PRESENT STATUS AND FUTURE PROSPECTS OF GLOBAL CONFECTIONERY SUNFLOWER PRODUCTION

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ABSTRACT

Although sunflower is mainly grown for the production of vegetable oils in the world, there are many countries that prefer confectionery sunflower hybrids and varieties (landraces). Confectionery sunflower breeding is characterized by the fact that different markets have different demands when it comes to the seed size, hull color and other traits, which makes this process more difficult and costly. Confectionery low-oil protein type is used in the snack food industry in the form of roasted sunflower seeds or dehulledas a part of snacks and baker's wares, as wellas for bird and pet feed. It currently represents less than 10% of total global sunflower production. Seed of high protein sunflower usually varies in color, from black, black with white stripes, to white and colorful. It is significantly bigger than the seed of oil type sunflower, with thicker hull loosely connected to the kernel. The hull is easily separated from the kernel and allows the whole seed to be dehulled. When creating confectionery hybrids it is very important to combine genes responsible for high yield potential and good technical and technological traits of the seed. In order to successfully obtain high yields and adaptability for confectionery sunflower the main direction in breeding is defining an ideal ideotype of plantfor specific agro-ecological conditions, sef-fertility rate, larger seed, increased 1000 seed weight, protein content and quality. While lowering the seed oil content and hull ratio and at the same time introducing resistance genes in order to achieve stability of sunflower resistance to certain pathogens. Major breeding goals are tolerance to biotic and abiotic stress conditions, resistance to diseases (*Plasmopara halstedii*, *Phomopsis helianthi*, *Sclerotinia sclerotiorum*), broomrape and herbicides. In the resent period introgression of genes from wild *Helianthus* species for herbicides resistance of confectionery hybrids (Imidazolinone (IMI) and Sulfonyl urea (SU)) has become a crucial breeding objective. By growing confectionery IMI hybridsto the same time control both broomrape and the main broad leave weeds. They have recently effectively increased the market share in many countries which prefer confectionery hybrids. Developing confectionery hybrids with modified oil quality(higher oleic acid and tocopherols) to increase in the nutritional value in seeds is also an important breeding objective. By introducing molecular markers, genetic maps, genomics, bioinformatics data and other developing techniques, many relevant sunflower traits, such as oil and protein quality, cms, fertility restoration genes, and resistance to diseases and abiotic stress can be verified. Armed with this knowledge and the possibility of further development of these techniques, in the future we should be able to pinpoint the desirable genes and more efficiently trace their transfer to the confectionery sunflower.

Key words: Confectionery sunflower, Breeding, Seed and protein yield, Resistance to disease and herbicides, MAS

INTRODUCTION

The genus *Helianthus* is comprised of a large number of species. One of the species is the cultivated sunflower *Helianthus annuus* L., which is a globally significantoilseed crop and an important source of non-oil confectionery seed. Native Americans gradually changed the genetic composition of the plant by repeatedly selecting the largest seeds (Yarnell, 1978). Sunflower oil and confectionery types arrived from the USA to Europe, first landing in Spain. They was transferred from Spain to France, England, Germany and other European countries and then spread along trade routes to Egypt, India, China and Russia (Brintall and Conner-Ogorzaly, 1986). In the mid-19th century, sunflower seeds oil and confectionery types were transferred to Bolivia, Paraguayand Argentina where sunflower was used for human consumption as a roasted and salted confection (Feoli and Ingaramo, 2015).

The agronomic development of sunflower for oil ("oilseed" types) and edible achenes ("confectionery" types) occurred in Eastern Europe and Russia, where by the late 1800s a number of landraces had been developed (Cronn, 1997). Russia is considered as a secondary domestication center for sunflower, as seeds of local sunflower varieties were reintroduced into the USA, and then spread to Canada and Argentina in the late 18th century by Russian Ukrainian and German immigrants. In commercial sunflower breeding there are two main types: oil and non-oil (confectionery) sunflower type (Duihua and Hoeft, 2009; Gontcharov and Beresneva, 2011; Hladni et al., 2011, 2012). Around 10% of the world's annual production of sunflower seed is used for non-oil purposes, mainly for confectionery and snack food, as well as for bird and pet food (National Sunflower Association, 2011). Market demands and production area of confectionery sunflower show a steady increase due to its nutritional value and use in human nutrition. Confectionery sunflower for human consumption has found its place in production in Turkey, China, USA, Canada, Spain, Russia, Ukraine, Israel, Argentina, Pakistan, Iran, and many other countries (Lofgren, 1997; Kaya, 2004; Zhang, 2004; Feoli, 2004; Dong, 2007; Kholghi, 2011). This type of sunflower has a small presence in the EU, which makes the EU (particularly Spain) a large importer of confectionery sunflower seeds (Nabloussi et al., 2011). In contrast to EU, confectionery sunflower represents more than 60% of sunflower production in China (Zhang, 2004).

Confectionery sunflower breeding is characterized by the fact that different markets have different demands regarding the seed size, hull color and other traits, which makes this process more difficult and costly. Although the favored seed color of confectionery hybrid in Turkey is white with gray stripes, in Balkan countries such as Serbia, Bulgaria, Moldova and Romania, as well as Russia black seeds are preferred (Ergen and Saglam 2005; Yaia et al., 2005; Sincik and Goksoy, 2014). Gray seeds with stripes are popular in the United States, Spain and China (Kaya, 2008).

Most customers prefer tasty, high-quality, and longer seeds for confectionery types. It is not easy to develop bigger kernels in breeding programs. For instance, consumers from China, Turkey, and some other countries require seeds that are at least 2 cm long, whereas in Eastern Europe such as the Balkans, Ukraine, and Russia consumers prefer big seeds with big kernels and reduced hull content. Confectionery sunflower is distinguished by a large hull ration, usually up to 40 or 50% (Jovanović, 2001), high mass of 1000 seeds which is usually higher than 100g (Hladni et al., 2011), should ideally contain less than 30% oil and has hull content up to 50% (Kaya et al., 2008). The hull is easily separated from the kernel and allows the whole seed to be dehulled (Gonzalez-Perez and Vereijken, 2007; Fernandez-Martinezet al., 2009; Hladni et al., 2012a; Kleingartner, 2015). Breeding advances allow confectionery sunflower to have similar yields to regular sunflowers (Feoli and Ingaramo, 2015). Based on its size confectionery sunflower is generally classified into three categories. The largest size seeds, called "in-hull seeds", go on hall market. They are salted, roasted and packaged for human consumption. Medium-size seeds, called "hulling seeds" are hulled and are usually the kernel market. Kernels are used, either roasted or not, as a snack food or in a number or confectionery or bakery products. Finally, smaller seeds, called "bird seeds", are mainly intended for feeding wild birds and pets (Holfland and Kadrmas, 1989; Lofgren, 1997; de Figueiredo et al., 2011, 2014).

Dehulled sunflower kernels are typically less expensive than some of the other nuts, used for confectionery, cakes, and other purposes in the food industry in North America (Miller and Fick and, 1997; Fernandez-Martinez et al., 2009; Škorić, 2012; Kaya et al., 2012). The bread and bakery industries are growing markets for sunflower kernel, which is also used for the fortification of foods by sunflower meal, especially meat and milk products, infant formulae, bakery and pasta products (Žilić et al., 2010). Growing confectionery sunflower for consumption is becoming more and more attractive in the whole world, currently production and research of confectionery sunflower is very low in comparison to the oil sunflower.The main goal in writing this paper was to present an overview of what has been done so far in confectionary sunflower breeding and production, along with the directions in which confectionery breeding is expected to develop in the future.

GENETICS AND BREEDING

An important quality of modern agricultural production is breeding for high yielding cultivars and hybrids tolerant to diseases, pests and unfavorable climate conditions. These cultivars and hybrids are developed primarily by employing different breeding techniques and methods which are based on the choice of favorable genotypes depending on the selection goals (Hladni, 2010).

Genetic resources

Land races/local populations have huge genetic variation and are well adapted to local soil types and climatic conditions as well as other environmental factors. They are the source of many desirable genes, especially those addressing higher adaptability to environmental conditions and resistance to certain diseases (Kaya, 2015). However, little is known about the levels and distribution of genetic variation within confectionery sunflower gene pool (Omar Gieco et al., 2013).There are several important confectionery sunflower collections in Turkey (Kaya et al., 2001), China (Jan et al., 1998), Spain (Velasco, 2014), Russia (Borodin, 2003; Mamonov, 2004), US (Marek, 2004) etc. Velasco et al. (2014) assessed variation in seed quality traits (seed weight, kernel percentage, oil content, fatty acid composition, squalene, tocopherol and phytosterol contents, and tocopherol and phytosterol composition) in a germplasm collection of 137 Spanish local landraces of confectionery sunflower, and found large variability for all traits evaluated. Other important genetic resources are: cultivars in production, breeding lines, synthetic varietiesand others. Cultivars in production are easier to use in breeding programs, good source of genes that confer high yield and quality disease resistance. The benefits of synthetic populations that came to be by recurrent selection maintained by open pollination are the development of inbred lines showing high values of combining ability as a result of hybrid combinations (Fernandez et al., 2009; Škorić, 2012; Kaya et al., 2012). That is why it is important in a breeding program for confectionery sunflower to create new synthetic population for creation of new confectionery lines and hybrids.

The directions of confectionery sunflower breeding

Sunflower breeding is directed towards the increase of: genetic potential for yield, yield stability, health safety and nutritive quality with the increase of production economy (Hladni, 2010). In creation of new sunflower hybrids, significant attention should be paid to increase of adaptability, stability, and attractiveness to pollinators and tolerant to dominant diseases, broomrape, insects, and stress conditions (high temperatures and drought conditions) (Hladni, 2010; Jocić et al., 2015).

Confectionery sunflower breeding is mostly similar to oil sunflower breeding, especially in increase of seed yield and resistance to main disease, but there are also certain specificities Jocić et al. (2015). Specific breeding goals for confectionery sunflower are: the increase of protein content and quality (>25%), 1000 seed weight (>100 g), hectoliter mass 90kg/hl, oil stability with decrease of its content in the seed (<40%), large achene and kernel size, uniformity in kernel size, increase of kernel ratio and decrease of hull ratio (<35%), uniformity in seed size, shape and color, ease of dehulling, seed quality maintenance in long term storage as well as tolerance to dominant diseases in the cultivation region (Hladni et al., 2009,2015; Škorić, 2012; Kaya, 2015). Seed size, shape, and color are especially important for confectionery-type sunflowers depending on the market. Consumer demand varies widely, especially for seed color.

In recent years, introgression of genes for resistance to herbicides (Imidazolinones (IMI) and Sulfonyl Urea (SU)) from wild *Helianthus* species has become a topical breeding objective for both oil and confectionery sunflower (Škorić, 2012). Drought stress is one of the most key aspects for crop yield losses in recent years and it seems that will be active threats for restricting crop productivity in the years to come, due to recent climatic changes and global warming (Peckan et al., 2016). In recent years, there have been many changes in research techniques, in particular, the possibility of determining the genotype of a plant and not just its phenotype Vear (2016). Marker technology is currently being used in breeding. Great steps have been made in obtaining essential knowledge of inheritance and linkage of target traits for breeding confectionery sunflower adapted to Australian production environments. The identified markers can be used in practical application of molecular markers (MAS), and further enhance the breeding process (Sun, 2009).

Confectionery sunflower breeding has become more prominent over the last decade (Sincik and Goksoy, 2014). In the world currently there are not a lot of Institutes and companies that have a confectionery breeding program. Market demand for confectionery sunflower seeds made Institute of Field and Vegetable Crops, Novi Sad initiate a special breeding program with the aim to develop modern confectionery open-pollinated hybrids.

Breeding goals

Two important criteria for introducing confectionery hybrids into production are high seed and protein yield (Hladni et al., 2009). Breeding for a desirable plant architecture and yield components requires a study of the gene effects, the number of genes controlling the expression of a particular trait, the mode of inheritance of quantitative traits. As well as the examination of general and specific combining abilities and interdependence of morpho-physiological traits with yield is of utmost importance in order for their breeding programs to be successful (Hladni et al., 2006; Škorić et al., 2012). For the creation of new sunflower hybrids with high genetic potential for seed and protein yield, it's important to find traits that have the biggest influence on the seed and protein yield formation. Presence or absence of correlations can contribute to the right choice of examined traits so as to enhance the efficiency of some selection criteria. Plant breeders commonly prefer yield components that indirectly increase yield (Kaya et al., 2007).

The most important criteria for introducing new confectionery hybrids into production are: protein and seed yield, plant height, head diameter, seed protein content, seed oil content, number of seeds per head, 1000 seed weight, seed size, color of seed, hull kernel ratio (Hladni et al., 2009,2016; Pekcan et al., 2015).

Protein and seed yield

Higher protein yield is an ultimate objective of confectionery sunflower researchers. When creating new confectionery hybrids it is important to find traits that are easily determined and at the same time show their interdependence and very strong direct effects with protein yield, based on which that those traits can become selection criteria (Hladni et al., 2011a, 2015). Traits such as seed yield, seed protein content, kernel ratio, 1000 seed weight have a very strong positive direct effect with protein yield and, that breeding for these traits simultaneously breeding for protein yield (Hladni et al., 2011; Sincik and Goskoy, 2014; Hladni, 2015). Seed oil content had a very strong negative direct effect on protein yield (Hladni, 2015). The greatest positive indirect effects on protein yield were exhibited by the 1000 seed weight, plant height, and head diameter though their impacts on seed yield (Sincik and Goksoy, 2014).

Selection for higher seed yield, and other traits should start during inbred line creation by defining the effects of heterosis and by analyzing and evaluating the correlations among them to develop a productive hybrid with the desired traits (Škorić et al., 2007; Škorić, 2012; Hladni, 2011b). Any increase in seed yield depends on increasing one of three main components: number of plants per hectare, seeds per plant, and 1000 seed weight traits (Kaya, 2015). One of the efficient ways of increasing seed yield is lowering hull ratio and increasing the kernel ratio. That is why inbreeding programs special attention is paid to the hull and kernel correlation (Jovanović, 2001). Kholghi et al. (2011) found that the head diameter and 1000 seed weight had positive direct effects on seed yields of confectionery sunflowers. According to Hladni (2015), path coefficientanalysis showed strong direct effect of kernel ratio on seed yield is shows that the kernel ratio important selection criterion for confectionery sunflower. A negative weak correlation between seed oil content and seed yield was determined by Kaya et al. (2008) and strong negative correlation between seed yield and seed oil content to the research performed by Hladni et al. (2008). A positive and important interdependence was determined among morphophisiological traits like plant height and head diameter with seed yield (Goksoy and Turan, 2007; Hladni et al., 2008,2010; Kaya et al., 2009).

Seed protein content is one of the indicators of sunflower seed quality. According to (Jovanović and Stanojević, 1996; Hladni et al., 2009a; Hladni, 2010), protein content varies and, depending on the genotype, agroecological conditions and the interaction of the genotype and environment conditions, it ranges from 16-28% with confectionery sunflower. With kernel increase, the amount of protein in the seed also increases so breeding for increased seed protein amount should be followed by the selection of genotypes with larger kernels (Hladni et al., 2009b). Proteins of sunflower seeds have high digestibility and high biological value and hence the increase in their use as a component of functional foods and a nutritionally balanced diet, especially in this day and age when consumers wish to protect themselves from genetically modified soy protein products (Dimić et al., 2006). When choosing the initial materials for selection, theyshould have enough variability before the application of adequate plant-breeding methods. Recurrent selection is one of the most appropriate methods to increase sunflower seed protein content (Fick and Miller, 1997; Fernandez-Martinez et al., 2009; Škorić, 2012; Kaya et al., 2012).

Plant architecture

Plant height plays a major role in the creation of new SC hybrids with different plant model and high genetic potential for seed yield, but it is strictly linked to total leaf area and petiole length, which are very important for seed yield per plant. At the same time it is a very important trait because it has influence on the stability of the plant i.e. the tolerant to lodging and some diseases (Hladni, 2010; Hladni et al., 2014; Kaya, 2015). Confectionery sunflower is normally a tall plant. The height of the plants is very dependenton climatic and soil conditions and while drought or poor soil drastically reduce it, irrigating and less water stress affect the plant height very positively (Kaya et al., 2012).

Head diameter is a very important trait in the sunflower seed yield structure greatly influenced by the environmental conditions similar to the plant height. Head size, expressed as head diameter (cm), is one of the sunflower yield components that directly influence hybrid model changes (Hladni, 2010). Sunflower breeders should consider optimal head size and head shape with optimum plant density to increase sunflower yield (Miller and Fick, 1997). Plant height showed significant and positive correlation with head diameter in confectionery sunflower consorted Sincik and Goksoy (2014).

Total number of seeds per sunflower head represents one of the most important components of sunflower seed yield. It is conditioned by the number of formed tubular flowers, the degree of self-compatibility, attractiveness towards the pollinators and the environmental conditions during flowering and pollination of sunflower (Hladni, 2010). To increase total number of seeds per head breeders should focus on developing bigger kernels which need to assimilate more during seed filling and should consider limiting factors for seed growth development during the flowering period (Pereira et al., 2000; Škorić, 2012).

1000 seed weight

Breeding for increase in 1000 seed weight, results in increased seed yield. Therefore it is considered an important criterion in the development of confectionery sunflower hybrids (Miller and Fick, 1997; Goksoy and Turan, 2007; Hladni et al., 2008; Yasin and Singh, 2010; Kholghiet al., 2011; Hladni et al., 2016). The analysis of simple correlation coefficient shows a very strong negative correlation between 1000 seed weight and kernel ratio, and very strong positive correlation with hull ratio (Kaya et al., 2008; Liet al., 2010; Hladni et al., 2015). Path coefficient analysis for 1000 seed weight at the phenotypic level showed that the length of seed and thickness of seed had a very strong direct positive effect on 1000 seed weight, which is in accordance with the simple correlation coefficient. Length and thickness of seed were the most important traits for 1000 seed weight, and can be used for the improvement of seed yield and evaluation of sunflower breeding materials (Hladni, 2016).

Seed size, shape, and color

Increased seed length is one of the main goals in confectionery sunflower breeding and it can be achieved by selection. Sun (2009) found that the polygenic system controls seed length in sunflower, but QTL analysis showed that only one or two major genes play an important role. In order to produce larger seeds, plants should first of all have good genetic potential for this trait. By studying the seed parameter inheritance in confectionery sunflower Dozet and Jovanović (1997) have found that the seed length and width were intermediary in F_1 generation in all hybrid combinations and in a three hybrid combinations expressed dominance and partial dominance by better parent for seed thickness. Shape is usually described from a side view of the kernel. Kernels may be round, oval, ovate, oblong with edges that are relatively straight when viewed from one edge, and rounded the variousdegrees the others (Janick, 2013). Confectionery types have seeds of variable colors black, white, or striped grey/black and white.

Drought tolerance

Water stress is a major limiting factor for sunflower production in the many regions in the world especially when the frequency and amount of rainfall are often quite variable during sunflower growing season. Therefore, drought tolerance became one of the most important goals in the sunflower breeding programs in the world (Pecan et al., 2015). Generally, drought stress reduces leaf area, stem extension and physiological activities as well as photosynthesis rate of plants resulting in decreasing seed yield (Anjum et al., 2011). Breeding for tolerant to drought and high temperatures is an important objective in many sunflower programs. Drought stress decrease grain filling period, grain length and yield potential (Anonymous, 2013). When setting up a breeding program for sunflower resistance to drought, it is important to decide in advance whether to aim for adaptation to a specific environment, adaptation to a variable environment, or combined selection for drought tolerant traits and high yield potential (Fick and Miller, 1997; Škorić, 2009; Pecan et al., 2016). Škorić (2009) in sunflower breeding for drought tolerant in oil sunflower, best practical results have been achieved using the phenomenon of stay-green. Confectionery sunflower showed that seed yield decreased significantly due to water stress (Anjum et al., 2011). In order to evaluate morpho-physiological traits of confectionery sunflower under different irrigation regimes, tested fifty six confectionery sunflower landraces in Iran, the effect of genotype × irrigation regime was significant for seed yield, kernel/ seed ratio and kernel weight (Gholinezhad, 2013). Growing the drought tolerant genotypes will contribute to more stable sunflower production. Furthermore, the screening of the response of sunflower cultivars or breeding lines to drought stress can play a crucial role in breeding programs (Onemli and Gucer, 2010).

Resistance to diseases and broomrape.

Diseases are the main limiting factor in the production of sunflower (*Helianthus annuus* L.) and they cause poor realization of genetic yield potential of sunflower hybrids (Jocić et al., 2010). Different diseases are dominant in different regions, depending on the prevailing environmental conditions. More than 30 different pathogens that attack sunflowers and cause economic loss in production have been identified so far (Škorić et al., 2012). Due to confectionery sunflower production in different scattered areas, the damage from birds, such as crow, sparrow and starling, is another factor reducing yield (Kaya,2015). Breeding for resistance or tolerance to diseases is one of the most important goals in sunflower breeding (Kaya et al., 2015). Although some sunflower diseases occur only locally or in specific environments, some of them result in great yield losses in sunflower production. The most serious ones for oil and confectionery sunflower are Downy mildew (*Plasmopara halstedii*), Phomopsis (*Diaporthe helianthi*), Sclerotinia stalk and head rot (*Sclerotinia sclerotiorum*), Charcoal rot (*Macrophomina phaseolina*) Verticillium wilt (*Verticillium dahliae*), Rust(*Puccinia helianthi*), Phoma black stem (*Phoma macdonaldii*), Alternaria (*Alternaria spp*.) and Rhizopus head rot (*Rhizopus spp*.). Chemical application is effective in the control of some diseases, but developing resistance genes is considered the most effective and sustainable control in sunflower. Sunflower breeders have achieved significant results in finding genes for resistance or high tolerance to certain diseases in wild species and in incorporating them into the cultivated sunflower genotypes. Besides drought conditions during seed filling, different diseases, and the main problemlimiting sunflower yield is the occurrence of broomrape (*Orobanche Cumana* Wallr.) infestations. Broomrape spreading rapidly to new areas in recent years leading to considerable yield losses up to 100% and reducing sunflower seed quality (Kaya et al., 2012; Pineda-Martos et al., 2013). Since broomrape is a highly variable parasite, the break down of resistance is a frequent phenomenon, and multiple sources of resistance are needed (Seiler, 2012). In Spain, broomrape was detected first in the Toledo Province (central plateau) in 1958, infecting confectionery sunflower (Gonzalez Torres et al., 1982). Herbicide-tolerant hybrids are in turn divided into two different classes: tolerant to Imidazolinones (IMI) and tolerant to Tribenuron methyl or Sulfonil urea (SU). The utilization of IMI sunflower along with herbicide treatment offers an effective control of broomrape what ever the path type might be (Alonso et al., 1998), since this combination prevents the multiplication and dissemination of the pathogen. One of our breeding projects aimed to incorporate desirable traits such as disease resistance and herbicide resistance into confection sunflower lines for public release (Yoe, 2007). The sunflower breeding program at Institute of Field and Vegetable Crops, Novi Sad has been directed towards creating lines and hybrids which are resistant to new broomrape races. Continued work on creating new sunflower hybrids resistant to broomrape demands the screening of breeding materials for resistance in both field conditions and in controlled conditions of a greenhouse (Hladni et al., 2012a). One of the main advantages of Clearfield hybridsis the simultaneous control of broomrape and a broad spectrum of weeds (Pfeninget al., 2008). The combination of both strategies of broomrape control, genetic resistance to broomrape and herbicide tolerance, will contribute to a more durable control of broomrape while simultaneously controlling a wide spectrum of weeds (Fernandez-Martinezetal, 2015). In particular, resistance to fungal diseases and broomrape will continue to be a key aspect of sunflower breeding

PRESENT SITUATION IN CONFECTIONERY SUNFLOWER BREEDING

Landraces/open-pollinated confectionery varieties are mainly used for confectionery sunflower production in the many countries such as China (Zhang, 2004), Turkey (Tan, 2010), Iran (Kholghi, 2011), Spain (Nabloussi, 2011). The main reason is that there is not enough certified seed production with desired quality. The landraces or local varieties are not suitable for combine harvesting because of their non-uniformity of plant development in the field (Tan, 2009; Tan, 2010). In Turkey, confectionery sunflower farmers do not get higher yields even under irrigated conditions, as farmers plant different local populations. In Hungary, the stripe-patterned confectionery sunflower is still produced at small farms. The traditional manual technologies do not involve use of chemicals. Spraying with field machines if needed can be carried out only in first few months of the growing period because of the height of plants, while the small field size excludes aerial spraying (Szabo et al., 2008, 2010). In Spain, confectionery sunflower production was maintained at a small scale, mainly based on local landraces (Nabloussi, 2011). Traditionally open-pollinated confectionery varieties of sunflower are cultivated almostevery where in China. These open-pollinated varieties have quite low average yield (Zhang, 2004). Open-pollinated varieties covered about 500 000 hectares in Russia (Goncharov and Beresneva, 2011). This type of seeds has special Russian name “mezheumok” and means intermediate. Their seeds are close to the oil-type one by structure but larger in size and 1000 seed weight, has bigger husk content and less oil content (Borodin, 2003; Mamonov, 2004). In Serbia large open-pollinated confectionery varieties were grown, in the last few years they have been replaced by NS confectionery hybrids which keep spreading. Several factors have contributed to this occurrence, including crop uniformity, suitability for mechanized harvesting, and optimalplant densityfor achieving the desired size, seed quality and color suitable for the Serbian market demands.

FUTURE PROSPECTS IN CONFESTIONERY SUNFLOWER BREEDING

Market demands and production area of confectionery sunflower show a steady increase due to its nutritional value and use in human nutrition. It is expected that a high productive confectionery hybrids will replace varieties, which will influence the increase of surfaces under confectionery sunflower. Newly developed confectionery hybrids should have higher yield potential, higher self-fertility rate, resistance to diseases, broomrape and herbicide, and larger seeds with high oleic acid and vitamin E (tocopherol) content to increase their nutritional value and prolong seed shelf life (Jocić et al., 2015; Kaya, 2015). Modern varieties of sunflower show great variability in height, but for achieving higher yields lower plants are preferred. Lower plants are also more convenient for mechanical harvesting. (Hladni et al., 2008). The main direction of sunflower breeding is creation of hybrids with high genetic potential for seed yield >5 t/ha and seed protein content >25%. In order to achieve high and stable confectionery hybrid yield it is important to create a model of a sunflower plant which would enable an increase of number of plants per hectare in the conditions of high agrotechnics and mechanized harvesting. It is necessary to pay more attention to the architecture of plant organs, like petiole angle, petiole length, plant height and number of leaves per plant, which directly influence the change of the photosynthetic apparatus. The optimal plant size of confectionery sunflower hybrids for mechanized harvesting is <175cm, while the optimal head diameter is 20-25cm. Direct yield components, like number of plants per unit area (ha):42-46000, seed oil content <35%, seed protein content >25%, number of seeds per plant >1500 seeds, 1000 seed weight up to 110g, and low husk percentage <25% also play an important role in obtaining high seed and protein yield. When breeding for confectionery hybrids it is important to create hybrids with different vegetation seasons: early (80–90 days), medium early (90–100 days), medium late (100–115 days).

Molecular markers have several advantages compared to classical morphological markers and enable increased efficiency of conventional breeding (Vasić, 2001). It can be expected that the marker assisted selection (MAS) and molecular markers will increasingly beused in confectionery sunflower breeding for introduction of many desirable and agronomically important traits, quality traits, disease resistance or stress tolerance.

Within the breeding program for confectionery sunflower, special attention needs to be directed towards creating hybrids for different types of consumption and production depending on the demands of the European, Russian, Ukrainian, US, Turkish and Chinese market. Testing confectionery sunflower under different production systems (classical or organic) can be useful in identifying hybrids with broad adaptability (Hladni et al, 2015a;2015b).

CONCLUSION

Confectionery sunflower breeding is characterized by the fact that different markets have different demands when it comes to the seed size, hull color and other traits, which makes this process more difficult and costly. When creating confectionery hybrids it is very important to combine genes responsible for high yield potential and good technical and technological traits of the seed. In order to successfully obtain high yields and adaptability for confectionery sunflower the main direction in breeding is defining an ideal ideotype of plant for specific agro-ecological conditions, sef-fertility rate, larger seed, increased 1000 seed weight, protein content and quality. In order to achieve high and stable confectionery hybrid yield it is important to create a model of a sunflower plant which would enable an increase of number of plants per hectare in the conditions of high agrotechnics and mechanized harvesting. Confectionery hybrids have siggnificantly higher seed yield than the open pollinated varieties. The advantage of confectionery sunflower in comaprison to varieties are crop uniformity, suitability for mechanized harvesting, optimal plant density for achieving the desired size, seed quality and color suitable. It is expected that confectionery hybrids will continue to spread more in production and eventually replace the varieties. One of the most important goals in breeding is creation of resistance or tolerance of hybrids to diseases, broomrape, and droughtand to incorporate herbicide tolerant traits in the adapted confectionery hybrids.

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