

BREEDING AND GENETIC CHARACTERISTICS OF SUGAR BEET POLLINATORS ACCORDING TO SUGAR CONTENT TRAIT

Based on diallel crosses by Heyman, the parameters of genetic control for sugar content trait are established as well as an additive-dominant model of its determination. The trait is determined to be controlled by six genes. Defined is genotypic structure of sugar content variation in topcross and diallel hybrids. Selected are hybrids with heterosis for sugar content, determined is direction of the trait dominance in six pollinator lines.

Keywords: *sugar content, genetic control, phenotype, inheritance, variation*

Introduction. Breeding process is effective as long as genetic conditions for agronomic traits are known. Productivity performance is formed with yield and sugar content, that is why genetic control of these traits contributes to the targeted selection of parent for hybridization.

Sugar content is an important productivity element of the sugar beet, which is a breeding purpose in creating hybrids based on CMS. Many researchers have pointed out that sugar content being an indication of varietal populations is characterized by large variation factor (15 to 21%). Its value is significantly lower than the yield [1, 2]. Having the same variation factor populations may differ in absolute value of sugar content and vice versa [3]. Some scientists have described the appearance of transgressive forms among high-sugar content progeny at low frequency (0.7-1.4%) [4].

Variation of sugar content depends on genotypic factors as well as on environmental conditions and their interaction. The variation of this trait in the populations depends largely on the additive effects of genes; in interline hybrids -on additive and nonadditive effects [5-7]. Influence of various factors (e.g. environmental, farming, etc.) masking the "genetic parameters" of the trait and creating difficulties in the selection of genotypes on phenotypic expression of the sugar content has been studied enough by many scientists [8,9]. On the contrary, genetic control of sugar content in sugar beet has been studied much less. A conventional point of view is that it depends on many genes. V.G. Peretiatko refers to I.I. Voitkevich study that predicted the presence of 4-6 genes [10]. Two types of inheritance as well as genetic control by not less than 4 allelomorphes has been reported by V.F. Savytskyi [11]. I.A. Shevtsov, V.I. Nikolaichuk indicated about genetic control by a small number of genes [12]. Digene hypothesis of inheritance and influence of multiple allele interaction were reported by V.H. Peretiatko [10].

The objective of our study was to investigate genetic conditions for sugar content trait within diallel and topcrosses and to select the hybrid combinations feature with the effect of heterosis for the trait.

Materials and methods. Genetic determination of sugar content trait was studied in experiment in 2010-2012 and based on topcross and diallel crosses of 6 pollinator lines (altogether 36 combinations) using the method of Heyman [13] described by M.A. Fedin D. Y. Sylis [14]. Crossed were inbred pollinator lines from breeding material collection of Uman EBS, which is essential for genetic analysis by Heyman. Hybrid combinations were tested in the station strain testing. Plot area - 13.5 m², repetition - four times, sugar content was determined with an automated line "Venema" [15].

Results and discussion. Having studied the structure of genotypic variation of sugar content in diallel hybrids we found out that share of nonadditive effects makes up 40.7%. Additive effects of parent's genes were almost equal (18.4 and 18.1%). Reciprocal effects may be determined only with the aid of diallel crosses; their share was 22.7% (Fig. 1).

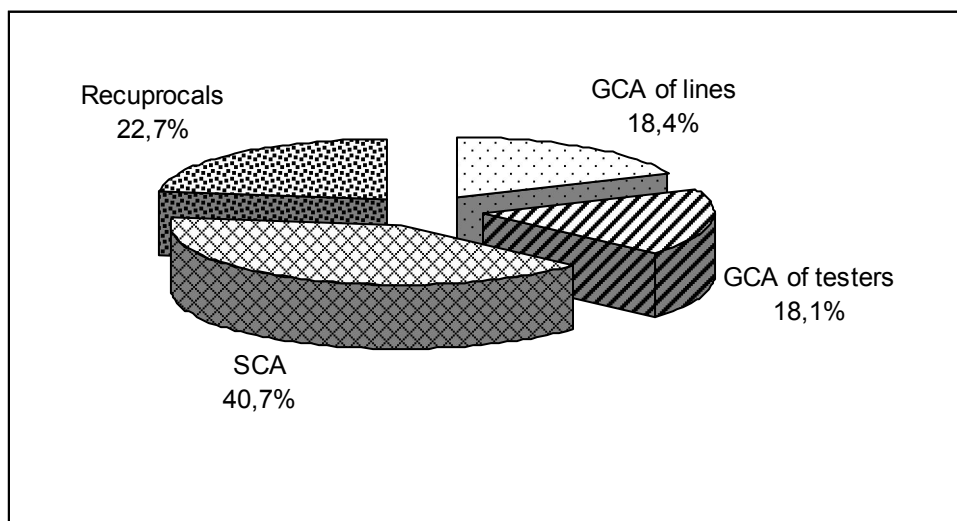


Fig. 1. Genotypic structure of sugar content trait variation in diallel crosses (2010-2012)

Having compared the contribution of genetic factors in different types of crosses we revealed that share of interaction between components in topcross hybrids was greater than in diallel crosses and made up 52.3 % versus 40.7%. The effects of male and female parent were almost equal (24.4 and 23.3%), but also higher (Fig. 2). Larger proportion of these factors should be referred to the fact that it is not possible to identify reciprocal effects in topcross hybrids with mathematical methods, which certainly reduces the accuracy of selection and genetic characteristics.

Determination of general combining ability (GCA) effects for two systems of controlled crosses showed that the best lines proved to be pollinator lines B31 and B32 (GCA effects in topcrosses of +0.35 and +0.29, respectively and in diallel hybrids of +0.1 and +0.35). The difference between the effects could be explained by influence of cytoplasm effect. When crossed these lines are expected to reveal heterosis effect (Fig. 3).

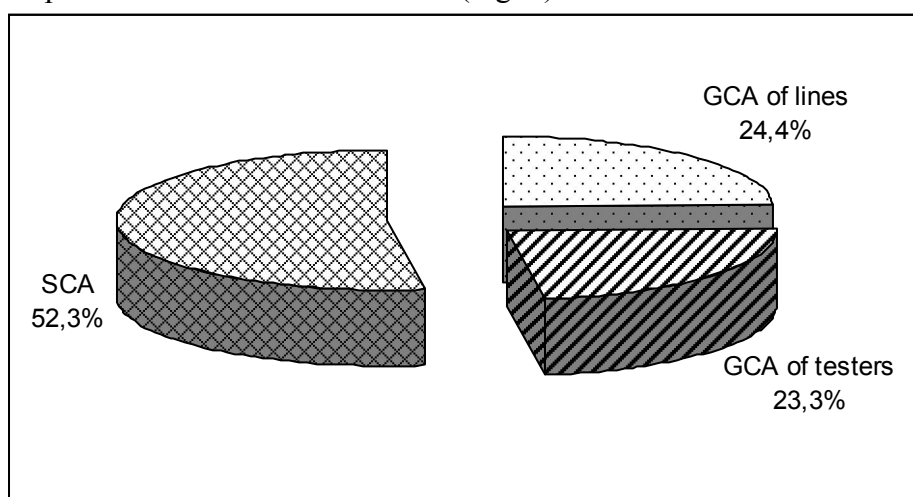


Fig. 2. Genotypic structure of sugar content trait variation in topcrosses (2010-2012)

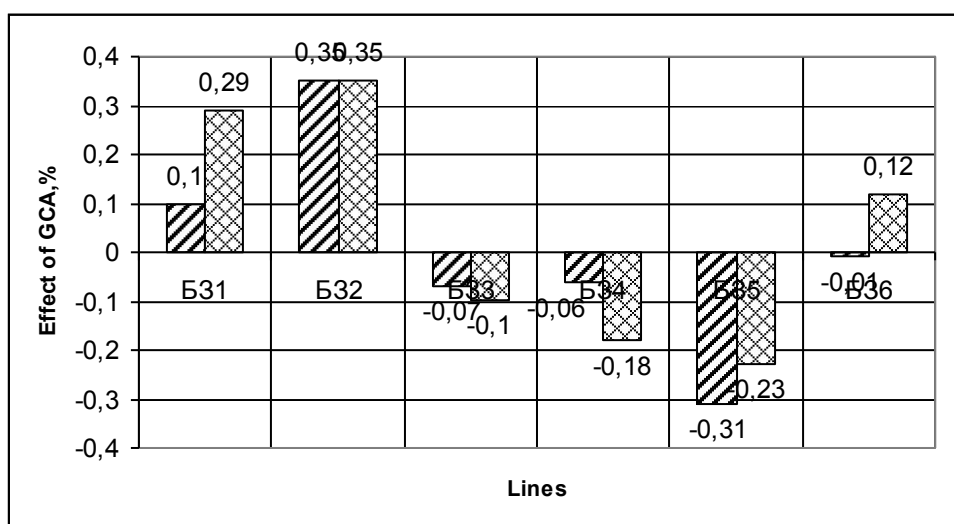


Fig. 3. GCA effects of line-pollinators in topcrosses and diallel crosses (2010-2012)

Carrying out diallel crosses provided not only the determination of GCA effects, but also the reciprocal effects of each hybrid combinations under study (Table 1). The highest reliable effects showed combinations of B33/B34 (+0.66 *) and B35/B34 (+0.28 *). Reciprocal effects in B35/B31, B32/B31 and B31/B34 were also significant (0.65, 0.37 and 0.33%).

Table 1

The effects of specific combining ability effects of lines and reciprocal hybrids of sugar beet derived from diallel scheme (2010-2012)

Lines	B3 1	B3 2	B3 3	B3 4	B3 5	B3 6
B3 1	#	0.21 ———— 0.37*	-0.06 ———— 0.05	0.20 ———— 0.33*	-0.03 ———— 0.65*	0.03 ———— 0.18
B3 2	0.21 ———— 0.37*	#	-0.15 ———— 0.15	0.18 ———— -0.20-	-0.10 ———— 0.15	-0.14* ———— -0.10
B3 3	-0.06 ———— 0.05	-0.15 ———— 0.15	#	0.66* ———— 0.08	-0.13 ———— 0.27	0.14 ———— 0.02
B3 4	0.20 ———— 0.33*	0.18 ———— 0.15	0.66* ———— 0.08	#	0.28* ———— 0.12	-0.43* ———— 0.18
B3 5	-0.03 ———— 0.65*	-0.10 ———— 0.15	-0.13 ———— 0.27	0.28* ———— 0.18	#	0.07 ———— 0.13
B3 6	0.03 ———— 0.18	-0.14* ———— -0.10	0.14 ———— 0.02	-0.43* ———— 0.18	0.07 ———— 0.13	#

*Note: numerator - the effect of specific combining ability;
denominator - reciprocal effect.*

True heterosis for sugar content, which shows excess of the value in hybrids compared to best parent is the result of a favourable combination of hereditary factors, interpreted GCA (additive effects) and SCA (nonadditive effects of genes).

Heterosis for sugar content in hybrids compared to the best parent was detected in 3 out of 36 combinations (Fig. 4). The excess relative to better parent (true heterosis) was significant and

ranged from +0.3 (B31/B32) to +1.3% (B33/B34) (absolute value of the trait). Previously, the heterosis in sugar content was reported by Balkov et al. [3].

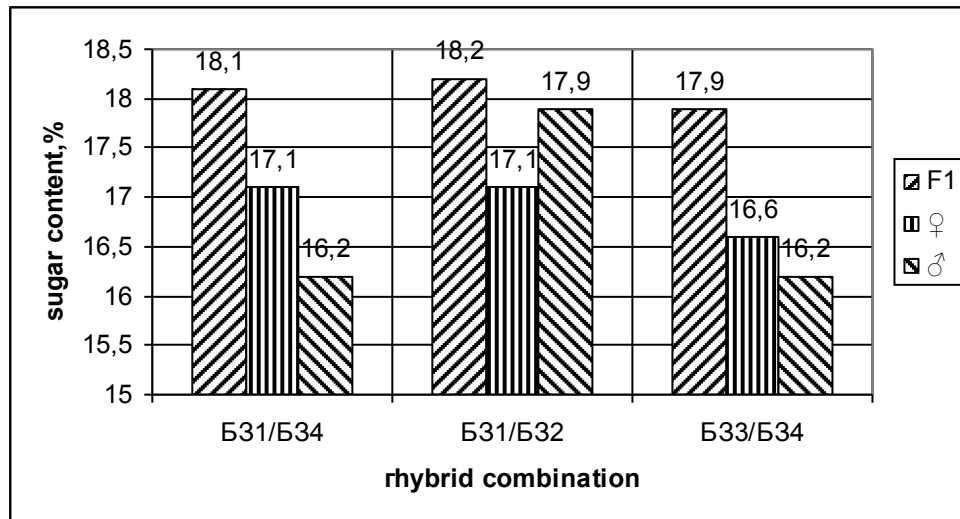


Fig. 4. Heterosis in the best diallel hybrids according to their sugar content compared to the male parent (2010-2012)

Based on the model of Heyman identified were components of genetic variance of the sugar content trait and their ratio (Table 2). It was found that D (additive effects) are under H_1 (dominance effects) (respectively 0.40 and 0.52), the ratio $H_1/D = 1.297$. This indicates that key role in the manifestation of this trait have dominant gene effects. The average degree of dominance was full also, as $\sqrt{H_1/D} > 1$ and totalled 1.139.

Table 2

Genetic parameters and degree of sugar content trait heritability in sugar beet according to diallel crosses data

Genetic characteristics	Value	
Degree of dominance value, H_1/D	1.297	
Mean degree of dominance, $\sqrt{H_1/D}$	1.139	
Asymmetry of dominant and recessive genes, $(0,25) H_2/4H_1$	0.165	
Ratio of genes in male parent, $[\sqrt{4DH_1 + F}]/\sqrt{4DH_1 - F}$	2.413	
Number of genes controlling the trait, h^2/H_1	5.767	
Degree of heritability (in the broad sense)	0.851	
Degree of heritability (in the narrow sense)	0.459	
Direction of line dominance F_1	0.447	
<i>The same</i>	F_2	0.517
-«-	F_3	0.481
-«-	F_4	-0.162
-«-	F_5	0.629
-«-	F_6	0.372

Ratio $H_2/4H_1$ indicates the distribution of dominant and recessive alleles in the parent. Our hybrids have this value equalled to 0.165, which is significantly different from the rate of 0.25 indicating the uniformity of their distribution between the parents. Dominant allele was 2.4 times greater than recessive.

Ratio h^2/H_1 indicates the number of genes (or groups of genes) that controls the trait under study. In our experiment, the sugar content trait was controlled by six genes (to be exact 5.767). It should be noted that, according to modern theory of ecological genetics of quantitative traits by V.A. Drahavtsev, “changing environmental factors that limit growth and development change as well the range and number of genes that determine the same quantitative trait”, in other words

limiting factor makes genes providing the greatest adaptability of the genotype to this factor to affect productivity trait [16].

The big difference between the degree of heritability in the narrow and broad sense suggests genetic variation to be determined mainly by nonadditive effects, i.e. simple selection according to phenotype can not provide predicted results, and improvement of the trait will largely depend on the selection of parents.

The positive value of $F (> 0)$ indicates that the lines (except line 4) have dominance directed toward increasing values of the traits under study. That means that hybrids derived from these lines are promising for further breeding processing to create experimental hybrids.

Based on genetic analysis data, Heyman graph (Fig. 5) gives the distribution of lines for the relative proportion of dominant and recessive genes controlling sugar content trait in the parental lines. The greatest number of dominant genes features line Б35 located in the lower left corner of the graph, and the largest number of recessive genes - line Б34 (upper right part of the graph). This differentiation of lines are more interesting in terms of genetic research, but these characteristics also allow aware selecting of parents.

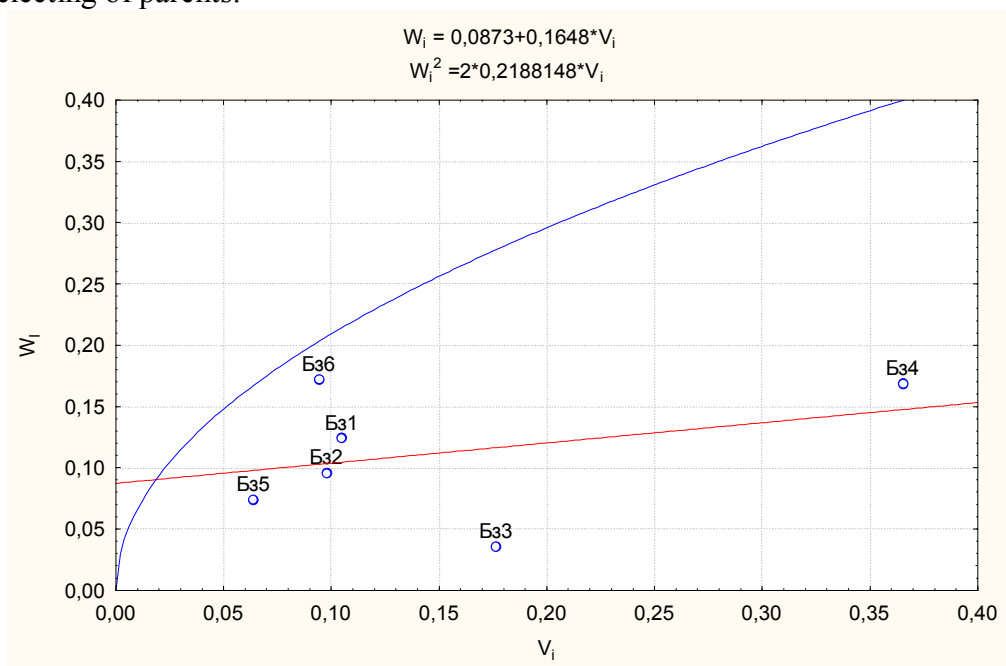


Fig. 5. Regression line (by Heyman) for sugar content trait in sugar beet

Thus, when creating hybrids feature with high level of heterosis one must consider the parameters of genetic control for sugar content trait. Based upon diallel analysis, the additive-dominant model of the trait inheritance which comprises predominately nonadditive and reciprocal effects of genes was established. Reliable GCA effects obtained such lines as Б31 and Б32 as well as SCA components of Б33/Б34 Б35/Б34. Identified were reciprocal effects in parental components. Proved was polygenic control of sugar content; this trait is controlled by six genes.

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Анотація

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Селекційно-генетичні особливості запилювачів цукрових буряків за ознакою цукристості

У статті на основі діалельних схрещувань за Хейманом визначено параметри генетичного контролю ознаки цукристості та встановлено адитивно-домінантну модель її детермінації. Встановлено, що ця ознака контролюється шістьма генами. Визначена генотипова структура мінливості цукристості у топкросних і діалельних гібридів. Відібрано міжлінійні гібриди з гетерозисом за цукристістю, встановлено напрям домінування ознаки у шести ліній - запилювачів.

Ключові слова: цукристість, генетичний контроль, фенотип, успадкування, мінливість

Аннотація

Корнеева М.А., Ненька А.В.

Селекционно-генетические особенности опылителей сахарной свеклы по признаку сахаристости

В статье на основе диаллельных скрещиваний по Хейману определены параметры генетического контроля признака сахаристости и установлено аддитивно-генетическую модель ее детерминации. Остановлено, что этот признак контролируется шестью генами. Определена генотипическая структура изменчивости сахаристости у топкроссных и диаллельных гибридов. Отобраны межлинейные гибриды с гетерозисом по сахаристости, определено направление доминирования у шести линий-опылителей.

Ключевые слова: *сахаристость, генетический контроль, фенотип, наследование, изменчивость*