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Evaluation of variation in *Triticum dicoccum* for wheat improvement in stress environments

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A collection of accessions of cultivated emmer wheat, *Triticum dicoccum*, was evaluated for economically important traits at Tel Hadya in northern Syria. Useful variation among and within accessions was detected for agronomic traits, including a high number of productive tillers and protein content. The results from the disease screening nurseries indicated that *T. dicoccum* offers a good source of resistance to common bunt and yellow rust. Most of the accessions tested were, however, susceptible to late frost, which occurred in the second season. In the dry areas of West Asia and North Africa (WANA) available moisture in the soil is limited, and biotic and other abiotic stresses, such as terminal heat stress, reduce the grain yield to a considerable extent. The present study indicates that *T. dicoccum* has a large potential for use in improvement of durum wheat for WANA, where 80 % of the world's production of this crop is grown.

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Triticum dicoccum (Schrank) Schuebl. ($2n = 4x = 28$), or cultivated emmer, is one of the most important older wheat species and, together with barley, was the earliest domesticated cereal grown in the Near East ca. 7500 BC (KUCKUCK 1970). It was taken to Ethiopia by the Hamites around 3000 BC. By about 2000 BC, *T. dicoccum* had arrived in the Indus river valley of the Punjab in India (SARASWAT 1986). *T. dicoccum* remained the old world's principal cereal until the first millenium BC. It originated probably due to mutation from *T. dicoccoides* Korn. (DARLINGTON 1969), its wild progenitor with a brittle rachis in the 'Fertile Crescent' (HARLAN and ZOHARY 1966), which comprises the mountain ranges flanking the plains of Mesopotamia and the Syrian desert.

It was grown in limited quantities in Czechoslovakia, Ethiopia, India, Iran, eastern Turkey, the Balkan states, and parts of central Italy, until a few years ago. But today, it has been replaced largely by free threshing durum and bread wheat varieties with a narrow genetic base (KUCKUCK 1970) although it is making a comeback in Italy because of its popularity as a health food.

A study of interspecific hybrids indicated that the genes for grain filling in *T. dicoccum* could be readily transferred to *T. durum* Desf. as there is complete genomic compatibility between the two species (YANCHENKO 1985b). Experiments on physiology of drought resistance in *T. dicoccum* and other primitive wheats indicated the former to be moderately resistant to moisture stress (CHINOY 1961). In another study, carried out at Dagestan in USSR (GASRATALIEV 1982), progenies of crosses between *T. durum* and *T. dicoccum* were evaluated for earliness, plant height, 1000-kernel weight, and productive tillering. Although the typical *dicoccum* traits of persistent glumes and ear brittleness were not entirely eliminated from the hybrids, their effects were reduced to commercially acceptable levels (GASRATALIEV and BOGUSLAVSKII 1985).

CORAZZA et al. (1986) evaluated *T. dicoccum* samples collected from the mountainous areas in central Italy for resistance to *Puccinia striiformis* Westend. f.sp. *tritici* (yellow rust), *P. recondita* Rob. ex Desn. f.sp. *tritici* (leaf rust), and *P. graminis* Pers. f.sp *tritici* (stem rust), and GRAS (1980) identified genes for resistance to rusts and *Erysiphe graminis* DC ex Merat. f.sp. *tritici* (powdery mildew) in other *T. dicoccum* lines. Resistance to rusts has also been reported by GASRATALIEV (1983) from the USSR, and in 'khapli' wheat (a variety of *T. dicoccum*) from Punjab province in India (MITHAL and KOPPAR 1990).

Breeders have always been interested in studying the inherent variation in agronomic characters within their germplasm before initiating a breeding program in order to maximize the efficiency of their efforts (MARSHALL and BROWN 1975). In order that genetic resources be utilized, a thorough study of variation and detection of useful traits among the accessions is essential. The aim of our work was, therefore, to investigate the within and among population variation in 41 accessions of *T. dicoccum* collected from different ecological and geographical areas within the 'Fertile Crescent' and screen them for disease resistance, especially against *Tilletia foetida* (Wall.) Liro and *T. caries* (DC) Tull. (common bunt) and yellow rust.

Materials and methods

Forty-one accessions of *T. dicoccum* from the wheat collection maintained by the Genetic Resources Unit of ICARDA were evaluated in an experiment with 5 locally well-adapted varieties as checks at Tel Hadya in northern Syria during 1988-1989. Thirteen promising accessions tolerant to drought were selected and were replanted in the subsequent season using the same varieties as constant checks, viz.: Cham 1 and Sebou (durum wheats), Cham 2, Nesser, and Cham 4 (bread wheats). The accessions were also planted in a screening nursery for reaction to common bunt and yellow rust inoculations using local isolates only. The rainfall patterns in the two relevant seasons are given in Table 1.

Tel Hadya is a moderately stressed site for growing wheat, with a long-term average rainfall of only 348 mm per season [Long. 36°.35'E and Lat. 36°.05'N, elevation 284 m above sea level]. The soil at this site is described as luvisol, which is transitional to vertisols (cracking soils). In older systems it was known as "terra rossa" or red Mediterranean type.

Observations on twenty-five characters relevant to breeding were recorded in both seasons. However, only some important characters useful for agriculture in moisture limited environments, such as days to heading and maturity, frost tolerance, plant height, total number and fertile tillers number, spike length and density, kernel weight per spike, and total protein content, are discussed here, Analysis of variance (ANOVA) was used to calculate variation between accessions. Variability within each accession for each character was also investigated.

Results and discussion

Variation among accessions was statistically highly significant in both years for all characters in this study. Such high variability in *T. dicoccum* has been reported from India (MITHAL and KOPPAR 1990) and in old Moroccan landraces by BENLAGHLID and MONNEVEUX (1989). MARIAM and MEKBIB (1988) evaluated *T. dicoccum* samples collected in Ethiopia for agro-morphological characters and also reported a high degree of variation in their samples.

Accessions IC 9132, 12430, 12442, and 12467 were as early as the checks in both years for days to heading and days to maturity. Earliness is a desirable attribute in breeding for the dry areas (YANCHENKO 1985a) since the plant can escape the harmful effects of a sharp drop in rainfall in the final part of the growing season, which is accompanied by an increase in temperature and potential evapo-transpiration. Accessions IC 12377, 12439, 12466, and 12469 were later in heading and maturity than the checks in both years. Lateness could be exploited when breeding for the high elevation zones (> 1000 m) of WANA, where soil moisture continues to be available till the end of the season, allowing a longer grain-filling period. However, the susceptibility to frost is a negative trait, which must be taken into account before use of this germplasm at high elevations is considered.

Plant height was not significantly different from the checks, which is a positive trait in this case as most landraces and other unimproved forms tend to be taller, often leading to lodging when rainfall

Table 1. Rainfall distribution at Tel Hadya, Syria, in two growing seasons, in mm/month

Season	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
1988-1989	41	61	84	10	66	18	0	15	235
1989-1990	10	78	35	30	51	9	14	6	233

Table 2. Range of number of total and fertile tillers of accessions IC 12426, 12427, 12439, and 12499 and the checks in both seasons

	Tel Hadya	
	1988–89	1989–90
No. of total tillers		
Checks range	2–3	10–30
Accession range	6–14	48–72
No. of fertile tillers		
Checks range	1–2	8–21
Accession range	3–6	20–35

Table 3. Range of weight of kernels/spike for three accessions with the highest values as compared to the checks in the two seasons

Weight (g) of kernels/spike	Tel Hadya	
	1988–89	1989–90
Checks range	0.24–0.43	2.1–3.0
Accession range	0.56–0.62	1.3–1.4

is higher than average, accompanied by gusts of wind.

Accessions IC 12426, 12427, 12439, and 12499 had higher number of total tillers and fertile tillers for both years. Table 2 illustrates the usefulness of these accessions for the two characters, compared to the checks. Since the spike number per plant is most adversely affected by moisture stress and largely determines the yield, it may be suggested that a variety with a high tillering capacity and a high spike/tiller ratio could be useful in improving yield under non-irrigated cultivation (ASANA 1979). A high tillering capacity can also provide animal feed in unfavorable years when grain yield is reduced and availability of straw for animal feed is at a premium.

Accessions IC 12377, 12466, and 12469 had longer spikes in both years. Their mean spike lengths at Tel Hadya ranged between 9.9–12 cm in the first season when the spike length of the checks ranged between 5.1–7.2 cm, and in the second season, between 12–13.7 cm when the checks ranged between 7.4–12.7 cm. Accessions IC 12427, 12431, 12439, 12448, 12453, 12454, and 12460 had denser spikes than the checks.

Accessions IC 12430, 12467, and 12469 had higher kernel weight per spike in both seasons (Table 3). *T. dicoccum* was superior to the checks in the first year for number and weight of kernels per spike, whereas in the second season the checks were superior. However, the former had significantly higher number of fertile tillers, raising prospects for its use in the low rainfall zones and unpredictable climatic patterns in the WANA. In the worst seasons, when there is very low rainfall, the cost of straw used to feed small ruminants can be higher than that of the grain itself, making even the nonfertile tillers a valuable source of fodder, which can subsidize a small farmer's meager income in WANA.

Protein content in accessions tested ranged between 18.6–20.9 %, whereas the checks were between 14.2 and 18.9 %. The higher protein content of *T. dicoccum* has also been confirmed by previous studies of DHALIWAL (1977), and PANDEY and RAO (1987) reported protein content ranging between 14.3–18.4 % with a 1000-kw of 45–55 g.

In disease nurseries 12 accessions were found to be immune to common bunt and four were resistant (ICARDA 1991). There were at least three accessions, viz. IC 12432, 12446, and 12454, which were resistant to common bunt (DAMANIA et al. 1990). This is a significant result since host resistance to this disease has not been reported before in *T. dicoccum* (O. MAMLUK, pers. commun.). Resistance to yellow rust has also been reported in 18 accessions of *T. dicoccum* (DAMANIA and SRIVASTAVA 1990).

Lines of *T. dicoccum* which were identified in this study as disease resistant and possessing a high seed protein content, were crossed with other tetraploid wheat varieties. These crosses are listed in ICARDA (1991) and have been sown in the 1990–91 season at Tel Hadya. A few crosses out of these appear to have a higher potential for development as genetic stocks for further use in breeding.

Conclusions

There is useful variability for desirable traits in primitive forms such as *T. dicoccum*. This variability can be exploited for crop improvement in three ways:

1. In breeding programs: Breeders seeking genes for biotic and abiotic stresses, to broaden genetic base of durum wheat targeted towards the low rainfall areas.

2. In production of hybrids: In recent years short strawed, solid stemmed, erect progeny lines of

durum wheat, possessing resistance to lodging and relatively good grain yield under unfavorable conditions, have been obtained from crosses where one of the parents has been *T. dicoccum*.

3. *T. dicoccum* forms per se: It is also suggested that primitive forms can themselves play a broader and more significant role in improving production than merely correcting specific shortcomings of otherwise well adapted wheat varieties.

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