Triticeae III

Editor **A.A. Jaradat**

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Upper row:
1. *Aegilops ovata (=Triticum ovatum)*. 2. *Triticum aegilopoides* (John Raupp). 3. *Triticum dicoccoides* (Moshe Feldman). 4. *Triticum monococcum* (Leonor Pena-Chocarro)

Middle row:
5. *Triticum dicoccum*. 6. *Triticum spelta* (Leonor Pena-Chocarro). 7. *Triticum durum* × *Aegilops* spp. (Natural hybrid). 8. *Triticum durum* (branched spike) (A. A. Jaradat). 9. *Triticum polonicum*. 10. *Triticum ispahanicum* (N. Watanabe).

Bottom row:
11. *Hordeum marinum*. 12. *Leymus condensatus* (Mary Barkworth). 13. *Lopophyrum elongatum*. 14. *Thinopyrum junceiforme* (P. Jauhar).

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7.4

Production and utilization of D genome synthetic hexaploids in wheat improvement

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Bridge crosses utilizing the D genome synthetic hexaploids (SH); *Triticum turgidum/T. tauschii* (2n=6x=42, AABBDD); are a potent means of improving bread wheats *(T. aestivum)* for biotic and abiotic stresses. This new SH germplasm enables incorporation of the genetic diversity of T. *turgidum* cultivars together with that contributed by the T. *tauschii* accessions. From the 620 SH wheats produced so far, an elite set of 95 has been prepared and partially characterized for morphological characteristics, growth parameters, some biotic and abiotic attributes. In essence, all SH wheats are cytogenetically stable. The elite set possesses an agronomically more desirable growth habit under two Mexican locations; Obregon (27°20'N,105°55'W, 39masl) and El Batan (19°31'N, 98°50'W, 2249masl). Some details of the germplasms production and maintenance are presented, as are partial results of screening of the SH wheats for three biotic stresses. Resistance diversity is available for spot blotch (*Cochliobolus sativus* Ito & Kuribayashi), karnal bunt (*Tilletia indica* Mitra), and *Septoria tritici* blotch (*Mycosphaerella graminicola* Funckel), and is based upon the disease screening data over several years in testing locations within Mexico. Resistant SH wheats are being utilized for bread wheat (BW) improvement for the above stresses, and advanced BW/SH derivatives further express the parental SH resistance diversity.

Introduction

Of the primary gene pool Triticeae species we have given priority to *Triticum tauschii* (Coss) Schmalh; syn. *Aegilops squarrosa* auct. non L. for wheat improvement. The species is a recognized source for new variability to several stresses (Cox et al., 1994; Eastwood et al., 1991; Cox and Hatchett, 1994; Gill et al., 1991). *T. tauschii* also contributes to yield components, increased photosynthetic rate and bread-making quality (Peña et al., 1991; Rees et al., 1994; Villareal et al., 1994). Our objectives in this paper address: 1. The indiscriminate hybridization of *Aegilops squarrosa* (2n=2x=14, DD) accessions with elite *Triticum turgidum* (2n=4x=28, AABB) cultivars for production of synthetic hexaploids (SH), followed by seed increase for global distribution of this AABBDD 2n=6x=42 SH germplasm. 2. Some morphological growth descriptors, and screening of the SH germplasm for three biotic stresses prevalent in our Mexican locations, namely: *Cochliobolus sativus* Ito & Kuribayashi (Asexual state *Helminthosporium sativum*), *Mycosphaerela graminicola* Fünckel (Asexual state *Septoria tritici* Rob. ex.

Desm.), and *Tilletia indica* Mitra (karnal bunt), and 3. Utilization of the resistance diversity of the SH wheats to *S. tritici* by crossing them to susceptible bread wheat cultivars and selecting resistant derivatives with superior agronomic plant types, from their advanced progenies.

Materials and methods

Germplasm development:

Elite durum wheat (*Triticum turgidum* L. s. lat.) cultivars were crossed with several hundred *Aegilops squarrosa* accessions. Embryos were rescued, plated in artificial media, differentiated, and yielded F_1 hybrids (2n=3x=21, ABD) that upon colchicine treatment produced 2n=6x=42, AABBDD synthetic hexaploids (SH). Accession acquisition and procedures for SH production have been described by Mujeeb-Kazi et al. (1996a). These SH wheats are maintained by increasing seed of each combination under controlled conditions by glassine bagging at least 50 spikes per combination at each increase cycle. Based upon growth performance in two Mexican locations (Ciudad Obregon and El Batan) an elite set of 95 SH entries has been assembled for global distribution. Distribution of this elite SH set is handled by CIMMYT's Genetic Resources Group.

Screening of SH germplasm for biotic stress

Cochliobolus sativus

SH germplasm was screened under field conditions (Table 1)in Poza Rica (20°32'N, 96°26'W, 60 masl), Mexico, over four years starting from the 1993-1994 November 25 to March 20 crop cycle. Natural epidemic of the pathogen prevailed over each crop cycle. The SH entries were maintained in hill plots and germplasm was evaluated for foliar disease occurrence, spike damage and seed blemish at maturity. Bread wheat cultivars BH1146 and Ciano 79 were included as the resistant and susceptible checks, respectively. Details of disease scoring parameter were identical to those described by Mujeeb-Kazi et al. (1996b).

Tilletia indica: Evaluations were conducted under field conditions in Ciudad Obregon (27°20' N, 105°55' W, 39 masl.), Sonora, Mexico, over four crop cycles during 1992-1993 and 1995-1996 from November 20 to May 15. Germplasm was also evaluated over three generations during 1993 and 1994 under greenhouse conditions in El Batan, Mexico. Ten spikes were boot-inoculated. The seed on these spikes were evaluated at maturity using procedures and scales as described by Warham et al. (1986). Results are presented in Table 2.

Septoria tritici: The SH wheats, one resistant (Bobwhite) and two susceptible bread wheat (Esmeralda 86 and Opata 85) cultivars were each planted in 2m double rows spaced 15 cm between rows, in 90 cm beds at Toluca (19°17'N, 99°39'W, 2640 masl.), Mexico, during May 1994, 1995 and 1996, for S. *tritici* blotch screening. Artificial inoculation was carried out by spraying a mixture of five isolates of the pathogen. The inoculum concentration of 10^8- 10^9 spores ml^{-1} of water was applied once a week for two weeks beginning at full tillering. S. *tritici* infection was assessed using a double digit scale (00-99) that measured foliar infestation. Disease scores were taken at soft to mid-dough growth stage of the grain, when at least four leaves were still alive and green. Results are presented in Table 3.

Screening of BW/SH cross derivatives

Elite, but S. *tritici*-susceptible bread wheat cultivars were hybridized as maternal or paternal parents to resistant SH wheats. The F_1 combinations were advanced according to conventional breeding protocols, along with disease screening using similar criteria as described above for the SH screening of S. *tritici*.

Kauz and Seri were the susceptible bread wheats. Advanced *S. tritici* resistant BW/SH or SH/BW derivatives were selected. Similar protocols for T. *indica* and *H. sativum* resistant transfers from SH wheats to elite susceptible bread wheats were adopted, and resistant derivatives selected (Data not shown).

Table 1. Some (*Triticum turgidum* cultivar / *Aegilops squarrosa*) synthetic hexaploids resistant to *Cochliobolus sativus* (*Helminthosporium sativum*) at Poza Rica, Mexico during the 1995-1996 and 1996-1997 crop cycle.

Synthetic combination with cross number	Crop cycle					
	1995-1996			1996-1997		
	Leaves[2]		Seed[3]	Leaves[2]		Seed
	a	b		a	b	
Cpt/Gediz/3Goo//Jo69/Cra/4/ *Ae. squarrosa* (409)[1] CIGM93.388	92	92	1	92	92	1
Doy1/ *Ae. squarrosa* (188) CIGM88.1175	93	94	2	92	93	1
Doy1/ *Ae. squarrosa* (333)CIGM92.1682	93	93	2	93	93	1
Doy1/ *Ae. squarrosa*(447) CIGM88.1344	92	93	2	92	93	1
Doy1/ *Ae. squarrosa*(458) CIGM92.1727	92	92	1	92	92	1
Gan/ *Ae. squarrosa* (408) CIGM90.824	92	92	1	92	92	1
Sca/ *Ae. squarrosa*(518) CIGM90.820	92	92	1	92	93	2
Scoop1/ *Ae. squarrosa*(358) CIGM90.820	92	93	2	92	92	1
Snipe/Yav79/Dack/Teal/3/ *Ae. squarrosa*(877) CIGM90. 906	92	92	2	93	93	2
68.111/Rgb-U//Ward/3/Fgo/4/rabi/5/ *Ae. squarrosa* (629) CIGM90-590	92	92	1	92	92	1
68112/Ward// *Ae. squarrosa*(369) CIGM.1313	92	93	2	92	93	1
Ciano 79 (Susceptible bread wheat check)	97	99	5	97	99	5
BH1146 (Resistant bread wheat check)	95	97	2	95	97	3

1: *Ae. squarrosa* accession number (Wide crosses); 2: Used double-digit scoring of Saari and Prescot (1975); a=data recorded at milk stage; and b=data collected during soft dough stage. The first digit indicates height of infection, where 5=up to mid-plant and 9=up to flag leaf; the second digit indicates disease severity on infected leaves, where 1=low and 9=total leaf destroyed; 3: grain infection scored for the severity of damage using a 1 to 5 scale (5=81-100% of grain have black point)

Results and discussion

Germplasm production

Crosses between elite T. *turgidum* and *Ae. squarrosa* accessions resulted in F_1 hybrids with 2n=3x=21, ABD plants. These hybrid seedlings after colchicine treatment led to hexaploid C-0 seed formation. Stable plants with 42 chromosomes called synthetic hexaploids (SH) were selected, seed increased and used for biotic stress screening. The germplasm offered abundant diversity for stresses that are significant for global bread wheat cultivation (Mujeeb-Kazi et al., 1996a). An elite SH set of 95 entries prepared from the 620 SH wheats are available for distribution. These germplasms are maintained and distributed by CIMMYT's germplasm bank.

Table 2. Some (*Triticum turgidum* cultivar / *Aegilops squarrosa*) synthetic hexaploids resistant to Karnal bunt (*Tilletia indica*). Mean scores for four cycles of screening at Yaqui valley, Cd. Obregon, Sonora, Mexico.

Cross Number	Synthetic combination	%KB Score*
CIGM87.2765	Altar84/ *Ae. squarrosa* (188)**	0
CIGM87.2768	Altar84/ *Ae. squarrosa* (198)	0
CIGM87.2761	Altar84/ *Ae. squarrosa* (221)	0.87
CIGM87.2762	Altar84/ *Ae. squarrosa* (223)	0
CIGM86.949	Croc1/ *Ae. squarrosa* (224)	0
CIGM88.1175	Doy1/ *Ae. squarrosa* (188)	0.25
CIGM86.953	Duegrand/ *Ae. squarrosa* (221)	0
CIGM90.561	Yuk/ *Ae. squarrosa* (217)	0
CIGM89.564	68.111/Rgb-U//Ward/3/Fgo/4/Rabi/5/ *Ae. squarrosa* (890)	0
CIGM88.1313	68112/Ward// *Ae. squarrosa* (369)	0.45
	WL711 (Susceptible bread wheat check)	65

* Mean karnal bunt score percentage for four cycles of field screening; ** *Ae. squarrosa* accession number (wide crosses).

Table 3. Some (*Triticum turgidum* cultivar / *Aegilops squarrosa*) synthetic hexaploids resistant to *Septoria tritic* (*Mycosphaerella graminicola*) at Toluca, Mexico.

Cross number	Synthetic combination	Septoria score*	
		1995	1996
CIGM90.525	Aco89/ *Ae. squarrosa* (309)**	2-1	2-1
CIGM86.942	Altar 84/ *Ae. squarrosa* (224)	3-1	3-1
CIGM90.566	Doy/ *Ae. squarrosa* (515)	1-1	2-1
CIGM88.1219	D76.2/P66.270// *Ae. squarrosa* (223)	3-1	3-1
CIGM90.824	Gan/ *Ae. squarrosa* (408)	2-1	2-1
CIGM90.879	Scoop1/ *Ae. squarrosa* (659)	1-1	2-1
CIGM90.849	Sca/ *Ae. squarrosa* (523)	1-1	2-1
CIGM90.818	Sm/ *Ae. squarrosa* (358)	1-1	3-1
CIGM89.463	Yar/ *Ae. squarrosa* (493)	1-1	2-1
CIGM88.1348	Yav/Dack//Rabi/3/Snipe/4/ *Ae. squarrosa* (460)	1-1	2-1
	Bobwhite (Resistant bread wheat)	4-1	4-1
	Esmeralda 86 (Susceptible bread wheat)	8-9	9-9
	Opata 85 (Susceptible bread wheat)	9-9	9-9

*: Used double-digit scoring of Saari and Prescot (1975); a=data recorded at milk stage; and b=data collected during soft dough stage. The first digit indicates height of infection, where 5=up to mid-plant and 9=up to flag leaf; the second digit indicates disease severity on infected leaves, where 1=low and 9=total leaf destroyed ; **: *Ae. squarrosa* accession number (Wide crosses).

Table 4. Agronomic characteristics and disease reaction of *Septoria tritici* (*Mycosphaerella graminis*) resistant spring bread wheat/synthetic hexaploid germplasm grown in Atizapan, Toluca, Mexico (Mean score of 3 crop cycles; *: WS= Watery stage of grainfill, MS=Milky stage, DS=Dough stage.)

Germplasm	Days to		Plant height, cm	1000-kernel wt (g)	Disease damage*		
	anthesis	physiological maturity			WS	MS	DS
CIGM90.358	83	132	100	39	1.1	1	2.1
CIGM91.191	83	138	100	38	1.1	2	2.1
CIGM91.153	83	132	95	37	1.1	1	1.1
CIGM92.248	88	142	100	33	1.1	1	2.1
CIGM92.337	83	138	95	35	1.1	1	2.1
CIGM90.483	80	132	90	25	1.1	2	2.1
CIGM90.248	83	142	90	29	1.1	1	2.1
CIGM90.250	83	138	85	41	1.1	1	1.1
CIGM90.250	83	138	85	41	1.1	1	1.1
CIGM90.412	83	138	100	39	1.1	1	2.1
Bobwhite CM33203, Resistant check	83	138	90	31	1.1	1	4.1
Kauz CM67458 Susceptible check	83	135	85	21	6.4	7	8.7
Seri 82 CM33027 Susceptible check	83	140	90	21	2.1	8	8.9

References

Cox, T.S., and J. H. Hatchett. 1994. Hessian fly-resistance gene H26 transferred from *Triticum tauschii* to common wheat. Crop Science 34:958-960.

Cox, T.S., W. J. Raupp, and B.S. Gill. 1994. Leaf rust-resistance genes *Lr41*, *Lr42*, and *Lr43* transferred from *Triticum tauschii* to common wheat. Crop Science 34:339-343.

Eastwood, R.F., E. S. Lagudah, R. Appels, M. Hannah, and J. F. Kollmorgen. 1991. *Triticum tauschii*: a novel source of resistance to cereal cyst nematode (*Heterodera avenae*). Australian Journal of Agricultural Research 42:69-77.

Gill, B.S., D.L. Wilson, W. J. Raupp, J. H. Hatchett, T. L. Harvey, T. S. Cox, and R. G. Sears. 1991. Registration of KS89 WGRC4 hard red winter wheat germplasm with resistance to Hessian fly, greenbug, and soil-borne mosaic virus. Crop Science 31:246.

Mujeeb-Kazi, A., V. Rosas and S. Roldán. 1996a. Conservation of the genetic variation of *Triticum tauschii* (Coss.) Schmalh. (*Aegilops squarrosa* auct. non L.), in synthetic hexaploid wheats (*T. turgidum* L. s. l. x *T. tauschii*; 2n=6x=42, AABBDD), and its potential utilization for wheat improvement. Genetic Resources and Crop Evolution 43:129-134.

Mujeeb-Kazi, A., R. L. Villareal, L. Gilchrist and S. Rajaram. 1996b. Registration of five wheat germplasm lines resistant to *Helminthosporium* leaf blight. Crop Science. 36:216-217.

Peña, R. J., M. D. H. M. William, A. Amaya, and A. Mujeeb-Kazi. 1991. Quality evaluation of some *Triticum turgidum* x *T. tauschii* synthetic hexaploids and their potential for wheat improvement. Agronomy Abstracts. p 189.

Rees, D., L. Ruis-Ibarra, E. Acevedo, A. Mujeeb-Kazi, and R. L. Villareal. 1994. Photosynthetic characteristics of synthetic bread wheats. CIMMYT Wheat Special Report No. 28, pp.1-40

Saari, E. E., and J. M. Prescott. 1975. A scale of appraising the foliar intensity of wheat diseases, Plant Disease Reporter 59, 377-80.

Villareal, R. L., A. Mujeeb-Kazi, E. Del-Toro, J. Crossa and S. Rajaram. 1994. Agronomic variability in selected *Triticum turgidum* x T. *tauschii* synthetic hexaploid wheats. Journal of Agronomy and Crop Science. 173: 307-317.

Villareal, R. L., A. Mujeeb-Kazi and S. Rajaram. 1996. Inheritance of threshability in synthetic hexaploid *(Triticum turgidum* x T. *tauschii)* by T. *aestivum* crosses. Plant Breeding 115:407-409.

Warham, E. J., A. Mujeeb-Kazi, and V. Rosas. 1986. Karnal bunt *(Tilletia indica)* resistance screening of *Aegilops* species and their practical utilization for *Triticum aestivum* improvement. Can. J. P1. Pathol. 8:65-70.