Breeding durum wheat for grain yield and quality

Josephides C.M.

in

Royo C. (ed.), Nachit M. (ed.), Di Fonzo N. (ed.), Araus J.L. (ed.).
Durum wheat improvement in the Mediterranean region: New challenges

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 40

2000
pages 485-488

Breeding durum wheat for grain yield and quality

C.M. Josephides
Agricultural Research Institute, P.O. Box 22016, 1516 Nicosia, Cyprus

SUMMARY – In Cyprus the practised breeding method, which is a modification of the pedigree method, retains for subsequent exploration F_3 lines with a higher frequency of potential genes for high quality. Thereafter, two site replicated yield testing of the F_4 bulk lines at two sites increases the chances of selecting individuals in this generation, which combine acceptable grain and processing quality along with higher frequency of desirable genes for grain yield. Five spikes selected from each of the F_4 bulk lines with higher average yield, are retained for subsequent exploration in the F_5. Outstanding lines enter the preliminary yield trials. The referred methodology resulted in the development of the high yielding and quality durum wheat cultivar "Macedonia" which is grown in most of the durum wheat areas.

Key words: Durum wheat, quality, breeding, genetics.

RESUME – *"Amélioration du blé dur pour le rendement et la qualité du grain". A Chypre la méthode de sélection pratiquée, qui est une modification de la méthode sur ascendance, retient pour une exploration ultérieure des lignées F_3 ayant une fréquence plus élevée de gènes potentiels pour une bonne qualité. Ensuite, deux essais de rendement avec répétition pour des lignées F_4 en mélange dans deux sites, augmentent les chances de sélectionner des individus dans cette génération, combinant un grain et une qualité de transformation acceptables en même temps qu'une fréquence plus forte de gènes pour le rendement en grain. Cinq épis sélectionnés à partir de chacune des lignées F_4 en mélange avec un meilleur rendement moyen, sont retenus pour une exploration ultérieure en F_5. Les lignées remarquables entrent dans les essais de rendement préliminaires. La méthodologie mentionnée a donné lieu au développement du cultivar de blé dur "Macedonia" à fort rendement et bonne qualité, qui est cultivé dans la plupart des zones à blé dur.*

Mots-clés : *Blé dur, qualité, sélection, génétique.*

Introduction

A durum wheat breeding program must be designed to ensure that any new released cultivar has acceptable agronomic characteristics to meet the demand of the farmers and the quality characteristics required by the processing industry. Thus, the plant breeder has to begin with the selection of parents for hybridization and through the long term of homozygosity is responsible for selecting the most promising lines with the desired combination of agronomic and quality traits.

The heritability is known for most of the desired quality traits and the agronomic characteristics with specific weakness on durum wheat productivity, such as late maturity, lodging, and others as plant height and spike characteristics that played a role in the plant form (Blanco *et al.,* 1988; Joppa and Williams, 1988). Hence, these have to be selected or eliminated as soon as it is permitted by their mode of inheritance and the available breeding tools.

Breeding for quality and agronomic characteristics

Durum wheat is used for a variety of food products, such as pasta, bread, couscous, burgur, etc. It has an amber, vitreous kernel and produces a yellow milling product. The yield of semolina is an important quality character and is affected by kernel characteristics, such as vitreousness, size, weight, shape and crease form. Durum lines differ in their genetic ability to produce kernels with the desirable characteristics, but most of these are highly influenced by a complex of environmental factors at the stage of grain development. However, Henson and Waines (1983) reported that differences among cultivars in percent of vitreous kernels related to their relative ability to translocate nitrogen compounds from the leaves and stems into the kernel.

Semolina color has been emphasized in most breeding programs and it has been identified as the result of certain xanthophylls. The color of the milled products of durum wheat is highly heritable and is controlled by additive gene effects (Johnston *et al.,* 1983). Recent studies indicate that the major genes are on chromosome 2A and 2B (L.R. Joppa, personal communication).

Spaghetti and crumb bread color is also affected by the amount of lipoxygenase. High levels of this enzyme in the milling products destroy the expected yellow color of pasta and bread products during their processing by oxidation of xanthophylls. Selection for low lipoxygenase levels in the breeding program has clearly been effective. Preliminary studies showed oligogenic action (L.R. Joppa, personal communication).

Cooking quality of spaghetti and burgur and bread characteristics are related to both quantity and, mainly, quality of the proteins present in the durum wheat endosperm. Protein content is a complexly inherited trait and varies more because of the environments than because of genetics. The proteins of wheat are divided into four classes based on solubility. The gliadins and glutenins are the important components influencing the processing and end-product quality of durum wheat. Separation of protein gliadins by polyacrylamide gel electrophoresis showed that those cultivars having a gliadin with the relative mobility (Rm) of 42 had weak gluten and those having an alternative allele coding for a gliadin with Rm of 45 had strong gluten (Damidaux *et al.*, 1980).

Joppa *et al.* (1983a) and others found that a single durum wheat cultivar can have 40 or more different gliadin polypeptides and these can be used to identify a cultivar as well as to determine gluten strength. Bournouf and Bietz (1984) proposed band 45 as genetic marker for selecting strong gluten cultivars. Later, Leisle *et al.* (1985) found an association between glume color and gluten strength in durum wheat. They reported that glume color could be used as field marker for selecting strong gluten genotypes early in the F_2.

In 1987 the author, together with his professors L.R. Joppa and V. Youngs, proved the large influence of chromosome 1B” on gluten strength and its further effect on spaghetti and bread quality. Further, the chromosome 1B” was found to be without any effect on semolina color, grain yield and some other agronomic characteristics of durum wheat.

Breeding for grain yield

In contrast to the quality traits and some specific agronomic traits correcting the productivity of durum wheat, grain yield is generally accepted as an inherited factor with hundreds of genes being involved. Gable (1962) pointed out that as the number of genes involved in the inheritance of a trait becomes greater, so does the influence by the environment. This indicated that the breeder is ineffective in selecting for yield either on an individual F_2 plant basis or on a line basis in the F_3 and/or in the later generations, because of the great heterozygosity and the genotype by environment interaction.

The likehood of fixation for two or three pairs of neutral alleles as early as F_3 increases rapidly. In contrast for 10 pairs of genes the likehood of fixation in the F_3 is only 0.06%. Thus, unless the number of loci is very small it seems unlikely that any individuals with the potential to produce the very best possible segregant will survive into the sample of near homozygous lines, where intensive evaluation for overall worth usually begins. One obvious countermeasure is to grow the largest feasible F_2 population and eliminate in generations F_2 through F_3 all individuals with visible or potentially measurable agronomic and quality defects. Thereafter, replicated progeny yield testing increases the chances of retaining individuals with higher frequency of desirable genes for yield early in the F_4. Five spikes selected from each F_4 bulk lines with higher average yield, are retained for subsequent exploration in the F_5. Outstanding F_6 lines enter the preliminary yield trials (Table 1).

Evaluation

The referred methodology resulted in the development of the high yielding and quality durum wheat cultivar “Macedonia” which is grown in most durum wheat areas of Cyprus (Josephides, 1994). Macedonia originated from a cross made in 1984 (KIA * 2/VIC CYD85-345-18D-OP-3P-OP) between the cultivar Vic introduced from North Dakota State University, USA, having high quality processing characteristics, and Karpasia, the commercially grown durum wheat cultivar in Cyprus. The F_1 was grown at ICARDA'S summer nursery. In the next growing season (1984-1985) plants selected from the F_2 generation were backcrossed to Karpasia. The consequent breeding methodology used up to the $BC1F_6$ generation is as stated in Table 1. Macedonia was evaluated in the multienvironmental testing program of the Institute at a total of 22 environments in three growing seasons (1990-1993). It gave the highest grain yield, 5731 kg/ha, which was 9%, 12%, 13% and 53% higher than the yield of Karpasia, Mesaoria, Aronas and Kyperounda, respectively. The main agronomic characteristics of Macedonia were similar to those of Karpasia. Mean values for the grain quality characteristics were: volume weight 77 kg/hL and vitreous kernels 91% compared to 78 kg/hL and 95% of Karpasia, respectively. Macedonia had also strong gluten and higher yellow pigment than Karpasia.

Table 1. Approach to breeding superior quality and high yielding durum cultivars

Year	Breeding materials	Location	Selection and testing methodology
I	a) Make the cross b) F_1 generation	Athalassa, summer nursery ICARDA	
II	F_2 generation	Dromolaxia (rainfed conditions)	1000-2000 plants/cross a) Select among crosses. Discard weak, late, susceptible crosses. b) Select within crosses for disease resistance, straw stiffness, maturity, glume color, if brown vs white exists. Take one head from each selected plant; 100-200 heads.
III	F_3 generation	Akhelia	Head rowed F_3 lines-1.0 m length. Discard weak, late, susceptible lines. Harvest bulk remaining lines. Eliminate lines with poor kernel characteristics (size, shape, vitreousness, and diseases), weak gluten and low yellow color.
IV	F_4 generation	a) Morokambos (fertile rainfed conditions) b) Dromolaxia (rainfed conditions, previous planted land)	Two location, replicated progeny yield testing. Record grain yield, and other agronomic characteristics. Before harvesting take 5 to 10 spikes from one rep. and one location. Evaluate agronomically selected lines for gluten strength, volume weight, kernel weight, vitrousness and yellow color. Thresh only those spikes which come from F_4 lines with higher average yield and superior quality.
V	F_5 generation	Akhelia (irrigated conditions or summer nursery)	Head rows, as in the F_3 generation.
VI	F_6 generation	a) Dromolaxia b) Morokambos (as in the F_4 generation)	Preliminary yield trials in simple lattice design.
VII-X	F_7-F_9 generation	Multi environmental testing	Identify the overall worth durum wheat cultivar.

However by the year 2000 a new durum wheat cultivar, named Vergina, will be proposed for release. It originated from a back cross made in 1986 (LLOYD/KIA * 3 CYD86-510-14D-OP-9P.2P-OP) between the cultivar Lloyd introduced from North Dakota State University, USA, and the Cyprus cultivar Karpasia. Vergina is a cultivar complementary to Macedonia. It has similar grain yield and other agronomic characteristics, but higher hectoliter weight and less stiff gluten which is baked to better Cyprus bread than Macedonia.

References

Blanco, A., De Pace, C., Porceddu, E. and Scarascia Magnoza, G.T. (1988). Genetics and breeding of durum wheat in Europe. In: *Durum Wheat: Chemistry and Technology,* Fabriani, G. and Lintas, C. (eds). AACC, Inc., St Paul, Minnesota, USA, pp. 17-36.

Bournouf, T. and Bietz, J.A. (1984). Reversed phase high performance liquid chromatography of durum wheat gliadins: Relationship to durum wheat quality*. J. Cereal Sci*., 2: 3-14.

Damidaux, R., Autran, J.C., Grignac, P. and Feillet, P. (1980). Mise en évidence de relations applicables en sélection entre l'électrophorégramme des gliadines et les propriétés viscoélastiques du gluten de Triticum durum Desf*. C. R. Acad. Sci. Ser. D,* 287: 701-704.

Gamble, E.D. (1962). Relative stability of the gene effects in different environments. *Can. J. Plant Sci*., 42: 628-634.

Henson, J.H. and Waines, J.G. (1983). Nitrogen metabolism and yellowberry of two bread wheat cultivars. *Crop Sci*., 23: 20-22.

Johnston, R.A., Quick, J.S. and Hammond, J.J. (1983). Inheritance of semolina color in six durum wheat crosses. *Crop Sci*., 23: 607-610.

Joppa, L.R., Khan, K. and Williams, N.D. (1983). Chromosomal location of genes for giadin polypeptides in durum wheat *Triticum turgidum* L. *Theor. Appl. Genet*., 64: 289-293.

Joppa, L.R. and Williams, N.D. (1988). Genetics and breeding of durum wheat in the United States. In: *Durum Wheat: Chemistry and Technology*, Fabriani, G. and Lintas, C. (eds). AACC, Inc., St Paul, Minnesota, USA, pp. 47-66.

Josephides, C.M. (1994). Macedonia: A new high yielding and high quality durum wheat cultivar. *Agricultural Research Institute, Nicosia, Technical Bulletin, 163*.

Josephides, C.M., Joppa, L.R. and Youngs, V.L. (1987). Effect of chromosome 1B on gluten strength and other characteristics of durum wheat. *Crop Sci*., 27: 212-216.

Leisle, D., Kovacs, M.I. and Howes, N. (1985). Inheritance and linkage relationships of gliadin proteins and glume color in durum wheat. *Can. J. Genet. Cytol*., 27: 716-721.