

Footnotes to Table 5.

*FLOW = flowering, PUB = pubescence, PIC = pigmentation, HT = height, AWN = awn color (LB = light brown, W = white, DB = dark brown, and B = black), P.MAT = physiological maturity, LR = reaction to leaf rust, SR = reaction to stripe rust, GWT = grain weight, H.SAT = reaction to *H. sativum*, SCAB = reaction to Scab, SEPT = reaction to Septoria, KB = reaction to Karnal bunt, HMW = high-molecular-weight glutenin subunits, LMV = low-molecular-weight glutenin subunit.

Locations in Mexico from where data was obtained: *H. sativum* = Poza Rica; Scab = Toluca; Septoria = Toluca; Karnal bunt = Obregon; FLOW, PUB, PIC, HT, AWN, P.MAT, and LR = Obregon; SR = Toluca; GWT = Obregon; and HMW and LMW = Batan.

† *Ae. tauschii* accession number in CIMMYT Wheat Wide Crosses working collection.

Scoring scales:

H. sativum and *S. tritici* = Two-digit scoring system: first digit = height of infection; 5 = up to mid-plant, and 9 = up to flag leaf; second digit indicates disease severity on infected leaves, where 1 = low and 9 = total leaf destroyed.

Scab = percentage of infected florets (Type 2).

Karnal bunt = percentage of grain infected.

None of the SH wheats were free-threshing. There was great diversity for pubescence on the spikes. Awn color ranged from white to a light and dark brown to black. Variation for anthocyanin pigmentation was well distributed. Similar diversity was observed for leaf and stem rusts in the SH elite set. From a screening of 95 SH wheats in Poza Rica for *H. sativum*, we observed diversity of resistance in the elite SH wheats. The durum cultivars involved in these SH combinations were susceptible both for the leaf infection and seed blemish parameters. Hence, resistance in an SH wheat was interpreted as being due to the involvement of the respective *Ae. tauschii* accession.

Those SH wheats with a leaf score of 95 or less and a seed damage of 3 or less (data not shown) are the preferred resistance-gene donors for wheat improvement. Scores for the respective durum parents involved in the SH wheats were 97 to 99 for leaf damage and 3 to 5 for grain blemish. This SH bridge is advantageous for crop improvement, because it not only allows the *Ae. tauschii* resistance to be exploited but also incorporates the genetic diversity of the A and B genomes of the respective durum wheat cultivars. Desirable levels for scab are 15 % or less (Type II), *S. tritici* 5-4 and less, and *N. indica* less than 3 %. The scoring scales are elaborated in the footnote of Table 5.

Conclusions.

—Crosses between *T. turgidum* cultivars and several accessions of *Ae. tauschii* have so far led to the production of 790 synthetic hexaploid wheats.

—An elite set of 95 SH wheats based upon growth habit under two locations in Mexico has been prepared, and seed has been increased and transferred to our germ plasm bank for global distribution.

—Several stress descriptors are being established that should facilitate utilization of SH wheats in crop improvement. Some of these descriptors are elucidated along with a few morphological features.

Reference.

Villareal RL, Mujeeb-Kazi A, Rajaram S, and Del Toro E. 1994. Morphological variability in some synthetic hexaploid wheats derived from *Triticum turgidum* x *T. tauschii*. *J Genet Breed* 48:7-16.

New synthetic hexaploids (Triticum dicoccum/Aegilops tauschii): their production, cytology, and utilization as a source for Russian Wheat Aphid resistance.

A. Mujeeb-Kazi, B. Skovmand, M. Henry, R. Delgado, and S. Cano.

Use of the dicoccom group in wheat improvement has been limited but recently received attention in our program, particularly because potent Russian wheat aphid resistance was identified in several accessions. *Triticum dicoccum* accessions were hybridized with some *Ae. tauschii* diploids, and fertile synthetics derived and screened for RWA resistance. This screening led to a candidate set of SHs for utilization in transferring the resistance to bread wheat cultivars (Table 6). These aspects of the germ plasm characterization and utilization are described.

The standard vernalization procedure resulted in very vigorous growth of the *Ae. tauschii* accessions with a flowering range of 90 to 135 days. Crossing with the two transplanted batches of the vernalized *T. dicoccum* accessions for a majority of the *Ae. tauschii* accessions was successful. Embryos were rescued at 18–20 days postpollination from all crosses. The small, translucent embryos had a definitive shape and were floating in a watery endosperm cavity. The embryos were plated on MS medium and given a 21 day cold shock (dark) at 4°C. The cold treatment

Table 6. Crossability, embryo recovery, plantlet regeneration, and doubled seed (C_0) outputs of various *Triticum dicoccum/Aegilops tauschii* accession cross combinations.

<i>T. dicoccum/Ae. tauschii</i> cross combinations	Florets pollinated	Seed set	Embryos excised	Plants obtained	C_0 seed progeny ¹
CWI 16900 ² /409 ³	56	20	13	8	77
CWI 16900/458	84	32	25	11	139
CWI 16900/498	56	10	10	4	82
CWI 16907/895	84	20	8	5	70
CWI 16907/897	56	16	15	13	63
CWI 16907/1027	56	15	15	13	108
CWI 16908/409	96	30	20	9	133
CWI 16908/454	96	14	10	6	87
CWI 16908/518	96	19	10	4	22
CWI 16916/454	56	10	10	5	25
CWI 16916/458	90	39	25	23	186
CWI 16916/1027	84	15	15	15	86
CWI 17066/309	120	44	41	35	1,594
CWI 17066/372	90	46	30	16	1,359
CWI 17066/700	64	37	30	22	320
CWI 17066/895	64	19	10	3	190
CWI 17089/518	84	34	20	9	33
CWI 17089/700	60	14	14	4	19
CWI 17089/879	84	38	30	9	30

¹ C_0 Seed progeny cumulative status from plants doubled by colchicine as well as those that doubled spontaneously.

² *T. dicoccum* entry in CIMMYT germ plasm bank.

³ *Ae. tauschii* accession number in CIMMYT wide crosses working collection.

allowed better seedling regeneration. The embryo-culture tubes were kept further in the dark at 22°C after the cold treatment. The embryos usually germinated within 30 days, after which the plantlets were transplanted into a soil medium and maintained in the greenhouse for examining cytology, and inducing amphiploidy. Crossability data for some combinations indicate the general trends for seed set, embryo recovery, plant regeneration, and the seed number of doubled plants (Table 6). C_0 seed from SHs that arose by spontaneous doubling had a greater cytological normalcy than their colchicine-doubled counterparts. All F_1 hybrids were stable with $2n = 3x = 21$ (ABD) chromosomes. After colchicine doubling, the C_0 synthetic seed generally possessed 42 chromosomes, though some hypo- or hyperploidy was observed and was subsequently purified by additional cytology and seed increase.

That *Ae. tauschii* is the source of the D genome was discovered by McFadden and Sears (1944, 1946), who also described the origin of *T. spelta*. Kihara (1944) also ascertained this D-genome source independently. A spelt-type hexaploid results when the wild tetraploid *T. turgidum* subsp. *dicoccoides* or its cultivated derivative (dicoccom group) is crossed with *Ae. tauschii*, and amphiploidy is induced. Cultivated emmers were in existence by the time the hexaploid forms appeared (2,000 years later than emmer cultivation). Several independent events combined different tetraploids, and *Ae. tauschii* led to the hexaploid gene pool. Recognizing the nature of occurrence of these events, it is not surprising that the production of the presently reported synthesis was relatively simple and the spontaneous doubling events for each hybrid combination were of a high frequency.

Although our agricultural focus is on stress resistance transfers, the basic information that has surfaced warrants reporting and demonstrates: 1) ease of crossability, 2) excised embryos with a well-defined shape, 3) rapidly growing vigorous hybrid seedlings, 4) high capacity of all hybrids to double spontaneously, and 5) presence of nominal aneuploidy in the spontaneously doubled synthetics. These categories of basic information drastically contrast the earlier

observations related to synthetics that involve elite *T. turgidum* cultivars instead of *T. dicoccum* (Mujeeb-Kazi et al. 1996).

Russian wheat aphid screening of synthetic hexaploids. The *T. dicoccum* parents were rated highly resistant or resistant to the aphid, with a majority scoring 1, which indicates high resistance. Comparing the disease reactions of the

Table 7. The emmer wheat derived synthetics rated as highly resistant under artificial Russian wheat aphid infestation at El Batan, Mexico.

Synthetic hexaploid pedigree	RWA score
<i>T. dicoccum</i> PI306535/ <i>Ae. tauschii</i> (518) *	1
<i>T. dicoccum</i> PI347230/ <i>Ae. tauschii</i> (498)	1
<i>T. dicoccum</i> PI349046/ <i>Ae. tauschii</i> (518)	1
<i>T. dicoccum</i> PI254147/ <i>Ae. tauschii</i> (879)	1

* *Ae. tauschii* accession number in CIMMYT wide crosses working collection.

56 *T. dicoccum*-based synthetics and their *T. dicoccum* parents showed that five of the synthetics were rated highly resistant, 44 were rated resistant/moderately resistant, and seven moderately susceptible. None were rated susceptible or highly susceptible. All the emmer parents were rated highly resistant or resistant. This demonstrates that the emmer resistance was expressed in the synthetics. However, in certain combinations, it may not be expressed to a high degree as shown by the parental emmer wheat. Table 7 shows the pedigrees of the synthetics rated as highly resistant, of which two SHs have the same *Ae. tauschii* parent.

Conclusion. *T. dicoccum/Ae. tauschii* F₁ hybrids

were produced with high frequency, gave vigorous seedlings, and all spontaneously doubled to yield fertile synthetic hexaploids. The synthetics involving several *T. dicoccum/Ae. tauschii* accessions were produced to serve as a source for RWA-resistance transfers via bridge crossing to bread wheat cultivars. The RWA resistance of *T. dicoccum* accessions was expressed over different categories of disease scoring in all synthetics tested. Four SHs exhibited high RWA resistance and are superior candidates for a bread wheat improvement program.

References.

- Kihara H. 1944. Die Entdeckung der DD-Analysatoren beim Weizen. Agr and Hort (Tokyo) 19:889-890.
 McFadden ES and Sears ER. 1944. The artificial synthesis of *Triticum spelta*. (Abstr) Rec Genet Soc Amer 13:26-27.
 McFadden ES and Sears ER. 1946. The origin of *Triticum spelta* and its free-threshing relatives. J Hered 37:81-89, 107-116.
 Mujeeb-Kazi A, Rosas V, and Roldan S. 1996. Conservation of the genetic variation of *Triticum tauschii* (Coss.) Schmalh. (*Aegilops squarrosa* auct. non L.) in synthetic hexaploid wheats (*T. turgidum* L. s.lat. x *T. tauschii*; 2n=6x=42, AABBDD) and its potential utilization for wheat improvement. Genet Res Crop Evol 43:129-134.

New synthetic hexaploids and a set of bread wheat/synthetic hexaploid derivatives as sources for scab resistance.

A. Mujeeb-Kazi, L.I. Gilchrist, and R. Delgado.

Fusarium head blight is one of the most devastating diseases of cereal crops that affects wheat, barley, and maize worldwide. Also known as scab, the disease reduces both grain yield and quality and also increases toxins in the grain that pose serious health risks to human and animal consumers. Head blight infections have caused several billion dollars worth of losses to the U.S. wheat sector alone over the last 5 years, not to mention its impact elsewhere in the world.

In bread wheat, limited resistance has been identified, and the diversity is not excessive in the conventional sources available. Predominant resistant sources are the cultivars Frontana, Sumai 3, and Ning. The potential for identifying resistance in diverse alien sources hence ranks high and has been an aspect that we have been exploring in Toluca, Mexico for the past several years. Among the Triticeae gene-pool species, one avenue is to exploit the primary D-genome donor grass *Ae. tauschii*, which has several hundred accessions. Several of these accessions have been combined with elite durum wheat cultivars to result in a synthetic hexaploid germ plasm resource. So far, a total of 790 synthetics have been produced. These synthetics have been screened in Mexico using the Type II-evaluation protocol. A new batch of synthetics with Type II (spread) scab resistance was identified in the summer of 1999 and are reported in Table 8. Bread wheat cultivars Frontana and Sumai-3 were the resistant checks, and Flycatcher was the susceptible check.