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Relationship of dryland productivity and drought tolerance with some molecular markers for possible MAS in durum (*Triticum turgidum* L. var. *durum*)

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SUMMARY – Durum (*Triticum turgidum* L. var. *durum*) is grown in the dryland of the Mediterranean region under abiotic stressful and variable environmental conditions. Drought tolerance research usually requires a large number of testing sites and seasons to determine the genotypic resistance to a given stress. Research on drought tolerance, use of molecular markers, exploitation of the genetic variation of the *Triticum* wild relatives to enhance resistance/tolerance to abiotic stresses are of major interest in CIMMYT/ICARDA dryland durum breeding program. In this study grain yield, yield components, stress physiological traits were associated with some molecular markers. Several markers showed strong relationships with grain, yield components, and stress physiological traits, there are potential markers to be used in marker assisted selection to improve durum drought tolerance in the Mediterranean region.

Key words: Drought, abiotic stress, carbon isotope discrimination, osmotic adjustment, molecular markers, marker-assisted selection, grain quality.

RESUME – *"Relation de la productivité en terres arides et de la tolérance à la sécheresse avec certains marqueurs moléculaires pour une utilisation possible en sélection assistée par marqueurs chez le blé dur (*Triticum turgidum *L. var.* durum*)". Le blé dur (*Triticum turgidum *L. var.* durum*) est cultivé dans les terres sèches de la région méditerranéenne dans des conditions environnementales variables et sous stress abiotique. La recherche pour la tolérance à la sécheresse requiert généralement un grand nombre de sites de testage et de saisons pour déterminer la résistance génotypique à un stress donné. La recherche sur la tolérance à la sécheresse, l'utilisation de marqueurs moléculaires, l'exploitation de la variation génétique des apparentés sauvages de* Triticum *pour augmenter la résistance/tolérance aux stress abiotiques sont du plus grand intérêt pour les programmes d'amélioration du blé dur dans les terres arides, du CIMMYT/ICARDA. Dans cette étude, le rendement en grain, les composantes du rendement, les caractères physiologiques liés au stress, ont été associés avec certains marqueurs moléculaires. Plusieurs marqueurs ont montré une forte relation avec le grain, les composantes du rendement, et les caractères physiologiques liés au stress, et sont des marqueurs potentiels pour utilisation en sélection assistée par marqueurs, afin d'améliorer la tolérance à la sécheresse du blé dur dans la région méditerranéenne.*

Mots-clés : *Sécheresse, stress abiotique, discrimination des isotopes du carbone, ajustement osmotique, marqueurs moléculaires, sélection assistée par marqueurs, qualité du grain.*

Introduction

Durum (*Triticum turgidum* L. var. *durum*) is grown mainly in the dryland of the Mediterranean region under stressful and variable environmental conditions. To identify drought tolerant germplasm, the empirical selection approach is employed. Evaluation for drought tolerance requires a large number of testing sites and seasons. Empirical selection approaches to genetically improve grain yield in drylands have been effective but they are time-consuming and require the employment of a large amount of resources. However, the analytical selection approach using the morpho-physiological traits has been slowly adopted for selection in the segregating generations in some dryland breeding programs (Nachit, 1992). The employed trait for dryland selection needs to be simple and rapid to use and less expensive than the field and design techniques used in the empirical selection approach.

Understanding the drought tolerance basis of the morpho-physiological traits offers the potential to select germplasm based on key-traits linked with grain yield in dryland. Morpho-physiological traits can be used as indirect selection criteria for grain yield in dryland, however, their effectiveness depends on their correlations with grain yield under drought and the degree to which each trait is genetically controlled. Usually, a dryland crop deploys a complex set of interacting to grow and survive under moisture stress (Nachit *et al.,* 1992). Therefore it is of interest to know the efficiency with which water is used by a crop in the dry area (mol CO_2 fixed per mol H_2O transpired).

The Carbon Isotopic Discrimination (CID) was found as a useful tool to screen for variation in Water Use Efficiency (WUE) (Farquhar *et al.,* 1989). CID was reported to be associated with WUE (Hubick and Shorter, 1986; Hubick and Farquhar, 1989; Nachit, 1998).

Molecular markers could serve to identify traits that are difficult to identify phenotypically (Autrique *et al.,* 1996). Durum drought tolerance had shown that some markers are associated with grain yield in dryland and with morphophysiological traits for drought tolerance (Nachit *et al.,* 1993).

Materials and methods

Durum wheat genotypes from CIMMYT/ICARDA program were analysed for morphophysiological traits and RFLP at ICARDA, Aleppo, Syria; Montpellier University, France; and Cornell University, USA. Grain yield was determined by converting plot weight to kg/ha. Kernel weight was measured as weight in grams of 200 kernels and converted to the weight of 1000 kernels. A scale of 1-9 was used for the following morphophysiological traits (1 = lowest value, 9 = highest value): early growth vigor, productive tillering, peduncle length, awns length, spike fertility, antemeridiem leaf rolling (morning, before 8 a.m.), and postmeridiem leaf rolling (afternoon, after 2 p.m.). Leaf rolling index is the ratio of the post- to antemeridiem leaf rolling. Further, the 25 genotypes were tested for canopy temperature, chlorophyll fluorescence inhibition, proline content, and leaf water potential under stressed and nonstressed conditions. The percentage for chlorophyll fluorescence inhibition (Q%); and the difference for canopy temperature (centigrade), leaf proline content (Δmg/g) and leaf water potential (Δy_F in MPa) from stressed and nonstressed conditions were computed, and CID (Nachit, 1998). For molecular markers, the clones used were from barley cDNA (BCD), oat cDNA (CDO), and wheat genomic (WG) libraries previously described by Heun *et al.* (1991). For each genotype genomic DNA was digested separately with EcorI as the restriction enzyme. Statistical analysis was performed as follows: the test durum genotypes were divided in two populations according to presence or absence of each molecular marker. The trait means of the two populations were compared using t-test analysis.

Results and discussion

Molecular markers were found to be associated with grain yield under dry conditions and with morphophysiological traits related to drought tolerance (Table 1). The markers CDO395 and BCD1661 in a genotype were associated with high grain yields. Molecular markers are particularly useful for traits that are highly affected by environmental variations. Leaf water potential, canopy temperature, chlorophyll inhibition, and proline content (Table 1) showed strong relationships with molecular markers. Indirect selection for molecular markers may have an advantage over direct selection as their “heritability” is 1.0. When the correlation between a molecular marker and a trait is greater than the heritability of the trait, marker assisted selection may be advantageous. These results are promising and suggest the usefulness of molecular markers to enhance drought tolerance in durum wheat for Mediterranean dryland conditions.

Further, relationships between grain yield, yield components, and CID were positively correlated (Table 2) among each other. The association of CID with grain yield was similar to that of number of fertile tillers and number of spike kernels with grain yield. Some molecular markers associated with grain yield and CID under the Mediterranean continental dryland. Several researchers (Johnson *et al.,* 1990; Read *et al.,* 1993; Ehdaie and Waines, 1994; Menendez and Hall, 1996) found low-medium heritability values for CID. As the “heritability” of molecular markers is 1.0 consequently they are particularly useful when evaluation is made for traits that are highly affected by environmental variations, such as grain yield and stress tolerance traits, such as CID. The progress in molecular markers mapping will allow the use of molecular markers to be integrated in studying drought tolerance; however, more fundamental studies need to be generated to devise the use of QTL analysis.

Table 1. Grain yield, morphological traits that associated with RFLP markers

Trait	Markers
Grain yield**	KSUG48, CDO1090, CDO395, BCD1661
Awns length***	BCD348
Peduncle length***	BCD782, BCD292
Early growth vigor**	BCD758
Productive tillering under stress**	BCD292
Spike fertility under stress**	BCD348
Kernel weight***	BCD342
Leaf rolling index**	BCD348, BCD1355f
Canopy temperature**	CDO669, BCD305
Fluorescence inhibition (Q%)***	BCD292, BCD758
Leaf water potential (MPa)**	BCD21, BCD758
Proline content (Dmg/g)**	BCD758
Carbon isotope discrimination***	CDO1090, CDO1312, KSUG48

,*Significant at 1, and 0.1% level, respectively.

Table 2. Correlation between carbon isotope discrimination (CID), grain yield and yield components

Trait	Grain yield	Fertile tillers	No. grains per spike	100 kernel weight
CID	0.54***	0.30***	0.42***	0.22**

,*Significant at 1, and 0.1% level, respectively.

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