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Use of heterosis in maize and sunflower breeding

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Abstract:A heterosis effect of first generation hybrids has been observed in almost all types of cross-pollinated and self-pollinated plants.The use of the heterosis effect of hybrid (heterosis, F_1) varieties is crucial for the intensive development of plant breeding in some field crops, such as maize and sunflower.In the selection of these crops, heterosis is used, expressed in a positive superiority of the F_1hybrid over its parents in terms of growth and adaptive potential of the plants of the generation, i.e.both increased power and vitality as well as increased productivity.The use of parental inbred lines with good combinatorial ability has been found to significantly improve the heterosis variety.The aim of the study is to summarize research related to the heterosis in F_1 and the mode of inheritance such as the dominance of quantitative traits important for selection, determining photosynthetic productivity and yield in maize and sunflower.As a result of breeding research in Bulgaria, a number of high-yielding hybrid varieties were obtained both in maize and in sunflower.

Key words:heterosis; hybrid variety; inbred line; yield; dominance

INTRODUCTION

With the help of selection methods, uniform and genetically constant selection forms are created, from which new varieties can be obtained. When using heterosis, the selection process proceeds on a fundamentally different basis compared to combinatorial selection.

Heterosis is understood as the higher power and viability of hybrids of the first generation compared to the initial forms. The first offspring (F_1 hybrid) can surpass both parents in grain yield and vegetative mass, in length of the growing season and many other characteristics.

Depending on the changes that have occurred in hybrid plants, heterosis is somatic (increase in vegetative mass), reproductive (increase in the number and weight of reproductive organs and seeds) and adaptive (increase in the resistance of the hybrid variety to cold, drought, diseases, pests and adverse soil and climatic conditions).

The exact reproduction of the economic qualities of hybrid varieties requires each year to cross genetically different (distant) groups of plants (self-pollinated or inbred lines, varieties, clones, etc.), whose individuals are in a homozygous state and have the same genetic constitution.

The characteristic of hybrid varieties that possess heterosis is that the amount of endosperm and the size of the embryo of hybrid seeds increase, the seeds germinate together, the growth and development of hybrid plants are greatly accelerated, especially in the initial phases of their development, and most importantly, the yield increases compared to that of the parental forms.

The heterosis effect of first-generation hybrids has been observed in almost all types of cross-pollinated and self-pollinated plants. The practical use of heterosis is one of the greatest achievements of genetics and selection. The yields of heterosis hybrids increase by 20% to 50% compared to direct varieties. Heterosis is most widely used in corn, sunflower, sorghum, sugar beet, and vegetable crops (Enchev, 1990).

For several decades, the selection of corn and sunflower has been entirely focused on 100%

production of F_1 hybrids, which is why the search for high-yielding heterosis varieties and the study of the biological phenomenon of heterosis is a current and scientifically significant problem.

The main goal is a thorough analysis of previously conducted studies related to the manifestations of heterosis in F_1 and the mode of inheritance (dominance) of quantitative characteristics important for selection and practice, determining photosynthetic activity and grain yield in corn and sunflower.

MATERIALS AND METHODS

Obtaining heterosis and studying F1 hybrids is done by the methods - diallel crossing and topcross, which are associated with the need for a lot of time and resources. The disadvantage of these methods is the limited possibility in the number of tested combinations, which reduces the coverage of the diversity of parental lines. For this reason, it is good to find methods for prediction. The essence of prediction is a targeted selection of such parents that best meet the selection goals and market requirements. Important signs in the selection of the maternal line for hybrid seed production are male sterility, yield and sowing qualities of seeds, resistance to seed-borne diseases transmitted with the seed and some gene markers, and for the paternal line - interesting signs missing in the female parent, such as branching in sunflower and fertility restorer genes (*Rf* genes).

When the value of the trait in the F_1 hybrid is higher than that of the parents, the heterosis is positive, and when it is lower - negative. But not always higher means better and vice versa. Very often the heterosis effect is manifested not in relation to the better parent, but to the average of the two parents. This manifestation of heterosis is estimated by the method of Omarov (1975) to the arithmetic mean value of the two parental forms - hypothetical and real - to the better parent. The determination of superiority is calculated by the quantitative biometric method of Mather & Jinks (1982).

RESULTS AND DISCUSSION

Studies of heterosis in maize in Bulgaria over the last 15 years

Maize has been one of the model objects for studying the unique phenomenon of heterosis for almost a century. New data on its manifestations are constantly accumulating, especially for traits that are indirectly related to yield, but are of great importance in modeling in various breeding programs. Table 1 includes Bulgarian studies from the last 15 years. Heterosis manifestations do not equally affect all traits and properties of the organism. In some of them, heterosis is strongly manifested, in others weakly, and in still others it is completely absent. This is explained by the discrete nature of inheritance of traits and the independent and free combination of the genes that determine them. For example, studies of the degree of dominance in F_1 of the yield elements of Bulgarian corn hybrids common in production at two planting densities indicate that the hybrids Kn 613 and Kn 625 exhibit heterosis for the traits: ear length, ear weight and grain weight at a planting density of 4000 plants/ha. In hybrid Kn 509, higher true heterosis is observed for all studied traits at a density of 8000 plants/ha and higher hypothetical heterosis for the ear length trait at the doubled density. Different planting densities affect the manifestations of heterosis of the yield elements of the studied hybrids for the respective study period, without changing the basic nature of inheritance - overdominance (Vulchinkova, 2008). Yordanov (2013) in the hybrid Kn 435 for the traits ear length and weight also confirmed the presence of heterosis and positive overdominance in the F_1 hybridgeneration and a high degree of depression in F_2. A similar result for hybrids of different maturity groups was reported by Ilchovska (2017) and Ilchovska et al. (2018). In a study othe manifestation of heterosis and the inheritance of ear parameters - length and weight in the hybrids Kn 561 and Kn 564 at three sowing densities - 40,000, 60,000 and 80,000 plants perhectare under non-irrigated conditions, the trait “ear weight” in the studied hybrids is inherited with a clearly expressed and high degree of true

Table 1. Evaluation based on literature data of the predominant-gene action sinthein heritance of quantitative traitsinmaize in Bulgaria over the last 15 years and their relationship with the manifestation of heterosis

Author, year	Variety	Trait	Effector mode of inheritance
Petrovska & Genova (2008)		✓ grain yield ✓ cob length ✓ grain length ✓ number of rows in the cob	heterosis due to overdominance, based on heterozygosity positive heterosis or absent the degree of dominance in F_1 ranges from incomplete dominance and intermediate inheritance to complete dominance and overdominance of genes
Valkova (2012)		✓ grain yield ✓ elements of extraction	heterosis for all studied traits except the number of rows in the cob
Ilchovska (2012)	Kn 611 Kn 613 Kn 625 Kn 683A Kn 689B	✓ total leaf area ✓ the length of the cob's leaf (CL) ✓ the width of CL	positive heterosis due to positive overdominance and epistasis
Petrovska (2014)	average late hybrids	✓ grain yield ✓ cob length ✓ grain length ✓ number of rows in the cob	heterosis in 37% of the tested hybrids
Valkova & Petrovska (2016)	Kn 442	✓ total height of plants ✓ stake height of the cob ✓ number of leaves ✓ area of the cob's leaf	clearly expressed high hypothetical true heterosis effect inheritance is due to positive overdominance Dominant effects play a major role in genetic control, and various types of epistatic interactions (aa, ad, dd) reduce its manifestation presence of a medium to strong heterosis effect, inheritance is due to positive overdominance, and the genetic control with the largest share is epistatic interactions and dominant actions
Vulchinkova et al. (2018a)	Kn 307 Kn 310	✓ height of the plants ✓ area of the cob's leaf ✓ photosynthetic pigment content ✓ grain yield ✓ number of leaves	clearly expressed hypothetical and true heterosis due to positive overdominance according to the degrees of dominance in F_1 Kn 301 - the hypothetical heterosis is the highest, and for Kn 307 a high heterosis effect was established for all studied traits weaker, but positive manifestation of heterosis
Vulchinkova et al. (2018b)	middle early hybrids: Kn 435 Kn 442	✓ height of the plants ✓ area of the cob's leaf ✓ photosynthetic pigments ✓ number of leaves	heterosis effect is reported inheritance is due to positive overdominance the degrees of dominance of epistasis (hp2 > hp1) with the exception of negative intermediate inheritance hp2 = - 0.42 for photosynthetic pigments of Kn 435 and dominance hp1 > hp2 for the same trait and hybrid in Kn 442 there is dominance and positive intermediate inheritance in photosynthetic pigments and overdominance and epistasis for the remaining studied traits
Ilchovska (2019)	Kn 307 Kn 435	✓ height of the plants ✓ stake height of the upper cob ✓ number of leaves on the stem	clearly expressed positive hypothetical and true heterosis heterosis effect in F_1 generation is due to positive overdominance (hp>1)
Vulchinkova & Vulchinkov (2021)	Kn 317 Kn 321 Kn 649	✓ height of the plants ✓ number of leaves ✓ photosynthetic pigments ✓ area of the cob's leaf ✓ cob length ✓ grain weight ✓ yield per hectare	different degrees of heterosis are observed in different hybrids for different traits the degrees of dominance in F_1 indicate that the heterosis affecting the studied traits is due to positive overdominance

heterosis of 78.7% and 102.3%. In both hybrids, the measured values of heterosis increase at higher planting densities.

This shows that they are more resistant and ecologically stable when growing conditions deteriorate compared to the parents - P_1, P_2 and the next generation F_2. The inheritance of ear weight in both hybrids occurs with positive overdominance of allelic gene interactions. The overdominant gene interaction affects the manifestations of heterosis, which does not change at different growing densities. Epistatic gene interactions also have a significant impact on the inheritance of the trait and the manifestations of heterosis. Manifestations of heterosis in the inheritance of "ear length" are less pronounced compared to ear weight. The measured true heterosis relative to the better parent is close in value for both hybrids, respectively 16.6% for Kn 561 and 14.3% for Kn 564. With increasing growing density, both the hypothetical and true heterosis increase progressively. This leads to the conclusion that hybrids are more adaptable to changing environmental conditions in terms of ear length (Yordanov, 2023).

Many authors (East, 1936; Vulchinkov, 1975; Hallauer et al., 2010; Ilchovska, 2012, 2019; Valkova & Petrovska, 2016; Ilchovska et al., 2018; Vulchinkova et al., 2018b), analyzing the predominant gene actions and interactions in the inheritance of quantitative traits as well as their relationship with heterosis, reported that a change in the conditions of the growing environment of hybrids affects the manifestation of heterosis and the degree of dominance, but does not change the nature of inheritance. The year of study influences to a greater extent than the density of sowing. The study of the essence of heterosis as a biological phenomenon complements the selection evaluation of corn.

Heterosis for the trait ear height was reported regardless of the type of hybrids studied, with inheritance being overdominant. For the trait number of aboveground nodes in five of the closely related hybrids, the true heterosis was 4 negative and one zero value (no manifestation), for which overdominance was not observed. Based on previous studies with the same hybrids for grain yield, similar genetic control for this trait and the number of aboveground nodes is outlined (Vulchinkov & Vulchinkova, 2013).

In the hybrid Kn 561, in terms of the manifestation of heterosis and genetic control in the inheritance of the more important leaf-area photosynthetic indicators, determining the productivity of grain and total biomass, it was established that the medium-late hybrid develops a large leaf area, both of the leaf at the ear, and a large total leaf area ofthe whole plant. The measured heterosis in the inheritance of the leaf area of the leaf at the ear of the hybrid, compared to the average value of the two parental forms is 23.5% (hypothetical), while the real one, compared to the better parental form is only 9.4%. The hybrid exhibits relatively high values of heterosis in the inheritance of the total leaf area of the whole plant. The measured hypothetical heterosis is 36.7%, and the real heterosis is respectively 22.1% compared to the total leaf area of the better parental form. For both studied indicators, the degrees of dominance in the F_1 hybrid generation are significantly above 1, indicating that they are inherited under a positive overdominant allelic interaction (Yordanov, 2019).

Vulchinkov et al. (2014) conducted a study on newly created lines that turned out to be promising for their inclusion in various breeding programs and especially in creating silage-type hybrids due to the presence of a different SSR profile compared to both the baseline and the tester. These new lines have a preserved status of "*leafy-like*" phenotype, and their combinatorial ability for yield, as well as other important agronomic indicators, have been improved. The dominant allele *Lfy* discovered by Shaver (1983) controls the greater number of leaves in corn. Such genotypes usually have more than 8 leaves in their upper tier - above the main cob. This type of silage corn is most suitable for biogas production as a renewable energy source.

No single hypothesis is able to provide a comprehensive explanation of the causes of the heterosis phenomenon, but three of them are generally accepted. These are the hypotheses for:

✓ dominance - for favorable dominant factors (In the process of evolution, the various genes that affect the growth and development of the organism pass into a dominant state, and the genes that do not have such an influence or act unfavorably on the organism, respectively, into a recessive state. In this way, the action of harmful recessive mutagenic alleles is suppressed by the dominant alleles of both parents. F_1 has the genotype AaBbCc.)

✓ overdominance - the hybrid, in which the allelic pairs are in a heterozygous state, should develop its signs and properties more strongly than the parental forms, where both the dominant and recessive allelic pairs of genes are in a homozygous state. It follows that the greater the number of allelic pairs in a heterozygous state exhibiting such an effect in relation to individual signs, the stronger the heterosis effect will be. In relation to one allelic pair, the overdominance of heterozygosity can be expressed as follows AA < Aa > aa.

✓ genetic balance - the balance of hereditary factors determining the vitality and productivity of organisms - when crossing between individuals, this balance can be expressed in a positive or negative direction with respect to factors favorable to growth and development, and heterosis or lack thereof can be observed, respectively.

Heterosis can be assessed when the parents of the hybrid have different alleles at a locus and there is some level of dominance among these alleles (Falconer, 1981). The observed dominance may be due to the interaction between alleles at the same locus, their interaction determining only one of their derivatives that we observe (strong dominance) or is the sum of both (different levels of incomplete dominance). But interaction between alleles at different loci can also occur (called non-allelic interaction or epistasis). The relationship between loci is a physical reality of the genetic system, which is the basis of heredity. There is a discussion about the relationship between the level of dominance and the manifestation of heterosis (expression). The following two hypotheses are the most likely - the dominance hypothesis and the overdominance hypothesis. According to the dominance hypothesis, heterosis is the result of complete or partial dominance. In overdominance, the level of heterozygosity is considered more important than the value of each homozygote (Fehr, 2011).

According to Fehr (2011), the difference between the two hypotheses can be illustrated by the cross AAbbCCxAABBcc. If we imagine that the value for allele A is 10 units, for B - 12 units, for b - 6, for C - 8 and for c - 4 and we replace, then the average will be for AA 10 units, for BB - 12, for bb - 6, for CC - 8 and for cs - 4. The representation in the parent AAbbCC will be 10+6+8 = 24, and for the second with genotype AABBcc, respectively 10+12+4 = 26. The representation in the hybrid will not be determined by allele A, because it has the same expression in both parents. If there is no dominance, the level of significance of the loci Bb and Cc will be averaged between the two alleles, and so for Bb = (12+6)/2 = 9 and Cc = (8+4)/2 = 6 and in the hybrid AABbCc (10+9+6 = 25) there will be no heterosis. However, if there is partial or complete dominance, as assumed by the dominance hypothesis, the value of the heterozygosity will be greater than the average of the two alleles at the locus. For example, if we assume that there is partial dominance for Bb, which gives it a value of 10 and for Cc it is 7, then the hybrid will show heterosis relative to the average of the parents - AABbCc = 10+10+7 = 27. The maximum value for the heterozygous loci Bb and Cc according to the dominance hypothesis are those that are with complete dominance BB = Bb = 12 and CC = cc = 8. In this case, the hybrid will show even greater heterosis than that with partial dominance - AABbCc = 10+12+8 = 30.

Under the hypothesis of overdominance, the value for heterozygosity is greater than that for complete dominance. The level of Bb would be greater than that for BB or bb (Bb> 12), and the level of Cc would be greater than that for CC or cc (Cc> 8). If Bb is 13 and Cc = 9, then the hybrid AABbCc would have the value 32 of 10+13+9.

There are arguments for or against both hypotheses depending on whether the traits observed are quantitative or qualitative and the number of loci. To determine the expression of several loci, a simple cross between two genetically contrasting parental forms of 5 loci can be performed. Capital letters are used to denote the „increasing“ alleles, and lowercase letters to denote the „decreasing“ ones; each locus contributes positively to the increase in the trait (e.g. yield, i.e. the phenotype); each increasing allele adds the same number of units to the yield (2 units), and the decreasing alleles add nothing; and this dominance is complete for an increasing effect.

The level of heterosis is measured by two methods: “F_1 minus the average of the parents”, called hypothetical heterosis “F_1 minus the better parent”, called true heterosis. If the true heterosis is positive, i.e. F_1 exceeds the value of the better parent, then the heterosis is the result of overdominance. In example 1, the better parent has a phenotype of 10 units and the F_1 hybrid has a phenotype of 10 units, i.e. they have the same yield and there is no heterosis. In example 2 (with the same alleles and properties, but with a different arrangement of the alleles in the parents), the better parent (Parent 1) has a phenotype of 6 units, and F_1 has a phenotype of 10 units, i.e. there is heterosis of 4 units and in practice F_1 is 40% more productive than the better parent(Table 2). In this case, it is necessary to observe at least 145 F_1 plants to be 99% sure that at least one sample of the desired genotype exists (Table 3).

Yield is a quantitative trait and is not controlled by 5 loci, but by many more. The table shows the number of genotypes needed to obtain a certain combination of alleles as the number of loci increases. It shows the number of plants that must be observed to be 90%, 95%, 99%, 99.5% and 99.9% certain that there is at least one genotype with the desired combination in cases with up to 20 loci. With 20 loci present, the breeder must evaluate nearly 5 million plants to be sure

Table 2. The level of heterosis

Example 1			
	Parent 1	**Parent 2**	**F_1**
genotype	AABBCCDDEE	aabbccddee	AaBbCcDdEe
phenotype (yield)	2+2+2+2+2 = 10	0+0+0+0+0 = 0	2+2+2+2+2+ = 10
Example 2			
	Parent 1	**Parent 2**	**F_1**
genotype	AAbbCCddEE	aaBBccDDee	AaBbCcDdEe
phenotype (yield)	2+0+2+0+2 = 6	0+2+0+2+0 = 4	2+2+2+2+2+ = 10

Table 3. Probability of obtaining at least one plant with a certain genotype

Number of locus	**Probability**				
	90 %	95 %	99 %	99,5 %	99,9 %
5 locus	76	94	145	167	218
6 locus	146	190	292	336	439
7 locus	294	382	587	676	881
8 locus	588	765	1177	1354	1765
9 locus	1178	1532	2356	2710	3533
10 locus	2357	3066	4713	5423	7070
20 locus	2414434	3141251	4828869	5555687	7243317

that he has obtained at least one of the desired ones.

Heterosis selection in sunflower

The growth of sunflower breeding work, which determines the diverse directions and specific tasks in the selection of this crop, is justified by its wide distribution. Sowing this trench crop helps to ensure proper crop rotation. Its economic importance is also determined by the fact that international trade in sunflower seeds is very successful. The creation of highly productive hybrid sunflower varieties is a top priority of modern sustainable agriculture. For many years, the goals of breeding work to obtain high-yielding varieties with a certain seed size and kernel-hull ratio were achieved through direct varieties, but with the reaching of a limit that is very difficult to overcome, the use of heterosis selection became necessary. Currently, only hybrid varieties are sown in Bulgaria. Modern hybrids combine high yield, low moisture at harvest, resistance to stress factors such as drought, high temperatures, diseases and blue wrist (Boeva et al., 2017; Hristova-Cherbadzhi, 2023).

Despite the earlier study of heterosis in sunflower in the selection of hybrids, it began to be used later than in maize. The reason for this is the bisexual tubular flowers of sunflower (Fig. 1) in contrast to the unisexual flowers of maize (Fig. 2), although both species are monoecious plants. This means that in maize the male and female flowers are in separate inflorescences and are located on different parts of the same plant, this device in a sexually reproducing crop greatly facilitates the production of hybrid seeds in large quantities, unlike in sunflower, where the flowers are hermaphroditic and this process is very difficult and expensive.

In maize, the separate arrangement of the reproductive organs on the stem facilitates the removal of the male organ from the mother plant, while in sunflower; castration must be performed by removing the stamens from the tubular flower

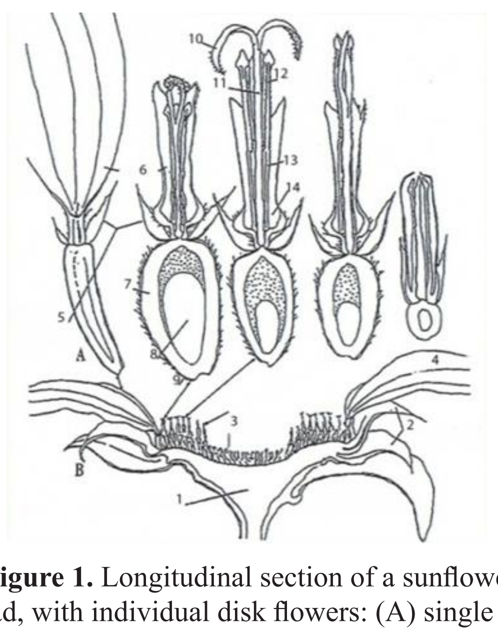

Figure 1. Longitudinal section of a sunflower head, with individual disk flowers: (A) single ray flower (left), four disk flowers in different stages of development (right), 3.5^x; (B) Head, 0,35^x. 1) receptacle, 2)bracts, 3)disk flowers, 4)ray flowers, 5)pappus (calyx), 6)corolla, 7)ovary, 8)ovule, 9) achene, 10)stigma, 11)style, 12)anther, 13)filament, 14)nectar (fromMcGregor, 1976).

Figure 2. Maize:(A) Tassel;(B) Ear

and leaving the stigma. To overcome this, a male-sterile plant can be used as the mother form, i.e. one in which there is no pollen (abortion or non-formation of pollen grains) or there is a complete functional inability of the male gametophyte (due to non-formation of stamens - anther sacs, presence of sterile pollen incapable of fertilizing the egg cell or defect in flower morphology) to fertilize the female flowers of one or another plant. The practical use of heterosis in sunflower became possible only after the discovery of a source of male sterility (Popov & Dimitrov, 1979).

For the first time, heterosis in sunflower was observed and described by Shull (1952) in 1906, but only in 1945 was the heterosis varietal hybrid Advance submitted for production testing in Canada, and in our country, research work began in the mid-1950s, with the tested simple interline hybrids showing a heterosis effect of 31.6 to 56% (Popov et al., 1965). Stoyanova (1978) reported that out of 100 hybrids, 81.8% showed a higher yield than the parental lines, 12.2% were like the parents, and only 6% had an intermediate yield. After the discovery of CMS (cytoplasmic male sterility) PET1 by Leclercq (1969), the practical use of the heterosis effect in the F_1 generation became possible. The hybrid seed production system has been used in Helianthus annuus since 1972 (Fick and Miller, 1997).

An important place in the seed production of hybrid sunflower varieties is given to the maternal line with cytoplasmic male sterility (Fig. 3), possessing the genotype (S)rfrf (A line or a sterile analogue of the sterility-maintaining line, with the genotype (F)rfrf-B line), obtained after several consecutive backcrosses), i.e. the creation of a sterile maternal parent in order to avoid castration of the stamens.

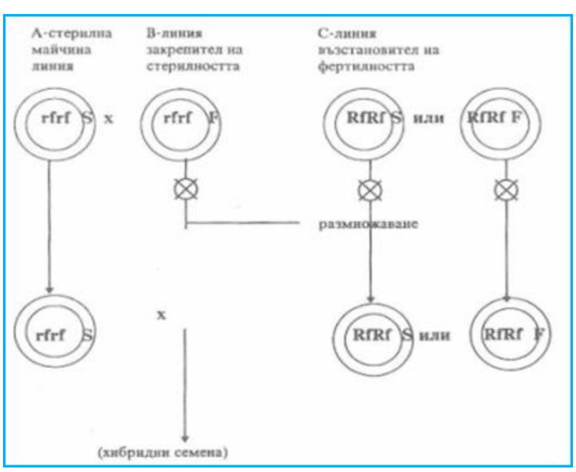

Figure 3. Lines needed for seed production.

75 different sources of CMS have been discovered in sunflower (Serieys and Christov, 2005), but only one (CMS PET1) from the cytoplasm is used in practice. The attachment of CMS in sunflower is controlled by a complex with changing interactions between nuclear and cytoplasmic genes. Differences are observed in the way of restoration and attachment of the different CMS sources. The way of restoration of fertility in CMS sources is different, as restoration can be controlled by one dominant or two, three and more independent complementary genes. The first report on finding a source carrying fertility restorer genes (*Rf* genes) was made by Kinman (1970). The identification of *Rf* genes and the creation of R(C) lines (a fertility restorer line, which is used as a paternal component of the hybrid and has the genotype (S)*RfRf* or (F)*RfRf*). (Christov & Petrov, 1988; Christov, 1992, 1996a, b, 1998, 1999, 2000; Hristova-Cherbadzhi, 2009; Hristova-Cherbadzi & Christov, 2009, etc.), carrying these genes, it becomes possible to use heterosis selection to increase the yield of hybrid seeds, from which 100% hybrid plants develop (Putt, 1997).

A number of studies have been conducted in Bulgaria on the manifestations and benefits of the heterosis effect in sunflower on important agronomic characteristics in various hybrid combinations (Encheva et al., 2015; Hristova-Cherbadzhi and Molle,2016; Georgiev et al., 2016, etc.).

The use of the heterosis effect in the F_1 generation is of crucial importance for accelerating not only seed production, but also for sunflower selection. The essence of the heterosis method in seed production is that the obtained high-yielding and high-quality F_1 hybrids (heterosis varieties) are used once, only in the first hybrid generation. This requires the production of new seed material annually through new crossing. The essence of the heterosis method in selection work is that after crossing closely related (intraspecific hybridization) or distant (distant hybridization - interspecific and intergeneric) parental forms, F_1 hybrids are obtained. After self-pollination of the first generation, the second (F_2) develops, which is characterized by the breakdown of traits (obtaining a segregating population). From here begins the selection of materials in which the desired diverse traits are combined. After several consecutive self-pollinations, new inbred lines (cross-pollinated plants) or pure (self-pollinated plants) are obtained. These can be the future parents of the hybrid variety after their phenotypic expression and combinative ability are evaluated (by performing topcross crosses). After analysis of the hybrid combinations (simple or complex), the parent lines are selected and propagated.

For example, Hristova-Cherbadzhi (2007, 2012) after using distant hybridization obtained interspecific and intergeneric F_1 hybrids, which self-pollinated for several consecutive years. After selecting in F_2 forms that combine desired traits, she selected several interesting inbred lines in the sixth generation, such as lines 2497 and 1018 originating from the cross *H. annuus*- l. 6075 A x *H.nuttallii*, line 2499 from the cross *H.pauciflorus* M002 x *H. annuus*- variety Peredovik, line 2942 from the reciprocal cross *H. annuus*- l. 6116 A x *H.pauciflorus* and line 3291 - from *H. hirsutus* M029 x *H. annuus* - variety Peredovik, respectively with oil content in seeds of 60.8%, 53.4%, 52.3% 52.5% and 50.6%. In the F_1 generation of the reciprocal cross *H.neglectus* x *H. annuus*, a superdominant influence of the variety Peredovik was recorded, while in the direct cross the trait stem height is inherited intermediately. The result is similar for the diameter of the central whorl and the number of tubular flowers in the whorl, traits important for sunflower productivity. It is interesting that when crossing line HA 89A with *H. hirsutus* in the F_1 generation the trait plant height is inherited intermediately in both directions of crossing. In both interspecific crosses no heterosis effect was recorded in the first generation.

CONCLUSION

It can be concluded that while in combinatorial selection the task is to create a new, stable variety, in heterosis selection the goal is to create and select suitable lines of parental pairs, from the crossing of which heterosis offspring is obtained, used directly for production purposes. Only the first generation (F1) is used, since in the following generations heterosis decreases due to genetic decay. Hybrid varieties for production purposes are used in a number of plant species. As a result of selection studies on heterosis, a number of high-yielding hybrid varieties have been obtained in Bulgaria, both in corn and in sunflower.

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