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Field evaluation of durum wheat landraces for prevailing abiotic and biotic stresses in highland rainfed regions of Iran

Reza Mohammadi[a,*], Behzad Sadeghzadeh[b], Hasan Ahmadi[c], Nowzar Bahrami[a], Ahmed Amri[d]

[a]Dryland Agricultural Research Institute (DARI), P. O. Box 67145-1164, Kermanshah, AREEO, Iran
[b]Dryland Agricultural Research Institute (DARI), Maragheh, AREEO, Iran
[c]Center of Agricultural Research and Natural Resources, Kurdistan, AREEO, Iran
[d]International Center for Agricultural Research in the Dry Areas (ICARDA), Rabat, Morocco

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A B S T R A C T

Biotic and abiotic stresses are major limiting factors for high crop productivity worldwide. A landrace collection consisting of 380 durum wheat (*Triticum turgidum* L. var. *durum*) entries originating in several countries along with four check varieties were evaluated for biotic stresses: yellow rust (*Puccinia striiformis* Westendorf f. sp. *tritici*) and wheat stem sawfly (WSS) *Cephus cinctus* Norton (Hymenoptera: Cephidae), and abiotic stresses: cold and drought. The main objectives were to (i) quantify phenotypic diversity and identify variation in the durum wheat landraces for the different stresses and (ii) characterize the agronomic profiles of landraces in reaction to the stresses. Significant changes in reactions of landraces to stresses were observed. Landraces resistant to each stress were identified and agronomically characterized. Percentage reduction due to the stresses varied from 11.4% (yellow rust) to 21.6% (cold stress) for 1000-kernel weight (TKW) and from 19.9 (yellow rust) to 91.9% (cold stress) for grain yield. Landraces from Asia and Europe showed enhanced genetic potential for both grain yield and cold tolerance under highland rainfed conditions of Iran. The findings showed that TKW and yield productivity could be used to assess the response of durum wheat landraces to different stresses. In conclusion, landraces showed high levels of resistance to both biotic and abiotic stresses, and selected landraces can serve in durum wheat breeding for adaptation to cold and drought-prone environments.

1. Introduction

Wheat landraces are variable, genetically dynamic, and in equilibrium with biotic and abiotic stresses in the environments where they evolve. The development of new varieties using wheat landraces is a practical strategy for improving yield and yield stability, especially under stresses and future climate change conditions. Wheat landraces adapt to changing climate

* *Corresponding author.*
E-mail address: r.mohammadi@areo.ir (R. Mohammadi).
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conditions and to harsh environments, owing to their population genetic structure, buffering capacity, and combinations of agro-physiological traits conferring adaptability to stress environments [1]. Wheat landraces are still cultivated in western Asia and North Africa, with some also found in Ethiopia, China, the Indian subcontinent, and small areas of Latin America. The proportion of wheat area planted to landraces also varies by wheat type and environment. For example, in developing countries, 23% of the area planted to durum wheat and 12% of the area planted to winter bread wheat are sown to landraces, while only 3% of the spring bread wheat area is still planted to landraces [2].

There is growing interest in use of available genetic resources in the development of new durum wheat cultivars that tolerate major biotic and abiotic stresses and for the improvement of crop productivity and quality [3]. This development will require thorough understanding of the available genetic variation in landraces, primitive wheats, and wild relative species. The rate of progress, however, will depend on the presence of genetic variation for desired traits and the availability of reliable methods for the identification, selection, and transfer of superior genes [3].

Drought stress is a major problem for agricultural production in many parts of the world. Because drought is the single largest abiotic stress factor leading to reduced crop yields, varieties that yield well even in environmentally stressful conditions are essential [4,5]. Climate change is projected to have a large impact on temperature and precipitation profiles, increasing the incidence and severity of drought. The extension of durum wheat into areas with cold winters is limited by the cold susceptibility of existing landraces. Low temperature often affects plant growth and crop productivity and causes severe crop losses [6]. Plants differ in their tolerance to chilling (0–15 °C) and freezing (<0 °C) temperatures [7]. Besides abiotic stresses, wheat yellow rust, caused by *Puccinia striiformis* Westendorf f. sp. *tritici*, the most common and widely distributed wheat rust in the world [8], and wheat stem sawfly [*Cephus pygmaeus* (L.) Hym. Cephidae], which is a major problem in the Mediterranean basin [9], limit wheat production.

Deployment of genetic resistance to these stresses is likely to be the most economical and environmentally friendly control measure [9–12]. Characterization of the population structure of wheat landraces is critical for identifying and correctly interpreting the association between functional and molecular diversity. Such information is essential for using landraces as trait donors in wheat breeding, defining the areas of their adaptation, identifying priority areas for promoting their on-farm conservation, and evaluating the genetic consequences of the interaction between climate change, growing environment, and farmers' practice. Accordingly, the main objectives of this study were to (i) quantify phenotypic diversity and identify variation in the durum wheat landraces for major biotic and abiotic stresses, (ii) characterize the agronomic profiles of different subsets of landraces (as resistant, moderately resistant, moderately susceptible, or susceptible) to different stresses and (iii) investigate the potential of landraces to combine tolerance to biotic and abiotic stresses with good agronomic performance. This information could greatly assist in the conservation of durum landraces and their efficient deployment in durum breeding programs.

2. Materials and methods

2.1. Plant materials and experimental layout

A subset of 380 durum wheat landraces collected from a wide range of agricultural zones worldwide were selected from the landraces conserved in the Iranian gene bank. The subset collection consisted of landraces from 16 countries: Iran (307; collected from a wide geographic area across the country), Japan (16), Afghanistan (8), Australia (9), Bulgaria (5), Portugal (5), Turkey (5), United States (5), former Yugoslavia (2), Italy (3), Iraq (2), China (2), Argentina (2), France (1), Greece (1), and Austria (1) and six landraces of unknown origin. This subset was evaluated at three rainfed research stations of the Dryland Agricultural Research Institute (DARI), Iran, during the 2009–2011 cropping seasons. The three research stations represent cold rainfed regions (Maragheh station, 37°22' N, 46°15' E and 1400 m.a.s.l. and Qamloo station, 35°23' N, 47°14' E and 1850 m.a.s.l.) and moderately cold rainfed regions (Sararood station, 34°19' N, 47°17' E and 1351 m.a.s.l.) for durum wheat production in Iran.

Each landrace was sown in two rows 2.5 m long with 20.0 cm row spacing in an unreplicated trial with four checks repeated every 20 entries at each research station. The checks consisted of two durum genotypes including Dena (a newly released durum variety originating from CIMMYT germplasm having high yielding performance, high pasta quality, and adaptation to favorable conditions) and Zardak (an old durum variety with high grain weight and average yield productivity and adaptation to unfavorable conditions) and two bread wheats including Saison (a winter variety from France having high yield and tolerance to terminal drought) and Verinak (a spring cultivar from CIMMYT with earliness and tolerance to terminal drought and heat stresses). Standard crop cultural practices were used at all test locations. Weeds were controlled manually as required. Fertilizer rate was 50 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1} applied at planting.

The landraces were evaluated for several drought-adaptive traits: days to heading (DTH), days to maturity (DTM), plant height (PLH), thousand-kernel weight (TKW), and grain yield (YLD) under rainfed conditions in each location and scored for cold stress, yellow rust and wheat stem sawfly (Table 1).

2.2. Statistical analysis

Data were statistically analyzed to identify landraces that were genetically different or similar based on the environmental stresses and agronomic traits measured. The grain yield data and other measured traits (DTH, DTM, PLH, and TKW) were analyzed separately with GenStat [14] for spatial analysis of un-replicated trials in which the responses of the repeated checks provide the basis for modeling the spatial variation in the field for adjusting genotype performance [15]. For each trait, the best linear unbiased predictions (BLUPs) from the best-fitting model were used as adjusted data.

To display the relationships among the landrace groups and measured traits, a graphical biplot, the genotype-by-trait (GT) biplot described by Yan and Rajcan [16] was constructed, for each of the environments differing in stress conditions, by