Hordeum vulgare × Triticum aestivum hybrids

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This paper presents information on the nature of homoeologous chromosome association in hybrids of H. vulgare cv. Manker × T. aestivum cvs. Bonza, Pavon and Chinese Spring. Furthermore, information is given on the phenotype of the hybrid plants, meiotic instability, non-reduction and on backcross (BC₁ and BC₂) seed formation.

Materials and methods

Hordeum vulgare cv. Manker plants were grown in pots and kept under field conditions at Ciudad Obregon, Mexico. Spikes were emasculated and pollinated with Triticum aestivum cvs. Bonza, Chinese Spring or Pavon two to three days after emasculation, depending upon stigma receptivity. Pollination was followed eight hours later by a gibberellic acid (GA₃) treatment, 75 ppm aqueous, into the floret cups as demonstrated by Kruse (1973). All efforts were devoted to obtaining intergeneric hybrids, and not toward compiling the basic crossability data. The embryos were excised 20 days after pollination, and cultured on a special medium for small embryos (Taira and Larter 1978). Upon differentiation the plantlets were transferred to peat pots, and maintained in the growth chamber under high humidity before ultimate transfer to pots with soil. The hybrids were identified on the basis of the somatic chromosome number using Mujeeb et al.'s., schedule (1978a). Depending upon plant vigour the hybrids were multiplied by cloning and kept under growth
chamber conditions of 15°C day/10°C night, 14 h day/10 h night, and 45% relative humidity. The self-sterile hybrids were backcrossed with *T. aestivum* to obtain first backcross (BC₁) seeds. The florets were clipped and pollinated earlier than is done conventionally, i.e. before stigma receptivity is visible. Mostly two applications of gibberellic acid (75 ppm, aqueous) were made into each floret cup using Kruse's (1973) procedure, eight and 32 hours after pollination. BC₁ seeds were allowed to develop for 20 days. The embryos were then excised and cultured on a special medium for small embryos (Taira and Larter 1978). BC₁ plants were transferred to soil in pots, and grown in the greenhouse environment of 16 h day/8 h night, 22°C day/15°C night, and approximately 45% relative humidity. The BC₁ plants were similarly pollinated by *T. aestivum* and treated with gibberellic acid, as was done earlier to the self-sterile F₁ hybrids, to produce BC₂ progeny. No embryo culturing of the BC₂ seeds was necessary.

Counting of the somatic root-tip chromosomes of the hybrids and the BC₁ plants was done according to the procedure of Mujeeb *et al.* (1978a). F₁ and BC₁ spikes for meiotic analyses were fixed in Carnoy's solution (6 ethanol: 3 chloroform: 1 acetic acid) for 24 hours, then transferred to 70% ethanol and refrigerated until use. Anthers were hydrolyzed in 1 N HCl for 4 minutes at 58°C, rinsed in deionized distilled water and stained with Feulgen. Squashes were made in 45% acetic acid, or 2% propionic orcein, and chromosome relationships were observed at metaphase I.

### Results and discussion

The hybrid spike phenotypes of *H. vulgare* × *T. aestivum* cvs. Bonza and Pavon appear to be influenced by the phenotype of the *T. aestivum* parent (Figs. 1, 2). The barley combination with the cv. Chinese Spring also had a similar phenotypic expression. Each hybrid was somatically stable for the somatic cells analyzed, and possessed n=4x=28 HABD chromosomes.

Homoeologous chromosome association was observed in each hybrid combination yielding mean chiasma frequencies per cell of 2.6, 2.5 and 2.6 respectively (Table 1). Surprisingly chromosome configurations of up to 14₁₁ were expressed as

<table>
<thead>
<tr>
<th>Hybrid combination</th>
<th>Number of cells</th>
<th>I (0–28)</th>
<th>Rod II (0–11)</th>
<th>Ring II (0–13)</th>
<th>III (0–2)</th>
<th>IV (0–1)</th>
<th>VI (0–1)</th>
<th>Mean chiasma frequency per cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manker × Bonza</td>
<td>331</td>
<td>23.87</td>
<td>1.40</td>
<td>0.45</td>
<td>0.09</td>
<td>0.03</td>
<td>0.01</td>
<td>2.60</td>
</tr>
<tr>
<td>Manker × Pavon</td>
<td>115</td>
<td>24.57</td>
<td>1.28</td>
<td>0.46</td>
<td>0.10</td>
<td>0.003</td>
<td></td>
<td>2.47</td>
</tr>
<tr>
<td>Manker × Chinese Spring</td>
<td>59</td>
<td>23.85 (11–28)</td>
<td>1.36 (0–5)</td>
<td>0.24 (0–6)</td>
<td>0.25 (0–2)</td>
<td>0.05 (0–3)</td>
<td></td>
<td>2.63</td>
</tr>
</tbody>
</table>
13_{II(\text{rings})} + 1_{II(\text{rod})}$, or $12_{II(\text{rings})} + 2_{II(\text{rods})}$, but in a low frequency. Among other relationships, unique separation of up to five chromosomes was observed. The meiotic configurations are presented in Figs. 3 and 4.

Fedak (1977) observed enhanced homoeologous chromosome association for *H. vulgare* cv. Betzes × *T. aestivum* cv. Chinese Spring hybrids with a chiasma frequency of 1.82/cell that was not autosyndetic. This was based on presumed barley-wheat chromosome associations expressed by the presence of heteromorphic bivalents, and was interpreted as an influence of the barley genome on the *Ph* locus. Mujeeb *et al.* (1978b) did not observe this relationship in *H. vulgare* cv. Manker × *T. turgidum* cv. Cocorit 71 and *H. vulgare* cv. Manker × *T. aestivum* cv. Tobari hybrids, where the possible role of germplasm may be a factor.

We do not consider the mean chiasma frequency of 2.57/cell (Table 1) to be enhanced homoeologous association, because the random association of the HABD genomes would allow for six combining possibilities and higher frequencies. Additionally, the heteromorphic bivalents observed by us in the barley × wheat hybrids have not been interpreted exclusively as a consequence of a barley-wheat chromosome association. This is based upon the chromosome size differences within the *T. aestivum* ABD genomes, which would allow the observation of heteromorphic bivalents should two unequal sized chromosomes pair as a rod bivalent.

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Fig. 1. Spike morphology of *H. vulgare* cv. Manker (left), *H. vulgare* × *T. aestivum* (center), and *T. aestivum* cv. Bonza (right). Note the phenotypic dominance of cv. Bonza in the hybrid.

Backcrossing the self-sterile F₁ plants to the respective T. aestivum parents produced 20 BC₁ seeds from which 19 embryos were excised and cultured. The endosperm was normal in all cases and the seeds may have matured on the spikes. However, caution was exercised so as to rapidly exploit the material produced and have a sizeable BC₁ population. Gibberellic acid treatment assisted seed setting for this backcross combination (Mujeeb-Kazi and Rodriguez 1980).

In barley × wheat hybrids, inducing amphidiploidy has not been possible when H. vulgare was the barley species. Thus, for the advance of a barley × wheat programme for practical agricultural gain, the alternate route would be to produce BC₁ progeny directly by pollinating the self-sterile F₁ hybrid with T. aestivum. The
procedure may be facilitated if a $n=4x=28$, HABD egg cell would be formed to be fertilized with $n=3x=21$, ABD pollen from *T. aestivum*, to produce a heptaploid $2n=7x=49$, HAABBDD BC$_1$ progeny. The BC$_1$ progeny plants obtained have been somatically identified to range from 27 to 50 chromosomes. This variation seems a consequence of F$_1$ meiotic instability and meiotic non-reduction that allowed varied chromosome numbers to transgress to the egg cell. Some BC$_1$ plants did possess the heptaploid $2n=7x=49$, HAABBDD composition with several meiocytes.
expressing the $21_{1I} + 7_1$ chromosome association. The plants with 27 to 28 chromosomes had a mean meiotic relationship of $23.42_{1I} + 1.36_{1II(rods)} + 0.33_{1II(rings)} + 0.17_{1III} + 0.04_{1IV}$ with a 2.60 chiasma frequency per cell. This was similar to the mean

![Fig. 4. Metaphase I chromosome association in Hordeum vulgare × Triticum aestivum hybrids. A, $5_{1II(rings)} + 1_{1II(rod)} + 16_1$, with unique separation. B, $6_{1II(rings)} + 1_{1III} + 13_1$, with unique separation of 1 chromosome arrowed. C, $3_{1II(rings)} + 2_{1II(rod)} + 1_{1IV} + 14_1$. D, $5_{1II(rings)} + 3_{1II(rod)} + 12_1$. E, $3_{1II(rings)} + 2_{1II(rod)} + 18_1$. F, $2_{1II(rod)}$.]

meiotic association observed in the $F_1$ hybrid (Table 1) and reported in detail by Mujeeb-Kazi (1981). These data may account for the recovery of cytologically normal euploids with the capacity of having subtle biochemical differences, as earlier observed by Kruse (1969) for $T. aestivum$ euploids derived from $T. aestivum ×$
Avena sativa hybridization.

Islam et al. (1975) have obtained heptaploids similarly by backcrossing the

\[ \text{TRITICUM AESTIVUM} \quad (2n=6x=42, AABDD) \]

\[ \text{HORDEUM VULGARE} \quad (2n=2x=14, HH) \]

HYBRID
\[ (2n=4x=28, ABDH) \]

AMPHIDIPLOID
\[ (2n=8x=56, AABBDHH) \]

UNREDUCED EGG CELL
\[ (2n=4x=28, ABDH) \]

\[ \times \quad \text{T. AESTIVUM} \quad (0^-) \]

BACKCROSS I SEED
\[ (2n=7x=49, AABDDH) \]

BACKCROSS II SEED
\[ (2n=6x=42, + 0\rightarrow 7 \quad H. VULGARE \quad CHROMOSOMES) \]

REPEATED BACKCROSSING TO T. AESTIVUM AND CYTOLOGICAL ANALYSES FOR RECOVERING

\[ 2n=6x=42 + 1 \quad H. VULGARE \quad CHROMOSOME \quad (7 \text{ POSSIBLE}) \]

\[ \text{T. AESTIVUM EUPLIFIDS} \quad (2n=6x=42, AABBD) \]

SELF

PRODUCE DISOMIC ADDITIONS OF BARLEY

X H. BULBOSUM

INDUCE TRANSFER VIA IRRADIATION OF SELFED PROGENY (KIMBER, 1971)

PRODUCE DISOMIC SUBSTITUTIONS OF BARLEY BY USING

OBTAIN
\[ n=3x=21 + 1 \quad H. VULGARE \quad CHROMOSOME \quad (7 \text{ POSSIBLE}) \]

COLCHICINE TREATMENT TO PRODUCE DISOMIC ADDITIONS (ISLAM ET AL. 1978)

MONOSOMICS
\[ \text{(UNRAU ET AL. 1956)} \]

DITELOSONICS

Fig. 5. Scheme of steps involved in synthesizing barley addition and substitution lines, obtaining genetic transfers, and for recovering T. aestival euploids.
self-sterile F₁ hybrid with *T. aestivum*, for barley addition line production. They have since reported (1978) an efficient alternate approach for obtaining disomic addition lines utilizing the *T. aestivum × H. bulbosum* chromosome elimination technique (Barclay 1975). Chapman and Miller (1978) first developed the *H. chilense × T. aestivum* amphiploid. Then by reciprocal crosses of this amphiploid to *T. aestivum*, 49 chromosome plants (2n=7x=49, HAABBDD) were obtained for addition line production.

The exploitation of gene transfers between genera is the ultimate goal desired by plant breeders. Where intergenomic pairing and spontaneous transfers do not occur the only alternatives are to develop addition and substitution lines, or to irradiate the addition lines to induce alien transfers (Kimber 1971, Fig. 5). Based upon the meiotic relationships of the F₁ hybrid it is difficult to expect the *T. aestivum* euploids produced after backcrossing (Fig. 5) to carry much barley genetic information. If a genetic transfer occurred, this only can be seen if the barley genes show expressivity. We are now exploring the possibilities of producing new wheat × barley hybrids by using the *Ph* mutant as the maternal parent. The *Ph* mutant source is in *T. turgidum* cv. Capelli and *T. aestivum* cv. Chinese Spring.

Pistilloidy problems are commonly encountered when barley is the maternal parent in crosses with wheat (Islam *et al.* 1975). The pistilloidy problem encountered with BC₁ plants did not prevent BC₂ seed production when the BC₁ plants were further backcrossed by *T. aestivum*. Early pollinations and the GA₃ treatment aided in BC₂ seed-setting. Over 100 BC₂ seeds were obtained from the BC₁ plants pollinated by the respective *T. aestivum* cultivars. The BC₂ progeny is being cytologically analyzed, and further study was programmed to develop *T. aestivum* germplasm carrying barley genetic information. Since difficulties were encountered in obtaining self-fertile progeny from the BC₂ plants, emphasis was currently placed on the reciprocal combinations where the *T. aestivum* cultivars are other than Chinese Spring. A hybrid of *T. aestivum* cv. Tesia × *H. vulgare* has since been obtained with n=4x=28 HABD chromosomes. Pollinating this self-sterile F₁ by *T. aestivum* cultivars Veery “S” and Nacozar has produced BC₁ seed set. The schematic of Fig. 5 exemplifies the advance of this combination. These results shall soon be reported in detail.

**Summary**

Three *Hordeum vulgare × Triticum aestivum* hybrids are described. The phenotypic expression of the hybrids was similar to *T. aestivum*. The overall mean chromosome association in the hybrids was 24.3I+1.33II (rods)+0.38II (rings)+0.15III+0.03IV+0.003VI with a 2.57 mean chiasma frequency per cell. Early pollinations of the hybrids, before stigma receptivity was evident, with respective *T. aestivum* cultivars, followed eight and 32 hours later by gibberellic acid (75 ppm aqueous) treatment into the floret cups yielded first backcross (BC₁) seed set. The plants that resulted after embryo culture ranged in chromosome numbers from 27 to 50. Similar early pollinations of the BC₁ plants with *T. aestivum*, coupled with two post-pollination applications of gibberellic acid after eight and 32 hours produced over 100 BC₂ seeds. All BC₂ plants remained self-sterile.
Acknowledgment

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References


— 1974. A 2, 4-D treatment prior to pollination eliminates the haplontic (gametic) sterility in wide intergeneric crossed 2 rowed barley, Hordeum vulgare ssp. distichum, as maternal species. Hereditas 78: 319.


