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ПРОДУКТИВНОСТЬ ЗЕМЛЯНИКИ САДОВОЙ И СЕЛЕКЦИОННЫЕ ВОЗМОЖНОСТИ ЕЕ ПОВЫШЕНИЯ

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На основе литературных источников обобщены сведения о признаке продуктивности земляники садовой *Fragaria* × *ananassa* (Duchesne ex Weston) Duchesne ex Rozier. Признак продуктивности имеет сложный полигенный характер. Независимое наследование отдельных компонентов продуктивности позволяет моделировать оптимальное их сочетание в новом сорте. В основе создания высокопродуктивных сортов земляники садовой лежит внутривидовая гибридизация. Установленная положительная корреляция между размером ягод и урожаем свидетельствует о возможности повышения продуктивности сортов путем использования крупноплодных форм в селекции. На современном этапе в различных зонах садоводства исследователи выделяют крупноплодные сорта отечественной селекции: ‘Атлас’, ‘Берегиня’, ‘Витязь’, ‘Гренада’, ‘Забелинская’, ‘Кемия’, ‘Наше Подмосковье’, ‘Нелли’, ‘Первоклассница’, ‘Русич’, ‘Солнечная Полянка’, ‘Соловушка’, ‘Фестивальная Ромашка’, ‘Фруктовая’, ‘Царица’, ‘Японка’, и зарубежной селекции: ‘Alba’, ‘Asia’, ‘Elsanta’, ‘Finesse’, ‘Florense’, ‘Vivaldi’, ‘Galia’, ‘Jive’, ‘Joly’, ‘M. Champion’, ‘Merced’, ‘Murano’, ‘Onda’, ‘Roxana’, ‘Rumba’, ‘Tarda Vicoda’, ‘Vima Kimberly’, ‘Vima Tarda’, ‘Vima Rina’, ‘Vima Xima’. Отмечена возможность достижения гетерозисного эффекта по признаку продуктивности при использовании метода инбридинга в селекции. Метод генетических модификаций растений имеет большое значение для селекции сложных количественных признаков продуктивности, включающих урожайность. Расширение генетической базы земляники садовой за счет октоплоидных и полиплоидных форм диких видов обеспечит увеличение продуктивности новых сортов благодаря включению в генотип признаков адаптивности к биотическим и абиотическим факторам. Использование современных методов исследований (скрининг метаболомного и биохимического профиля, ДНК-паспортизация, молекулярное маркирование) повышает объективность исследований и эффективность селекционного процесса.

Ключевые слова: земляника, продуктивность, селекция, признак, сорт

PRODUCTIVITY OF GARDEN STRAWBERRY AND BREEDING POSSIBILITIES TO IMPROVE IT

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The information on the productivity trait of garden strawberry Fragaria × ananassa (Duchesne ex Weston) Duchesne ex Rozier has been summarized on the basis of literary sources. The productivity trait has a complex polygenic character. Independent inheritance of individual productivity components allows modeling their optimal combination in a new variety. The creation of highly productive varieties of strawberries is based on intraspecific hybridization. The established positive correlation between the size of berries and the yield indicates the possibility of increasing the productivity of varieties by using large-fruited forms in breeding. At present, in various zones of horticulture, researchers distinguish large-fruited varieties of domestic breeding: ‘Atlas’, ‘Bereginya’, ‘Vityaz’, ‘Grenada’, ‘Zabelinskaya’, ‘Kemiya’, ‘Nashe Podmoscovie’, ‘Nelly’, ‘Pervoklassnitsa’, ‘Rusich’, ‘Solnechnaya Polyanka’, ‘Solovushka’, ‘Festivalnaya Romashka’, ‘Fruktovaya’, ‘Tsaritsa’, ‘Yaponka’, and foreign breeding: ‘Alba’, ‘Asia’, ‘Elsanta’, ‘Finesse’,

‘Florense’, ‘Vivaldi’, ‘Galia’, ‘Jive’, ‘Joly’, ‘M. Champion’, ‘Merced’, ‘Murano’, ‘Onda’, ‘Roxana’, ‘Rumba’, ‘Tarda Vicoda’, ‘Vima Kimberly’, ‘Vima Tarda’, ‘Vima Rina’, ‘Vima Xima’. It was noted that when using the inbreeding method, it is possible to achieve a heterotic effect on the basis of the productivity trait. The method of genetic modifications of plants is of great importance for breeding of complex quantitative traits of productivity, including yield. Expansion of the genetic base of garden strawberry by means of octoploid and polyploid forms of wild species will ensure an increase in the productivity of new varieties due to the inclusion of traits of adaptability to biotic and abiotic factors in the genotype. The use of modern research methods (screening of the metabolomic and biochemical profile, DNA certification, molecular labeling) increases the objectivity of research and the efficiency of the breeding process.

Keywords: strawberry, productivity, breeding, trait, variety

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Garden strawberry is the most widespread berry crop in the world production. Its popularity is due to the high economic efficiency of cultivation, consumer demand, and the rich biochemical composition of fruits [1].

In 2019, 8.9 million tons of strawberries were produced in the world. The production leaders are China (3.21 million tons), the USA (1.02 million tons), Mexico (0.86 million tons), Turkey (0.47 million tons), Egypt (0.46 million tons). Russia ranks seventh in the world rating of producers - 0.21 million tonnes were produced in 2019[1].

The profitability of cultivation of garden strawberries is determined by the ratio of many factors, of which the most important at present is the yield [2].

The yield of a variety depends on the productivity potential inherent in the genotype, as well as on many external factors that affect its manifestation and the possibility of implementation in specific conditions [3, 4].

Increasing productivity in modern conditions is one of the main tasks of all breeding programs, regardless of the conditions of the zone for which the variety is being developed [5, 6].

The purpose of the research is to summarize information about the productivity trait in garden strawberries on the basis of domestic and foreign literary sources analysis to identify ways to increase the priority trait at the present stage of breeding development.

A sign of productivity, the components of productivity in garden strawberries. In biology productivity refers to the amount of biomass produced per unit of time[2]. Plant productivity in relation to agricultural fruit crops is the yield per plant[3]. Ultimately, the yield of the variety depends on the productivity - the amount of products obtained from a unit of area. The productivity of a plant is determined by its genotype and environmental conditions that influence the disclosure of the potential of a particular plant, variety [2, 3, 7]. The level of manifestation of the productivity trait in strawberry cultivars depends on the type of fruiting (short daylight cultivars, fall-bearing types, neutral day cultivars) and cultivation technologies (controlled conditions, open ground) [8–12].

The following components of productivity are distinguished in garden strawberry: the number of horns (shortened annual shoots), the number of peduncles, flowers, the number and weight of fruits

[1]FAO. FAOSTAT— Food and Agriculture Organization Corporate Statistical Database. [accessed May 13, 2021] URL: http: // www.fao.org/faostat/en/#data/QC (accessed May 13, 2021).

[2]Biological dictionary on-line //http://bioword.ru/B/B178.htm (accessed: 04/29/2021).

[3]Kudryavets R.P. Encyclopedic Dictionary of the Gardener / ed. I. M. Kulikov. Moscow: Ed. House of SMEs, 2007. 605 p.

per plant[4,5] [13]. Moreover, the components are specific for each variety. The number of fruits per plant and their average weight are of decisive importance [14]. Currently, varieties that are capable of producing 500–600 g of berries and more per bush are considered highly productive [15, 16].

With an optimal combination of productivity components, the number of flowers and ovaries on one peduncle is of great importance. Among the existing variety of the assortment, varieties with a large, medium and small number of flowers and ovaries on a peduncle stand out. Moreover, the more flowers and ovaries on one peduncle, the less the average weight of berries, as a rule. The number of peduncles per bush more than 10 in the second year of planting characterizes the variety as potentially highly productive [17, 18]. A large number of peduncles in strawberry plants can be caused both by the formation of many peduncles on a small number of horns, and by a large number of horns with several peduncles on each [19].

In most strawberry varieties, the first berry is much larger than the rest, which is a biological feature and is explained by the structure of the peduncle [20]. Considering the independent nature of the inheritance of individual components of productivity (the number of horns, the number of peduncles, the number of flowers and ovaries, the weight of the fruit), it is possible to identify donor forms of a high level of these traits (both individually and in combination) and include them in the breeding process as initial parent forms. In order to identify the optimal combination of productivity components in a new variety during the development of a breeding program, a model of the future variety is theoretically substantiated, which serves as the basis for subsequent selection in hybrid offspring[6] [21].

Selection of garden strawberry for high productivity. Among industrial berry crops, strawberry is one of the youngest domesticated plants [22]. The modern cultivated strawberry (Fragaria × ananassa) is the result of an accidental hybridization between Fragaria virginiana Mill. and Fragaria chiloensis (L.) Mill. in the 18th century. [23]. Interest in strawberries as an agricultural crop increased with the development of agricultural technologies, the processing industry, and the identification of the nutritional and dietary value of fruits. Professional researchers replaced amateur breeders from the beginning of the XX century. [24]. The high ecological plasticity of garden strawberry plants contributed to the rapid spread of the crop to various ecological-geographical zones and to the increased demand of producers for high-yielding varieties.

The creation of highly productive varieties of garden strawberry is based on the traditional method - intraspecific hybridization. The tasks of research in the implementation of breeding programs are to identify the mechanisms of inheritance of the studied traits, to develop methods for accelerating the breeding process and managing it. With the help of modern research methods, including biochemical, metabolomic analysis, genetic screening, DNA marking of traits, it was possible to significantly increase the objectivity of the assessment of both the initial material for selection and the resulting hybrid populations. The use of statistical methods for data analysis makes it possible to predict the breeding process and increase its efficiency. Attracting large-fruited varieties in the breeding process is the most frequently used method of increasing productivity in strawberries. The established positive correlation between the size of berries and productivity in garden strawberries indicates the possibility of breeding for high productivity by using large-fruited forms [25]. It is effective to cross large-fruited varieties with each other to increase large-fruitedness [26, 27]. Large-fruited varieties include varieties with an average berry weight of 9–12 g or more[7]. In the studies of V.I. Lapshin and V.V. Yakovenko [28], studying the coefficients of heritability h2 of the large-fruited trait for parental strawberry varieties, a high relationship between genotype and phenotype in the variability of the trait and pronounced additive genetic effects was established.

Such method of breeding for high productivity is inbreeding. However, this method has not found wide application due to the length and complexity of the process. At the same time, positive results were obtained - a heterotic effect was achieved in

[4]Zubov A.A. Genetic characteristics and selection of strawberries (guidelines). Michurinsk, 1990.81 p.

[5]A.A. Zubov, I.V. Popova Strawberry breeding. Program and methodology for breeding fruit, berry and nut crops / under the general editorship of E.N. Sedova. Oryol: VNIISPK; 1995.S. 387–416.

[6]Gorelikova O.A. Improvement of the assortment of garden strawberries for intensive cultivation technologies in the Krasnodar Territory: PhD in agriculture. Krasnodar: FGBNU SKZNIISVV; 2017.

[7]Shokaeva D.B., Zubov A.A. Wild strawberries, garden strawberries, zemklunika. Program and methodology for the variety study of fruit, berry and nut crops / under the general editorship of. E.N. Sedova, T.P. Ogoltsova. Oryol: VNIISPK, 1999.S. 417-443.

terms of productivity when crossing inbred seedlings (see footnote 4).

The rate of creation of new varieties of strawberries is quite high. Currently, there are about 15 thousand varieties, lines and forms in the world[8]. A comprehensive study of the genetic resources of the species Fragaria × ananassa has led to the fact that in recent years breeders have paid attention to the need to expand its genetic base [29]. In this regard, distant hybridization is of particular importance. Hybridization of pineapple strawberry varieties with forms of other octoploid species has the greatest effect [30].

At the present stage, instrumental research methods are widely integrated into selection. Molecular markers are actively used to identify DNA polymorphism, genetic diversity, and population structure of the germplasm set in Fragaria × ananassa [31]. Polygenic inheritance of economically valuable traits in Fragaria × ananassa (2n = 56) complicates the implementation of genetic control when planning breeding programs (see footnote 4). For selection based on characters with complex polygenic control, the method of genomic selection is effective, eliminating the need for many years of genetic research preceding the selection process [32].

Genetic modifications of plants, involving the insertion of genes for the transfer of certain traits that are not found in nature in a given species, are used for selection for resistance to abiotic and biotic factors. However, this technique currently has limited application for the selection of complex quantitative traits, which includes yield [33]. No high yielding varieties have been created by molecular methods alone [34].

The manifestation of potential productivity due to the genotype of the variety is significantly influenced by abiotic and biotic factors, technologies and methods of growing crops. In this regard, standards of high productivity are distinguished for various production zones. According to domestic researchers, currently in the Krasnodar Territory the most productive varieties are: 'Nelly' (1725.8 g / bush); 'Vivaldi', 'Rumba', 'Joly', 'Jive' (1044.7 g / bush) [16]. High productivity in combination with large fruit, density of berry pulp and the amount of sugars in this zone of horticulture are found in the following varieties: 'Vima Tarda', 'Onda', 'Vima Xima', 'Florense', 'Tarda Vicoda', 'Galia', 'Kemiya' , 'Nelly' [6]. According to the results of the assessment of biological productivity, the following varieties are considered the most productive in the Oryol region: 'Alba' (346 g / bush), 'Asia' (435), 'Tsaritsa' (463), 'Solovushka' (959 g / bush) [13]. In the conditions of the Central Black Earth Region of the Russian Federation, varieties are distinguished for high productivity in combination with other economically valuable traits: 'Roxana' (up to 675 g / bush), 'Alba', 'Vima Kimberly', 'Elsanta' (up to 540), ' Vima Rina ',' Florence '(486-513 g / bush) [35]. For the Non-Chernozem zone, the following are distinguished as the most productive varieties: 'Bereginya' (690.9 g / bush), 'Our Podmoskovye' (527.0), 'Rusich' (501.8), 'Solovushka' (467.5), 'Vityaz' (437.6 g / bush) [36]. The most productive varieties in the forest-steppe conditions of the Altai Territory are: 'Zabelinskaya' (up to 580 g / bush), 'First-grader' (up to 769), 'Solnechnaya Polyanka' (up to 602), 'Festivalnaya Daisy' (up to 583 g / bush) [37]. In the conditions of the Kamchatka Territory, varieties with high productivity potential have been identified: 'Japanese', 'First-grader', 'Atlas', 'Fruit', 'Grenada' (308.0–869.4 g / bush) [38].

Scientists from Brazil, based on the results of studying nine new varieties, identified the most productive ones: 'Merced' (453–547 g / bush) and 'Camarosa' (434–537 g / bush) [39]. The new European variety 'Rendezvous' is capable of producing up to 1300 g of fruits per plant [40]. According to East Malling researchers, the following varieties are highly productive: 'Murano' (613 g / bush), 'M. Champion " (747), 'Finesse' (854 g / bush)[9].

The role of breeding in increasing the productivity of garden strawberries is obvious, since back in the 1980s. varieties with a yield of 250-350 g / bush ('Festivalnaya', 'Komsomolskaya Pravda', 'Zarya', 'Purple', 'Generous', 'Pennant', etc.) were classified as highly productive [10].

Independent inheritance of traits - productivity components - in garden strawberry allows selection according to the planned parameters of the combination of components.

[8]Global Conservation Strategy for Fragaria (Strawberry). Rye. K.E. Hummer. Scripta Horticulturae. 2008. URL: https://www.ishs.org/scripta-horticulturae/global-conservation-strategy-fragaria-strawberry.

[9]SF96a – East Malling Strawberry Breeding Club [E-resource]. – Annual report 2019-20.URL: https://ahdb.org.uk/sf-096a-east-malling-strawberry-breeding-club-emsbc.

[10]Yarkova K.T., Filosofova T.P., Zubov A.A., Rorova I.V., Konstantinova A.F., Kopan K.N., Kopan V.A., Kirtbaya E.K. Strawberry breeding. Program and methodology for breeding fruit, berry and nut crops / under the general editorship of G.A. Lobanov. Michurinsk: VNIIS, 1980. pp. 278–318.

Expansion of the genetic base of Fragaria × ananassa with the involvement of other octoploid species and polyploid forms of wild species provides a further increase in productivity in new varieties due to the realization of the potential due to the inclusion of traits of adaptability to biotic and abiotic factors in the genotype.

The widespread involvement of modern methods of studying the phenotype and genotype (screening of the metabolomic and biochemical profile, DNA certification, molecular labeling) contributes to increasing the objectivity of research and the efficiency of the breeding process.

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