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BREEDING OF CEREAL CROPS AT DOBRUDZHA AGRICULTURAL INSTITUTE – GENERAL TOSHEVO, BULGARIA

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Abstract
The climate of Bulgaria is very diverse in spite of its small territory. The soil and climatic conditions in the region where Dobrudzha Agricultural Institute is situated are suitable for obtaining high and stable yields from all winter cereals. The breeding program of the institute is aimed at developing high-yielding cultivars of common and durum wheat, triticale, malting and feed barley adaptable to growing under variable soil and climatic conditions. The aim of this investigation is to present the major directions, problems and achievements of the breeding work on the winter cereals at Dobrudzha Agricultural Institute.The results were summarized on several levels:Evaluation of the risk factors for the development, the yield formation and the quality indices;Developing and study on a gene pool of the best world and Bulgarian accessions;Developing of own initial material by using the methods of intervarietal hybridization, experimental mutagenesis and other biotechnology approaches;Developing of a more efficient methodology for field and laboratory evaluation of the breeding materials;Testing of new varieties and production of certified planting material.The portfolio of the institute is quite variable. From the cultivars developed here, 36 genotypes of common wheat and 5 genotypes of durum wheat, 11 triticale cultivars and 6 winter barley varieties have been included in the National Vareital List of Bulgaria.

Keywords: breeding program, wheat, barley, triticale, stress factors.

Introduction

In growing of cereals, the choice of a suitable cultivar is an important factor for the efficiency of production. The frequent stress factors during the comparatively long vegetative growth determine the high importance of this choice. The breeding of cereal crops in Republic of Bulgaria is carried out at several centers, which have at their disposal rich initial breeding materials and apply specific approaches for evaluation. The genetic potential of the developed materials is tested under conditions of permanent stress. In this way the most promising genotypes are sorted out; they are then subjected to testing within the system of the national Executive Agency of Variety Testing, Field Inspection and Seed Control, and further introduced in practice. Dobrudzha Agricultural Institute (DAI) is the largest breeding center for cereals in Bulgaria. It is located in a region where the conditions are suitable not only for obtaining of high and stable yields from these crops but also allow testing of the breeding materials under different types of stress. The portfolio of DAI is highly diverse. Out of the cultivars developed here, 36 genotypes of common wheat, 5 genotypes of durum wheat, 11 cultivars of triticale and 6 varieties of winter barley are included in the Varietal List of Bulgaria. The aim of this investigation was to outline the main trends, problems and achievements of the breeding work with the winter cereals at Dobrudzha Agricultural Institute.

Material and methods

The historical overview is based on reports and statements published in the research communication volumes of DAI. Data are presented on the cereals included in the national varietal list (Table 1). The observations have been made within competitive varietal trials designed in 15 m^2 plots in five

replicates. The sowing norm was 420 germinating seeds (g.s.) per 1 m^2 for two-rowed barley, 450 g.s. for the feed barley forms and 550 g.s. for wheat and triticale. The previous crop was grain pea. At the beginning of February, nutrition with 4 $t.ha^{-1}$ active matter of nitrogen was done. The agronomy practices not subject to this investigation were in accordance with the technology approved for growing of the respective crop. The region of Dobrudzha, where the Institute is located, has soil and climatic conditions favorable for the development of the cereals. In the winter months, the low temperatures may be critical without snow cover. The absolute minimum temperature measured in this region is -29.4°C, and the absolute maximum +41.1°C. Due to the frequent flows of ground-level cooling air currents, the spring comes here with 10-15 days later. The summer is cool and the autumn is long, with gradually decreasing temperatures. Winds are frequent, with predominant northern component. Especially damaging is the hot air mass transport during the grain filling stage. There are two well expressed periods of drought during March – April and July – August. The mean annual precipitation sum is 510 mm. The predominant soils in the region are the leached chernozems. Due to the heavy soil composition, the values of the hydrological indices are comparatively high.

Table 1. Registered cereal varieties of DAI included in the Varietal List of Republic of Bulgaria (2017)

Winter wheat
Aglika, GTP Albena, Antonovka, Bozhana, Boliarka, Galatea, Goritsa, Demetra, GTP Dragana, Enola, Iveta, GTP Kalina, GTP Kami, Karat, GTP Karina, GTP Katarzhina, GTP Kiara, GTP Korona, Kosara, GTP Kristal, Kristalina, GTP Kristi, Lazarka, GTP Laska, Merilin, GTP Milena, GTP Neda , Nikodim, Pchelina, GTP Rada, Sladuna, Stoyana, GTP Tina, Todora, Fani, Zhana
Durum wheat
Melina, Mirabel, Mirela, Saturn 1, Severina.
Triticale
Akord, Atilla, Borislav, Blagovest, Bumerang, Dobrudzhanets, Doni 52, Irnik, Kolorit, Lovchanets, Respekt
Winter malting barley
GTE Ahat, Kaskadyor 3, Oniks, GTE Yaspis
Winter feed barley
Pagane, Tangra

Results and discussion

Wheat breeding in Bulgaria has a history of more than 110 years. After the approval of the first breeding program in 1964, a series of cultivars were developed at DAI which possess high productivity, quality grain and comparatively short stem (Panayotov and Rachinski 2002). The attempts to develop triticale started at the same time. With the release of the first hexaploid triticale, Bulgaria became the seventh country in the world to synthesize this crop. The main goals were to combine the high productivity of wheat with the low requirements of rye to the soil fertility and the nutrition regime, and with its disease resistance. The research programs on the breeding of durum wheat and barley started much later. They were focused on the improvement of the level of frost resistance, which is a problem in this crop. Cereal crops with a typical winter type of development are grown in the region of Dobrudzha. To be able to express all their positive qualities and realize their production potential, the plants have to over winter without significant damages. When vegetative growth resumes in spring, frost damages are observed most frequently. The Dobrudzha plateau is open to the north – north-west, which makes it vulnerable to the influx of cold air masses. When this is combined with strong winds and lack of snow cover, the plants are subjected to critical low temperatures. A peculiarity of the breeding at DAI is the high level of frost and winter resistance, which is decisive under the changeable conditions of Bulgaria. The criteria for evaluation are high and are similar to the Russian and Ukrainian breeding requirements. Apart from

being tested under field conditions, the breeding materials are also tested in low-temperature chambers with the aim to differentiate them well. The rainfalls in the region of Dobrudzha are unevenly distributed and frequently are a limiting factor for production. The autumn droughts influence mostly the preparation of the sowing areas and sowing itself. Often the emergence of the plants is not uniform, and they sometimes enter the winter months at an unsuitable stage of development. Especially unfavorable are the summer droughts, which are usually soil and atmospheric ones (Petrova 2013). They are characterized with high temperatures, low air humidity, and soil moisture less than 70 % from the maximum field water capacity. Their effect on the nutrition of grains is negative, and the crops ripen prematurely. The peculiarities of the cultivars developed at DAI are the following: 1) faster resumption of vegetative growth in the spring months allowing faster rate of biomass accumulation by utilization of the autumn and winter moisture reserves; 2) earlier date to heading allowing flowering, pollination and fertilization to occur also under more favorable conditions; 3) expressed dynamic relationship between duration and rate of grain filling. As a result from the combined use of different laboratory techniques and multiple individual selection in the hybrid populations, the developed wheat cultivars possess high productivity and resistance to low temperatures and drought (Tsenov et al. 2012a; Tsenov et al. 2012b):

Cultivars with high level of frost resistance – Aglika, GTP Albena, Bozhana, Bolyarka, Demetra, Iveta, Lazarka, GTP Laska, Merilin, GTP Milena, Todora, Fani.

Cultivars tolerant to drought – GTP Albena, Galateya, GTP Dragana, Enola, Iveta, GTP Kristal, GTP Kristi, Lazarka, GTP Laska, GTP Rada, Todora.

The cultivars released during the last decade represent a step forward in the breeding of this crop. An indication for their adaptability potential is the high yields realized, which are stable over years under changeable soil and climatic conditions. An unequivocal success are cultivars Akord and Respekt, which by their level of frost resistance correspond to the standards Bezostaya 1 and Mironovskaya 808. The durum wheat cultivars Severina, Mirabel, Melina and Mirela developed at DAI have no alternative in the European varietal list with regard to this type of stress. Progress was made in the breeding of barley, too. Cultivars GTE Yaspis и Pagane are with a high level of frost and winter resistance. The two-rowed barley GTE Ahat is tolerant to drought. The resistance to diseases of the cultivars introduced in the practice is at a sufficiently high level. Due to the long-term systematic breeding work they do not differ from the accessions developed under conditions of high pressure from various pathogens. Analysis and evaluation for resistance of the developed initial breeding material are done at the laboratory of plant pathology, and the lines and new cultivars are tested against infection field background. The changes in the race composition of the pathogen casual agents of brown rust and powdery mildew are investigated (Ivanova 2014; Stanoeva and Iliev 2014). The resistance to them and its stability and durability are clarified. When investigating the physiological specialization of powdery mildew on wheat, genes *Pm 3c*, *Pm 7* and *Pm 3b* demonstrated highest efficiency to the studied populations. Genes *Pm 4в*, *Pm 5* and *Pm 3d* had low efficiency. Completely inefficient were genes *Pm 6*, *Pm 8* and *Pm 2+6*. With regard to brown rust, genes *Lr* 9, *Lr* 19, *Lr* 40, *Lr* 41, *Lr* 42, *Lr* 43 and *Lr* 51 were with absolute efficiency. Genes *Lr* 24, *Lr 25, Lr* 29, *Lr* 35, *Lr 36, Lr* 47, *Lr* 50 and *Lr* 52 were highly efficient, while *Lr* 3ка, *Lr 11, Lr 15, Lr 18, Lr 26* and *Lr* 30 were absolutely inefficient. In the recent years, net blotch is becoming an economically important disease on barley. The causal agent (*Drechlera teres* Ito.) is aggressive and under suitable conditions its fast development defoliates the plants at the most critical vegetative stages. Purposeful research work on this pathogen has not been carried out at DAI but the field investigations showed high resistance of two of the new registered cultivars - GTE Ahat and Tangra. The phytosanitary situation in Bulgaria is currently complicated due to various reasons. High attacking rates of infection caused by diseases with previous sporadic occurrence are becoming more frequent. This imposes the necessity to reconsider the main directions of research work, to quickly identify sources of resistance and to include them in the breeding process. The improvement

of quality has always been a priority of the breeding programs at DAI. Among the wheat cultivars, of which seed production is carried out, 24 % belong to the group of the strong wheats (Aglika, GTP Albena, GTP Laska, GTP Milena, Demetra, Iveta, Lazarka, Merilin, Pchelina), and 43 % are medium with increased strength (Bozhana, Bolyarka, Enola, Galatea, Goritsa, GTP Dragana, GTP Kami, GTP Katarzhina, GTP Kristi, GTP Neda, GTP Rada, Kosara, Kristalina, Sladuna, Stoyana). Although there are no preferential prices for quality, the vision of the research team is to introduce in practice cultivars which allow the production of foods without improvers. Triticale bread is very suitable for people with gluten intolerance. Therefore, the Breadmaking Laboratory is searching for possibilities to make flour mixtures of triticale with common wheat types (Tsvetkov and Stoeva 2003). This type of bread has pleasant taste, aroma and durability. The developed durum wheat cultivars carry gene γ 45, which is an indicator of high quality. According to the reports of independent experts, some of them possess exceptional gluten characteristics and represent a unique type especially suitable for culinary use corresponding to the international standards (Petrova et al. 2013; Petrova et al. 2015). In 2017, a new winter malting barley cultivar Oniks was registered. The results from the technological analysis proved the high level of Oniks as a malting barley variety. The mean malt extract is above 80 % and reaching 81.5 % at one of the testing locations. These characteristics of the cultivar entirely meet the high criteria of the European Brewery Convention. After adopting and improving a number of methodologies for fractionation of storage proteins, the Laboratory of Biochemistry solves numerous tasks assisting the breeding process (Todorov 2006): 1) identification of the allelic composition of storage proteins; 2) applying express methods for determining the quality potential; 3) planning hybrid combinations based on the fraction composition of the parental forms; 4) using bio chemical markers in the variety maintenance and preserving the homogeneity in the reproduction process, etc. The yield is a resultant trait and the efforts for its enhancement relate to a number of theoretical and applied researches on certain qualities and properties. Morphological traits have been improved, which are related to the more efficient utilization of the environmental factors, including also the nutrition regime. Plant height was significantly reduced (Tsenov et al. 2009). Until recently, quite different genes were involved in Bulgarian breeding for reduction of stem height (Tsenov *et al.* 2009) in comparison to the West European breeding. The reasons for this are numerous, mainly the higher susceptibility to abiotic stress (primarily drought), the later date to heading, and a significant negative pleiotropic effect on the yield (Panayotov, 2013). At this stage, thanks to the efforts of our research team, the correlation between plant height and resistance to lodging was successfully broken. The fact that a part of the new triticale cultivars are medium high but their stem is strong and flexible is indicative. This problem is most serious in barley. In connection with the breeding for resistance to lodging, the phenomenon was investigated from a mechanical point of view (Mihailov et al. 2005). The physical and mechanical characteristics of the barley plant were determined, as well as the dynamics of their physiological change over stages of development (Mihailov et al. 2005). A model of the plant was developed in condition of tension and deformation at stages critical for the occurrence of lodging (Mihailov et al. 2006). The effects of the nitrogen norm and the previous crop on the degree of lodging was investigated (Tonev et al. 2006). The correlations between the main traits connected to lodging were investigated in systematic barley groups, which are easily applicable criteria for selection at various stages of the breeding process. As a result, the new cultivars are with a significantly higher resistance to lodging (Mihova et al. 2014). The investigations focused on the duration of the vegetative growth are mainly within the context of the strategies for avoidance of a certain type of stress and formation of the qualitative indices (Mihova 2012). During the individual periods, they have been updated but always remain specific for each crop. The most recent investigations on the effect of the environment show that there is no significant difference between the early and the late wheat cultivars with regard to yield (Mihova 2012). The accent is on the formation of a good dynamic relationship between duration and rate of grain filling.

In barley, the earlier date to heading is not a priority, the most suitable time being 1st – 5th May. The late spring frosts are typical for the region of Dobrudzha; they cause serious damages and high sterility rate of the spikes (Mihova 2013). All new barley cultivars have their dates to heading within the above period and the variation over years is low. The durum wheat cultivars have a date to heading close to the national standard Saturn 1 (20th – 2nd May). Concerning the other crops, the following cultivars have earlier date to heading: 1) common wheat – GTP Albena, Bolyarka, Galateya, Enola, Iveta, GTP Kalina, GTP Karina, GTP Kristal; 2) triticale Akord, Kolorit. It is a disputable question if "a plateau" has been reached in breeding and what is the way to increase the production potential. Most often, this is related to improving the biology and physiology of the crops (Tsenov et al. 2009). An evidence for a progress in this respect is the fact that the recently introduced wheat cultivars exceed by yield the varieties developed a decade ago with 12 – 18 %. As a result from the serious research work carried out on triticale, the progress is even greater (15 – 25 %). In the process of data accumulation, the structure of yield also changes. Until recently, the higher spike productivity was at the basis of the breeding strategy in wheat, primarily through higher number of florets and grains formed per spikelet at the expense of lower number of productive tillers. The contemporary high level of breeding and the demands of the market impose the necessity to search for new approaches to increase productivity. One of the options to do this is to simultaneously increase the number of productive tillers (Panayotov 2013). Some of the *Rht* genes used in the breeding centers abroad are especially interesting. They ensure a favorable stem/spike ratio allowing the use of intensive production technologies. In the breeding program of barley, there is no such discussion; the goal has always been a balance between the components of yield. The main reason for this is the biology of the crop (Mihova et al. 2017). In barley, each spikelet has only one floret. After the segmentation of the spike and the setting of the spikelets, this crop does not have the potential to react by forming higher grain number even under favorable conditions. Thousand kernel weight is a comparatively conservative trait which varies within a narrow range, especially in the poly-rowed forms. The data collected show that the focus should be on keeping the tillering coefficient but also on the equal contribution to yield of the productive tillers formed (Mihova and Dimova 2012). Among the wheat varieties developed at DAI, these have the highest tillering potential: Demetra, GTP Karina, GTP Kristal, GTP Milena and Todora. The initial seed production of the developed cereal varieties is the linking element between science and practice. It includes 36 genotypes of common wheat and 5 genotypes of durum wheat, 11 triticale cultivars and 6 winter barley varieties (Figures 1 and 2). The use of authentic sowing material is a component of the production, which cannot be compensated for by other measures. The scheme of seed production and variety maintenance is scientifically sound and goes through several main stages: 1) selection of spikes authentic for the cultivar; 2) two-year testing of the progenies; 3) preliminary propagation; 4) pre-basic seeds; 5) basic seeds. Apart from the cultivars, which Dobrudzha Agricultural Insttitute offers, the Cereals Breeding Department has signed by now contracts for granting exclusive licenses for reproduction and distribution of 8 common winter wheat cultivars in Bulgaria. After having been registered, the wheat cultivars Aglika, Galatea, Enola, Lazarka, Merilin and GTP Milena were included in the varietal list of Republic of Turkey. With the assistance of our partners from Tekirdag, Konya and Kirkaleli, common wheat varieties Bozhana, Goritsa, GTP Dragana, GTP Kalina, GTP Kami, GTP Kiara, Pchelina and GTP Rada, durum wheat Melina and Mirabel, and triticale Akord and Respekt are being tested at the moment. Our team is also actively working on the international programs of CIMMYT and ICARDA, and on joint projects with breeding centers in Krasnodar – Russia, Fundulea – Romania, Beltsi – Moldova and Odessa – Ukraine. They allow the possibility not only to exchange genetic materials and share ideas, but also to correctly investigate the new breeding lines and cultivars.

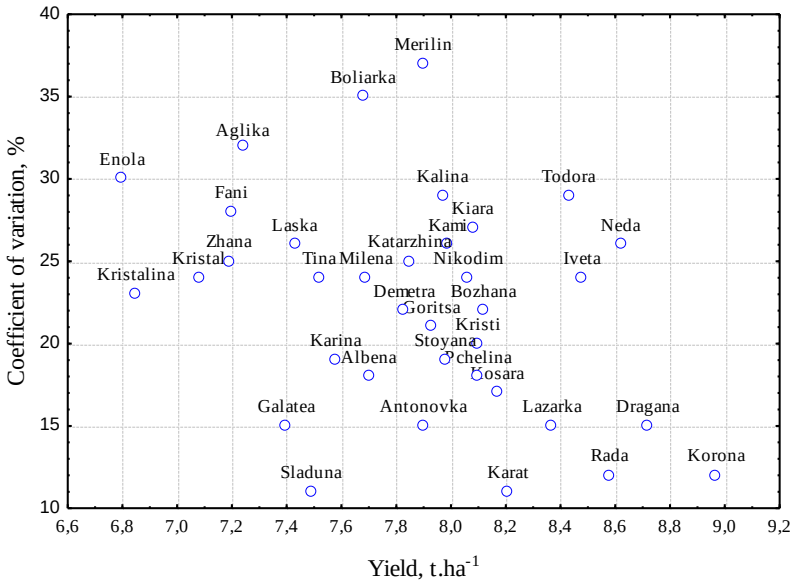
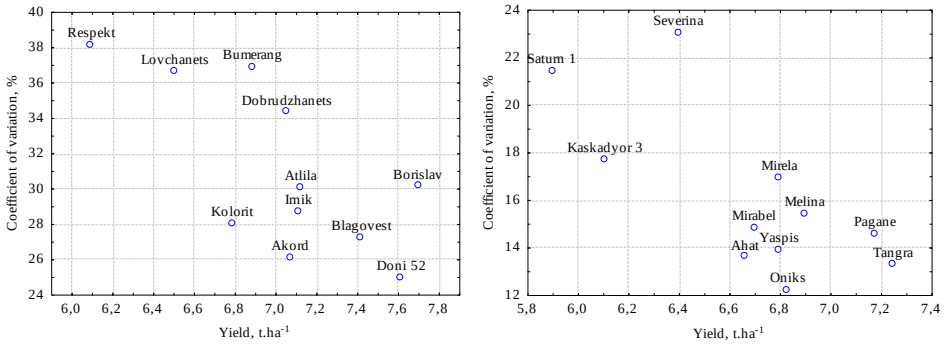


Figure 1. Average yield (2012-2016) from common wheat cultivars to be introduced in practice from which DAI provides seeds.



A) B)

Figure 2. Productivity of new and already introduced in production cultivars of triticale (A), durum wheat, feed and malting barley (B), (average 2012-2016).

Conclusions

A total of 102 common wheat varieties and 7 durum wheat cultivars, 13 triticale forms and 6 cultivars of winter barley have been developed at DAI. Over 35 % of the wheat areas in Bulgaria are sown with cultivars, which are the scientific product of our research institute. In triticale, there is practically no successfully introduced foreign breeding. The level of frost resistance of the durum wheat forms has no alternative. An indisputable advantage of the new barley varieties is their resistance to lodging in combination with tolerance to stress. The rich and diverse varietal list of DAI allows the producers to choose the cultivars, which are best for them and to develop their appropriate varietal structure. The cultivars are with confirmed adaptability and possess good balance between productivity potential and stability of its realization under unfavorable growing conditions. Under the increasing market competitiveness, a new vision for the breeding program of the cereal crops is outlined. The strategy for improvement of a complex of traits has been reconsidered, including the structure of yield. In compliance with the traditions, however, the accent is still on the high efficiency in production and on introduction of products for quality foods.

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