

Short Communication

Inheritance of threshability in synthetic hexaploid (*Triticum turgidum* × *T. tauschii*) by *T. aestivum* crosses

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Abstract

Triticum tauschii provides breeders with a valuable source of resistance and tolerance genes. Elucidation of the inheritance of traits in this species that hinder its use in breeding programmes is therefore of interest to wheat breeders. Inheritance of threshability was investigated in the crosses of four non-free-threshing (NFT) synthetic hexaploids (*Triticum turgidum* × *T. tauschii*) and two free-threshing (FT) *T. aestivum* cultivars during four crop seasons over 3 years at El Batan and Ciudad Obregon, Mexico. The parents, their F₁ hybrids and individual F₂ plant-derived F₃ progenies of the crosses revealed that 'Altar 84'/*T. tauschii* (219), 'Chen'/*T. tauschii* (205), 'Chen'/*T. tauschii* (224), and 'Duergand'/*T. tauschii* (214) have independently segregating loci with two dominant alleles controlling threshability. Intercrosses among the synthetics, except 'Altar 84'/*T. tauschii* (219), showed the genes to be allelic to each other. The cross between the FT cultivars showed no segregation in the F₃ generation, indicating common recessive genes. Based on these findings, population sizes of the synthetic-derived breeding materials should be increased to improve the chances of selecting FT desirable plants in the programme.

Key words: *Triticum aestivum* — *Triticum tauschii* — synthetic hexaploid — threshability — inheritance

Goatgrass (*Triticum tauschii* (Cross.) Schmal; formerly *Aegilops squarrosa* L.), the D genome donor to bread wheat (*T. aestivum* L.; Kimber and Feldman 1987), is attributed with a wide range of resistances/tolerances to biotic/abiotic stress factors that can contribute to bread wheat improvement (Limin and Fowler 1981, Gill et al. 1986, Warham et al. 1986, Cox et al. 1992, McKendry and Henke 1994). Because of the screening constraints, winter growth habit, and the tendency for shattering and for potential weed problems of the *T. tauschii* accessions, hybridization with durum wheats (*T. turgidum*) has more adequately facilitated evaluation of the resulting synthetic hexaploids ($2n = 6x = 42$) without having to deal with vernalization (Mujeeb-Kazi 1995). On the other hand, the use of *T. tauschii* in crosses also introduces undesirable characters, such as tough-threshing glumes, that affect its practical utilization in the germplasm development programme (Kerber and Dyck 1969, Kerber and Rowland 1974, Villareal et al. 1994). All *T. tauschii* accessions in the Germplasm Bank of the International Maize and Wheat Improvement Center (CIMMYT) are non-

free-threshing (NFT) and exhibit glumes that are extremely hard, stiff, tough and tenacious.

All *Triticum* diploid progenitors possess the NFT habit, while both free-threshing (FT) and NFT forms occur in the tetraploid and the hexaploid groups (Kerber and Rowland 1974). The kernels of the NFT wheat are closely invested in the spikelet by tough tenacious glumes, lemma, and palea that are not readily detached with pressure or vigorous rubbing. Conversely, only slight rubbing or threshing action is required to separate the glumes from the spikelet of an FT wheat to release its kernels. Variations in the degree of threshability occurs among the FT *T. aestivum* cultivars. Early studies revealed numerous minor and one major mutation as being involved in the evolution of FT hexaploids. MacKey (1966) reported a polygenic system scattered through all three genomes that counteracts rachis brittleness and tough, tenacious glumes. A second system which suppresses these primitive tendencies is that of the *Q* factor located on chromosome 5A. All FT hexaploids carry this dominant factor, while indirect evidence indicates that only *T. carthlicum* Nevski (= *persicum* Vav.) of the FT tetraploids possesses it (McFadden and Sears 1946, MacKey 1966). Swaminathan (1966) and Tsunewaki (1966) suggested that *Q* exists in different strengths among FT and NFT *Triticum* species. There was a consensus based on previous studies that *Q* is a complex locus. NFT hexaploids and tetraploids evidently carry the recessive *q* allele.

A genetic system governing threshability in hexaploids is associated with the D genome (Kerber and Dyck 1969). The synthetic hexaploid produced by combining the FT AABB tetraploid extracted from the ssp. *vulgare* cv. 'Canthatch' with *T. tauschii* was NFT, despite the expected presence of the *Q* factor in the homozygous state. Inheritance studies of threshability in crosses between each of the synthetic hexaploids and 'Canthatch' indicated that a partially dominant gene, apparently introduced from the *T. tauschii* parent, results in NFT spikelets. Other reports on synthetic hexaploids obtained from hybrids between naturally occurring tetraploid wheats and *T. tauschii* are NFT except those that have *T. carthlicum* as the source of the A and B genomes, which would be due to the presence of *Q* (Kihara and Lilienfeld 1949, Tsunewaki

Table 1: Per cent threshability of parental cultivars and F_1 s at Cd. Obregon, Sonora, Mexico, for the 1992-93 wheat season: NFT, non-free-threshing; FT, free threshing

Materials	Type	Mean (%) of threshed grains
Parental cultivars		
Synthetic hexaploid		
'Altar 84'/ <i>T. tauschii</i> (219)	NFT	1.5
'Chen'/ <i>T. tauschii</i> (205)	NFT	1.2
'Chen'/ <i>T. tauschii</i> (224)	NFT	0.7
'Duergand'/ <i>T. tauschii</i> (214)	NFT	1.5
Bread wheat		
'Opata 84'	FT	93.2
'Seri 82'	FT	91.2
F_1		
'Altar 84'/ <i>T. tauschii</i> (219)//'Seri 82'	NFT × FT	5.0
'Chen'/ <i>T. tauschii</i> (205)//'Seri 82'	NFT × FT	3.8
'Chen'/ <i>T. tauschii</i> (205)//'Opata 84'	NFT × FT	4.0
'Chen'/ <i>T. tauschii</i> (224)//'Seri 82'	NFT × FT	3.5
'Chen'/ <i>T. tauschii</i> (224)//'Opata 84'	NFT × FT	4.5
'Duergand'/ <i>T. tauschii</i> (214)//'Seri 82'	NFT × FT	5.7
'Duergand'/ <i>T. tauschii</i> (214)//'Opata 84'	NFT × FT	4.7
'Chen'/ <i>T. tauschii</i> (205)//'Chen'/ <i>T. tauschii</i> (224)	NFT × NFT	2.5
'Chen'/ <i>T. tauschii</i> (224)//'Duergand'/ <i>T. tauschii</i> (214)	NFT × NFT	2.7
'Duergand'/ <i>T. tauschii</i> (214)//'Chen'/ <i>T. tauschii</i> (205)	NFT × NFT	3.0
'Opata 84'/'Seri 82'	FT × FT	92.7

1966). The results of Kerber and Rowland (1974), however, revealed that all hexaploids synthesized from tetraploids and *T. tauschii* are NFT, regardless of the presence or absence of the *Q* factor. They found a partially dominant gene for tenacious glume, *Tg*, which is present in chromosome 2D of *T. tauschii* and inhibits the expression of *Q* in synthetic hexaploids. The recessive allele, *tg*, must be present for the development of nontenacious glumes. They also found that the *Q* and the *tg* genetic systems complement each other, hence, both must be present to confer the FT character.

The objective of this study was to determine the inheritance of the NFT character in synthetic hexaploids used in the CIMMYT bread wheat improvement programme.

Eleven crosses were made in 1991 at El Batan, Mexico involving four NFT synthetic hexaploids and two FT Mexican bread wheat cultivars 'Opata 84' and 'Seri 82' (Table 1). The synthetic hexaploid wheats were developed from the Wide Crosses Programme at CIMMYT. They are 'Altar 84'/*T. tauschii* (219), 'Chen'/*T. tauschii* (205), 'Chen'/*T. tauschii* (224) and 'Duergand'/*T. tauschii* (214). The F_1 s were grown in Cd. Obregon, Sonora, Mexico, harvested in bulk and space-planted as F_2 populations at El Batan. For each of the 11 crosses, F_3 lines were obtained by harvesting 179 to 325 randomly-chosen F_2 plants (Table 2). Genetic analysis was conducted on parents, their F_1 s and individual

F_2 plant-derived F_3 s space-planted 10 cm apart in 75 cm beds as two-row plots, 1 m long with 20 cm between rows in Cd. Obregon during the 1992-93 wheat season. The trial received 150 kg N/ha and 40 kg P/ha, irrigation and selective herbicide (Puma = Fenoxaprop-Ethyl = Ethyl (R) -2-[4[(6-chloro-2-benzoxazolyl)oxy]phenoxy] propanoate; 2.5 l/ha). A fungicide (Folicur = Tebuconazole = Alfa-tertiari-butyl- α (*p*-chorofenetil) -1H-1, 2, 4-triazole-1 ethanol; 0.5 l/ha) was applied to control leaf and stem rusts. Insect control was not required.

At maturity, 10 spikes which had completely lost their green colour were randomly-harvested from each test plot. Selected spikes were kept in separate bags and oven-dried at 75°C for 2 days. Threshability of spikes was determined using a petrol-powered Vogel plant/head thresher. The thresher was maintained at a speed range of 950-960 r.p.m. and constantly monitored using a Tachometer. This speed was found to be best to differentiate the threshing ability of the parental types during the pretest. In addition, the thresher's air intake control was shut off and the straw-chaff outlet covered completely to recover all threshed and unthreshed grains including chaff of the spike for evaluation. Only one thresher was utilized throughout the study to minimize machine variation. Threshability was determined by counting the number of threshed and unthreshed grains in a spike and then averaged for 10 spikes.

Chi-square analysis was used to compare the distribution of the observed genotypic frequencies to those expected for each cross.

The four NFT synthetic parents had very low mean threshed

Table 2: Segregation of random F_3 lines for per cent threshability score at Cd. Obregon, Sonora, Mexico for the 1992-93 wheat season; NFT, non-free-threshing; FT, free-threshing

Cross	F_3 lines		Ratio NFT: FT	χ^2 Value	P
	NFT ^a	FT ^b			
'Altar 84'/ <i>T. tauschii</i> (219)//'Seri 82'	251	15	15:1	0.10	0.70-0.80
'Chen'/ <i>T. tauschii</i> (205)//'Seri 82'	275	20	15:1	0.14	0.70-0.80
'Chen'/ <i>T. tauschii</i> (205)//'Opata 84'	309	16	15:1	0.03	0.80-0.90
'Chen'/ <i>T. tauschii</i> (224)//'Seri 82'	236	14	15:1	0.17	0.50-0.70
'Chen'/ <i>T. tauschii</i> (224)//'Opata 84'	236	15	15:1	0.03	0.80-0.90
'Duergand'/ <i>T. tauschii</i> (214)//'Seri 82'	257	18	15:1	0.04	0.80-0.90
'Duergand'/ <i>T. tauschii</i> (214)//'Opata 84'	242	15	15:1	0.07	0.70-0.80
'Chen'/ <i>T. tauschii</i> (205)//'Chen'/ <i>T. tauschii</i> (224)	179	0	No segregation		
'Chen'/ <i>T. tauschii</i> (224)//'Duergand'/ <i>T. tauschii</i> (214)	214	0	No segregation		
'Duergand'/ <i>T. tauschii</i> (214)//'Chen'/ <i>T. tauschii</i> (205)	206	0	No segregation		
'Opata 84'/'Seri 82'	0	217	No segregation		

^a Either segregating or homozygous for non-free-threshability

^b Homozygous for the parental type of free-threshability

grain scores while on the FT cultivars more than 90% of the grains were threshed (Table 1). The per cent threshed grains of the F_3 s involving the synthetic hexaploid \times bread wheat crosses varied from 3.5% to 5.7%. Based on this reaction, the NFT character of the synthetic hexaploids appeared to be dominant over FT character of the bread wheat cultivars. Similarly, the F_3 s of the synthetic hexaploid \times synthetic hexaploid crosses resulted in low threshability scores comparable to the parents ($P > 0.05$; statistical analysis not shown). The F_1 between the two FT cultivars gave a threshed grain score similar to its parents.

In order to estimate the number of loci involved in each cross, F_3 lines were grouped into two classes: (1) either homozygous or segregating for NFT and (2) homozygous for the FT parental type (Table 2). In the seven synthetic hexaploid \times bread wheat crosses, distributions of F_3 lines were in accordance with those expected for segregation at two loci. From the intercrosses of the NFT parents, no FT plant was observed in the F_3 lines. This indicated that the synthetics, Chen/*T. tauschii* (205), Chen/*T. tauschii* (224) and Duergand/*T. tauschii* (214) carry two common genes for NFT character. Because Altar 84/*T. tauschii* (219) was not crossed with other synthetic hexaploids, it was not possible to establish whether its two genes were different. Based on the segregation pattern, it can be postulated that a minimum of two major genes for the NFT character is present in each of the four synthetic hexaploids. The cross between the FT cultivars showed no segregation for FT F_3 plants.

Our efforts to produce new synthetics using diverse accessions from the CIMMYT germplasm bank and other genetic sources centres, will continue. Based on the findings of this study, an increase in population size of the breeding material will increase the probability of selecting desirable FT plants in the programme. Selection in F_2 and F_3 generations will result in progenies homozygous for the FT classes which would lead to their efficient utilization and rapid expansion throughout the *T. aestivum* population.

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