Identification of rare quantitative traits of leaf and a flower in *Rosa L.* and analysis of correlations

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**Abstract.** The article examines the quantitative traits of leaves and flowers in 49 varieties of roses from the collection of the Tsytsin Main Moscow Botanical Garden of Academy of Sciences. The method for determining the coefficients of originality of Smirnov made it possible to identify unique and typical gradations of traits that are important for directional selection. The varieties Snowflake, Peer Gynt, Akito Blushing, Mainzer Fastnacht, Heidelberg, Troika are the most original in terms of their complex of characteristics. Pearson’s method of correlation analysis showed positive relationships between leaf traits.

1. **Introduction**

Representatives of the genus *Rosa L.* are demand in landscape design and in floral design [1-2]. Professional exhibitions are held annually with the presentation of original varieties [3-5]. But in the concept of an original variety or an original gradation of a trait there is a high proportion of subjectivity. Therefore, the use of mathematical methods to assess originality is relevant and significant to study plant biodiversity. Information on the frequency of manifestation of a trait is of great importance for assessing plant introduction, directional breeding and making recommendations for the use of plants. An important point, traits can have a direct or inverse relationship with an undesirable trait, and this can partly be tracked by determining the correlation coefficients [6-11].

The purpose of the study is to identify rare gradations of quantitative traits, to determine relationships between traits and to identify varieties that are carriers of unique manifestation of quantitative traits of a leaf and a flower.

2. **Materials and methods**

The collection of material was carried out in the rose garden of the Tsytsin Main Moscow Botanical Garden of Academy of Sciences in the period from 2008 to 2018. All plants are grown in the same soil and climatic conditions using the same cultivation technique.

The objects for the study were 49 varieties of roses, which belong to the following groups according to the international classification:

- Floribunda - varieties Pomponella, Scentimental, Bailando, Leonardo de Vinci, Berstein Rose, Midsummer, Mona Lisa, Botticelli, Hansestadt Rostock, Isberg, Marie curie, Kosmos, Betty Boop, Gartenspass, Mind Games, Petit Trianon, Blauwestad, Stadt Eltvile, Lions Rose, Queen of Hearts, Grimaldi, Domstadt Fulda, Krasnyy Krym, Deep Impression, Rotilia, Gebruder Grimm, Absent Friends, Allgold, Rosemaru Harkness.
Hybrid Kordesii – varietie Heidelberg;
Hybrid Wichurana - varietie New Dawn;
Spray - varieties Ruby Star и Snowflake;
Florists Rose - varieties Akito, Akito Blushing, Wow, Carina;
Hybrid Tea - varieties Mainzer Fastnacht, Troika, Ambassador, Nostalgia, Peer Gynt
Hybrid Rugosa - varieties Robusta, Purple Roadrunner, Romantic Roadrunner, Pink Robusta, Martin Frobisher, Grootendorst Supreme, Parsla.

The quantitative traits of the leaf and flowers were studied according to the established method [12]. The calculation of the coefficients of originality was carried out according to quantitative traits, which are listed in table 1. Previously, we conducted a statistical analysis of the sample and proved the normal distribution for each quantitative trait, and then divided it into classes to determine the gradations of the trait [13].

Previously, all the initial data were unified into a digitized (1/0) nominal scale for calculating the originality coefficient [13]. The weights of the gradations were determined by the frequency of their presence. The calculation was made according to the following formulas:

\[
w_k^+ = \frac{N - n_k}{n_k} \quad (1)
\]

\[
w_k^- = \frac{n_k}{N - n_k} \quad (2)
\]

Where \(w_k^+\) - weight of presence of the k-th grade; \(w_k^-\) - weight of the absence of the k-th grade, \(N\) – total number of objects; \(n_k\) – the number of objects that have the k-th modality.

3. Results
The analysis of the values of the weights made it possible to identify rare, therefore significant gradations of traits that are important for breeding work. They are shown in bold in table 1.

Table 1. The weights of modalities of traits based on their presence and absence in *Rosa L.*

| Trait name                      | Modality name | Number of varieties, pcs | Weight by presence | Weight by absence |
|---------------------------------|---------------|--------------------------|--------------------|-------------------|
| 64.3-104.0                      | 5             | **8.80**                 | 0.11               |
| 104.1-145.0                     | 27            | 0.81                     | 1.23               |
| 145.1-186.3                     | 17            | 1.88                     | 0.53               |
| 3                               | 1             | **48.00**                | 0.02               |
| Number of leaves on a plant leaf, mm |                |                          |                    |
| 37.7-50.7                       | 12            | 3.08                     | 0.32               |
| 5                               | 31            | 0.58                     | 1.72               |
| 7                               | 14            | 2.50                     | 0.40               |
| 9                               | 3             | **15.33**                | 0.07               |
| 50.8-63.8                       | 26            | 0.88                     | 1.13               |
| 63.9-76.3                       | 11            | 3.45                     | 0.29               |
| 19.7-31.3                       | 11            | 3.45                     | 0.29               |
| Maximum apical leaf width, mm   |                |                          |                    |
| 31.4-43.0                       | 28            | 0.75                     | 1.33               |
| 43.1-54.3                       | 10            | 3.90                     | 0.26               |
| 29.3-39.9                       | 9             | **4.44**                 | 0.23               |
| Lateral leaf length, mm         |                |                          |                    |
| 40.0-50.6                       | 24            | 1.04                     | 0.96               |
| 50.7-61.6                       | 16            | 2.06                     | 0.48               |
| Lateral leaf width, mm          |                |                          |                    |
| 18.3-27.3                       | 16            | 2.06                     | 0.48               |
| 27.4-36.4                       | 25            | 0.96                     | 1.04               |
The calculation of Pearson’s correlation coefficients showed the presence of a strong positive correlation between the characteristics of the leaf. The traits of a flower are partly related to each other by weak positive bonds. Figure 1 shows only reliable correlations.

4. Discussion
The analysis of gradations of traits and varieties (table 1) showed the following:

- Plant leaf length, mm – most often, the varieties have medium and long leaf lengths, a unique gradation is interval 64.3-104.0 mm (weight by presence = 8.8) for varieties Allgold, Mainzer Fastnacht, Troika, Peer Gynt, Heidelberg. The total range of variation is from 64.3 to 186.3 mm;
- Number of leaves on a plant leaf, mm (total interval from 3 to 9 leaves) – 3 pieces (grading weight = 48) were noted for the Snowflake, 9 pieces (weight =15.33) – for Purple Roadrunner, Romantic Roadrunner, Martin Frobisher;
- Length and maximum width of the apical leaflet, mm – traits without unique modalities;
- Lateral leaf length (29.3-61.6 mm) – the interval 29.3-39.9 mm is the smallest of all in size and in the number of varieties with this modality (weight =4.44). These include Absent Friends, Allgold, Rosemaru Harkness, Troika, Carina, Ruby Star, Heidelberg, New Dawn, Martin Frobisher;
• Lateral leaf width, mm (18.3-45.3 mm) – the interval 36.5-45.3 mm (weight=5.13) is the largest of all in size, but only 8 varieties have this modality (Scentimental, Berstein Rose, Blauwestad, Mainzer Fastnacht, Peer Gynt, Wow, Robusta, Pink Robusta);

• Petiole length to first leaflet 21.0-46.0 mm – this is shortest length recorded in only three varieties - Mainzer Fastnacht, Peer Gynt, Heidelberg. The general limits of variation are from 21.0 to 123.3 mm;

• Leaves petiole length (1.0-4.7 mm) – the rarest modality (weight =23.5) is an interval of 3.6-4.7 mm, it is found only in Peer Gynt and Akito Blushing;

• Stipules length in the interval of 2.3-10.3 mm (weight=11.5) occurs in Mainzer Fastnacht, Troika, Akito Blushing, Carina varieties. The total range of variation is from 2.3 to 26.7 mm;

• Number of buds at the end of the shoot (from 1 to 30 pcs) – 19-30 buds are extremely rare (modality weight 23.5). This indicator was observed only in Rotilia and Snowflake varieties;

• Corolla diameter (from 11.7 to 113.3 mm overall range) – very small size (11.7-36.7 mm) found in 5 varieties (weight =8.8), such as Akito Blushing, Carina, Ruby Star, Snowflake, Grootendorst Supreme, small size (36.8-61.8 mm) was found in six varieties (weight 7.17) – Pomponella, Bailando, Rotilia, Absent Friends, Akito, Robusta;

• Flower height (from 14.0 to 63.7 mm) – only 6 of 49 varieties have a large flower height (46.2-63.7 mm, weight =7.17), such as Kosmos, Rosemaru Harkness, Mainzer Fastnacht, Nostalgia, Wow, Pink Robusta;

• The number of petals (from 5 to 113 pcs) – the highest indicator is in the interval of 89-113 pcs, it is also the rarest (weight = 15.33). The varieties Bailando, Queen of Hearts, Deep Impression possess such an abundant number of petals;

• The number of stamens (from 24 to 183 pcs) – this trait has unique extreme modalities with the smallest (24-64 pcs, weight =7.17) and largest number (147-183 pcs, weight = 8.8) of stamens. The first group includes the varieties Bailando, Midsummer, Akito, Akito Blushing, Ruby Star, Snowflake, the second – Kosmos, Mind Games, Petit Trianon, Lions Rose, Grootendorst Supreme.

Correlation analysis was performed to check for the presence of related traits. Its results are shown in figure 1. The bold solid line indicates that there are strong positive correlations between the plant leaf length, apical leaf length, maximum apical leaf width, lateral leaf length and width, petiole length to first leaflet. The long dashed line shows the negative average relationship between the number of leaves on a plant leaf and maximum apical leaf width, as well as between the number of buds at the end of the shoot and corolla diameter. The length of the stipules and the number of petals no connection with any signs and are independent pleiades.

5. Conclusion

Rare and unique gradations of leaf traits are the leaf length 64.3-104.0 mm, the number of leaves on a plant leaf is equal to three, the lateral leaf length is 29.3-39.9 mm, the lateral leaf width is 36.5-45.3 mm, the petiole length to first leaflet is 21.0-46.0 mm, the leaves petiole length is 3.6-4.7 mm, the stipules length in the interval of 2.3-10.3 mm.

Gradations of flower traits that gained the greatest weight – the number of buds at the end of the shoot 19-30 pcs, the diameter of the corolla 11.7-36.7 mm, the height of flower 46.2-63.7 mm, the number of stamens 147-183 pcs.

Snowflake is the most original variety in terms of a complex of quantitative traits, as well as separately for leaf and flower traits. Representative of the Spray group. It has small leaves (64.3-104 mm), there are only 3 leaves in a composite leaf. The width of the apical leaflet is included in the maximum length interval – 43.1-54.3 mm, and the of the lateral ones – in the smallest interval (18.3-27.3 mm). The length of the leaves is large – 3.6-4.7 mm, only 2 varieties from the sample have this trait. The length of stipules is the shortest in the sample – 2.3-10.3 mm, this trait is found in 4 varieties of the sample. The variety has an impressive number of buds at the end of the shoo – 19-30 pcs, this
trait is only in 2 varieties in the sample, while the flowers are the smallest of all (11.7-36.7 mm diameter of the corolla). On average, the number of stamens is 24-64 pcs, only 6 varieties in the sample have this modality.

![Diagram](image)

**Figure 1.** Correlogram of reliable bonds between traits, where strong positive correlation (r>0.7), mean positive correlation (0.5<r<0.6), weak positive correlation (r<0.4), weak negative correlation (r<0.4), 1- plant leaf length, mm, 2 - number of leaves on a plant leaf, mm, 3 - apical leaf length, mm, 4 - maximum apical leaf width, mm, 5 - lateral leaf length, mm, 6 - lateral leaf width, mm, 7 - petiole length to first leaflet, mm, 8 - leaves petiole length, mm, 9 - stipules length, mm, 10 - number of buds at the end of the shoot, pcs, 11 - corolla diameter, mm, 12 - flower height, mm, 13 - number of petals, pcs, 14 - number of stamens, pcs.

Owners of a complex of rare traits are Peer Gynt, Akito Blushing, Mainzer Fastnacht, Heidelberg, Troika. Rotilia has unique flower traits. Interesting varieties are Troika and Bailando. The first one has unique gradations of the leaf traits and completely typical flower, and the second, on the contrary.

The most typical representatives are Mona Lisa (Floribunda group), Betty Boop (Floribunda), Krasnyy Krym (Floribunda), Botticelli (Floribunda), Ambassador (Hybrid Tea), Parsla (Hybrid Rugosa).

For direct selection, it is important to know about strong positive correlation between the traits of plant leaf length, apical leaf length, maximum apical leaf width, lateral leaf length and width, petiole length to first leaflet. A negative mean relationship was found between the number of leaves on a plant leaf and maximum apical leaf width, as well as between the number of buds at the end of the shoot and corolla diameter. The length of the stipules and the number of petals no connection with any signs.

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