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MAIN TRENDS IN OAT (*Avena sativa* L.) BREEDING AT THE INSTITUTE OF AGRICULTURE IN KARNOBAT, BULGARIA. I. WINTER OATS

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Abstract: In the 1980s, under the influence of the worldwide breeding achievements, the Institute of Agriculture in Karnobat launched its program for breeding new oat varieties. 80 % of the breeding program included winter oats, and 20 % - spring oats.

The goal of these two main directions has been to create genotypes combining high and stable productive potential, high quality grain, complex resistance to stressful effects from abiotic and biotic environmental factors. It is necessary to make specialized collections, to create suitable source material, to adapt and apply new methods and approaches to assess the breeding material and to clarify some genetic and biological issues of theoretical and applied nature, which support the breeding process to realize the set goals. The priority areas in the breeding programs focus on overcoming low winter resistance, drought tolerance and productivity, reduction of the vegetation period, high stem and poor lodging resistance, increased grain quality, and others. Conventional, biotechnological, physiological and biochemical methods were used to evaluate the created genotypes.

Key words: oats, hybridization, mutation breeding, in vitro cultivation, abiotic and biotic stress resistance, grain yield, grain quality

Karbonat Tarım Enstitüsü (Bulgaristan)'ndeki Yulaf (*Avena sativa* L.) Yetiştiriciliğinde Güncel Yönelimler, I. Kış Yulafları

Özet: Karbonat'daki Tarım Enstitüsü, dünyadaki yetiştiricilik başarılarının etkisi sonucunda 1980lerde yeni yulaf çeşitleri yetiştirme üzerinde bir program başlatmış ve bu programın %80'ini kış, %20'sini de ilkbahar yulafları oluşturmuştur.

Bu iki başlıca yönelimin hedefi yüksek ve kararlı üretkenlik potansiyeli, yüksek tane kalitesi ve biyotik ve abiyotik çevresel stres faktörlerine karşı kompleks dayanıklılık özelliklerini birleştirerek yeni genotiplerin elde edilmesi olmuştur. Özel koleksiyonlar oluşturmak, uygun kaynak materyalleri yaratmak, çaprazlamada kullanılacak yeni metot ve yaklaşımları benimseyip uygulamak ve teori ve uygulamadaki bazı genetik ve biyolojik konuları açıklığa kavuşturmak, üretim programının istenilen hedeflerine ulaşılması bakımından önemlidir. Üretim programında öncelik verilen alanlar düşük kış dirençliliğinin, kıraklık toleransının ve üretkenliğin üstesinden gelinmesi, vejetasyon süresinin kısaltılması, tane kalitesinin arttırılması gibi konular üzerine yoğunlaşmaktadır. Elde edilen genotiplerin değerlendirilmesi amacıyla geleneksel, biyoteknolojik, fizyolojik ve biyokimyasal yöntemler kullanılmıştır.

Anahtar kelimeler: yulaf, hibritleme, mutasyon ıslahı, in vitro yetiştirme, abiyotik ve biyotik stres dirençliliği, tane verimi, tane kalitesi

Introduction

Oats stand out as crops with high nutrient, assimilation and calorie values. It partakes in all the kinds of feed for young, lactating and breeding animals. Over the last years the healing and dietary properties of oat have been highly estimated (Hasler 2002, Kerckhoffs et al. 2003, Gray 2006, Michalkova et al. 2009, Georgieva and Zorovski, 2011).

Due to its variegated use as feed and raw material in the production of foods and medical products, oat a main and one of the most preferred crops in a number of countries (Batalova 2004, Brennan and Cleary 2005). It ranks sixth after wheat, maize, rice, barley and sorgo in terms of world production. The countries with highest oat production in the world are Russia, Canada and the USA (Ivanov 2006.).

At the Institute Agriculture in Karnobat, the onset of the oat breeding program was in 1942, but its significant development of scope was reached after 1988.

In the period of 1988-1998, the priority of the breeding program was to create wintering oat varieties, which in the Bulgarian conditions realized their potential more fully (Tanchev et al. 2002, Georgieva and Savova 2005, Zorovski et al. 2013). Later on, the breeding program included the task to improve the varietal content of spring oats (Panayotova et al. 2005) and in 2008 in connection with the increasing application of oat in human nutrition work on creating naked oat varieties started (Vasel 1988, Sterba and Moudry 2001, Antonova 2005).

The oat breeding program is of complex nature. The direction and approaches of its implementation are directly related to the set goals and tasks, to the variety use, to unsolved problems which limit the biological potential of the crop and to the main criteria for the varietal ideal.

The main goal of the complex oat breeding program was to create new winter and spring varieties (husked and naked oats grain), forms of high-yielding potential and grain quality with complex resistance to the stress influence of abiotic and biotic environmental factors.

Breeding Methods

The main method in the breeding research was the combination breeding method (intervarietal hybridization – simple, complex, backcross, diallel combinations). Homogenization of the created hybrids was performed by the individual selection method.

The breeding technique chosen to be implemented in the breeding program which develops biotic and abiotic stress resistance (cold resistance, drought tolerance, diseases) was backcrossing and evaluation of obtained genotypes through field and laboratory methods.

To make an efficient selection of equal morphological generations and lines with specific traits direct field observations, biochemical, physiological and biometric analyses and evaluation tests were conducted.

Gamma rays and sodium azide mutagenic treatments were used to create a greater genetic diversity.

A new approach in oat breeding was the application of biotechnological methods, which included in vitro cultivation of mature embryos and selection of somaclonal lines with expressed traits and in vitro selection of selection media for selection of regenerants with enhanced cold and drought resistance. Also, another new approach was the use of morphological and biochemical markers to study the genetic diversity of oats and the control on its varietal purity and for this purpose SDS electrophoresis of protein was applied.

Breeding Directions and Tasks

I. Winter oat

The direction of creating winter varieties was a main and priority direction in the oat breeding program. It assumed about 80 % of the breeding research for this crop. The long-term investigation in the region proved the advantages of winter varieties over spring ones, some of which are better use of moisture supplies in winter and of rainfall in spring, early vegetation regeneration in spring, avoidance of the negative effect of high temperatures and dry winds during grain filling and ripening and formation of 30-40 % higher grain yield (Tanchev et al. 2002; Georgieva and Savova 2005).

The model of the new winter variety was formed on the grounds of specific parameters of the main traits, which characterize the variety; i.e. increased winter resistance, cold resistance and tolerance to diseases, reduced length of vegetation period and stem height and improved lodging resistance and grain quality.

Model of the varietal ideal

- Productivity – 8-10 % above standard
- Productive tillering - 800-1000 productive tillers per sq.m.
- Cold resistance - LT_{50} = minus 11-12 ^{0}C
- Disease tolerance – high
- Vegetation period – early and mid-early ecotype, panicle emergence in the second half of May
- Stem– average height (90 -110 cm)
- Lodging resistance - high (rating 9)
- Panicle - large, well grained, upright, resistant to grain shattering and sprouting
- 1000-grain weight - over 35 g
- Weed rate – lower than 25 %
- Protein content - over 12,5 – 13,0 %

Direction of winter and cold resistance. One of the main tasks in breeding winter oat varieties is to increase its resistance to the effects of low winter temperatures.

The development of the direction of winter and cold resistance started with the varieties of Panema (LT_{50} –11,8 ^{o}C), Abritus-2 (LT_{50} –11,4 ^{o}C), Checota (LT_{50} –11,1 ^{o}C) and Dunav-1 (LT_{50} –10,6 ^{o}C). Gradually the collection of winter resistance was enriched with new accessions from the world collection and at the moment it has the main share in the range of oat varieties at the Institute (60 %).

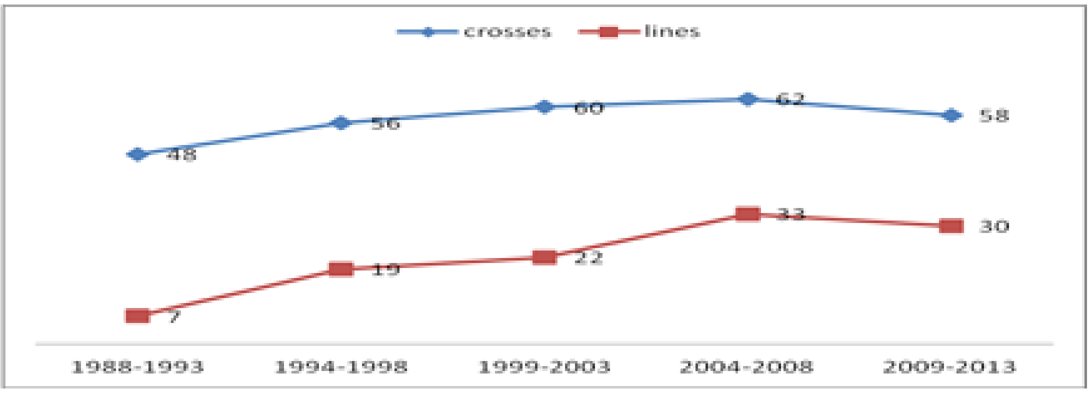

Figure 1. The numbers of crosses and breeding lines with high cold resistance.

Table 1. Advanced breeding lines with high cold resistance

Advanced breeding lines	Cold resistance (LT_{50})	Grain yield (kg ha-1)	%
Mean standard	**-11,3**	**4480**	**100**
CR 619-4	-11,6	4910**	110
CR 645-3 3У	-11,6	4822**	108
CR 619-4	-11,6	4740*	106
3У 757-4-3	-10,9	4683*	104
Z 501-1-8	-11,6	4610*	103

5 advanced lines in cold resistance were submitted for testing at the State Variety Testing in this period (Table 1).

Due to the polygene nature of winter resistance, this direction mainly applied complex crossing. On the grounds of the numerous combinations made with the participation of cold resistant accessions and purposeful selection genotypes of high cold resistance (LT_{50} over minus 10 ^{o}C) were created. A total of 284 crosses were made during the period of 1988-2013 and 39 % of the hybrids created in this direction were genotypes with good demonstration of this trait (Figure 1).

Direction of earliness. Another important task standing before the winter oat breeding was connected with shortening the length of vegetation period. Its acceptance as a priority was necessitated by the mainly available late varieties in production. In Bulgarian conditions, these varieties suffer greatly from the summer heat and dry winds, as they coincide with the stages of grain filling and ripening. Therefore, the late varieties cannot realize their potential.

The first genotypes with reduced length of vegetation period were created based on the American ultra-early varieties Florida 502, Nodaway, Nora and lines 3.0.39, 718-5, whose panicle emergence is on average 10-20 days earlier than the standard varieties. This purposeful selection of early forms, however, resulted in creating early genotypes with unsatisfactory productivity. It necessitated reconsidering the breeding strategy in this direction. As a result of applying a number of backcrosses with high-yielding forms and inclusion of new, mid-early sources, genotypes were created which combined in various degree earliness and productivity. A total of 161 lines were created over this period, and they had different degree of earliness and productivity at and above the standard level (Figure 2).

Table 2 shows part of the advanced breeding material in this direction, which was submitted for State Variety Testing in the period of 1988-2013. Line Rh 459-2-2 was recognized as variety.

Direction of low stem and lodging resistance. In connection with overcoming oat lodging, the breeding work was aimed at creating forms with reduced stem height. Due to the existing negative correlation between yield and plant height, we pursued to create forms, which combined the two traits in optimal parameters. Breeding by lodging resistance began on the grounds of accessions originating from North and Central America and with stem height of 70-80 cm (Ozark, Nora, Froker, Preston, Elan, Nodaway 70). They manifested good genetic base for the two traits but they were not competitive in yield. The first results in improving the productivity of low-stem genotypes were realized through a series of combinations with the high-yielding varieties of Dunav 1 and Abritus 2, which have a high stem, non-resistant to lodging. Later, other genotypes which were created in the direction of yield were included as sources of productivity. As a result of the breeding work to improve the traits advanced lines with stem height of up to 90-110 cm and high lodging resistance were created, stable by years (Table 3). A positive combination with productivity was achieved with 35 % of the lines.

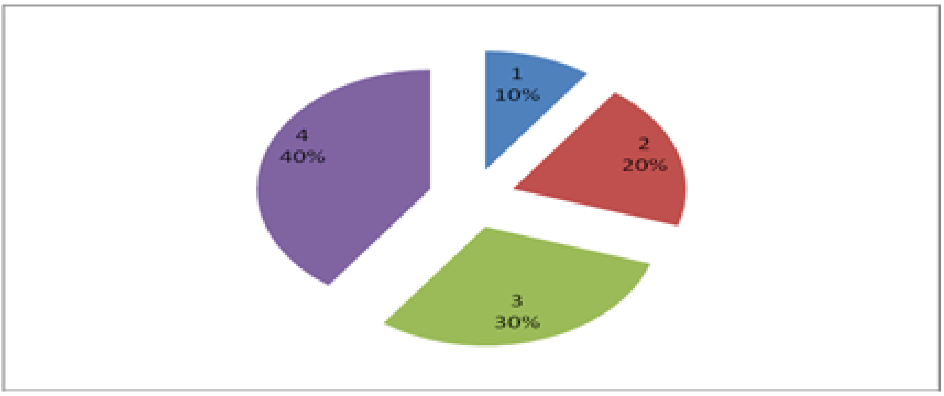

Figure 2. Percentage of lines by earliness
1- over 15 days before standard; **2-** 10-15 days before standard;
3- 5-10 days before standard; **4-** up to 5 days before standard.

Table 2. Advanced earliness breeding lines

Advanced breeding lines	Vegetation period (days)	± standard	Yield of grain (kg ha-1)	%
standard	283	X	4480	100
Rh 459-2-2	273	-10	4995	111
Rh 459-2	274	-9	4881	109
Rh 703-2	271	-12	4829	108
Rh 718-1	271	-12	4620	103
R 478-1-4	272	-11	4611	103

Mean for the period of 1988-2013, the share of created low-stem genotypes was about 70 %, whereas the reduction of stem height compared to standard was 17 cm. A positive combination of low stem, lodging resistance and yield, with the yield exceeding standard with about 8 %, was achieved with 35 % of the lines (Figure 3).

Direction of productivity. The most important goal of a breeding program is to increase productivity. It is the main criterion to evaluate a variety.

Table 3. Mean values and variance of stem height and lodging resistance

Groups by plant height	Plant height (cm) min	max	X	Vc, %	Lodging resistance, Vc %,
up to 70 cm	57	73	65	16,33	9,63
70-80 cm	66	89	77	11,58	8,91
80-90 cm	71	97	89	19,06	7,48
90-100 cm	83	114	96	17,10	10,02
100-110 cm	87	122	108	26,48	9,11
110-120 cm	99	131	114	24,36	17,12
120-130 cm	115	138	127	20,15	23,43

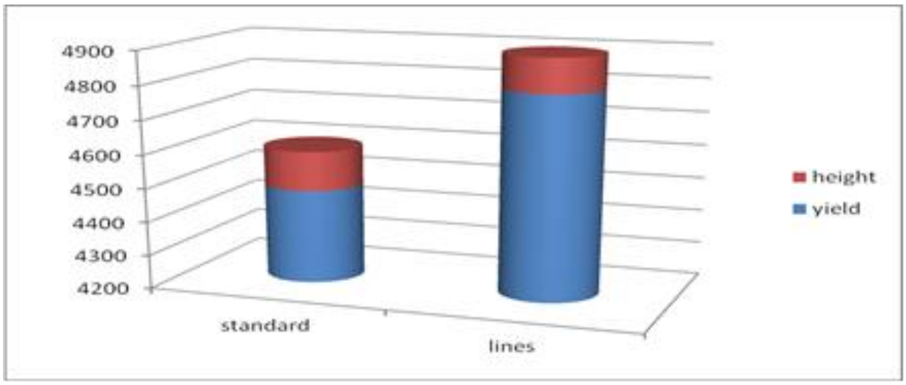

Figure 3. Plant height and yield of breeding lines from the direction of low stem. The mean values for the period of 1988-2013 were given.

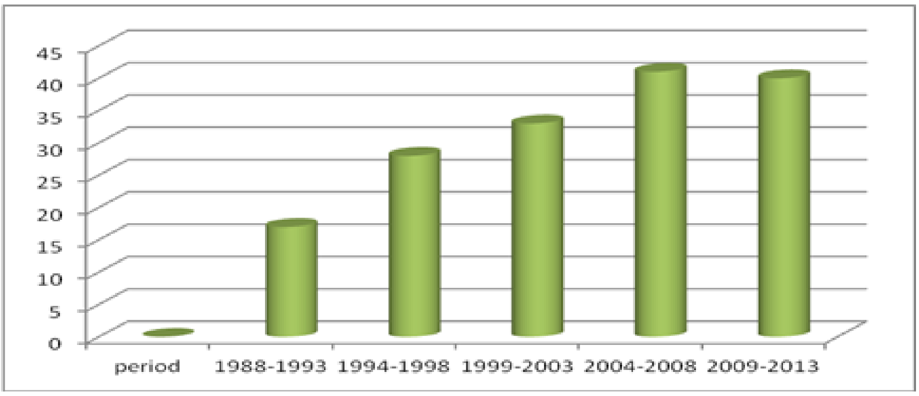

Figure 4. Percentage of lines with yield above standard

Considering the high biological crop potential, the efforts were aimed at creating genotypes with high panicle productivity, which in the normal stem position of 900 productive stems per sq.m., could realize an yield of over 5000-6000 кg ha-1.

Breeding by productivity had two stages. During the first stage, the breeding work in this direction was conducted with comparatively limited genetic resources. The genotypes created over this period could not manifest their potential because of their unsatisfactory lodging resistance, uneven ripening of panicle and poor grain uniformity.

The next stage of development in this direction was connected with introducing new genetic sources and a new approach in evaluating the parent material in productivity. After enriching the parent material, another criterion was introduced in selecting the parental forms – panicle productivity, whereas the harvest index was introduced for the late-ripening and high-stem sources. Over the period of 1988-2013, in the specialized collection of productivity over 400 accessions, out of which 178 were selected by main trait and 63 – by a complex of traits were studied. On the grounds of expanded and purposeful work in this direction, in this period high-yielding genotypes (Figure 4), which in 59 % of the material were also accompanied by good manifestation of other traits significant in breeding were created.

This direction submitted 6 advanced lines with proven high productivity for State Variety Testing. Two of them were recognized and entered in the European List of varieties as the Kechlibar and Eley varieties. There are two other candidate-varieties Kt 7007 and Kt 7008, which in 2014 are going to complete their ecological testing and expected to be recognized. The reported yields of these candidate varieties are 8 to 28 % above of standard of the average of the country.

Direction of grain quality. An important task in the oat breeding program was to create genotypes with improved grain quality. Breeding aimed at developing varieties with 1000-grain weight of over 35 g and protein content of over 12,5 %. To achieve the breeding goals, genetic plasma from Germany, USA and Canada was used. On the grounds of hybrid combinations with the high-protein varieties of Mostyn (16,16 %), B-525-631 (15,85), STH-3330 (16,0 %), Y-10-34-15 (16,5 %) and high-yielding lines the negative relation between the two traits were overcome and advanced lines, which combined quality and yield to a great extent were created. The parameters set in the variety model regarding the protein content were achieved in 16 % of the lines in this direction, and for 1000-grain weight – in 32 % (Figure 5).

The greatest number of lines, corresponding to the parameters of the varietal ideal were created in the directions of cold resistance, earliness and low stem (over 50 %). The breeding efficiency in the directions of productivity and lodging resistance was about 30 %, and 17-18 % - for grain quality and disease resistance, respectively (Figure 6).

Table 4. Breeding lines with high productivity

Breeding lines	Yield (kg/ha)	1000-grain Weight (g)	Winter resistance (9-1)	Vegetation period (± st.)	Plant height (cm)	Lodging resistance (9-1)
standard	4480	28,0	8	283	122	6-7
Kechlibar	6540	37,5	8-9	-10	87	8-9
Eley	5400	29,3	8	-11	99	8
Kt 7007	5401	28,0	8	-8	106	7-8
Kt 7008	5330	31,5	8	-5	108	7-8
661-10	5401	30,5	8-9	-6	102	8
Y 718-2	5077	27,0	8-9	-3	106	8
Y 1047-6	5021	32,0	8	-10	92	8-9
Y 1041-26	5255	29,5	8-9	-3	107	8

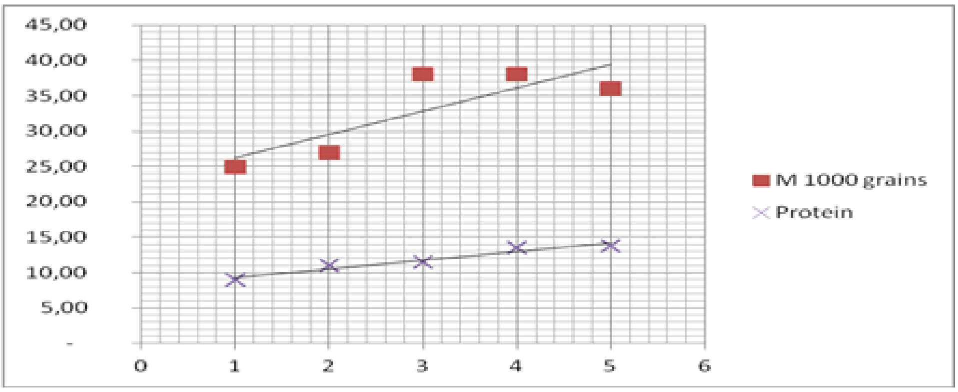

Figure 5. Improving protein content and 1000-grain weight

1-1988-1993; **2**- 1994-1998; **3**- 1999-2003; **4**- 2004-2008; **5**- 2009-2013

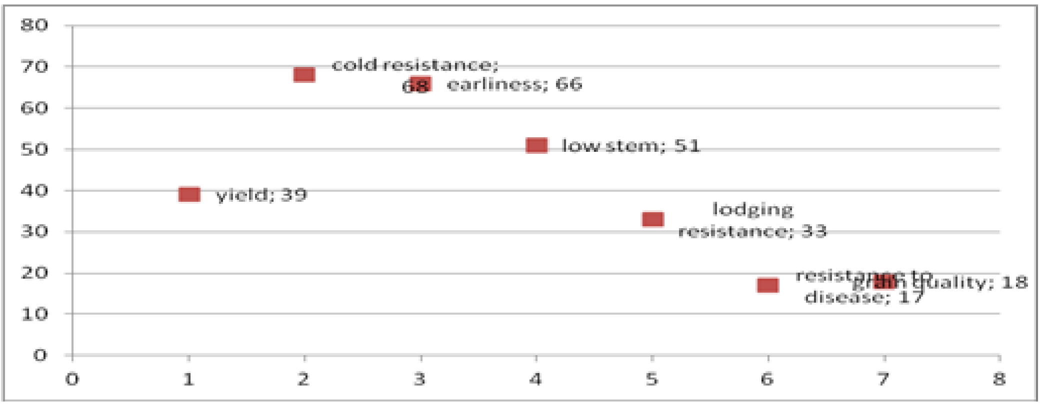

Figure 6. Percentage of lines with parameters corresponding to varietal ideal

Conclusion

A significant progress in the directions for breeding winter oats was achieced at the Institute of Agriculture in Karbonat in the period of 1988-2013 by means of conventional and modern breeding methods. Greatest efficiency was achieved in the directions of cold and winter resistance, earliness and low stem. There was a significant progress in breeding by productivity and lodging resistance and an insignificant progress in the directions of grain quality and disease resistance.

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