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STUDY OF THE ECOLOGICAL STABILITY OF SOME ESSENTIAL-OIL AND OILSEED TECHNICAL CROPS IN BULGARIA

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Abstract

In the present work, the "genotype-environment" interaction of the yields of essential oil and oilseed technical crops in Bulgaria is investigated and analyzed. Data are presented for a fourteen-year period related to yields of: rose, lavender, mint, coriander, valerian and lemon balm, sunflower, canola, soybeans, peanuts, pumpkins. It was established that among the essential oil crops with the highest yields is mint (9250 kg/ha), and with minimum yields – coriander (914.3 kg/ha). Mint proves to be the crop with the greatest degree of susceptibility to environmental factors in terms of yields compared to other crops of this group. Among the oilseed technical crops, rapeseed has the highest, but unstable, yields (2063.8 kg/ha). Pumpkins for seeds are the lowest (662.9 kg/ha). The most resistant to external factors are sunflowers and pumpkins, which makes them a preferred crop for cultivation in regions with changing climatic conditions.

Key words: *ecological valence, essential oil crops, one-way analysis of variance, technical oil crops.*

INTRODUCTION

The broad application of essential oil and technical crops determines the interest of scientists in research in this field. Their importance for people's quality of life is profound. On the one hand, this necessitates an increase in the quantity and quality of their production, both nationally and globally. On the other hand, the less sensitive they are to environmental conditions, the more stable their yields will be. This will make them an attractive crop for farmers to grow.

Some essential oil crops are trees or shrubs, others are herbaceous plants. Oilseed industrial crops are grown for seed or fruit. They are distinguished by their high fat content. The oils extracted from them have a wide range of uses in the pharmaceutical industry, perfumery, as well as for human and animal food.

Research has been done in the field of application of essential oils for medicinal purposes (Asamenew et al., 2017; Jerbi et al., 2017; Raut and Karuppayil, 2014).

Ahmadi-Dastgerdi et al. (2017) studied the antimicrobial and antioxidant properties of essential oils by dispersion analysis. They proved that the essential oil extracted from the flower has a stronger effect than that extracted from the leaves. Fejer et al. (2018) obtained sterile mint cultures. They studied their propagation and evaluated essential oil production under in vitro conditions.

Agroecosystems face enormous challenges with increased inter-annual weather variation due to climate change (Lobell & Gourdji, 2012). Higher weather variation is associated with higher frequency of abnormal heat, flood, and drought events (Hatfield et al., 2011). Weather variation explains approximately one-third of the variation observed in crop yield (Ray et al., 2015).

Different aspects of climate variability-temperature, precipitation, and the interaction of the two-may affect crop growth and resultant productivity disproportionately. Therefore, enhancing the stability of crop production under a changing climate becomes vital for agricultural sustainability (Liu et al., 2019).

Ecological valence is an important indicator to study the resistance of a plant to environmental changes. A number of methods have been developed to assess it (Wricke, 1962; 1966; Dorogova et al., 2016).

Resistance to stress factors is of great natural and ecological importance, since the ability of plants to adapt to the conditions of existence is one of the factors that determines the range of distribution of species and cultures (Tyshchenko et al., 2023). In this regard, there is a growing need for an accurate assessment of the adaptive potential of plants, which is impossible without studying the physiological bases of their resistance and developing agrotechnical, selection-genetic, and genetic engineering methods for increasing the resistance of cultivated plants to abiotic stresses using new fundamental knowledge about the mechanisms of resistance.

In plant breeding program yield stability is an important feature to measure consistency in relative performance of genotypes across a wide range of environments. The relative performances of genotypes for quantitative traits i.e. yield and other characters were influence from one environment to another (Fasahat et al., 2015).

The aim of the present study is to investigate the stability of the productive qualities of essential oil and oilseed crops in Bulgaria to changes in climate and soil characteristics by analyzing the genotype-environment interaction.

MATERIALS AND METHODS

The object of the study was the average yields of essential oil and oilseed crops on the territory of Bulgaria, based on data for the period 2003-2016.

A longer period of time in the study of the ecological sustainability of plants allows for more objective results. In this way, the effect of random events, such as extreme low or high temperatures, floods or other natural disasters, which are not characteristic of the respective territory or ecological features of the environment, is minimized.

Statistical data, undergoing mathematical processing, were obtained from the Department of Agricultural Statistics of the Ministry of Agriculture, Food and Forestry.

The plants were grouped into two groups. The first included those rich in essential oils: oil rose, lavender, mint, coriander, valerian and lemon balm. The second consists of: sunflower, rapeseed, soybean, peanut and pumpkin seeds, which are high in fat.

The aim of the author is to study the ecological stability of the above crops to changes in environmental factors and their degree of resistance and adaptability to different external conditions.

A one-way analysis of variance (ANOVA) and Duncan's multiple range test were applied to assess differences between yields of these crops. On the one hand, it was used to obtain a comparative estimate of the mean yields of each crop. On the other hand, the stability of the genotype-environment interaction was studied.

One-factor analysis of variance is based on an examination of between-group and within-group variance. A variance estimate based on the within-group deviation is calculated by:

$$SS_W = \sum_{j=1}^{c} \sum_{i=1}^{n_j} \left(X_{ij} - \bar{X}_J\right)^2$$

$$s_W^2 = \frac{\sum_{j=1}^{c} \sum_{i=1}^{n_j} \left(X_{ij} - \bar{X}_J\right)^2}{c(n-1)}$$

where:

- s_W^2 - estimation of sampling variance based on within-group deviation SS_B
- X_{ij} - i-th value of the indicator in the group j
- $\bar{X}_J$ - average mean of j-th group
- c - number of the groups
- n - number of the elements in the group

An estimate of the total variance based on the between-group deviation is calculated by:

$$s_{\bar{X}}^2 = \frac{\sum_{j=1}^{c} \left(\bar{X}_J - \bar{\bar{X}}\right)^2}{c-1}$$

$$s_B^2 = \frac{\sum_{j=1}^{c} \left(\bar{X}_J - \bar{\bar{X}}\right)^2 n_j}{c-1}$$

where:

- $s_{\bar{X}}^2$ - estimation of sampling variance based on between-group deviation
- s_B^2 - estimation of sampling variance
- $\bar{X}_J$ - average mean of group j
- $\bar{\bar{X}}$ - average mean of all values μ
- c - number of the groups
- n_j - number of the elements in j-th group.

After obtaining both estimates of the unknown variance, the ratio is calculated:

$$F = \frac{s_W^2}{s_B^2}.$$

The ecological coefficients were calculated using the algorithm of Wricke (1962; 1966).
Ecovalence (W_i^2), measure was also computed to further describe stability (Goa & Mohammed, 2013).
The ecovalence (W_i) or stability of the i-th genotype is its interaction with the environments, squared and summed across environments and expressed as:

$$W_i = \sum_{j=1}^{n} (Y_{ij} - \overline{Y_i} - \overline{Y_j} + Y)$$

where Y_{ij} is the mean performance of genotype i in the j-th environment and $\overline{Y_i}$ is the marginal mean of the i-th genotype and $\overline{Y_j}$ is the marginal mean of the j-th genotype and Y is the overall mean (Haile & Yilma, 2021). For this reason, genotypes with a low W_i value have smaller deviations from the mean across environments and thus more stable.
The studied crops were grouped according to similarity in their productive qualities and degree of stability through cluster analysis and principal component analysis.
There are some methods for applying hierarchical cluster analysis and various similarity measures. The coefficient of divergence was calculated, which provides information on the adequacy of the applied method.Clustering of the cultures was done by hierarchical cluster analysis using the method of between linkage and the similarity measure squared Euclidean distance by:

$$D(A,B) = \frac{1}{n_A n_B} \sum_{i=1}^{n_A} \sum_{j=1}^{n_B} d(x_i, x_j)$$

$$d(x_i, x_j) = \sum_{m=1}^{p} (x_{im} - x_{jm})^2, i, j = \overline{1,n}.$$

Computer processing was performed using the statistical software IBM Statistics SPSS 24 (Field, 2013, Weinberg and Abramowitz, 2016) and MS Excel (Mokreva et al., 2001).

RESULTS AND DISCUSSIONS

As a result of the applied one-way analysis of variance, statistically significant differences between the yields of both essential oil and oil-bearing industrial crops were proved (significance level less than the error $\alpha = 0.05$).
A similar result was obtained for the ecological stability of the respective yields.
It was shown that mint had the highest yield of the essential oil crops studied (9250 kg/ha) (Table 1). All other crops had yields that had no statistically proven differences. The lowest yields were obtained from coriander (914.3 kg/ha). The high values of the stability coefficients are due to the high yields of mint compared to other crops and the resulting high values of the corresponding differences and their squares, which are the basis of the algorithm for their calculation.

Table 1. Results of one-way analysis of variance of mean yields and ecological assessment of essential oil crops by one-way analysis of variance according to Duncan's test at significance level α = 0.05

Crops	Yield	W-Eco coefficient
Rose	2389.3^b	1634.05^b
Lavender	2251.4^b	20728.335^b
Mint	9250.0^a	409578.33^a
Coriander	914.3^b	14877.32^b
Valerian	2314.0^b	23210.343^b
Lemon balm	1818.5^b	19434.1^b

Given the diagram in Figure 1, mint should be considered to have the most unstable, although maximum, average yield over the study period.

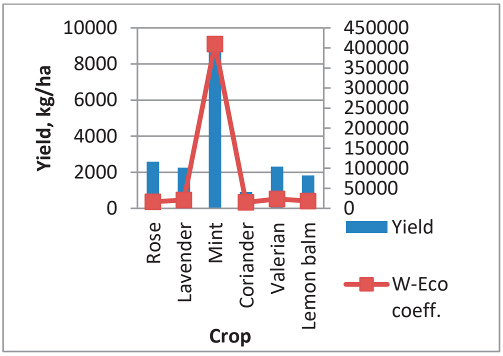

Figure 1. Graphic presentation of the results for the stability of the average yields of essential oil crops in Bulgaria

This proves that, in terms of average yield per decare, mint is not a stable crop. This fact is probably the reason for the repeated decrease in mint production over the study period. Yields of coriander are the most stable, but they are also minimal compared to other crops. Considering the average yield and the ecological valence, oil rose (2389.3 kg/ha) has the best indicators. This fact can be explained by the long tradition and experience that Bulgaria has in rose cultivation and rose oil production.

Figure 2 presents the result of the clustering procedure of the essential oil crops according to the degree of similarity by their average yields and ecological stability.

Two or more crops are included in one group (cluster) if there are no statistically proven differences between their average yields and stability. Given the productive qualities of the studied crops and their resistance to external factors, it is found that they are grouped into two clusters.

Formation of two clusters was established. The first consists of the oilseed rose, coriander, lavender, lemon balm and valerian, which is conditioned by the results described earlier (low and stable yields). Changes in climatic features cannot significantly increase the yields of these crops.

The second includes mint, being highly productive and at the same time sensitive to external changes, which makes it significantly different from the other crops. This fact determines its separation into an independent cluster, joining the first one at a maximum Euclidean distance of 25 units.

The grouping of crops through principal component analysis is similar (Figure 3).

This result proves that if mint is grown under favorable conditions, yields will be high. In the event of unforeseen climatic or natural changes, farmers should expect a significant reduction in the amount of production.

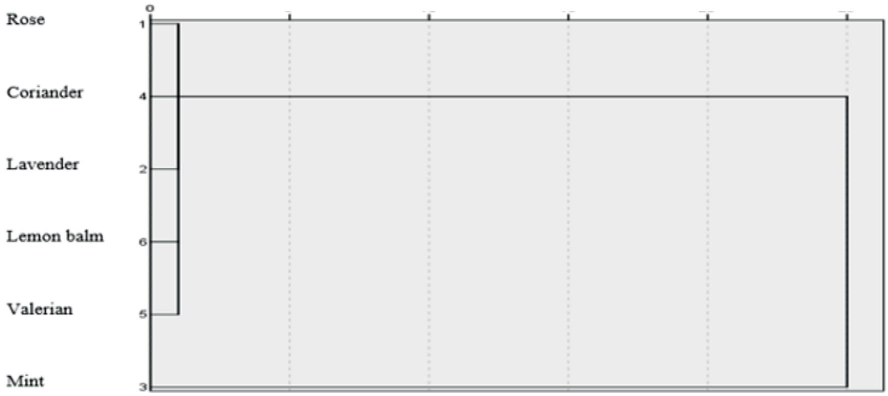

Figure 2. Grouping of essential oil crops according to productive qualities and resistance to environmental factors

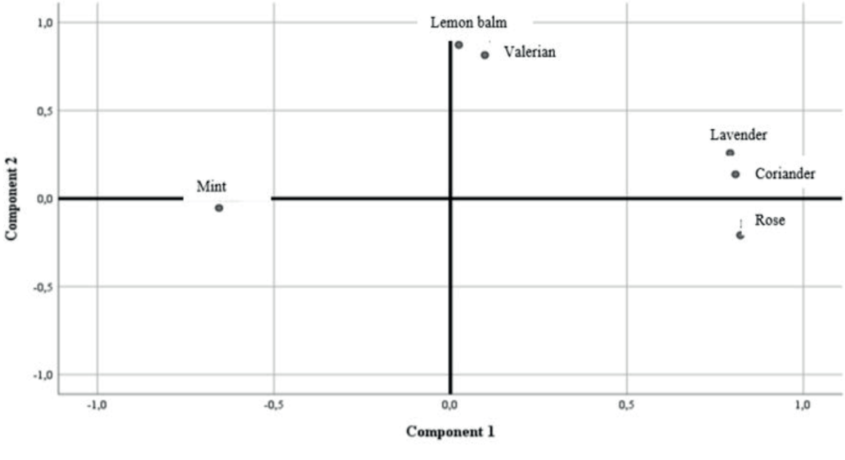

Figure 3. Grouping of essential oil crops by Principal Component Analysis

The analysis of the statistical data proved that canola (2063.8 kg/ha) had the highest yields of the oilseed crops studied, and pumpkins for seeds (662.9 kg/ha) had the lowest (Table 2).

Table 2. Results of one-way analysis of variance of average yields and ecological assessment of oil crops by one-way analysis of variance according to Duncan's test at significance level α = 0.05

Crop	Yield	W-Eco Coefficient
Sunflower	1700.6[b]	391.56[b]
Canola	2063.8[a]	1273.65[ab]
Soybeans	1466.4[b]	1877.26[a]
Peanuts	1647.7[b]	1289.18[ab]
Pumpkins	662.9[c]	621.26[b]

Yields of soybeans were the most unstable, while those of sunflower were the most stable (Figure 4).
This fact makes sunflower the most preferred oilseed crop in terms of yield stability.
It is more adaptable to changes in the climatic and soil characteristics of the area concerned. The farmer can more easily avoid the impact of adverse and unforeseen natural events.

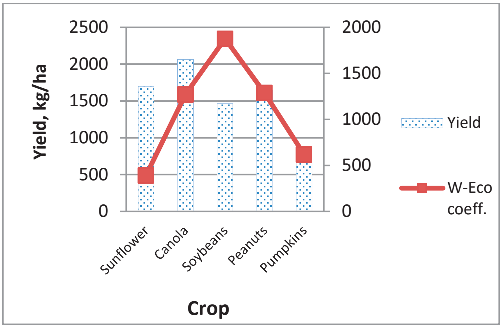

Figure 4. Graphic presentation of the results for the stability of the average yields of oilseed crops in Bulgaria

Visualization of the grouping of oilseed crops was done by cluster analysis (Figure 5) and principal component analysis (Figure 6).
Two clusters were formed. The first includes: canola, peanut and soybean, due to their higher sensitivity to the environment. The second consists of sunflower and pumpkin seeds, which are more adapted to external factors.

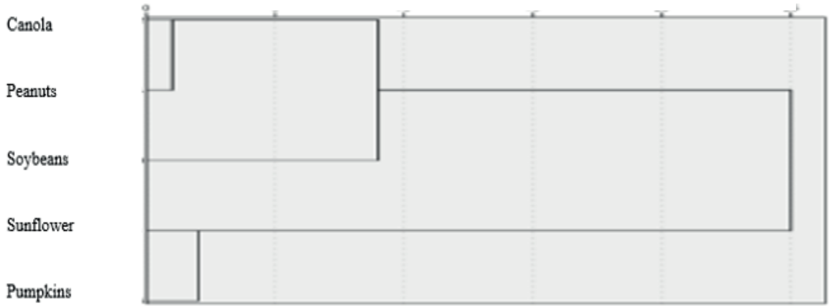

Figure 5. Grouping of oilseed crops according to productive qualities and resistance to environmental factors

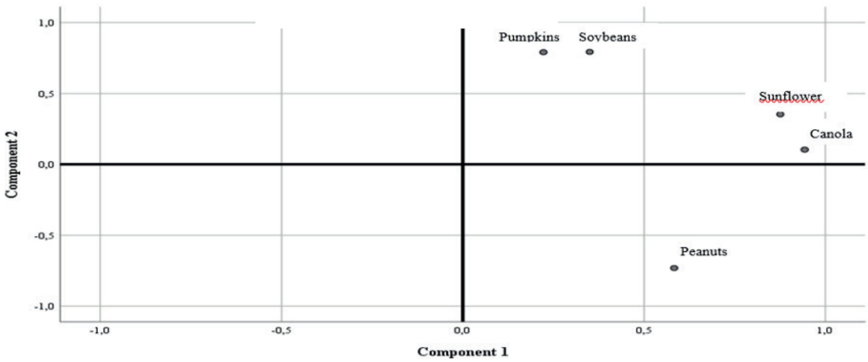

Figure 6. Grouping of oilseed crops by Principal Component Analysis

CONCLUSIONS

Of the essential oil crops studied, mint had the highest but also the most unstable yield. Yields of coriander were the most stable but minimal. Oilseed rose had the best yield-ecological stability ratio. Rapeseed had the highest average yield of all the oilseed industrial crops, followed by sunflower and peanuts. However, the most preferred crop in this group would have to be sunflower. It has been found to have relatively high yields and the greatest stability over time.
The obtained results can be a basis for future selection activities in order to increase the resistance of these cultures. This will increase the interest of farmers in them.

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