with resistance to leaf and stem rust (Dyck and Kerber, 1970; Gill and Raupp, 1987; Kerber, 1984; Kerber and Dyck, 1969; Raupp *et al.*, 1983; Sharma and Gill, 1983), Hessian fly (Gill and Raupp, 1987; Hatchett *et al.*, 1981; Martin *et al.*, 1982) and greenburg (Gill and Raupp, 1987; Harvey *et al.*, 1980; Joppa and Williams, 1982; Joppa *et al.*, 1980; Martin *et al.*, 1982) derived from this species has been developed.

For efficient utilization of *T. tauschii* as a source of disease and insect resistance and other agronomic traits, information is needed on the genetic transfer and expression of *T. tauschii* genes in common wheat. Two methods of genetic transfers have been utilized. In the first method, *T. tauschii* is hybridized with a tetraploid wheat (*Triticum turgidum* L.) and the resulting self-sterile F_1 hybrid produces upon doubling a synthetic hexaploid (SH) (Kerber and Dyck, 1978; Kihara *et al.*, 1957). In the second method, *T. tauschii* is crossed directly with hexaploid wheat and the F_1 hybrid ($2n=4x=28$) obtained by embryo rescue is backcrossed to bread wheat (Gill and Raupp, 1987; Raupp *et al.*, 1983). Genetic transfer is usually successful with either method. However, the expression of the transferred gene is not always predictable and depends on the specific pathogen or insect resistance factor (Gill *et al.*, 1986). For example, some studies have demonstrated that the expression of rust and powdery mildew resistance genes may be altered or suppressed in some genetic backgrounds (Dyck, 1982; Kerber, 1984; Kihara *et al.*, 1965; Raupp *et al.*, 1983). On the other hand, *T. tauschii* genes conditioning green-

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bug and Hessian fly resistance have been fully expressed in common wheat in all cases (HARVEY *et al.*, 1980; HATCHETT *et al.*, 1981; JOPPA and WILLIAMS, 1982). Very limited documentation exists on the influence of *T. tauschii* genes on the morphology of the SH plants.

Interspecific hybridization efforts were initiated in 1986 in the Wide Crosses Program of the International Maize and Wheat Improvement Center (CIMMYT). *Aegilops* (*Ae.*) species, now merged with *Triticum* (BOWDEN, 1959), received priority, as they are considerably easier to hybridize with wheat, e.g., *Ae. umbellulata* (= *T. umbellulata*) for Karnal bunt resistance and *Ae. uniaristata* (= *T. uniaristata*) for aluminum toxicity tolerance. The diverse range of hybrids produced between *T. aestivum* and other *Aegilops (Triticum)* species has been explicitly documented by KIMBER and FELDMAN (1987). The potential resistance of *T. tauschii* to numerous wheat pathogens mentioned earlier has also been considered. Among the durum × *Ae.* SH wheats developed at CIMMYT, those involving *T. tauschii* are the most noteworthy and show considerable promise in increasing the genetic variability of materials in a wheat breeding program. In this paper, as a first step towards utilizing *T. tauschii* variability for wheat improvement, the readily usable morphological descriptors of the SH wheats were established and are discussed. Character relationships among the test materials are also summarized using cluster analysis to place similar genotypes into phenetic groups.

MATERIALS AND METHODS

Production of synthetic hexaploid wheat germplasm

T. tauschii ($2n=2x=14$, DD) accessions were obtained from the CIMMYT germplasm bank in Mexico; Pakistan (National Agriculture Research Council); England (Agriculture and Forestry Research Council-Institute of Plant Science Research); and the USA (Kansas State University, Oregon State University, University of Missouri, University of California-Riverside and USDA-Beltsville). A total of 490 accessions were acquired and seed increased for utilization in crosses with several *T. turgidum* ($2n=4x=28$, AABB) cultivars. The latter were obtained from the CIMMYT durum wheat breeding program. The cultivars involved in the SH wheats described here are Altar 84, Chen, Duergand and Laru (Tables 1 and 2).

Vernalization, hybridization, colchicine doubling and seed increase

After *T. tauschii* seeds were planted in Jiffy peat pellets in trays and allowed to germinate, they were placed in a growth chamber for vernalization. The conditions were set for 8°C, 8 h light, for 8 weeks. After vernalization, the seedlings were transplanted in the field in Obregon, Sonora, Mexico, and given supplemental light. The *T. turgidum* cultivars (spring growth habit) were planted when the *T. tauschii* accessions were transplanted followed by two subsequent dates of planting spaced at 10 day intervals in order to ensure a crossing niche. The hybridization, embryo rescue and colchicine treatment procedures were identical to those reported earlier (MUJEEB-KAZI *et al.*, 1987). The seeds set on the colchicine treated plants were harvested, germinated, cytologically checked mitotically in root-tips (MUJEEB-KAZI and MIRANDA, 1985) and increased for further utilization in various studies.

Material for morphological study

Lines derived from 240 original doubled plants with $2n=6x=42$ chromosomes were grown at the Mexican Institute of Forestry, Agriculture, and Livestock, Campo Agricola Experimental Valle del Yaqui (CAEVY) Research Station, Sonora, Mexico (27° 20'N, 105° 55'W, elevation 39 m above sea level) during the 1988-89 wheat production season to select materials for the morphological study. At maturity, 50 SH lines were selected from the nursery based on uniformity of the plot, good agronomic characteristics and field resistance to leaf rust (*Puccinia recondita* Rob. et Desm. f. sp. *tritici*) and stem rust (*Puccinia graminis* Pers. f. sp. *tritici* Erikss. et Henn). The durum wheat and *T. tauschii* backgrounds of the selected materials are listed in Table 1.

The 50 selected SH lines were grown in a field trial at CAEVY during the 1989-90 wheat cycle to observe and record their morphological characteristics. Plots consisting of three rows, each 2.0 m long and 15 cm apart, were space planted at one seed per 10 cm. Fertilizer was applied prior to seeding at the rate of 150 kg N/ha for ammonium sulfate and 40 kg P/ha for tri-superphosphate. The trial was surface irrigated just after planting. Irrigation was continued as required until the latest maturing SH wheat reached physiological maturity. A selective herbicide was used to control the weeds and a full protection program against birds was employed. Insect control was not required.

Morphological descriptions and measurements

The descriptions and measurements of morphological traits were taken from the central row of each test plot to minimize border effects. The wheat descriptors were based on those used at CIMMYT and the International Board for Plant Genetic Resources (CIMMYT, 1985; IBPGR, 1985; VILLAREAL, 1988).

Botanical and agronomic traits measured included seedling vigor (1 to 9, 1 being vigorous), days to

TABLE 1

Seedling vigor, leaf, culm and glume characteristics of synthetic hexaploid wheats derived from *Triticum turgidum* × *T. tauschii* and *T. turgidum* parents at CAEVY, 1989-90

Entry No.	Test entry*	Genotype Code	Seedling Vigor**	Leaf Blade Color	Leaf Sheath Color	Flag Leaf Angle	Straw Strength	Tiller Angle	Glume Pubescence
1	Altar 84/219	1A219	3	green	green	horizontal	weak	intermediate	less dense
2	Altar 84/219	2A219	3	green	green	horizontal	weak	spreading	less dense
3	Altar 84/219	3A219	1	dark green	green	horizontal	weak	intermediate	less dense
4	Altar 84/224	4A224	5	green	purple trace	horizontal	weak	spreading	less dense
5	Altar 84/224	5A224	3	dark green	green	horizontal	weak	spreading	less dense
6	Altar 84/224	6A224	3	dark green	green	horizontal	weak	spreading	less dense
7	Altar 84/224	7A224	5	dark green	green	drooping	weak	spreading	less dense
8	Altar 84/221	8A221	5	green	green	horizontal	strong	spreading	less dense
9	Altar 84/223	9A223	3	dark green	green	horizontal	weak	spreading	less dense
10	Altar 84/223	10A223	3	dark green	green	horizontal	weak	spreading	less dense
11	Altar 84/192	11A192	5	purple trace	green	horizontal	strong	spreading	less dense
12	Altar 84/198	12A198	5	purple trace	green	horizontal	strong	spreading	less dense
13	Altar 84/198	13A198	1	purple trace	green	horizontal	weak	spreading	less dense
14	Altar 84/198	14A198	5	purple trace	green	horizontal	strong	spreading	less dense
15	Altar 84/211	15A211	3	purple trace	green	horizontal	weak	spreading	less dense
16	Chen/205	16C205	5	green	green	semi-erect	strong	spreading	very dense
17	Chen/205	17C205	7	green	green	horizontal	weak	spreading	very dense
18	Chen/205	18C205	7	green	green	horizontal	strong	spreading	very dense
19	Chen/205	19C205	7	green	purple trace	horizontal	strong	spreading	very dense
20	Chen/205	20C205	7	green	purple trace	horizontal	strong	spreading	very dense
21	Chen/205	21C205	3	green	purple trace	horizontal	strong	spreading	very dense
22	Chen/205	22C205	3	dark green	purple trace	horizontal	strong	spreading	very dense
23	Chen/205	23C205	3	dark green	purple	horizontal	strong	intermediate	very dense
24	Chen/205	24C205	3	purple trace	purple	drooping	strong	intermediate	very dense
25	Chen/205	25C205	3	green	purple	horizontal	weak	spreading	very dense
26	Chen/215	26C215	3	purple trace	purple	horizontal	strong	intermediate	very dense
27	Chen/215	27C215	3	purple trace	purple	horizontal	strong	intermediate	very dense
28	Chen/224	28C224	3	green	green	horizontal	weak	intermediate	very dense
29	Chen/224	29C224	5	green	green	horizontal	weak	spreading	very dense
30	Chen/224	30C224	3	dark green	green	horizontal	weak	intermediate	very dense
31	Chen/224	31C224	5	green	green	drooping	weak	spreading	very dense
32	Chen/224	32C224	3	dark green	green	drooping	weak	spreading	very dense
33	Chen/224	33C224	1	green	green	horizontal	weak	intermediate	very dense
34	Chen/224	34C224	1	green	green	horizontal	weak	intermediate	very dense
35	Chen/224	35C224	3	green	green	horizontal	weak	intermediate	very dense
36	Chen/224	36C224	3	dark green	green	drooping	weak	intermediate	very dense
37	Chen/224	37C224	3	dark green	green	horizontal	weak	intermediate	very dense
38	Chen/224	38C224	3	dark green	green	horizontal	weak	intermediate	very dense
39	Duergand/214	39D214	1	dark green	green	semi-erect	lodge	intermediate	very dense
40	Duergand/214	40D214	1	dark green	green	semi-erect	lodge	intermediate	very dense
41	Duergand/214	41D214	1	dark green	green	horizontal	lodge	intermediate	very dense
42	Duergand/214	42D214	3	dark green	green	horizontal	lodge	spreading	very dense
43	Duergand/221	43D221	1	dark green	green	semi-erect	lodge	intermediate	very dense
44	Duergand/221	44D221	1	dark green	green	erect	lodge	intermediate	very dense
45	Duergand/221	45D221	1	dark green	green	semi-erect	lodge	intermediate	very dense
46	Duergand/221	46D221	1	dark green	green	semi-erect	weak	intermediate	very dense
47	Laru/309	47L309	3	purple trace	green	semi-erect	weak	intermediate	less dense
48	Laru/309	48L309	3	green	green	semi-erect	weak	intermediate	less dense
49	Laru/309	49L309	7	dark green	green	horizontal	weak	spreanding	less dense
50	Laru/309	50L309	5	purple trace	purple trace	horizontal	weak	intermediate	less dense
	Altar 84		3	green	green	semi-erect	weak	intermediate	very dense
	Chen		3	green	green	erect	strong	compact	very dense
	Duergand		3	green	green	horizontal	weak	intermediate	less dense
	Laru		5	dark green	green	semi-erect	weak	intermediate	less dense

* = *Triticum turgidum/T. tauschii* (accession) cross combinations and *T. turgidum* parents.
** = 1 to 9 scale, 1 = extra vigorous, 9 = very weak.

TABLE 2

Plant traits measured or calculated from synthetic hexaploid wheats derived from *Triticum turgidum* × *T. tauschii* crosses, and bread wheat check cultivar Seri 82 at CAEVY, 1989-90

Entry No.	Synthetic Cross	Genotype Code	Days to Anthesis	Physiological Maturity (days)	Plant Height (cm)	Culm Length (cm)	Spike Length (cm)	Leaf Blade			Grain		1000-grain Weight (g)
								Length (cm)	Width (cm)	Area (Sq. cm)	Length (mm)	Width (mm)	
1	Altar 84/219	1A219	103	136	98	86	12	25.7	1.4	36.0	8.71	2.99	59.0
2	Altar 84/219	2A219	103	136	104	92	12	24.0	1.5	36.0	8.63	2.75	56.0
3	Altar 84/219	3A219	102	132	102	89	13	23.5	1.4	32.9	8.87	3.18	57.0
4	Altar 84/224	4A224	104	136	100	88	12	23.0	1.4	32.2	9.06	3.14	60.0
5	Altar 84/224	5A224	103	136	97	85	12	23.9	1.4	33.5	8.23	3.18	59.2
6	Altar 84/224	6A224	103	136	100	87	13	24.1	1.4	33.7	8.75	3.27	58.6
7	Altar 84/224	7A224	106	138	88	75	13	25.7	1.4	36.0	8.75	3.15	59.1
8	Altar 84/221	8A221	106	138	92	80	12	24.1	1.7	41.0	7.73	3.56	58.8
9	Altar 84/223	9A223	106	138	100	88	12	24.3	1.6	38.9	8.23	3.18	56.4
10	Altar 84/223	10A223	106	138	103	90	13	24.4	1.5	36.6	8.98	3.12	58.6
11	Altar 84/192	11A192	106	138	101	89	12	25.2	1.5	32.8	7.92	3.77	59.3
12	Altar 84/198	12A198	106	138	97	85	12	25.6	1.5	38.4	8.08	3.46	61.3
13	Altar 84/198	13A198	106	136	104	92	12	23.8	1.5	35.7	9.01	3.74	61.4
14	Altar 84/198	14A198	106	136	102	90	12	25.6	1.6	41.0	7.94	3.39	61.0
15	Altar 84/211	15A211	106	138	100	88	12	25.2	1.7	42.8	8.37	3.41	60.1
16	Chen/205	16C205	96	138	89	76	13	29.1	1.8	52.4	8.36	3.47	56.3
17	Chen/205	17C205	103	138	83	72	11	23.2	1.6	37.1	8.90	3.92	50.8
18	Chen/205	18C205	98	138	83	71	12	26.2	1.5	39.3	8.30	3.44	55.8
19	Chen/205	19C205	97	138	79	68	11	25.9	1.7	44.0	8.24	3.37	52.4
20	Chen/205	20C205	100	136	81	68	13	26.2	1.7	44.5	8.23	3.42	54.9
21	Chen/205	21C205	96	136	86	73	13	29.4	1.4	41.2	8.45	3.43	52.9
22	Chen/205	22C205	100	136	86	73	13	25.0	1.7	42.5	8.26	3.44	51.8
23	Chen/205	23C205	100	138	89	76	13	25.9	1.6	41.4	8.32	3.42	49.2
24	Chen/205	24C205	100	138	88	75	13	23.2	1.7	39.4	8.17	3.51	47.8
25	Chen/205	25C205	96	138	90	77	13	28.8	1.7	49.0	8.64	3.08	50.3
26	Chen/215	26C215	97	138	83	71	12	23.7	1.7	40.3	8.08	3.36	54.4
27	Chen/215	27C215	97	138	86	74	12	25.2	1.7	42.8	8.31	3.30	53.9
28	Chen/224	28C224	95	124	100	87	13	27.6	1.6	44.2	8.40	3.37	59.8
29	Chen/224	29C224	97	124	90	77	13	28.2	1.6	45.1	8.37	3.45	61.5
30	Chen/224	30C224	99	136	93	80	13	26.8	1.6	41.9	8.36	3.41	60.9
31	Chen/224	31C224	101	136	87	74	13	23.6	1.5	35.4	8.35	3.42	64.6
32	Chen/224	32C224	101	136	91	78	13	23.0	1.5	34.5	8.41	3.35	58.7
33	Chen/224	33C224	95	120	94	81	13	23.0	1.5	34.5	8.27	3.44	57.5
34	Chen/224	34C224	95	120	91	79	12	23.4	1.6	37.4	8.35	3.41	61.6
35	Chen/224	35C224	95	124	91	79	12	24.4	1.6	39.0	8.48	3.45	63.3
36	Chen/224	36C224	97	130	91	77	14	21.8	1.5	32.7	8.45	3.51	60.3
37	Chen/224	37C224	96	124	94	82	12	25.4	1.6	40.6	8.44	3.43	62.3
38	Chen/224	38C224	104	136	98	86	12	28.6	1.7	48.6	8.32	3.32	47.9
39	Duergand/214	39D214	98	130	106	95	11	26.0	1.6	41.6	8.24	3.51	61.4
40	Duergand/214	40D214	98	130	107	96	11	26.0	1.6	41.6	8.17	3.47	58.8
41	Duergand/214	41D214	98	134	100	88	12	24.6	1.5	36.9	7.43	3.33	55.9
42	Duergand/214	42D214	101	134	105	94	11	29.0	1.6	46.4	7.65	3.38	57.9
43	Duergand/221	43D221	95	124	110	98	12	26.4	1.8	47.5	8.16	3.38	56.1
44	Duergand/221	44D221	95	120	104	92	12	28.4	1.7	48.3	7.43	3.36	56.3
45	Duergand/221	45D221	95	120	104	92	12	27.0	1.8	48.6	8.02	3.27	51.9
46	Duergand/221	46D221	95	120	102	91	11	29.0	1.7	49.3	8.17	3.36	56.7
47	Laru/309	47L309	103	136	101	89	12	23.0	1.5	34.5	8.10	3.36	54.1
48	Laru/309	48L309	102	136	98	87	11	26.0	1.4	36.4	7.72	3.31	54.6
49	Laru/309	49L309	104	138	94	82	12	24.0	1.5	36.0	7.99	3.33	51.7
50	Laru/309	50L309	103	138	96	85	11	23.6	1.4	33.0	8.29	3.26	56.4
	Seri 82		86	133	98	88	10	30.0	1.4	42.0	6.01	3.15	38.2
	LSD (0.05)		2	4	3	3	1	4.5	0.2	3.5	0.12	0.12	2.1

flowering, days to physiological maturity and plant height. Physiological maturity was recorded when 95% of the spikes in a plot had lost their green coloration.

Tiller characteristics included culm color, culm length, culm solidness, tiller angle and straw strength. The leaves were measured for blade length, width and area, colors of blade, sheath, ligule and auricle plus the flag leaf angle (Tables 1 and 2).

Spike characteristics included measurements of spike length, spikelet density, spike shape, awnedness, awn color, glume pubescence, glume shoulder shape and stigma color.

Grain characteristics recorded at maturity were length width, size, shape, color, shrivelling, 1000-grain weight and threshability.

Data analysis

The PROC CLUSTER SAS procedure (SAS Institute, 1988) was used to perform a complete linkage cluster analysis on means of 11 quantitative traits recorded on the 50 SH wheats and *T. aestivum* cultivar Seri 82 (Table 2). The means of the traits were standardized to a mean of 0 and a standard deviation of 1 because traits were measured on different scales. A dendrogram was constructed based on the analysis to depict the degree of similarity and infer relationships amongst the test entries. The ultimate goal is to use the variation of SH lines for broadening the genetic variation in hexaploid wheat germplasm.

RESULTS AND DISCUSSION

Favorable growing conditions led to excellent plant growth and development of the materials during these experiments. Mean temperatures during the 1988-89 and 1989-90 wheat seasons were similar at 18.4 °C (mean maximum + minimum/2 screen air temperature over the season) as compared to the long-term average temperature 17.6 °C at CAEVY. The total rainfall during the 1988-89 growing cycle was (104.3mm), 36% more than the 1989-90 precipitation (66.7mm). However, this difference was not important because the study was conducted under full irrigation.

Data on the qualitative and the quantitative morphological traits of the SH wheats derived from *T. turgidum* × *T. tauschii* crosses are presented in Tables 1 and 2.

Seedling vigor and leaf characteristics

Seedling emergence and rapid growth are desired traits of commercial wheat varieties for better competition against weeds especially when grown under suboptimal farming conditions. The seedlings of the SH test entries generally exhibited vigorous vegetative growth (1 to 5 on a 1 to 9 scale, Table 1) except four lines (entries 17 to 20) derived from the Chen/*T. tauschii* cross and one line (entry 49) from the Laru/*T. tauschii* cross which had reduced plant vigor. The vigor rating for the durum parents ranged between 3 and 5 (Table 1).

The leaf characteristics studied exhibited interesting morphological differences (Table 1). The leaf blade coloration varied among the synthetics from green to dark green, and in some cases, with traces of purple. Leaf sheath color at the base of the plant varied between green, purple and traces of purple. No durum cultivar was pigmented other than green. There was no variation in collar and ligule colors which were green and light green, respectively. Auricles were mostly purple except for entries 42 to 44 of the Duergand/*T. tauschii* cross which were green similar to the uniformly green color of durum cultivars. Of the entries evaluated, 72% had flag leaves positioned horizontally. Other lines possessed drooping, semi-erect or erect flag leaves. Of the 15 lines derived from Altar 84/*T. tauschii* cross, all except entry 7 had horizontal flag leaves. Only entry 44, a line from the Duergand/*T. tauschii* cross possessed erect flag leaves. Duergand is characterized by having horizontal flag leaves.

Culm (without leaf sheath) length, color and thickness were obtained on the main culm of each entry shortly after anthesis (Table 1). Culm color evaluated at flowering was generally green except for being purple for entries 19 to 27. Another evaluation of culm color was made at maturity to monitor the color change with tissue maturity. All test materials earlier green now possessed a purple coloration. All durum cultivars had a green color at flowering that changed to a straw color at maturity. The SH lines had completely hollow culms with thin to moderately thick walls. No attempt, however, was made to quantify the thickness of the culm walls. Unfortunately, there were no culms with completely solid stems, a resistance mechanism against sawfly (*Cephus cinctus*). This solidity character is associated with homoeologous group 3, and certain alien species have transmitted it to wheat (MUJEEB-KAZI, 1990). Culm strength and angle were also recorded at physiological maturity. Straw strength varied among the entries, and 72% of the materials had weak straw and were lodged at maturity. The tiller angle was generally of the spreading type (52%) and the rest had an intermediate growth habit. Weak culms with spreading growth habit are highly related to lodging susceptibility in wheat. Except for cultivar Chen, all durums had weak straw.

Glume, spike and grain characteristics

During anthesis, the stigma color was white for all entries. Variation for glume pubescence was indicated by the density of the trichomes present on the lemma and palea shortly after full bloom. All materials had pubescent glumes with more than 60% of the entries having very dense trichomes, particularly those lines derived from Chen/*T. tauschii* and Duergand/*T. tauschii* crosses. In contrast, all Altar 84/*T. tauschii* and Laru/*T. tauschii* lines had fewer trichomes on their glumes. Glumes had an elevated shoulder shape with no variation observed. Spike shape was fusiform with an intermediate spikelet density for all entries. All test entries were fully awned, and awns were green at the flowering stage except for entries 5 and 6 of Altar 84/*T. tauschii* which had black awns. At maturity, 82% of the awn colors changed to black while the rest (entries 26, 27, 32, 33, 35 and 47 to 50) were straw colored. All durum cultivars possessed green full awns. The tightness of the lemma and palea was similar for all entries, resulting in hard threshability and nonshattering of the grains at maturity. This characteristic could be partly explained by the action of the *Q* genes inherited from the *T. tauschii* cultivars (MORRIS and SEARS, 1967). The entries had red, elliptical and large grains except for medium size grains in entries 17, 18, 21 and 36. The degree of seed shrivelling was high among the genotypes, and the seed of some lines had a deep crease. Both of these characteristics are indicative of nonplumpness or poorly-formed wheat grains.

Morphological trait measurements

Plant morphological trait measurements are summarized in Table 2. More than 50% of the materials flowered 100 days or more after planting. The earliest flowering date recorded was 95 days after seeding. Maturities ranged from 120 days for the earliest maturing entry to 138 days for the latest maturing genotypes, with 74% requiring more than 130 days to mature physiologically. The tallest genotypes were from the Duergand/*T. tauschii* cross, and few tall genotypes also occurred in the Altar 84/*T. tauschii* group. The tallest (107 cm) genotype was entry 40 while the shortest entry (19) was 79 cm. The shortest culm length (68 cm) was recorded for two lines (entries 19 and 20) of the cross Chen/*T. tauschii* and the longest (96 cm) was for entry 40 of the Duergand/*T. tauschii* cross. Spike length ranged from 11 to 14 cm. The longest leaf was 29.4 cm (entry 21), a Chen/*T. tauschii* derived line, while the widest leaf was 1.8 cm for entry 16 of the cross Chen/*T. tauschii* and entries 43 and 45 of the Duergand/*T. tauschii* cross. For leaf area, the highest value obtained was 52.4 cm^2 for entry 16 and the lowest (32.2 cm^2) was an Altar 84/*T. tauschii* derived line (entry 4). In general, the synthetics from the Laru/*T. tauschii* cross had smaller leaf areas than the genotypes of the other three crosses. Longitudinal dimensions of the grains ranged from 7.43 to 9.06 mm. The widest grain width (3.92 mm) was recorded for entry 17, a line from Chen/*T. tauschii.* The mean length and width for all the materials were 8.30 mm and 3.37 mm, respectively. Lines derived from the Chen/*T. tauschii* cross recorded the highest (64.6 g for entry 31) and the lowest (47.8 g for entry 24) 1000-grain weight. The overall 1000-grain weight mean was 56.9 g compared to 38.2 g of bread wheat check cultivar Seri 82. Descriptors established for Seri 82 (Table 2) indicate their uniqueness from the SH lines serving as suitable selection markers in segregating generations of derivatives to be obtained from the Seri 82/SH lines combinations. MUJEEB-KAZI (1992) has attributed resistances to some biotic/abiotic stresses in SH lines that are limiting in *T. aestivum.* Susceptible but high yielding cultivar Seri 82 is a logical candidate for further improvement and has been included in our present diagnostic comparisons.

Clustering of genotypes based upon similarity of characters

Clustering of the 50 SH wheats and the bread wheat cultivar check Seri 82 based on similarity of quantitative traits (Table 2) produced four major groups, A, B, C and D (Fig. 1). The A group comprised the largest cluster with 30 genotypes. It possessed the highest overall mean for 1000-grain weight (58.9 g) and spike length (12.3 cm) as compared to the other genotype groups. Fifty percent of these materials have the cultivar Altar 84 as

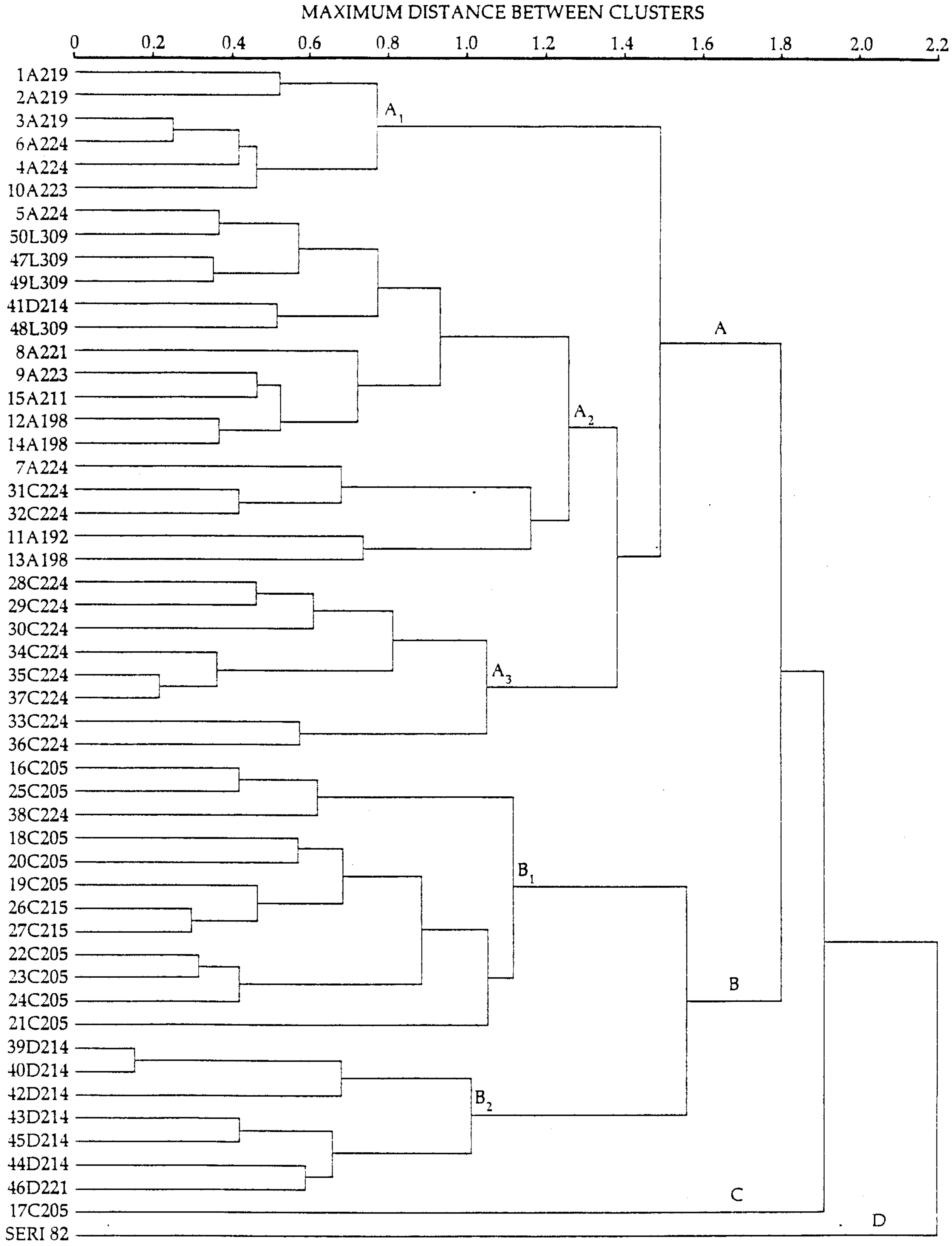

Figure 1 - Dendrogram depicting average distance between clusters or groups of synthetic hexaploid wheats and the bread wheat cultivar Seri 82 as determined from complete linkage cluster analysis of quantitative data. Genotype abbreviations are defined in Table 1.

the *T. turgidum* parent while *T. tauschii* contributions were from nine divergent sources (Accessions 192, 198, 211, 214, 219, 221, 223, 224 and 309). Three distinct genotype subgroups (A1 to A3) existed within the A cluster. The A1 subgroup genotypes were all derived from crosses involving Altar 84. Fifty-six percent of the genotypes in A2 subgroup were also derived from Altar 84, whereas the lines in subgroup A3 came from Chen/*T. tauschii* (Accession 224).

There were 19 SH wheat lines grouped in the B cluster. The group's overall mean leaf area (44.7 cm^2) was the largest of the materials tested. The two subgroups (B_1 and B_2) formed within this cluster were related to the durum cultivars used in making the synthetics, i.e., the 12 lines in the B1 subgroup were all derived from Chen, while the seven B2 lines came from crosses involving Duergand. For the B1 and B2 subgroups, the principal *T. tauschii* contributors were accessions 205 (75%) and 214 (85.7%), respectively.

The C group was composed of only one genotype, and it was derived from a Chen/*T. tauschii* (Accession 205) cross. This group had the shortest plant height mean (83.0 cm) and was the latest to mature physiologically (138 days) compared to the other SH groups. Seri 82 emerged as a separate group from the SH entries. The material that flowered earliest possessed long-narrow leaves, short spikes and small grains. These are traits that could be improved through hybridization with SH wheats.

Distinctive combinations of characters and parents were apparent in each of the three major groups of materials. The results of this study demonstrate that relatively simple taxonomic procedures and data analysis can be used to classify and describe SH wheats that may be useful in germplasm utilization. Better understanding of the variation among these materials will aid in utilization of these valuable germplasm resources.

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