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REVIEW OF THE METHODS FOR BREEDING OF SESAME VARIETIES (*SESAMUM INDICUM* L.) IN BULGARIA

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Abstract

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An overview of Bulgarian methods for breeding of sesame varieties suitable for mechanized harvesting is presented. Thirty-year scientific work is conditionally divided into four periods. In the first period (1987 – 2003) has been received genotypes enable breeders to improve the quality of their products. In the second period (2004 – 2008) has been created a method for measuring the strength for breaking up of non-shattering sesame capsules. It has been created the first Bulgarian sesame variety with closed capsules at maturation, which is intended to mechanize harvesting. In the third period (2006 – 2011) has been developed a new method for evaluating the possibility for mechanized harvesting of breeding materials. A placenta which is attached to seeds up to full maturity has been discovered in the new breeding materials. All of them are susceptible for inertial threshing which does not lead to mechanical damaging of seeds. In the fourth period (2011 – 2017) has been developed a new objective method for evaluating the suitability of the hybrids for mechanized harvesting. This period continues with selection of varieties that retains the seeds in the capsules while matured sesame plants are on the field and are subjected to tilting by the wind.

Key words: breeding sesame; mechanized harvesting; methods of breeding

Introduction

Currently the sesame is a plant, grown by small farmers in the developing countries mainly. Although the production in the world is increasing it is not essential in countries with high level of agricultural mechanization (Langham, 2001a; Langham and Wiemers, 2002; Langham, 2007). Kang (1996) reported that during the period 1987 – 1992 production of sesame in Korea was half decreased because of appreciation on manual labor. According to Bennet & Wood (1995) still miss fully adapted technology for mechanized harvesting of sesame. For this reason about 99% of sesame areas in the world are harvested manually (Weis 2000; Langham 2001b; Langham and Wiemers, 2002; Georgiev and Stamatov, 2005; Langham, 2007). At several international meetings on the issues of sesame many researchers pointed out that if sesame harvesting would not been mechanized in the next 25-30 years, its production will drop significantly (FOSTAT, 2016).

In Bulgaria is farmed a sesame that belongs to Asiatic and *Abyssinian branch ssp. bicarpelatum* (Georgiev, 2000). In 1987 at the Institute of Plant Genetic Resources – Sadovo (Bulgaria) started a program aimed at breeding of sesame varieties, suitable for mechanized harvesting. Thirty – year scientific work is conditionally divided into four periods with different tasks and usage of different approaches and methods.

The purpose of the study is an overview of the breeding methods and approaches for creating sesame varieties, suitable for mechanized harvesting in Bulgaria for a period of over 30 years.

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Results and Discussion

Thirty-year scientific work for creating sesame varieties, suitable for mechanized harvesting in Bulgaria is divided into four periods.

Breeding methods from First Period (1987-2003)

In 1987 at the Institute of Plant Genetic Resources – Sadovo was imported sesame sample № 87010 from the Research Institute for oilseeds (VNIIMK) – Krasnodar – Russia. It was characterized by non-shattering capsules and has been included in the hybridization with Bulgarian lines for creating new sesame varieties, which are suitable for harvesting with the grain harvester. The primary hybrid materials were characterized with deformed stems and leaves with strongly altered form, resembling damage from herbicide and large flowers with extra appendages. The top of these plants ends with 4 – 5 short branches with a minimum number of capsules and central stem has low-lying side branches. The plants have thick stems with strong shortened internodes and undeveloped side branches in the top part. The capsules are small size and untypical number. There were observed a large percentage of aborted capsules and significant susceptibility to diseases. Many of these undesirable traits have been removed after repeated selection and reciprocal crosses with new sesame lines (Georgiev, 2000, 2002 b).

The approach applied in the first period consists of breeding varieties that keep capsules closed at maturation. It was thought that creating such kind of varieties is the only way for solving the problem with the losses from mechanized harvesting of sesame. Moreover, the selection of new varieties offers enough powerful opportunities to reach this aim. (Georgiev, 2000a, 2002; Georgiev and Stamatov, 2005).

Possibilities of mechanized harvesting of sesame forms with non-shattering capsules have been examined by Kollev, Ishpekov and Stamatov (2012). Obtained forms have several disadvantages (Georgiev et al., 2008; Ishpekov et al., 2008; Ishpekov et al., 2014a; Ishpekov et al., 2014b; Stamatov, 2008). The closed capsules keep moisture of seeds above 15% at maturation. In this condition the seeds are highly susceptible to mechanical damage and are not able to endure the impact of the thresher in grain harvester Trifonov et al. (2013). For this reason is suggested application of two-phase technology for mechanized harvesting of this type variety (Ishpekov, 2013; Ishpekov et al., 2015a; Ishpekov et al., 2016b). The first phase consists of picking up closed capsules and after drying conducting of the second phase – their threshing.

Breeding methods from Second Period (2004 – 2008)

Stamatov (2008) has performed completely agro-biological study of 21 breeding lines with non-shattering capsules. Plants of these genotypes are characterized by pyramidal habitus. The height of the central stem is 1.1 -1.5 m and has from one to seven branches of the first order. Plants reach technological maturity for about 88 – 94 days. These breeding lines are characterized with low yield which vary from 508 to 757 kg/ha. When harvesting with combine harvester most of seeds (25.9% – 50.0%) remain in the capsules, moreover their germination decreases significantly due to mechanical damaging.

It was founded out that the morphological characteristics which make the plant suitable for mechanized harvesting are in negative relation to those for high yield (Georgiev et al., 2008). Plants do not dry out on the field without application of defoliants. The seeds of these genotypes are threshed hard despite impacting significant forces for crushing capsules (Ishpekov et al., 2008). The searching of a way for effectively mechanized harvesting of this type of sesame continues to this day.

It is considered that sesame with non-shattering capsules can be successfully harvested through two-phase technology (Ishpekov et al., 2015 a). Experiments have been conduct for harvesting only sesame capsules while they are closed. After drying seeds are separated through a new kind of apparatus which first crumbles then threshes capsules (Kolev et al., 2012). The threshing of capsules is successful, but till now still has not been found appropriate way for picking up them on field (Ishpekov et al., 2014c, Naydenov et al., 2016). The experimental results show the evidence that the pre-dried capsules of variety Victoria and breeding line Sadovo 3959 release up to 91% of the seeds through threshing by the mentioned apparatus. Seeds have no broken surface and their germination reaches 75%.

In this period has been patented the first Bulgarian sesame variety with non-shattering capsules named Victoria. Besides a method for measuring the force necessary for crushing non-shattering capsules has been developed (Ishpekov et al., 2008). A technology for two-phase mechanized harvesting of these genotypes was suggested and examined (Ishpekov et al., 2015a).

During this period has been selected new type sesame varieties attended for mechanized harvesting of the seeds. Their capsules open the top but retain seeds to the placenta up to full maturity. Many representative experiments have been conducted for direct harvesting of mentioned varieties through the conventional grain harvester (Trifonov et al., 2013). A techno-economic evaluation of this way of harvesting has been also conducted (Ishpekov et al., 2014c). The results show that the harvester New Holland CX8060 squanders up to 22 % of seeds by the header. The high seed's humidity of 14.4 % has been the main reason for decreasing their germination capacity from 20 to 50 % due to the impacts of the thresher (Trifonov et al., 2013). Generally, the grain harvester does not met requirements for harvesting sesame at Bulgarian conditions, therefore was recommended developing a specialized tools for this agricultural operation.

Breeding methods from Third Period (2006 – 2011)

In 2006 with aim to remove shortcomings of existing varieties were launched activities for improving sesame forms with non-shattering capsules. The best of them were involved in hybridization with lines and varieties which have shattering capsules at maturation. The resulting hybrids of F1 progeny were characterized by shattering capsules that cannot keep the seeds when plants have been ripened on the field (Georgiev at al., 2011; Stamatov and Deshev, 2014; Deshev, 2015). In some of F2 progenies were found anatomical features, which facilitate retention of seeds. These capsules are slightly open at the top and are not split longitudinally. The examination of these samples showed that their yield is from 1053 to 1313 kg/ha, which are higher than obtained in the previous periods and possess qualities that make them suitable for mechanized harvesting.

The most significant result from the third period is selection of three Bulgarian sesame varieties that are suitable for mechanized harvesting – Aida, Nevena and Valya. Their indices of inertial threshing show significant improvement of susceptibility for mechanized harvesting (Ishpekov et al., 2016a).

Breeding methods from Fourth Period (2011 – 2017)

Two main tasks have been assigned to breeders in the fourth period. The first is obtaining hybrids offspring that are high yield and suitable for mechanized harvesting. The second task is to find appropriate method of team progeny. Deshev (2015) founds that the yield per a plant of new hybrids is formed regardless of the number of capsules on the central stem and these from branches. The results of the component analysis indicate two significant groups of factors that explain 91.8% of the total variability. The group 1 incorporates the indicators high yield, plant height, average length of the branches, height of the bet of branches, height of the bet of first capsule in the central stem, the height of the bet of first capsule in the branches. The group 2 includes the signs responsible for susceptibility of sesame variety for mechanized harvesting. These results open up new opportunities for team and allow selecting genotype that combines the architecture suitable for mechanized harvesting and high yield.

Georgiev et al. (2011) founded opportunity for obtaining high heterocyst in F1 hybrids and important signs associated with the architecture of the plant and the high yield. Georgiev, Stamatov and Deshev (2012, 2014) established the way for increasing the number of capsules by appropriate choice of parental pairs.

In 2011 Bulgarian breeders aimed selecting propagated hybrids and assessing the strength of the attached placenta through objective criteria (Ishpekov et al., 1997). A subjective-independent method for assessing the effects of the attached placenta and the shape of capsules on seeds releasing has been developed and gives positive results (Ishpekov et al., 2015a; Ishpekov and Stamatov, 2015c). Moreover the resulting indices allow recommending the appropriate way for harvesting tested sesame variety which can be manual, by conventional harvester or by inertial thresher (Stamatov et al., 2016).

This period continues with study the ability of different genotypes to dry naturally under field conditions. The ability of varieties to hold seeds in capsules on technological maturity under tilting and accelerating of stems have been explored (Ishpekov at al., 2017). The results show good opportunity of lateral feeding of sesame stems into the harvester (Naydenov et al., 2016). It can reduce scattering losses of seeds up to 4 times in comparison with the upper feeding of stems by the conventional reel at 6.2% moisture content of seeds.

As a result of long time research has been reached significant progress in plant breeding of sesame suitable for mechanized harvesting. The yield of new varieties has been increased significantly after each period. During the second period the average yield was 586 kg/ha, but in the fourth period it reaches 1354 kg/ha (Figure 1). Moreover the morphological abilities of capsules and plants have been improved, which increases the suitability of resulting genotypes for mechanized harvesting.

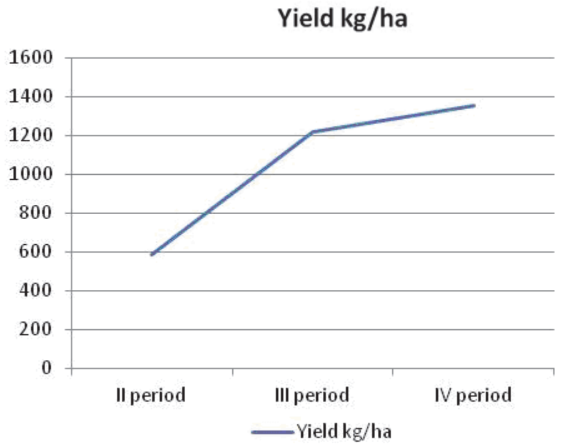

Fig. 1. Average yields of seeds (kg/ha) of different periods

During 2011 – 2013 the varieties Victoria and Nevena were planted in large-size areas with the aim to determine their suitability for mechanized harvesting with conventional combine harvester (Trifonov et al., 2013; Ishpekov et al., 2015a). The results showed that the field losses were from 17% to 50% and depended on working mode of the harvester and the moisture content of seeds. Two-thirds of these losses were due to the header and the rest to the thresher. Seed quality was poor and the majority of them was mechanically damaged and with reduced germination. It was found that when the moisture content of the seed is below 10% then predominant losses are by the header but when the moisture content is above 10% – by the thresher. Evaluation the indices of conventional combine harvester at sesame harvesting showed poor economic efficiency of its work (Ishpekov et al., 2014c).

In 2011 have been selected sesame forms whose capsules have open top and seeds that are attached to the placenta up to full maturity (Deshev, 2015) (Figure 2). This result pushes giving proof of a new principle for threshing of sesame which is called inertial and does not lead to losses and mechanical damages of the seeds (Ishpekov et al., 2015b; Zaykov et al., 2016; Ruschev et al., 2017). Subsequently, has been developed and patented a prototype for threshing these varieties which confirms the excellent results at applying inertial principle for releasing seeds from capsules (Ishpekov et al., 2016a, Ishpekov et al., 2017a). The developed inertial thresher releases over 95% of seeds of varieties Aida and Nevena with 13% moisture content of seeds without compromising their germination (Figure 3 and 4). The proportion of impurities among seeds is from 20.9 to 38.4% for different varieties. Inertial thresher attained 225 times higher output than one person. Parallel threshing through the combine harvester decreased germination of seed by 27%. Impurities among seeds were 56.5%, half of which do not allow separation by conventional grain cleaner. The specific power consumed by the developed inertial thresher is 4.81 times smaller than that of overcoat threshing apparatus with the same bandwidth. This result is due to different principles of threshing that are applied in both mechanisms (Zaykov et al., 2017).

The collaboration between breeders and engineers has lead to development an objective method for assessing and selection of new hybrid materials with improved susceptibility for mechanized harvesting (Ishpekov and Stamatov, 2015c; Ishpekov et al., 2017). Bulgarian breeders started to use advanced techniques, which increase the production in new materials (Georgiev et al., 2011; 2012; 2014; Stamatov and Deshev, 2014).

Regardless of the results achieved the research work for improving Bulgarian sesame varieties with respect to make

Fig. 2. Sesame capsule with attached placenta

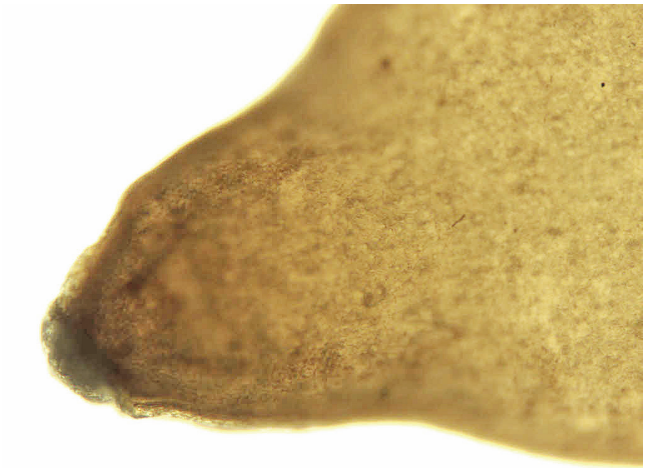

Fig. 3. Sesame seed threshed by the inertial thrasher

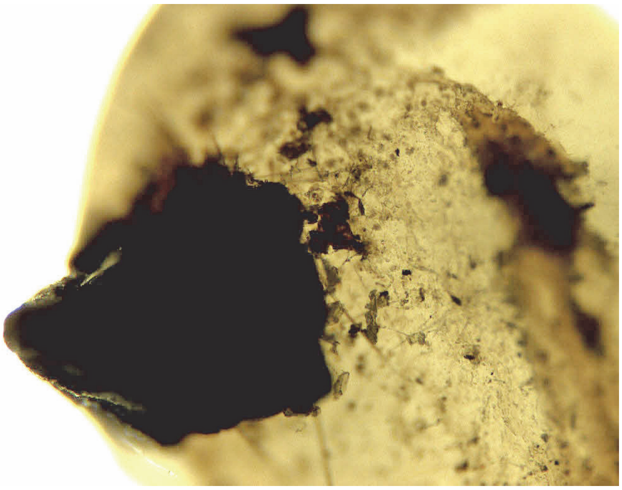

Fig. 4. Sesame seed threshed by threshing apparatus of grain harvester

them high yielded and suitable for mechanized harvesting continues. The next tasks to solve are:

– Mechanized feeding the sesame stems into harvester without significant losses from squandering of seeds on field;

– Increasing the duration in which capsules retain seeds in full maturity.

Conclusion

In Bulgaria the selection of sesame suitable for mechanized harvesting continues over 30 years and conditionally divides into four periods. During first and second periods Bulgarian breeders believe that solution of the problem related with losses of mechanized harvesting can be achieved only through the methods of selection, but the results are unsatisfactory. In the third period were initiated using of engineering methods and approaches together with agronomic. As a result of the collaboration between breeders and engineers have been selected and recognized four sesame varieties that are suitable for mechanized harvesting – Victoria, Aida, Valya and Nevena. The abilities of combine harvesters to harvest mentioned sesame varieties have been evaluated through representative experiments. New technologies and new methods of threshing sesame have been proved. A method for objective assessment the susceptibility of sesame forms for mechanized harvesting has been developed. As a result of long time research the average yield has been increased from 586 kg/ha to 1354 kg/ha. Furthermore, the susceptibility of new varieties for mechanical harvesting has been improved significantly. The research work for improving Bulgarian sesame varieties with respect to make them high yielded and suitable for mechanized harvesting continues.

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