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TRANSFER OF STEM RUST SEEDLING RESISTANCE FROM WILD DIPLOID EINKORN TO TETRAPLOID *DURUM* WHEAT BY MEANS OF A TRIPLOID HYBRID BRIDGE[1]

Z. K. GERECHTER-AMITAI[1], I. WAHL[2], ALIZA VARDI and D. ZOHARY[3]

Volcani Institute of Agricultural Research, Bet Dagan[1], Israel Department of Botany, Tel Aviv University[2], and Institute of Biology, Hebrew University of Jerusalem, Israel[3]

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SUMMARY

Transfer of stem rust resistance from diploid wild einkorn, *Triticum boeoticum*, to susceptible Mindum and Spelmar, varieties of cultivated *T. durum*, was achieved by means of a triploid hybrid bridge and subsequent backcrossing to the tetraploid parent. Seedlings of the second hybrid generation segregated for resistance to race 14 of *Puccinia graminis* f.sp. *tritici* which was used as test race in this investigation. The F_3 and F_4 progenies included segregants which displayed seedling resistance also to races 17, 19, 21, 40, 53, 194, 222, 315 and 322. Since these were the same races which proved avirulent to the *T. boeoticum* donor but virulent to the *T. durum* recipients, it was concluded that the full pattern of resistance determined in the wild diploid parent of this cross was transferred to the tetraploid *durum*-like hybrid derivatives.

INTRODUCTION

A recent survey of the wild diploid members of the wheat group (*Triticum-Aegilops*) revealed that the local Middle Eastern populations frequently include forms which are resistant to the various races of the wheat rusts encountered in Israel (GERECHTER-AMITAI, 1967). Field observations indicate that the diploid and tetraploid species of *Triticum* and *Aegilops* are loosely interconnected in nature by means of an occasional, spontaneous hybridization. Furthermore, evidence was presented to demonstrate that wheat interspecific triploid hybrids are not fully sterile; they consitute an effective bridge for a diploid to tetraploid introgression (VARDI and ZOHARY, 1967). When the diploid donor species and the tetraploid recipient species share one genome, such gene flow is a quick and neat process. Back-pollination of the triploid F_1 hybrid by the tetraploid species will frequently result in the formation of more or less stabilized tetraploid products. Such second generation derivatives enrich the gene-pool of the recipient species.

Of particular interest are wild diploid einkorn, *T. boeoticum* (genomic constitution

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AA), and *Aegilops speltoides* (BB), since their chromosome sets are identical with those present in tetraploid *durum* (AABB) (RILEY, 1956). In screening tests for stem rust resistance, promising plants were found in each of these two diploid progenitors. Here we will confine ourselves to a transfer-experiment from resistant wild einkorn to susceptible cultivated wheat.

In this investigation, a representative line of *T. boeoticum* with seedling resistance to wheat stem rust was crossed with two susceptible tetraploid cultivars of *T. durum*. The triploid hybrids thus produced served as a bridge for backcrossing and for the transfer of resistance to the cultivated wheat.

MATERIALS AND METHODS

Accession G–21 of *Triticum boeoticum* spp. *aegilopoides* ($2n = 14$), collected 25 km west of Tekirdag in the district of Thrace, Turkey, was selected as a diploid donor. In the seedling stage this accession proved to be resistant to most physiologic races of wheat stem rust isolated in Israel in recent years, including all the common races.

Two cultivars of *T. durum* ($2n = 28$), Spelmar and Mindum, were chosen as tetraploid recipients. These two varieties, which are included in the standard differential set for identification of wheat stem rust races (STAKMAN et al., 1962), proved to be susceptible to all isolates of this rust in Israel studied during the last decade.

Isolate GSR-739 of *Puccinia graminis* f.sp. *tritici* race 14 served as tester for the transfer of stem rust resistance. This isolate was originally collected in 1960 on wild barley, *Hordeum bulbosum*, in the foothills of the Judean mountains, Israel. Both the resistance of the diploid donor and the susceptibility of the tetraploid recipients to isolate GSR-739 were verified; this isolate was then used in all inoculation tests with race 14.

EXPERIMENTAL PROCEDURES AND RESULTS

In the attempt to transfer rust resistance from wild *T. boeoticum* to cultivated *T. durum* the introgression technique described by VARDI and ZOHARY (1967) was followed. Triploid interspecific hybrids between the two species served as bridges for the transfer. The following diagram shows the experimental design employed:

♀ *T. durum* × ♂ *T. boeoticum* spp. *aegilopoides*

(Cultivars Spelmar and Mindum) | (wild from G-21)
Susceptible tetraploid recipients | Resistant diploid donor

↓

♀ Triploid F_1 hybrid × ♂ *T. durum*

↓

Second generation hybrid derivatives
(backcross products)

↓

Subsequent stabilized tetraploid hybrid derivatives *a. F_1 triploid hybrids*

The crosses between the tetraploid *durum* varieties and the diploid einkorn selections made in 1964 were of two combinations: (1) *T. durum* cultivar Spelmar × *T. boeoticum* G-21, and (2) *T. durum* cultivar Mindum × *T. boeoticum* G-21. Each plant of the parental stock used in the experiment had been previously tested in the seedling stage for its typical reaction to stem rust race 14.

From these crosses, 32 triploid hybrids were obtained in combination (1) and three in combination (2).

At seedling stage, the *durum* × *boeoticum* triploids (genomic constitution AAB) were tested for their reaction to wheat stem rust race 14. In this trial, all 35 F_1 plants proved resistant, displaying the same in fection type as their diploid parent. After the seedling test, the young triploid plants were transferred to a nursery plot and interplanted with Spelmar and Mindum individuals. The F_1 hybrids showed marked vegetative vigor under nursery conditions in Jerusalem, and exceeded their parental lines in height and in number of tillers produced; however, they all were completely male-sterile. Pollen abortion in the triploids was about 98–99%, and there was no subsequent dehiscence of their anthers. However, being exposed to clouds of pollen produced by Spelmar and Mindum plants, the F_1 hybrids did set 1–2% of backcross seed. Some 300 well-developed kernels were found in the spikes of the triploid plants.

b. Second generation hybrid derivatives

A sample of a 43 backcross progeny from Spelmar × *T. boeoticum*, combination (1), and an additional sample of 12 descendants from Mindum × *T. boeoticum*, combination (2), were used as representatives for the second generation. The seedlings, which were tested for their reaction to wheat stem rust race 14, segregated into two distinct classes. In combination (1), 24 seedlings showed resistance while 19 proved susceptible; in combination (2), nine seedlings were found to be resistant and three were susceptible.

A wide range of variation in development and morphology was noted in the second generation plants. But significantly, these plants were morphologically *durum*-like and many showed pronounced vigor and even exceeded the original parental lines in development. In their cytology and fertility, these samples were very similar to the second generation plants already described by VARDI and ZOHARY (1967). They were tetraploid or almost tetraploid (with AABB genomic constitution) and showed remarkable restoration of fertility; seed set values, in the majority of plants, amounted to 50–100%.

c. *Subsequent generations*

The 33 resistant seedlings of the second generation, representing the progenies of combinations (1) and (2), were transplanted into nursery plots to serve as parents for subsequent generations. From the F_3 seed produced by these plants, seedlings which proved resistant to stem rust race 14 were grown for one more generation. Seedlings grown from the F_4 seed continued to segregate for reaction to the stem rust test isolate. The F_3 and F_4 bulk seed was used for a series of seedling inoculation tests with various races of wheat stem rust.

In one experiment, seedlings of the parental stock and of the F_3–F_4 hybrid derivatives were inoculated with 12 races of wheat stem rust, each race separately. In this test, the hybrid derivatives segregated in their reaction to ten races, viz races 14, 17, 19, 21, 40, 53, 194, 222, 315 and 322, whereas no resistance was found to races 316 and 317. Correspondingly, the wild parent *T. boeoticum* G–21 proved resistant to the former ten races but susceptible to the last two. Both cultivars that had been used as the recipient parents, i.e., Spelmar and Mindum, were susceptible to all 12 test races. These results clearly show that the full pattern of resistance found in the diploid donor was transferred to the tetraploid *durum*-like hybrid derivatives.

In a second experiment, seedlings grown from the F_3 bulk seed were inoculated first in the one-leaf stage with race 14. When segregation for reaction to this race occurred, about 90 resistant and 45 susceptible seedlings were inoculated on their second leaves with one of the remaining nine races avirulent to the wild parent, i.e., ten resistant and five susceptible seedlings per race. This test showed that seedlings resistant to race 14 also displayed resistance to each of the other nine stem rust races avirulent to the diploid donor. At the same time, seedlings susceptible to race 14 were also susceptible to any one of the other races.

In a third experiment, ten F_3 plants with seedling resistance to race 14 and an equal number of plants susceptible to this race, were each inoculated – on different sections of their second leaves – with isolates of stem rust races 14, 17, 19, 21 and 53. It was found that each of the tested seedlings was either resistant or susceptible to all five test races. This experiment indicates that, even though the selection for resistance to stem rust in the hybrid derivatives was made only with regard to race 14, the resistance transferred from the wild diploid parent to the tetraploid *durum* wheat was effective against a number of additional races.

DISCUSSION

In our investigation we are apparently dealing with the transfer of a single dominant resistance gene. This is reflected by the resistance obtained in all the triploid F_1 hybrids and the segregation pattern in the second generation. That we are indeed dealing with a single resistance factor (or, alternatively, a set of linked factors) is also indicated by the multiple race test, in which all resistant segregants of the third generation showed the same resistance spectrum that was found in the wild diploid parent.

The results obtained indicate that it is possible to transfer stem rust resistance from a diploid wild progenitor to the cultivated *durum* wheat, employing triploid hybrids as 'bridges' for the introgression, i.e., the process which operates in the wheat group in nature (VARDI and ZOHARY, 1967). Furthermore, the experiment demonstrates that such transfer can be comparatively easily performed. This technique does not demand artificial chromosome doubling or any other complicated breeding procedure. The only critical stage here is an effective mass-pollination of the triploid F_1 hybrids by *durum* wheat. If this can be assured, a more or less stabilized *durum*-like tetraploid progeny can be secured in one or two generations.

As both *T. boeoticum* and *A. speltoides* were found to include a wide array of types resistant to stem rust, leaf rust and yellow rust, these species may be considered as potential sources for resistance to the rust diseases of wheat. Diploid to tetraploid introgression via a triploid hybrid may serve as an effective and relatively easy means for extensive exploitation of the wild gene-pools offered by the diploid progenitors of the cultivated wheats.

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