Variability assessment of productivity traits and quality of berries in the genetic collection of garden strawberry (Fragaria ananassa Duch.) in the Orenburg region

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Abstract. Nowadays the study of the interrelation of the genotype of strawberry plants in garden and climatic conditions is extremely relevant. Due to the various systems of genetic control and the modifying effects of growing conditions on the manifestation of quantitative traits, there is the need to assess the genotypic variability of economically valuable features, focused on the identification of genotypes characterized by stability and adaptive qualities in growing conditions. The study examined 15 varieties of garden strawberries of domestic and foreign selection. The field experiments and surveys were carried out according to the Program generally accepted in the Russian Federation and methodology for the variety study of fruit, berry and nut crops. We studied such features as the number of peduncles (pcs/bush), number of berries (pcs/bush), average weight of berries (g), total and marketable yield (g/bush), sugar content in berries, soluble solids and ascorbic acid.

The purpose of this work was to assess the genotype-year interrelation in terms of the variability of productivity features and berry quality and to identify strawberry varieties with a stable genotype. As a result of two-way analysis of variance for the variety-year interrelation, the obtained values were 1.10-8.50 at standard Fst. - 1.24. Statistically important differences had indicators of productivity of a bush between the first and second clusters (t = 5.89 at p <0.01), the first and third (t = 15.83 at p <0.01), the second and third clusters (t = 8.13 at p <0.01), as well as the average berry weight between the first and third, second and third clusters (t = 15.50 and 6.99 at p <0.01, respectively). Significant differences in the value of the Euclidean distance were revealed for varieties Mishutka (54.5), Daryonka (54.5), Pervoklassnitsa (58) realizing their productivity potential in different years of cultivation.

1. Introduction

The creation and maintenance of collections is focused on the solution a whole range of fundamental and applied problems, including the systematics and taxonomy of plants [1, 2]. The authors Guevas et al. [3] and Wang et al. [4] in their scientific publications indicate that collections of agricultural plants are safely used for breeding varieties, cultivated plants and introduction.

The variety of garden strawberry Fragaria x ananassa Duch known as a berry crop well adapted to various soil and climatic conditions. At the same time, the number of varieties is indicated from 3 thousand [5] to 20 thousand [6] in various scientific sources. However, K. Hammer claims that the world collection of strawberries numbers is about 15 thousand samples including about 12 thousand varieties and 3 thousand elite hybrids [7].
Many researchers who studied this variety [6, 8] note that for the successful cultivation of garden strawberries, an important condition is a competent selection of varieties adapted to local cultivation conditions and cultivation technology. Genotype-environment interrelations often make it difficult to determine the best genotypes in a variety of growing conditions. The process of plant development formation, manifested by the normal reaction of the genotype to soil and climatic conditions, is different and changes according to the variety. Therefore, nowadays research works on the study of the reaction rate of strawberry varieties in various ecological and geographical conditions are relevant [9].

It is known from literary sources that if a variety preserves high stable productivity in one region, then it has a specific adaptation. At the same time, general adaptation means that the variety has high productivity in regions of different conditions and has an extensive growing area. The varieties of this type, weakly react to changes in the environment and preserve the main varietal characteristics, a stable yield with typical fruit quality, despite the deterioration of cultivation conditions [10].

Productive varieties are those characterized by the following components: large fruits, the number of peduncles of plant, the number of berries [11]. The main indicator of the quality of strawberries is the chemical composition expressed by the content of sugars, acids, dry substances and vitamins. The stability of the biochemical composition of berries reflects the adaptability of the variety with the coefficient of variation of their main indicators over the years not exceeding 30% [5].

The purpose of the study is to assess the genotype-year interrelation in terms of the variability of productivity features and quality of berries and to determine the varieties of garden strawberries with a stable genotype in the conditions of the Orenburg region.

2. Materials and methods
The research was carried out in 2018 - 2020 at the experimental site of the Orenburg branch of the Federal State Budgetary Scientific Institution of the Federal Research Center of Horticulture in soil and climatic conditions typical for the Orenburg region. The soil cover of the experimental site was relatively homogeneous, represented by ordinary black soil. The agricultural technology and production methods were those generally accepted for the Orenburg region. The climate was moderately continental, a sharp fluctuation in temperature during the day. The air in the months of summer warmed up to + 38-40°C, in winter it cooled down to -33-38 °C. Often at the beginning of winter there were severe frosts and the absence of snow, which negatively affected the over wintering of strawberry plants. The object of the study was 15 introduced strawberry varieties of various ecological and geographical origin such as Orlets, Rosinka, Polka, Studencheskaya, Bereginya, Osokoryanka, Tsaritsa, Honeoye, Troubadour, Pervoklassnitsa, Urozhanayaya TsGL, Mikhail, Daryonya, Kokinskaya Zarya, Zenga Zengana.

In the course of the cultivation varieties in collections, a planting scheme of 0.9x0.25 m was used in an irrigated site. The observations and counting were carried out according to the Program generally accepted in the Russian Federation and methodology for the variety study of fruit, berry and nut crops (1999). We studied the following features such as the number of peduncles (pcs/bush), the number of berries (pcs/bush), the average weight of a berry (g), the total and marketable yield (g/bush), the sugar content in berries (GOST 15113.6-77), soluble solids (GOST ISO 2173-2013), ascorbic acid (by high performance liquid chromatography, GOST 24556-89). For mathematical processing of experimental data on productivity components and biochemical parameters of strawberries, we used two-way analysis of variance without repetitions using the Microsoft Office Excel 10 analysis package, where A was the variety, B was the year. We also applied Ward cluster analysis and Euclidean distance using the Statistica software package 10.

3. Results and Discussion
In the conditions of the experimental site of 2018-2020 between the studied varieties, at a 5% significance level, the significant differences were revealed for all features. The results of two-way analysis of variance by the factor “sort”, the obtained F values were noted 2.02 - 140.2 with the standard value of Fisher's criterion Fst. 2.06; by factor “year” it was 2.57 - 13.2 at standard Fst. 3.34; by the interrelation grade-year it was 1.10-8.50 at standard Fst. 1.24. The realization of the characteristics of
productivity and quality of fruits of strawberry varieties, expressed by the norm of the genotype reaction to climatic conditions, is different and changes according to the variety. Consequently, the study of the reaction rate in different years of cultivation is presented as the next step in genetically determined stability and adaptability of the properties of strawberry varieties. The analysis of variance of strawberry varieties revealed that the influence of the genotype-variety is higher than the influence of the growing conditions of the year (Table 1). The genotype of the variety had the greatest influence on the maximum (97%) and average weight of berries (95.9%), productivity (92.2%), and the minimum influence on the content of sugars and ascorbic acid. The influence of the conditions of the growing year had the opposite effect on the same indicators.

Table 1. Interrelation of factors of variety and year according to the characteristics of garden strawberry

| Characteristics                  | Interrelation, % |
|----------------------------------|------------------|
|                                  | variety | year | error |
| Number of peduncles per bush     | 81,0     | 3,1  | 15,9  |
| Number of berries per bush       | 77,5     | 7,9  | 14,6  |
| Maximum berry weight             | 97,0     | 1,8  | 1,2   |
| Average weight of berries        | 95,9     | 1,6  | 2,4   |
| Productivity                     | 92,2     | 3,7  | 3,9   |
| Soluble solids                   | 55,4     | 22,2 | 22,4  |
| Sugars                           | 43,4     | 13,5 | 43,1  |
| Ascorbic acid                    | 43,9     | 11,2 | 44,9  |

Thus, our results comply with the research data of V.I. Lapshin et al. (2019) who found that the contribution of the genotype of the variety is maximally manifested in the average weight and productivity and the total yield does not depend on the year of cultivation and the interrelation between variety and year.

According to the obtained average annual values of eight characteristics (the number of berries, the average weight of berries, the maximum weight of berries, the number of peduncles, productivity, the content of sugars, soluble solids and ascorbic acid) we compiled an informative complex of features for each of the varieties recorded in different years, analyzed using cluster analysis by Ward's method (Fig. 1). This method of clustering provided the grouping of objects according to the criterion of the maximum intergroup and minimum intraspecific dispersion. As a consequence, this approach will make it possible to identify the most distinct groups of varieties. The cluster results show (fix) that at the level of 40 relative units there are three groups of varieties (6 varieties in the first, 23 in the second and 16 in the third). The average values of the characteristics for each of the selected groups of varieties are shown in Table 2.
Figure 1. Cluster analysis of strawberry varieties
From 1 to 15 varieties of strawberries (2018): 1. Zenga Zengana, 2. Orlets, 3. Rosinka, 4. Polka, 5. Studencheskaya, 6. Bereginya, 7. Osokoryanka, 8. Tsaritsa, 9. Honeoye, 10. Troubadour, 11. Pervoklassnitsa, 12. Urozhaynaya TsGL, 13. Mishutka, 14. Daryonka, 15. Kokinskaya Zarya; from 16 to 30 varieties (2019): 16. Zenga Zengana, 17. Orlets, 18. Rosinka, 19. Polka, 20. Studencheskaya, 21. Bereginya, 22. Osokoryanka, 23. Tsaritsa, 24. Honeoye, 25. Troubadour, 26. Pervoklassnitsa, 27. Yield CGL, 28. Mishutka, 29. Daryonka, 30. Kokinskaya dawn; from 31 to 45 grades (2020): 31. Zenga Zengana, 32. Orlets, 33. Rosinka, 34. Polka, 35. Studencheskaya, 36. Bereginya, 37. Osokoryanka, 38. Tsaritsa, 39. Honeoye, 40. Troubadour, 41. Pervoklassnitsa, 42. Urozhaynaya TsGL, 43. Mishutka, 44. Daryonka, 45. Kokinskaya zarya.

Table 2. Average values of characteristics for each group of garden strawberry varieties

| Characteristics         | Cluster 1 | Cluster 2 | Cluster 3 |
|-------------------------|-----------|-----------|-----------|
| Number of peduncles per bush | 5,1727    | 4,365     | 4,1143    |
| Number of berries per bush | 27,0909   | 25,43     | 22,7286   |
| Average weight of berries | 13,1      | 10,87     | 9,5214    |
| Maximum weight of berries | 28,1818   | 25,175    | 21,6929   |
| Productivity          | 354,1664  | 275,729   | 216,0636  |
| Soluble solids        | 10,06667  | 9,93684   | 9,46364   |
| Sugars                | 7,05333   | 6,83158   | 7,00909   |
| Ascorbic acid         | 42,44     | 50,36842  | 56,9      |

The average values of the characteristics in different clusters were subjected to pairwise comparison using the Student test. It was found that the values of ascorbic acid did not have statistically significant differences between the clusters, as well as the content of sugars and soluble solids between the second and third clusters. The number of berries per bush differed between the first and third clusters (t = 4.45 at p <0.01), between the second and third clusters (t = 3.85 at p <0.01). The number of peduncles differed between the first and second, first and third clusters (t = 5.16 and 9.10, with p <0.01, respectively).

Statistically significant differences had productivity indicator of a bush between the first and second clusters (t = 5.89 at p <0.01), the first and third (t = 15.83 at p <0.01), the second and third clusters (t = 8.13 at p <0.01), as well as the average berry weight between the first and third, second and third clusters (t = 15.50 and 6.99 at p <0.01, respectively). The first cluster included the varieties of garden
strawberries with the highest productivity: Tsaritsa 385.0 - 348.48 g per bush and Bereginya 378.08 - 354.9 g per bush (Table 3).

| Variety (year) | 1  | 2  | 3  | 4  | 5  | 6  | 7  |
|----------------|----|----|----|----|----|----|----|
| Zenga Zengana (a) | 4.9* | 25.6* | 9.2 | 235.52* | 8.9 | 6.3 | 55.2* |
| Zenga Zengana (b) | 4.6 | 24.6 | 8.9 | 218.94 | 10.2 | 6.9 | 46.8 |
| Zenga Zengana (c) | 4.3 | 22.5 | 9.0 | 202.5 | 7.3 | 6.5 | 55.2* |
| Orlets (a) | 4.4 | 23.7* | 9.0 | 213.3* | 9.3 | 6.3 | 53.1 |
| Orlets (b) | 4.0 | 21.7 | 8.7 | 188.79 | 9.1 | 6.2 | 53.3 |
| Orlets (c) | 3.5 | 19.5 | 9.1 | 177.45 | 8.6 | 6.8 | 49.8 |
| Rosinka (a) | 3.9 | 26.3 | 9.4 | 247.22 | 11.2 | 6.0 | 53.8* |
| Rosinka (b) | 4.2* | 27.7* | 9.4 | 260.38* | 12.1 | 8.3 | 45.7 |
| Rosinka (c) | 3.9 | 24.3 | 9.0 | 218.7 | 11.3 | 8.0 | 43.6 |
| Polka (a) | 5.2 | 27.4 | 10.7 | 293.18 | 11.9 | 6.7 | 52.4 |
| Polka (b) | 5.6* | 29.3* | 11.2 | 328.16* | 13.3 | 9.1 | 52.4 |
| Polka (c) | 5.3 | 26.7 | 10.4 | 277.68 | 9.6 | 8.1 | 55.6* |
| Studencheskaya (a) | 4.6 | 22.8 | 11.0 | 250.8 | 10.9 | 6.2 | 50.7 |
| Studencheskaya (b) | 5.0* | 25.9* | 11.7 | 303.03* | 12.9 | 8.8 | 51.8* |
| Studencheskaya (c) | 4.1 | 21.2 | 10.3 | 218.36 | 12.1 | 8.2 | 49.1 |
| Bereginya (a) | 5.7 | 27.2 | 13.5 | 367.2 | 11.2 | 7.7 | 65.5* |
| Bereginya (b) | 6.1* | 27.8* | 13.6 | 378.08* | 12.6 | 8.6 | 58.1* |
| Bereginya (c) | 5.4 | 27.3 | 13.0 | 354.9 | 12.3 | 6.5 | 54.5 |
| Osokoryanka (a) | 3.8 | 22.8 | 10.0 | 228.0 | 9.2 | 7.9 | 59.2* |
| Osokoryanka (b) | 4.5* | 25.8* | 10.3 | 265.74* | 11.3 | 7.7 | 52.9 |
| Osokoryanka (c) | 4.2 | 24.4 | 9.8 | 239.12 | 9.1 | 6.4 | 49.6 |
| Tsaritsa (a) | 5.6 | 26.9 | 13.7 | 368.53 | 8.7 | 7.1 | 43.5 |
| Tsaritsa (b) | 5.9* | 29.0* | 13.3 | 385.7* | 9.0 | 6.7 | 47.3 |
| Tsaritsa (c) | 5.2 | 26.4 | 13.2 | 348.48 | 8.9 | 6.9 | 54.3* |
| Honeoye (a) | 3.8 | 22.7 | 9.9 | 224.73 | 8.3 | 7.4 | 56.3 |
| Honeoye (b) | 4.1 | 23.3 | 10.0 | 233.0* | 9.7 | 6.6 | 47.2 |
| Honeoye (c) | 3.9 | 21.7 | 9.6 | 208.32 | 8.0 | 6.3 | 50.1 |
| Troubadour (a) | 4.2 | 23.2* | 10.9 | 252.88 | 9.8 | 6.6 | 60.7* |
| Troubadour (b) | 4.4* | 21.7 | 11.7 | 253.89* | 10.1 | 7.0 | 55.7 |
| Troubadour (c) | 3.6 | 20.2 | 10.8 | 218.16 | 6.8 | 7.1 | 52.7 |
| Pervoklassnitsa (a) | 4.3 | 25.9 | 13.3 | 344.47 | 8.5 | 6.1 | 63.1 |
| Pervoklassnitsa (b) | 4.5* | 27.4* | 13.8 | 357.42* | 7.9 | 6.7 | 52.9 |
| Pervoklassnitsa (c) | 3.9 | 25.9 | 13.3 | 344.47 | 8.9 | 6.1 | 56.9 |
| Urozhaynaya TsGL(a) | 3.7 | 24.9 | 10.6 | 263.94 | 9.0 | 6.4 | 60.3* |
| Urozhaynaya TsGL (b) | 3.7 | 25.9* | 10.6 | 274.54* | 9.5 | 6.7 | 54.3 |
| Urozhaynaya TsGL (c) | 4.4* | 24.9 | 10.6 | 263.94 | 7.0 | 6.9 | 53.1 |
| Mishutka (a) | 3.6 | 22.9 | 11.4 | 271.70 | 11.2 | 8.3 | 46.1 |
| Mishutka (b) | 3.9 | 24.8 | 11.4 | 280.72 | 12.1 | 8.0 | 47.2 |
| Mishutka (c) | 4.6* | 25.8* | 11.4 | 282.72* | 10.4 | 7.8 | 47.1 |
| Daryonka (a) | 4.1 | 25.7 | 11.8 | 307.98 | 10.6 | 7.2 | 46.2 |
| Daryonka (b) | 4.7* | 26.1 | 12.2 | 318.42 | 10.3 | 7.2 | 46.6 |
| Daryonka (c) | 4.4 | 26.8* | 11.8 | 327.98* | 10.0 | 6.9 | 54.3* |
| Kokinskaya zarya(a) | 4.2 | 26.2 | 10.9 | 277.72 | 11.9 | 6.9 | 57.7* |
| Kokinskaya zarya (b) | 4.5 | 26.2 | 10.9 | 285.58 | 11.9 | 7.7 | 49.2 |
| Kokinskaya zarya (c) | 5.2* | 27.7* | 10.6 | 288.72* | 9.2 | 6.3 | 52.6 |

a – 2018, b – 2019, c – 2020,
1 - number of peduncles, 2 - number of berries per bush, 3 - average weight of berries, 4 - productivity of a bush, 5 - content of soluble solids, 6 - content of sugars, 7 - content of ascorbic acid.

The varieties included in the second cluster had an average productivity: Daryonka (2019-2020) with 305.08 - 318.42 g per bush, Pervoklassnitsa (2018, 2020) with 344.47 g per bush, Kokinskaya zarya (2020) with 328.16 g per bush, Studencheskaya (2019) with 303.03 g per bush.

The lowest productivity was shown by the varieties from the third cluster: Orlets (2018-2020) 177.45 - 213.3 g per bush, Zenga Zengana (2020) 202.5 - 218.94 (2019) g per bush, Honeoye (2020) - 208.32 g per bush, Rosinka (2020) - 218.7 g per bush, Studencheskaya (2020) - 218.36 g per bush.

The results indicate that the Tsaritsa and Bereginya varieties were giving high productivity for three years, while the Orlets and Zenga Zengana varieties were consistently low. At the same time, in 2020, the varieties Studencheskaya, Honeoye, Rosinka did not have a high yield. Perhaps they could not fully realize their potential due to climatic conditions.

One of the ways to assess the genotypic differences of varieties grown in different years is to measure the Euclidean distance between them based on the results of the cluster analysis. Consequently, the cluster analysis is carried out taking into account the Euclidean distances between objects. This value can be used to assess the potential genetically determined differences between varieties. The difference between varieties depends on the level of the contribution of this interrelation to the total variability. According to the calculation data of this algorithm, we obtained the following Euclidean distances: in terms of productivity between the first and second clusters, the first and the third was 78.43 and 138.103, respectively. At the same time, for the varieties in different years of cultivation, the following Euclidean distance in ascending order was found: Zenga Zengana and Orlets - 45, Polka and Studencheskaya - 48.5, Honeoye - 48.8, Osokoryanka - 49.7, Rosinka and Troubadour - 50.5, Kokinskaya zarya - 51.0, Bereginya - 52, Tsaritsa and Urozhaynaya TsGL - 53, Mishutka and Daryonka - 54.5, Pervoklassnitsa - 58.

More significant differences were found in the varieties Bereginya, Tsaritsa, Urozhaynaya TsGL, Mishutka, Daryonka, Pervoklassnitsa, realizing their productivity potential in different years of cultivation. On the contrary, the Euclidean distances were not significant for the varieties Zenga Zengana, Orlets, Polka, Studencheskaya, Honeoye, Osokoryanka.

The study of strawberry varieties shows that they are characterized by different productivity traits and berry quality. Analyzing the obtained data, on average for three years for 15 varieties of strawberries, the number of peduncles per bush was 4.55 pcs., and the coefficient of variation (hereinafter V) was 16.64, the number of berries per bush was 24.65 pcs. (V = 10.766), average fruit weight was 10.64 g (V = 14.76), productivity per bush was 263.244 g (V = 22.3).

The authors C.H. Fredericks et al. in their work indicated that strawberry varieties should have a dry matter content of at least 12%, sugars at least 8%, acids not more than 3%, and vitamin C at least 80 mg% [12]. Stolnikova N.P. et al. stated that varieties with ascorbic acid content of at least 60 mg% were medium-vitamin and those above 80 mg% were high-vitamin [13].

Thus, analyzing the results of our research, it is necessary to note that the following varieties met the content of soluble solids in strawberries, according to the requirements for varieties by the aforementioned authors: Polka (13.3 - 11.9%) Rosinka (12.1 - 11.2%), Studencheskaya (12.9 -12.1%), Bereginya (12.6-12.3%) depending on the year.

The assessment of the accumulation of sugar content in strawberries in the conditions of the Orenburg region varied from 6.0-9.1% in different years of cultivation. According to laboratory data, the highest content of ascorbic acid was in varieties: Bereginya (65.5 mg%), Pervoklassnitsa (63.1 mg%), Troubadour (60.7 mg%), Urozhaynaya TsGL (60.3 mg%).

Thus, during the identification of promising strawberry varieties for cultivation in the Orenburg region, it is initially recommended for scientific institutions to use cluster analysis based on an informative complex of characteristics with the calculation of Euclidean distances between varieties grown in different years.
4. Conclusion
During the research we studied the dependence of the norm of the genotype reaction and the year on the complex of economically valuable traits that determine the productivity and quality of garden strawberry varieties grown in the Orenburg region, taking into account their stability. It was found that the genotype of the variety had the greatest influence on the maximum (97%) and average weight of berries (95.9%), productivity (92.2%), and the minimum influence on the content of sugars and ascorbic acid. In addition, we found that the number of peduncles and berries of a bush, productivity and average weight of a berry had a high close correlation.

Thus, the results showed that more significant differences in Euclidean distances were found in the varieties Bereginya, Tsaritsa, Urozhaynaya TsGL, Daryonka, Pervoklassnitsa, which realized their productivity potential in different years of cultivation. On the contrary, the Euclidean distances were not significant in the varieties Zenga Zengana, Orlets, Studencheskaya, Honeoye, Osokoryanka. Therefore, the varieties (Bereginya, Tsaritsa, Urozhaynaya TsGL, Mishutka, Daryonka, Pervoklassnitsa) were of interest both for cultivation in the Orenburg region and for their further use in selection.

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