UDC 633.63.631.52
KORNIEIEVA M.O., CSc
NENKA M.M., postgraduate student
VAKULENKO P.I., CSc
Institute of Bioenergy Crops and Sugar Beet NAAS of Ukraine

BREEDING AGRO BACKGROUND PRACTICE IN ESTIMATING ADAPTABILITY OF SUGAR BEET HYBRID COMPONENT

This paper discusses the need for improving estimation of breeding items for their adaptability through agro backgrounds that are various combinations of mineral fertilizing background and growing space. We found the most volatile and stable to environmental factor components. Established is the structure of phenotypic expressing productivity in simple sterile hybrids of sugar beet. Consideration of combining ability variability allows breeding of high-yield hybrids using adaptive potential effect of the phenotype-environment interaction.
***Keywords**: sugar beet; hybrid; breeding agro background; flexibility; stability; productivity*

Introduction. Recently breeders more and more recognize an ecological-genetic theory of quantitative traits organisation founded by V.A. Drahavtsev et al. in 1984-2012 [1, 2]. The main result of this theory is decryption of mechanisms of developing methods for forecasting the effects of genotype-environment interaction, transgressions, environment-dependent heterosis, traits, and levels of genotypic and environmental correlations, shift of dominance, homeostasis performance, etc. V.A. Drahavtsev was right to point out that only the effects of genotype-environment interaction are the most powerful remedy to enhance productivity in eco-genetic way [3]. That is why our scientists recently focus on the study of adaptive ability in modern varieties and hybrids.

M.I. Vavilov once wrote "... a serious defect in the theory of genetic breeding is self-discharge of genetics from studying complex economic characteristics. It is necessary to divide this complex ... into basic biological factors, study them analytically; taking into account the complex relationships ... The issue of quantitative traits needs wider coverage"[4]. It is known that quantitative traits in their phenotypic manifestations are the result of both genetic conditions and the effects of environmental factors (regulated and unregulated) that contribute to the variability of modification [5]. Some scientists rightly believe that due to the modification variation, an organism is able to function more or less normally in changing environment, and this determines its adaptive ability [6, 7]. Flexibility of newly created varieties reasonably designated as their modification variability that can produce economically beneficial adaptive effects [8, 9].

Knowledge of breeding materials response for the controlled environmental factors, as opposed to non-regulated ones caused by placing area of a culture and weather- climatic conditions, is insufficient. However, these factors may provide some elements of production technologies (mineral fertilizers background, growing space, timing of harvesting, etc.) and significantly influence the ecological and genetic enhancement of crops productivity, in particular, of sugar beet.

The goal of our work was to establish combining variability of hybrid components and phenotypic manifestations of productivity based upon controlled environmental factors.

Materials and methods. Experiment was performed on Verkhniaky Experimental Breeding Station in 2008-2013 against following breeding agro background: normal mineral nutrition background - normal growing space 45 x 22.5 cm^2 (NBNGS); normal background - extended growing space (NBEGS); enhanced background - normal growing space (EBNGS); enhanced background - extended growing space 45 x 45 cm^2 (EBEGS). Our subjects were: CMS lines, sterility maintainers, polyspermous pollinators, hybrids of Verkhniaky and Uman origin and top-cross hybrids created on their basis according to V.K. Savchenko [10]. Interpretation of general (GCA) and specific combining ability (SCA) effects was performed by Tarutina-Hotyloviova method [11]. Ecological flexibility-stability was estimated by the method of Eberhard-Russell [12].

Results and discussion. Test of top-cross CMS hybrids with participation of two testers - diploid Б3-3 and tetraploid ВТ-7against different fertilizing backgrounds and growing space made it possible to reveal response of the materials to the modifying factors. GCA effects of CMS components of Verkhniaky breeding for yield and sugar content is shown in Fig. 1 and 2.

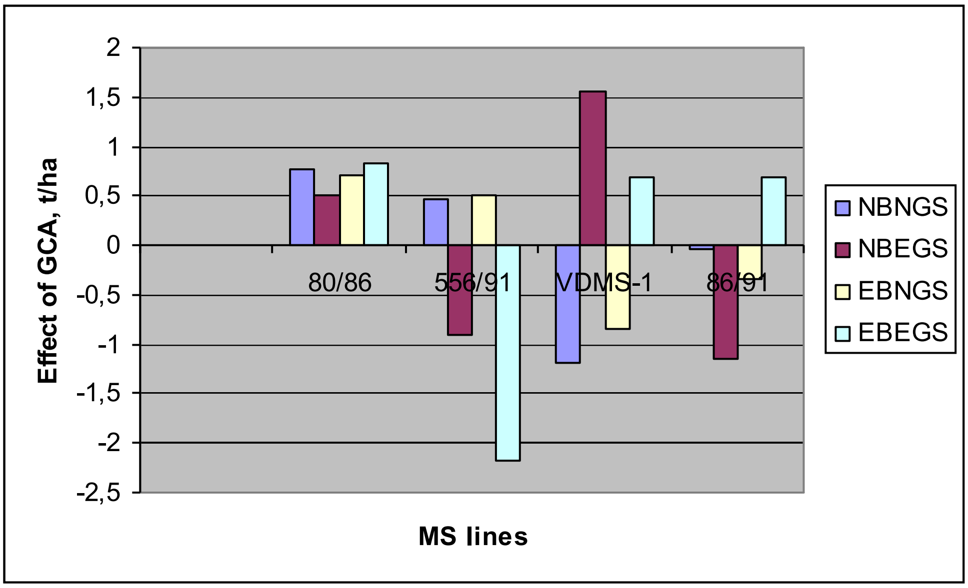

Fig. 1. GCA effects of CMS of Verkhniaky origin on the basis of yield as dependant on breeding agro background, 2008-2010

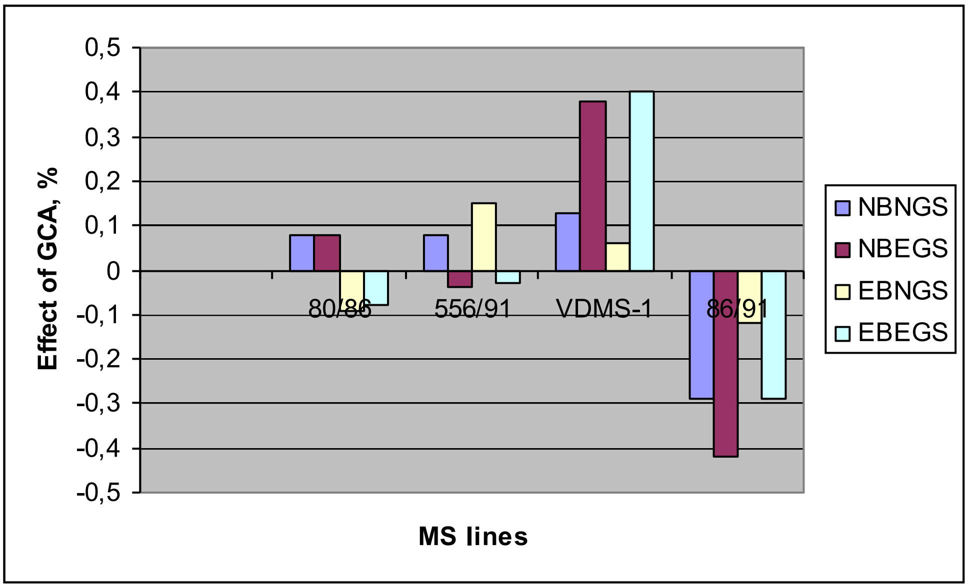

Fig. 2. GCA effects of CMS of Verkhniaky origin on the basis of sugar content as dependant on breeding agro background, 2008-2010

The analysis showed a specific response of CMS lines to changing environment. Thus, CMS line 80/86 was characterized by positive GCA effects for the yield (from 0.50 to 0.83) against all the breeding agro backgrounds; line 556/91 revealed breeding value at normal growing space on both fertilizing backgrounds: its GCA was, respectively, 0. 46 and 0.50, and on the extended growing space it has negative GCA effects (-0.90 and -2.17, respectively). Line VDCMS-1, however, reduced the GCA effects on a regular growing space, and raised them on the extended (Fig. 1).

For sugar content CMS line 86/91 provided reducing the trait expression in hybrids against all the breeding agro backgrounds, while VDCMS-1 revealed a positive effect on phenotype expression in hybrids, especially on extended growing space (GCA effects were, respectively, 0.38

and 0 40). The other two lines 80/86 and 556/91 were slightly responsive to changing modifying factors (Fig. 2).

Hybrid combinations 556/91/B3-3 had high non-additive effects on yield at EBNGS (4.1) and 80/86/BT-7 at NBEGS (1.9).

In 2011-2012 we studied trait of sugar yield in simple sterile hybrids served as female parent. Five pollen sterile CMS lines and five sterility maintainers (SM) crossed in various combinations served genotypic factors, and four above mentioned breeding backgrounds served as modifying factors. The experimental data of simple sterile hybrids, average for CMS lines, show that addition of modifying factors increases sugar yield (Fig. 3).

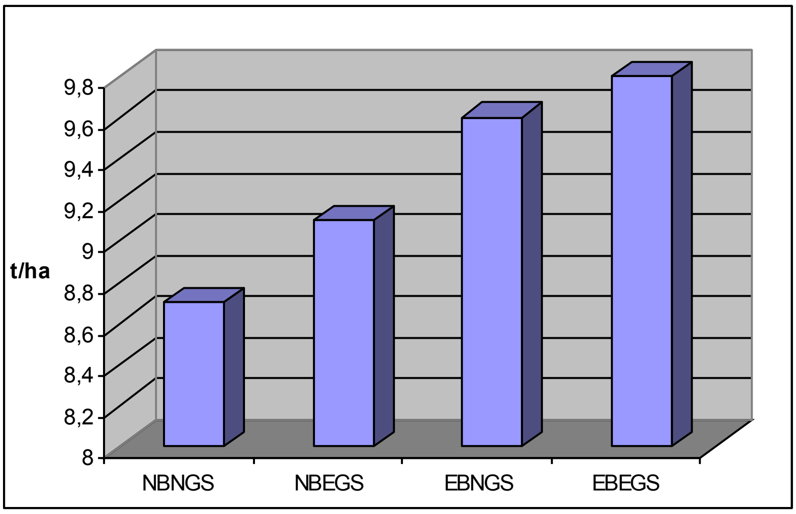

Fig. 3. Influence of breeding agro background on sugar yield of CMS lines 2011-2012

Three-factor variance analysis, where factor A was agro background, factor B - CMS line and factor N - sterility maintainer showed their significant impact on the trait of sugar yield (Fig. 4).

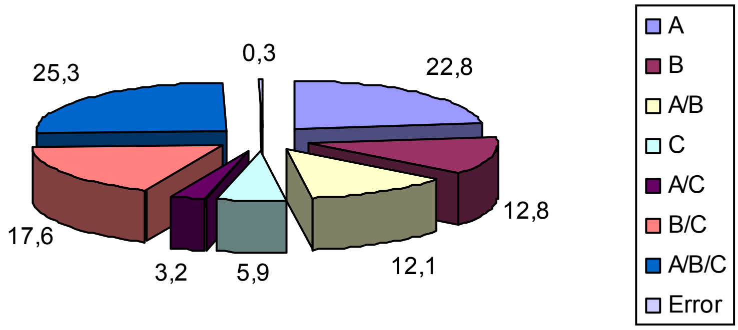

Fig. 4. Factors share and their interactions in the structure of variability on the ground of sugar yield in simple sterile hybrids (%) 2011-2012

As shown in Fig. 4, the greatest impact on the trait variability had hybrid interaction with the environment (breeding agro background), the share of which amounted to 25.3% and the environment (22.8%). The impact of the CMS lines and their interaction with the environment were more significant (respectively 12.8 and 12.1%) as compared with the figures in the 3C (5.9 and 3.2 %, respectively), indicating more important role of pollen sterile lines than their fertile sterility maintainers.

As mentioned above, the negative impact of unfavourable abiotic factors can be significantly reduced with high adaptive potential of modern hybrids. This determines a need for hybrid components feature genetically determined adequate response to favourable agro background. Therefore, while studying simple sterile hybrids of sugar beet served a female parent, we determined their environmental parameters of flexibility and stability and selected the best to create high-adaptive CMS heterotic hybrids. Productivity of these breeding items and their indices of flexibility to environmental factors (breeding agro background) is given in the table.

Table

Production performance and flexibility indices of simple sterile hybrids at different breeding agro backgrounds, VEBS, 2011-2012

CMS	Breeding background				Variation index, V,%	Genotypic effect, E_i	Flexibility index, b_i
	NBNGS	NBEGS	EBNGS	EBEGS			
Yield, t/ha							
CMS 1/Ot2	55.0	61.7	53.4	58.0	6.4	-0.09	-1.54
CMS 1/Ot4	58.1	54.9	58.2	61.8	4.8	1.14	0.98
CMS 1/Ot5	58.3	58.7	64.5	61.0	4.7	3.51	1.94
CMS 2/Ot1	54.9	54.9	57.8	56.9	2.6	-0.99	1.01
CMS 3/Ot1	55.7	55.2	62.8	58.8	5.7	0.91	2.30
CMS 3/Ot2	61.5	62.5	59.4	58.6	3.0	3.39	-1.05
CMS 3/Ot4	46.2	48.4	53.3	57.1	9.6	-5.86	2.54
CMS 3/Ot5	56.8	53.9	60.6	57.3	4.8	0.04	1.72
CMS 4/Ot5	57.7	61.1	56.7	57.6	3.3	1.16	-0.97
CMS 5/Ot1	54.4	53.8	53.9	53.7	0.6	-3.16	-0.08
CMS 5/Ot2	55.5	51.7	62.9	47.5	1.0	-2.77	2.21
CMS 5/Ot4	58.2	53.7	63.8	63.4	8.0	2.66	2.95
Sugar content, %							
CMS 1/Ot2	16.5	17.8	17.7	18.2	4.2	0.42	7.42
CMS 1/Ot4	16.6	17.2	17.7	16.8	2.8	-0.06	3.02
CMS 1/Ot5	16.5	18.1	17.2	17.5	3.8	0.19	6.15
CMS 2/Ot1	17.3	17.2	17.8	17.4	1.5	0.29	0.58
CMS 3/Ot1	17.3	17.8	16.5	17.8	3.5	0.22	1.02
CMS 3/Ot2	16.5	16.3	16.6	17.9	4.3	-0.31	2.28
CMS 3/Ot4	17.3	16.9	16.6	15.3	5.2	-0.61	-5.42
CMS 3/Ot5	17.8	17.2	17.6	16.4	3.6	0.12	-4.12
CMS 4/Ot5	17.5	17.2	16.5	16.6	2.9	-0.18	-3.54
CMS 5/Ot1	17.3	16.7	17.7	18.1	3.4	0.32	0.68
CMS 5/Ot2	16,4	17.7	17.3	17.6	3.4	0.12	6.12
CMS 5/Ot4	16.9	16.2	16.8	16.6	1.9	-0.51	-2.18
Sugar yield, t/ha							
CMS 1/Ot2	9.1	11.0	9.5	10.5	8.7	0.25	-0.23
CMS 1/Ot4	9.6	9.4	10.3	10.4	5.0	0.15	1.60
CMS 1/Ot5	9.6	10.6	11.1	10.9	6.0	0.70	1.92
CMS 2/Ot1	9.5	9.5	10.3	9.9	3.9	0.03	1.39
CMS 3/Ot1	9.7	9.8	10.1	10.5	3.6	0.25	0.92
CMS 3/Ot2	10.1	10.2	9.9	10.5	2.5	0.40	-0.17
CMS 3/Ot4	8.0	8.1	8.9	8.7	5.3	-1.35	1.61
CMS 3/Ot5	10.1	9.2	10.7	9.4	7.0	0.08	1,26
CMS 4/Ot5	10.1	10.5	9.3	96	5.4	0.10	-1.76
CMS 5/Ot1	9.3	9.0	9.5	9.7	3.2	-0.40	0.74
CMS 5/Ot2	9.1	9.1	10.9	8.3	11.8	-0.42	2.26
CMS 5/Ot4	9.9	8.7	10.7	10.5	9.0	0.18	2.46

Note: *LSD_{05} for yield -2.4 t/ha; HIP_{05} for sugar content - 0.4 % ; LSD_{05} for sugar yield – 1.5 t/ha.*

As table shows, breeding agro background EBNGS and EBEGS provided higher yield compared to NBNGS and NBEGS, on average by 0.5-1.8 t/ha. The maximum yield of these agro backgrounds ranged between 54.4-64.5 t/ha. The variation index of productivity within specific combinations was 0.6-12.0% and described each genotype response to changing environmental factors. High sensitivity to changing conditions showed CMS5/Ot2 and low - CMS5/Ot1.

On the ground of sugar content simple sterile hybrids had different response to an environment that is characterized by a specific reaction to certain breeding agro background. Thus, of 12 hybrids under study the best hybrids were CMS1/Ot2 (16.5 -18.2%) and CMS5/Ot1 (16.7-18.1%) with genotypic effect 0.42 0.32 %, respectively. Variation index ranged from 1.5 to 5.2% (absolute value of sugar content from 0.3 to 1.7%).

The relative change in response to abiotic factors gives sugar yield deviation, i.e. a difference between the largest and the smallest productivity against an agro background. The highest value has hybrid CMS1/Ot2 (1.9 t/ha), the lowest CMS3/Ot2 (0.6 t/ha). This means that hybrids, created with different CMS lines and same O-type showed contrasting responses to this factor, indicating that the response to fluctuations in agro background depends on the genotype of crossed forms and their interactions. Hybrids created with line CMS 1 and O-types 2, 4 and 5 showed deviation from 1.0 to 1.9 t/ha. Relative measure of variability is variation index, which varied from small to medium (2.5-11.8%).

In the breeding of hybrid components grounded on response to modifying factors prevail those samples, which have their genotypic effect positive; flexibility index is assessed depending on the desired model of a genotype: either flexible or stable. The Table shows that hybrids CMS1/Ot5, CMS1/Ot4 and CMS5/Ot4 combine high genotypic effect of sugar yield and high flexibility. The best among them is CMS1/Ot5 features the highest in the experiment genotypic effect (0.70 t/ha). They respond well to improve conditions and show high economic characteristics under intensive cultivation technology. Hybrids CMS1/Ot2 CMS3/Ot2 (genotypic effect 0.25 and 0.40 t/ha, respectively) with negative flexibility index (-0.23 and -0.17) are low sensitive to growing conditions, i.e. relative stable (tolerant) to abiotic factors; they will have an advantage when grown according to mid-cost technology. Hybrid CMS3/Ot1 with a high genotypic effect (0.25 t/ha) and flexibility index close to one (0.92), is predicted to conform to change its productivity in alternating growing conditions.

Conclusions. To evaluate the adaptability of hybrid components for sugar beet it is reasonable to use agro backgrounds, i.e. normal (enhanced) mineral fertilizing background and normal (extended)growing space, which help better identifying genetic determination of the productivity components and their response to changing environment. The most stable among Verkhniaky breeding lines are CMS 80/86 (for yield) and VDCMS-1 (for sugar content). In the phenotypic manifestations of productivity, the biggest share belongs to genotype-environment interactions (25.3%) and the actual environment (22.8%) with a significant contribution of CMS genotype and sterility maintainers. Selected were high-flexible hybrids significantly increasing sugar yield (CMS1/Ot5, CMS1/Ot4 and CMS5/Ot4) and stable ones (CMS1/Ot2, CMS3/Ot2 involved in further breeding process. To obtain stable sugar yield it is necessary to consider the rate of a hybrid reaction to regulated environmental factors associated with improved agro background.

References

1. Драгавцев В.А. Новый метод генетического анализа полигенных количественных признаков растений // В.А. Драгавцев // Идентифицированный генофонд растений и селекция: монография / отв. ред. Б.В. Ригин, Е.И. Гаевская ; Рос. акад. с.-х. наук, Гос. науч. центр Рос. Федерации, Всерос. науч.-исслед. институт растениеводства им. Н. И. Вавилова. – СПб.: ВИР, 2005. – С. 20-35.

2. Драгавцев В.А. Модель эколого-генетического контроля количественных признаков растений / В.А. Драгавцев, П.П. Литун, Н.М. Шкель // Доклады АН СССР. – 1984. – Т. 274. – № 3. – С. 720-723.

3. Драгавцев В.А. О путях создания теории селекции и технологий эколого-генетического повышения продуктивности и урожая растений / В.А.Драгавцев // Фактори експериментальної еволюції організмів: зб. наук. пр. / НАН України, НААН України, НАМН

України, Ін-т молек. біології і генетики НАН України, Укр. т-во генетиків і селекціонерів ім. М.І. Вавилова; редкол. : В.А. Кунах (гол. ред.) [та ін.]. – К.: Логос, 2013. – Т.13. – С. 38-41.

4. Вавилов Н.И. Генетика и селекция / Н.И.Вавилов // Избранные сочинения. – М.: Колос, 1966. – 529 с.

5. Роїк М.В. Генетична детермінація гетерозису за продуктивністю ЧС гібридіів цукрових буряків, створених за участю самонесумісних і самофертильних ліній-запилювачів / М.В. Роїк, М.О. Корнєєва // Фактори експериментальної еволюції організмів: зб. наук. пр. / НАН України, НААН України, НАМН України, Інститут молекулярної біології і генетики НАН України, Укр. т-во генетиків і селекціонерів ім. М.І. Вавилова; редкол.: В.А. Кунах (голов. ред.) [та ін.]. – К.: Аграрна наука, 2003. – С. 303-309.

6. Питиримова М.А. Норма реакции как мера адаптации генотипа к варьирующим условиям среды / М.А. Питиримова, М.В. Ткачев, Л.Б. Подошкина // Норма реакции растений и управление селекционным процессом : сб. науч. тр. ; [отв. ред. О. Г. Усьяров] / ВАСХНИЛ, Агрофиз. НИИ. – Л.: Астрофизический НИИ, 1982. – С. 38-44.

7. Базалій В.В. Обгрунтування еколого-генетичних основ адаптивної селекції озимої пшениці / В.В. Базалій // Вісник УТГіС. – 2005. – Т. 3, № 1-2. – С. 115-130.

8. Островерхов В.О. Сравнительная оценка экологической пластичности сортов сельскохозяйственных растений / В.О. Островерхов // Генетика количественных признаков сельскохозяйственных растений. – М.: Наука, 1976. – С.128-141.

9. Литун П.П. Взаимодействие генотип-среда и изменчивость растений / П.П. Литун // Взаимодействие генотип - среда у растений и его роль в селекции : сб. науч. тр. – Краснодар, 1988. – С. 49-60.

10. Савченко В.К. Генетический анализ в сетевых пробных скрещиваниях / В.К. Савченко. – Минск: Наука и техника, 1984. – 273 с.

11. Тарутина Л.А. Взаимодействие генов при гетерозисе / Л.А. Тарутина, Л.В. Хотылева. – Минск: Наука и техника, 1990. – 176 с.

12. Eberhart S. A. Stability parametres for comparing varieties / S.A. Eberhart, W.A. Rassel. // Crop. Sci. – 1966. – № 6. – P. 36-40.

Анотація

Корнєєва М.О., Ненька М.М, Вакуленко П.І.

Застосування селекційних агрофонів для оцінки адаптивності компонентів гібридів цукрових буряків

У статті йдеться про необхідність удосконалення оцінок селекційних номерів у селекції на адаптивну здатність на основі використання селекційних агрофонів із різним поєднанням фонів мінерального удобрення і площ живлення. Виявлено найбільш мінливі і стабільні до модифікуючих чинників довкілля компоненти гібридів. Встановлена структура фенотипового прояву продуктивності у простих стерильних гібридів цукрових буряків. Урахування мінливості комбінаційної здатності дозволить цілеспрямовано вести селекцію високопродуктивних гібридів із використанням можливих адаптивних ефектів, пов'язаних із впливом взаємодій генотип - середовище.

Ключові слова*: цукрові буряки, гібрид, селекційний агрофон, пластичність, стабільність, продуктивність*

Аннотация

Корнеева М.А., Ненька М.Н., Вакуленко П.И.

Использование селекционных агрофонов для оценки адаптивности компонентов гибридов сахарной свеклы

В статье обсуждается необходимость совершенствования оценок селекционных номеров в селекции на адаптационную способность на основе использования селекционных агрофонов с различным сочетанием фонов минерального удобрения и площадей питания. Выявлены наиболее изменчивые и стабильные компоненты гибридов. Установлена *структура фенотипического проявления продуктивности у простых стерильных гибридов сахарной свеклы. Учет изменчивости комбинационной способности позволит целенаправленно вести селекцию высокопродуктивных гибридов с использованием возможных адаптивных эффектов, связанных с влиянием взаимодействий генотип-среда*

Ключевые слова*: сахарная свекла, гибрид, селекционный агрофон, пластичность, стабильность, продуктивность*