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BREEDING FOR WINTER HARDINESS IN TWO-ROWED BARLEY USING THE MAJOR GENE OF A SIX-ROWED BARLEY VARIETY

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Abstract

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The goal of our breeding program was to improve the winter hardiness in two-rowed winter barley using their high yielding ability and high lodging resistance. In the first step, KH Kincsem two-rowed winter barley variety was developed with the cross of a two-rowed Sladoran variety (>) with high yielding ability, short and firm stem and a very low degree of winter hardiness and a six-rowed Kompolt 4 variety (+). The latter is resistant to extreme winter climatic conditions and according to our knowledge it is mainly determined by the major gene. KH Kincsem variety was crossed with Rex variety having a low degree of winter hardiness in order to improve the yield potential, stem strength and resistance of KH Kincsem variety retaining its excellent winter hardiness. Major gene for winter hardiness from Kompolt 4 variety was transferred also to KH Kincsem x Rex cross progenies. It was applied for registration in autumn of 1998 and it was released as KH Malko variety in 2001. In the Hungarian EBC trials among the foreign varieties, the KH Malko variety had the most excellent winter hardiness and it gave also the highest yield. So, the KH Malko variety is one of the best winter hardy two-rowed barley varieties in Hungary, also having excellent agronomical traits.

Key words: Winter barley - malting barley - winter hardiness - major gene - resistance - cold stress.

Резюме

Мурани, И., Е. Почай. 2007. Селекция на зимоустойчивост при двуредни сортове ечемик, използвайки главни гени на шестредни сортове ечемик

Целта на нашата селекционна програма бе да се подобри зимоустойчивостта при двуредния ечемик, използвайки тяхната висока продуктивна способност и висока устойчивост на полягане. При първата стъпка, двуреден зимен ечемик сорт КН Кіпсsem беше получен при кръстосване на двуредния сорт Сладуран (>), който притежава висока продуктивност, късо и здраво стъбло и много ниска степен на зимоустойчивост с шестредния сорт Коmpolt 4 (+). Последният притежава устойчивост при екстремни климатични условия през зимата и според нас се кодира от доминантен ген. Сортът КН Кіпcsem бе кръстосан със сорта Rex, имащ ниска степен на зимоустойчивост, за да се подобри продуктивността, здравината на стъбло и устойчивостта на КН Кіncsem, запазвайки неговата отлична зимоустойчивост. Основният ген за зимоустойчивост на сорт Коmpolt 4 бе пренесен в потомството на кръстоската Кincsen x Rex. Той бе

предложен за регистрация през есента на 1998 и въведен като сорт КН Malko през 2001. При унгарските EBC опити в сравнение с чуждестранните сортове, сортът КН Malko проявява най-висока зимоустойчивост и същевременно най-висока продуктивност. Сортът КН Malko е един от най-добрите зимоустойчиви двуредни сортове ечемик в Унгария с отлични агрономически качества.

Ключови думи: Зимен ечемик - пивоварен ечемик – зимоустойчивост доминантен ген - устойчивост - студов стрес.

INTRODUCTION

Barley is one of the major crops in the world. Two types of barley - feed and malting - are grown. Earlier, high protein feed varieties for livestock were developed. Recently, barley breeding has been focused on malting varieties. In general, the primary gaols of barley breeding programs are to develop high yielding varieties that are disease resistant, and that demonstrate exceptionally high malting and brewing qualities.

Two-rowed barley varieties having many favourable properties, for example: much better brewery qualities, higher lodging resistance, more excellent tillering capacity, higher storm resistance, stronger ears and lower sensitivity to ear-neck break down than the six-rowed barley varieties. On the contrary, their degree of winter hardiness is much lower than that of the six-rowed ones. In spite of this fact, many two-rowed barley varieties came to registration and growing, especially with the increasing of the production of the two-rowed winter malting barley. In the countries of continental climatic conditions the growing of the low winter hardy varieties means a great risk also for the growers.

In the early 1980 years only six varieties of winter barley were available for the growers in Hungary as compared to 59 currently registered. In enlargement of variety assortment, growers claimed local varieties with high yielding ability, short and firm stem and a very high degree of winter hardiness. Among the Hungarian varieties, only the Kompolt 4, Kompolt early and Rachel varieties had appropriate degree of winter hardiness. Two Yugoslavian varieties, Rodnyik and Sladoran were applied for registration in Hungary in 1984. These two-rowed varieties (especially Sladoran varietiy) had high yielding ability, short and firm stem, but their winter hardiness did not prove to be convenient to the Hungarian climatic conditions. In winter of 1987, Sladoran variety totally perished in trials, therefore it was not registered in Hungary. Rodnyik variety was registered, but it could not be distributed in Hungary because of its low degree of winter hardiness. Similar experiences were gained with the German and French two-rowed varieties, among them Igri variety. A Croatian variety (Rex) was registered in 1991, but in spite of its excellent high yielding ability and short and firm stem it could be grown only in South Hungary because of its low degree of winter hardiness. Without the two-rowed varieties of Kompolt, other two-rowed varieties were not registered in Hungary because they did not meet the requirements for winter hardiness and agrotechnical demands. In the middle of 1980s, the goal of The Research Institute of Kompolt was to develop two-rowed winter barley varieties with appropriate degree of winter hardiness and excellent high yielding ability and short and firm stem. At the beginning of our breeding program, the six-rowed Kompolt 4, Sladoran and Rovnvik varieties were selected to reach our goals. Environment and climatic conditions are decisive for the breeding for winter hardiness where the selections are carried out. Kompolt is situated in North-Hungary at the feet of M6tra mountain, where temperatures of -15°C degree without snow occurs very often. This cold effect provides opportunity for appropriate selections.

Winter barley needs to be very hardy to survive the cold winter environment in Hungary. Winter barley has evolved adaptive mechanisms that are temperature regulated and involve cold acclimation processes that enable seedlings to survive numerous stresses during the over-wintering period. The process of cold acclimation and the maintenance of winter hardiness are a very complex thing. In order for winter barley to survive the cold

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winter conditions, it has to acclimate or acquire cold tolerance during the autumn growing period. This cold acclimation process is governed by a genetic system that is induced by low temperature. Under normal field conditions, eight to twelve weeks of growth are usually required for the full development of winter hardiness.

The fully acclimated winter barley is very tolerant to cold stress as long as crown soil temperature remains below freezing and the plants have an adequate energy supply. Soil temperature is a dominant factor influencing both the amount of over winter stress and the ability of plants to tolerate the stress.

The genetic basis of resistance to pathogens is well studied in crops. In agricultural systems, one of the primary mechanisms of plant resistance to pathogen involves genefor-gene interactions (Crute and Pink, 1996; Agrios, 1997). Such an interaction is characterized by allelic variation at a single locus in the host and at the single locus in the pathogen, such that infection success is determined by the combined genotypes of host and pathogen. The host is resistant only if it carries at least one copy of the resistance allele and the pathogen carries one copy of the avirulence allele (Flor, 1971).

The yield stability is strongly influenced by winter hardiness. In 2003, winter hardiness of the variety determined the yield of winter barley in 79.6% (Matyk, 2003).

In the present study, the breeding results for winter hardiness of the two new tworowed winter barley varieties (KH Kincsem, KH Malko) are described.

MATERIALS AND METHODS

In the middle of 1980s two-rowed winter barley genotypes with appropriate degree of winter hardiness were not at our disposal.

The breeding for winter hardiness in two-rowed winter barley varieties (KH Kincsem, KH Malko) begun in 1986. To the most successful cross, a two-rowed Sladoran and Rovnyik varieties(>) with high yielding ability, short and firm stem and a very low degree of winter hardiness and a six-rowed Kompolt 4 variety (+) were used. The latter is resistant to extreme winter climatic conditions and according to our knowledge it is mainly determined by the major gene (Table 1.). From Kompolt 4 x Rovnyik cross, considerable progenies could not be selected. Kompolt 4 x Sladoran cross (K-86-11-25) was carried out on five ears (60 flowers). From Kompolt 4 x Sladoran cross 22 seeds (Fo) were harvested in 1986. The seeds of F1 generation were sown on 2 x 10 m one-row plot in 1987.

Table 1. Breeding process of KH Kincsem two-rowed winter barley variety

Traits	Kompolti 4 X (six-rowed)	Sladoran (2-rowed)
Winter hardiness	8,0	1,0
Yielding ability	7,0	9,0
Stem strength	6,0	8,5

The selections were begun in the F_2 generations. The selected ears of F_3 - F_5 generations were sown in individual plots. Progeny plants of the cross showed excellent variability and the traits of the two varieties well combined with each other. The selected two- and six-rowed genotypes were separated. In F_5 generation, 64 "A" lines were selected based on their properties and homogeneity and they were sown in 5 m² plots as "B" line. From these, the best 32 "B" lines were sown in 10 m² plots in two replications in 1992 as "C" line. Many lines proved very perspective and only 5 lines were pre-propagated on 100 m² plots.

In 1992, KH Kincsem variety was crossed to Rex variety, which has a low degree of winter hardiness, in order to improve the yield potential, stem strength and resistance to powdery mildew of KH Kincsem variety, retaining its excellent winter hardiness (Table 2.).

Individual selections were applied for screening of perspective phenotypes with excellent winter hardiness similarly way to KH Kincsem variety.

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able 2. The breeding	g process of KH Malko two-rowed winter ba	rley variety
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1992.	KH Kincs	KH Kincsem x Rex		
Winter hardiness	6,5	1,5		
Yielding ability	7,5	8,5		
Stem strength	7,5	8,5		

RESULTS AND DISCUSSION

One of the basic goals of barley breeding program of Kompolt is to improve and preserve the winter hardiness influencing significantly the yield stability. The winter hardiness of the barley varieties of Kompolt is significantly better than the average in the Hungarian barley variety list. Results of variety comparative trials on winter barley varieties at different locations of Hungary in the early and medium maturation group are shown in Table 3 and Table 4.

 Table 3. Results from variety comparative trials on winter barley varieties in the early maturation group

	Scale-values of winter Yield, tons/ha					ha				
Variety	Kompolt	Dalmand	Kecskemét	Debrecen	Átlag	Kompolt	Dalmand	Kecskemét	Debrecen	Átlag
Botond	7,5	7,3	9,0	5,4	7,4	4,15	5,55	3,40	2,36	3,9
KH Viktor	7,4	7,8	9,0	4,0	7,2	4,34	6,41	3,84	2,63	4,3
Prima	5,3	6,0	9,0	3,4	6,3	3,81	6,41	4,37	2,58	4,3
Palinka	3,8	2,8	9,0	4,4	5,6	3,58	4,83	3,33	2,32	3,5
Plaisant	5,0	3,8	6,5	4,2	5,5	3,34	4,91	2,80	2,68	3,4
KH Korsó	4,3	5,8	6,5	2,8	5,5	2,74	4,88	2,61	1,48	2,9
Kunsági2	4,4	3,8	8,0	1,0	5,0	1,87	4,35	2,60	2,23	2,8
Gotic	3,8	2,3	6,8	2,6	4,7	3,58	4,27	3,03	1,71	3,1
GK Rezi	1,3	4,8	5,3	2,2	4,1	1,69	5,71	2,65	0,60	2,7
Metál	1,8	2,3	5,5	2,2	3,8	1,84	4,88	2,24	1,02	2,5
Replic	2,9	1,0	3,3	2,6	3,4	2,65	2,59	2,03	1,26	2,1
Fantázia	1,0	2,3	3,0	2,2	2,7	0,01	2,76	1,60	0,40	1,2
GK Stramm	1,0	1,0	1,3	1,0	1,3	0,01	3,26	0,60	0,01	1,0

Many gene-sources were used, but the best results were obtained by using the major gene of the Kompolt 4 variety. The winter hardiness of the barley varieties was severely tried by the 1992/93 year's cold weather. Besides the cold effect, winter barley was covered by thick snow and barley varieties suffered also from snow mould injury.

After the 1992/93 year's very severe cold winter, among the two-rowed barleys, breeding line K-86-11-25 gave the best results with a 6.5 of scale-value of winter hardiness.

Eight breeding materials gave 6 of scale-value, and the remaining breeding materials were frozen or they did not exceed the 2 of scale-value. Based on its excellent winter hardiness and very good agronomic traits breeding line K-86-11-25 was applied for registration and in 1996 it was released as KH Kincsem variety. From the pedigree and the phenotype of the winter hardy lines, it can be concluded that winter hardiness of Kompolt 4 variety is determined by a major gene which can be transferred by crossing into new genotypes.

From the results it can be seen that the degree of winter hardiness of the two-rowed barley varieties is much lower than that of the six-rowed ones (Table 5). In the course of our

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trials it was also observed that KH Kincsem variety has a high degree of resistance to *barley yellow dwarf viruses* and *wheat dwarf virus* (Pocsai et al., 2006).

Table 4. Results from variety comparative trials on winter barley varieties in the medium maturation group

	Scale	-values	s of win	ter harc	liness	Yield, tons/ha				
Variety	Kompolt	Dalmand	Kecskemét	Debrecen	Átlag	Kompolt	Dalmand	Kecskemét	Debrecen	Átlag
Petra	6,5	7,0	8,8	5,6	6,9	4,4	5,8	3,1	2,6	4,0
KH Center	8,5	6,5	8,0	5,2	7,1	4,3	3,2	2,6	4,3	3,6
KH Malko	6,2	7,0	9,0	5,4	6,9	4,0	6,3	2,8	2,7	3,9
Venus	6,6	7,0	8,0	5,2	6,7	3,9	5,4	3,3	2,6	3,8
KH Rezko	7,8	6,0	7,3	4,8	6,5	5,3	5,3	2,8	2,4	3,9
Angora	7,1	6,0	8,0	5,0	6,5	3,7	4,8	2,2	2,1	3,2
Carola	5,4	5,8	9,0	4,8	6,3	3,8	5,6	2,7	2,3	3,6
Catania	6,0	6,8	7,5	3,8	6,0	4,2	5,4	2,6	2,0	3,5
Bogesa	6,3	6,0	8,0	4,4	6,2	4,1	4,8	2,8	2,2	3,5
KH Agria	6,1	6,8	7,3	3,0	5,8	3,6	5,3	2,2	1,8	3,2
Paris	6,7	4,8	7,8	4,6	6,0	4,2	3,9	2,6	2,2	3,2
Tiffany	5,5	5,0	7,8	5,6	6,0	3,6	5,3	2,1	2,5	3,4
Vanessa	5,1	4,8	8,0	5,2	5,8	4,2	5,0	2,8	2,4	3,6
Anita	4,2	6,8	6,3	4,0	5,3	3,0	5,1	2,8	2,3	3,3
Hardy	5,6	4,3	7,0	3,4	5,1	3,4	4,2	2,8	1,6	3,0
Attila	3,4	4,3	6,8	2,8	4,3	2,9	4,9	2,5	2,0	3,1
Siberia	4,2	2,8	7,3	4,2	4,6	3,9	3,7	2,1	1,9	2,9
GK Omega	1,9	2,0	6,0	2,6	3,1	1,7	3,5	2,1	1,5	2,2
Lambic	1,9	1,0	5,8	3,0	2,9	2,2	3,0	2,4	2,0	2,4
Reni	1,6	1,0	5,8	2,6	2,8	1,8	4,2	2,1	1,9	2,5
Luca	1,5	1,0	4,0	4,4	2,7	1,8	3,1	1,9	1,9	2,2
Nelly	1,0	3,0	2,0	4,0	2,5	2,5	5,4	1,8	2,3	3,0
Rex	1,1	2,8	4,0	2,2	2,5	3,7	4,8	1,9	0,6	2,7
Esterel	1,0	1,0	2,5	3,0	1,9	3,5	2,9	1,2	1,0	2,2

Table 5. Scale-values of winter hardiness of the six and two-rowed barley in 2003

Average of reistered six-rowed varieties	5,7
Average of six-rowed varieties of Kompolt	7,1
Highest value (Botond)	7,5
SzD _{5%}	1,5
Average of registered two-rowed varieties	4,7
Average of two-rowed varieties of Kompolt	6,3
Average of KH Malko variety	7,1
The most higher value (KH Malko)	7,1
SzD _{5%}	1,5

The best result showing K-2173 breeding line was selected which contained the major gene of winter hardiness of the Kompolt 4 variety. It was applied for registration in autumn of 1998 and it was released as KH Malko variety in 2001. This variety proved its excellent winter hardiness in 2003. In the Hungarian EBC trials among the local and foreign varie-

ties, the KH Malko variety had the most excellent winter hardiness and it gave also the highest yield. In the variety comparative trials on winter barley varieties done by the National Institute for Agricultural Quality Control KH Malko variety gave 6.43 tons/ha during the period 2003-2005. Its yield exceeded the average of barley varieties by 110.9% (Table 6.). So, KH Malko variety is one of the best winter hardy two-rowed barley varieties in Hungary, also possessing excellent agronomical properties, too. These two varieties besides the high degree of winter hardiness also have excellent yielding ability and stem strength.

Mariati	Grain yie	Maturity	
variety	t/ha	%	group
KH Malko	6,43	110,9	II.
KH Agria	6,36	109,7	II.
KH Tas	6,31	108,8	Ι.
KH Viktor	6,23	107,4	Ι.
KH Center	6,22	107,2	II.
KH Rezko	6,15	106,0	II.
Siberia	6,13	105,7	II.
Nelly	6,07	104,7	II.
Palinka	6,03	104,0	I.
KH Korsó	5,98	103,1	I.
Paris	5,92	102,1	II.
Lomerit	5,91	101,9	II.
Gotic	5,90	101,7	I.
Catania	5,88	101,4	II.
Kinsági 2	5,88	101,4	I.
Rex	5,86	101,0	II.
Botond	5,82	100,3	I.
Attila	5,81	100,2	II.
Vanessa	5,80	100,0	II.
Venus	5,78	99,7	II.
GK Metal	5,75	99,1	I.
Carola	5,72	98,6	II.
Plaisant	5,64	97,2	I.
GK Sztáromega	5,60	96,6	II.
Fantázia	5,56	95,9	I.
GK Stramm	5,54	95,5	I.
Esterel	5,52	95,2	II.
Replic	5,52	95,2	Ι.
Tiffany	5,38	92,8	II.
Bogesa	5,29	91,2	II.
GK Rezi	5,28	91,0	Ι.
Angora	5,16	89,0	II.
Lambic	5,13	88,4	II.
Average	5,80		
SzD _{5%}	0,82	14,1	

Table 6. Results from variety comparative trials on winter barley varieties in the period of 2003-2005

(Czirák. et al. (2005): Államilag elismert fajták kísérleti eredményei, Kalászos Gabonák OMMI, 45 p)

According to the results, it can be concluded that to the breeding for winter hardiness, a determined intention, an appropriate gene materials and a breeding place suitable for screening of winter hardiness are indispensable.

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