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VARIATION OF FLOWER QUALITY IN *Liatris spicata* IN RELATION TO PLANTING DATE AND FERTILIZATION SYSTEM

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Abstract

The study evaluated the quality of the flowers of the species Liatris spicata (L.) Wild., in relation to the date of planting and the fertilization applied. Planting was done at three different times, March 6 (PD1), March 13 (PD2) and March 20 (PD3). At planting, and at the formation of the floral stem, vermicompost type fertilizers were applied, in solid (VC-S) and liquid (VC-L) form, independently and in combination (VC-S/VC-L). Nine experimental variants resulted, including the control variant (T1 to T9). At the time of flowering, plant height (PH), flower stem length (FSL) and spike flower length (SL) were evaluated. The highest value for plant height was recorded under the conditions of planting date PD1 and fertilization VC-S/VC-L (T1), PH=52.05±1.11 cm. In the case of flower stem length (FSL), the highest value was in the PD1 variant with VC-S/VC-L fertilization (T1), FSL=42.70±1.44 cm. The highest value for the length of the spike-shaped inflorescence (SL) was recorded for variant PD2 with VC-S/VC-L fertilization (T4), respectively SL=9.95±037 cm. Polynomial equations of the 2nd degree described the variation of SL in relation to PH (R^2=0.968, p<0.001) and FSL (R^2=0.862, p=0.00264). According to PCA, PC1 explained 92.907% of variance, and PC2 explained 7.093% of variance. Regression analysis was used to evaluate the variation of SL in relation to PH and FSL, as a direct and interaction effect. 3D and isoquants models, plane format, were obtained to describe the variation of SL in relation to PH and FSL.

Key words: *flower quality, Liatris, model, ornamental plants, vermicompost*

INTRODUCTION

Ornamental plants present a very high diversity through the large number of species and genotypes, through the ornamental elements (flowers, leaves, or their combinations), the architecture and typology of the plants, the space for which they are intended to be used (indoor, outdoor), the period of vegetation, relationship and tolerance to climatic conditions and stress factors, etc. [1, 8, 11, 18, 39]. They are not just "luxury", but a primordial-functional human necessity, because they allow and at the same time facilitate people to realize in increasingly anthropized urban ecosystems, elements through which to connect with nature, and facilitate multiple functionalities [7, 11, 13, 25]. Ornamental plants, accompanied by specific horticultural practices, offer multiple functions and benefits, aesthetic, social, ecological, economic, etc. [4, 11, 14]. As a result of the interest in ornamental plants, from different perspectives, a particularly important field of ornamental plants has developed, considered as "ornamental plant industry" as a result of the economic contribution of this field [4].

In the case of ornamental plants through flowers, the defining ornamental elements (flowers), show importance by size, color, length of the floral stem (in the case of cut flowers), period and duration of flowering, etc. [2, 10, 11].

The improvement of ornamental plants through flowers is a basic concern in order to obtain new genotypes and improve floral attributes for aesthetic, cultural, technological and market purposes [19, 26, 30, 34]. Technological procedures (cultivation / maintenance technologies) to produce ornamental plants and control floral attributes are of interest [3, 22. 31, 32].

Liatris spicata (L.) Wild., known as "Blazing star", is a perennial species, from the Compositae Family, originating in North America. The genus Liatris is a taxonomic group that includes approximately 37 species [29] distributed in almost all American states, east of the Rocky Mountains to Southern Canada and Northern Mexico

Liatris spicata is the most cultivated species; it grows in full sun but also tolerates less light [35]. The soil must be well drained, with favorable physico-chemical and microbiological parameters [33], but plants also tolerate soils with low fertility, but too fertile lands (especially nitrogen) lead to the disappearance of corms from the soil.

More and more landscapers from different countries are looking for solutions to create an adequate biodiversity in urban areas, which are increasingly crowded and polluted. In more and more countries, perennial flower species are used for the arrangement of urban green spaces, along with decorative grasses and woody species [27, 36, 37]. Some studies evaluated urban ecosystems at a microzonal level based on test plants, indices and expressive parameters [5], while other studies evaluated urban ecosystems on a large scale, through remote sensing techniques [17], in order to characterize these anthropogenic ecosystems. Imaging analysis was used to evaluate the qualitative ornamental aspects of some perennial urban landscapes [36], and from the perspective of small-scale evaluation (at leaf level), imaging analysis proved to be very useful in early, non-destructive detection, of the health status of the plants [6]. The present study aimed to evaluate some qualitative aspects of the species *Liatris spicata* (L.) Wild., in relation to the date of planting corms, and fertilization, using for this floral attributes given by the floral stem, flower size, and used regression analysis to find models of description of the variation of the floral size in relation to the biometric parameters of the plants.

MATERIALS AND METHODS

The study took place within the Teaching and Research Base, University of Life Sciences "King Michael I" from Timisoara, between March and July, 2018. For planting Liatris corms, pots and universal substrate were used with the properties: pH=5.0–7.0, N=1.9%, P_2O_5=0.5%, K_2O= 0.9% (contents related to dry matter). For fertilization, vermicompost was used in solid form (VC-S), in liquid form (VC-L) applied independently or combined (VC-S / VC-L). Planting was done at three different times, namely on March 6 (PD1), March 13 (PD2) and March 20 (PD3).

The biological material was represented by Liatris corms (*Liatris spicata*), of superior quality, Figure 1.

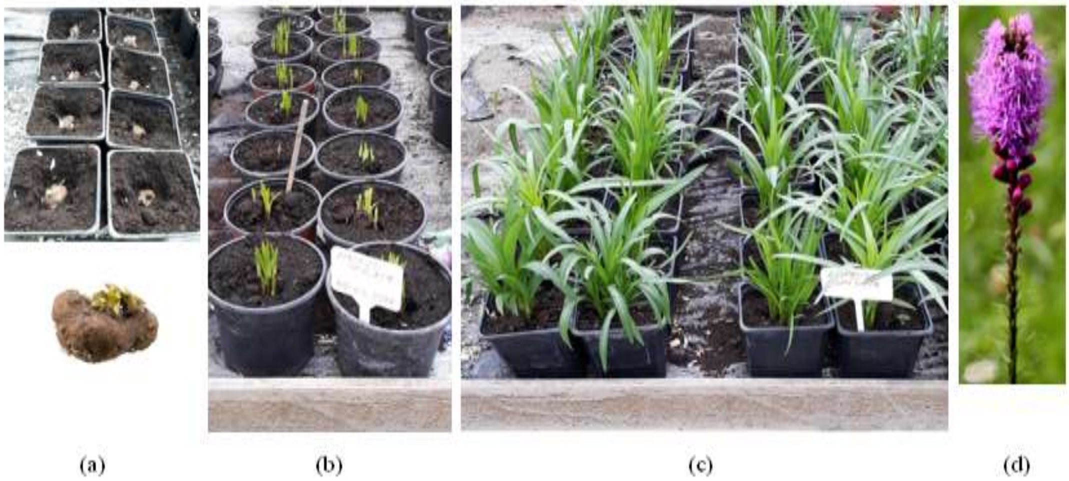


Fig. 1. Sequential aspects of the *Liatris spicata* experiment; (a) – corm, and corms at sprouting; (b) – sprouted plants; (c) - plants in the vegetation stage; (d) Liatris flower, single stem
Source: Original photos.

From the combination of the planting data (T1, T2, T3), of the fertilization system (VC-S, VC-L, or VC-S/VC-L), nine experimental variants (T1 to T9) resulted. The experiments were organized in three repetitions, and sequential aspects of the experiment are presented in Figure 1.

In relation to the specificity of plants and flowers as an ornamental and commercial product, in order to appreciate the quality of the flowers, the height of the plants (PH), the length of the floral stem (FSL) and the length of the inflorescence in the form of a spike (SL) were evaluated, in relation to each experimental variant.

The recorded results were properly analyzed, through appropriate mathematical and statistical methods, to evaluate the safety of the data, the presence of variance in relation to the experimental variables, the differences between the variants, as well as the particularities of the variants in the generation of quality results. A series of tests and specific statistical analyzes were made; Anova test, PCA analysis, cluster analysis, regression analysis, correlation analysis, and appropriate parametric statistics were used to assess the reliability of the results [15, 38].

RESULTS AND DISCUSSIONS

The plants of *Liatris spicata* (L.) Wild were evaluated in relation to the date of planting and the nutrition provided based on the vermi-compost product (solid or liquid form) administered differently at planting and in vegetation, at the formation of the floral stem.

The ornamental quality of the plants was evaluated, based on the height of the plants (PH), the length of the floral stem (FSL) and the length of the inflorescence in the form of a spike (spike length - SL).

High quality, with a high commercial value, is considered in the case of a developed inflorescence (long, well-developed spike), with a long floral stem, which is obtained from well-developed plants, associated with a performing biological material and an appropriate technology of culture.

The recorded values were compared with a control variant (Ct). The results recorded for the parameters and quality indices considered, in relation to the ornamental specifics of the studied species, are presented in Table 1.

The highest value for plant height was recorded under the conditions of PD1 planting date and VC-S/VC-L fertilization (T1), PH=52.05±1.11 cm. In the case of flower stem length (FSL), a high value for the analyzed parameter was recorded in the PD1 variant with VC-S/VC-L fertilization (T1), FSL=42.70±1.44 cm.

The highest value for the length of the spike-shaped inflorescence (SL) was recorded in the PD2 variant with VC-S/VC-L fertilization (T4), respectively SL=9.95±037 cm.

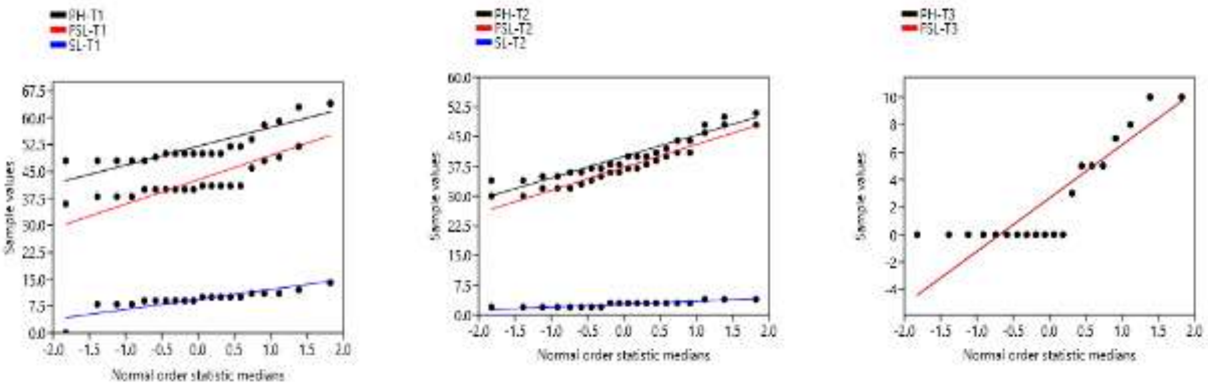
Table 1. The values recorded for *Liatris spicata* in relation to the planting date and applied fertilization

Planting date	Fertilization	Trial	PH	FSL	SL
			(cm)		
PD1	VC-S/VC-L	T1	52.05±1.11	42.70±1.44	9.35±0.59
	VC-L/VC-L	T2	40.00±1.15	37.25±1.22	2.75±0.16
	Ct	T3	6.63±0.82	6.63±0.82	0.00±0.00
PD2	VC-S/VC-L	T4	49.15±0.34	39.20±0.36	9.95±0.37
	VC-L/VC-L	T5	38.65±1.00	35.35±0.83	3.30±0.33
	Ct	T6	7.00±0.82	7.00±0.82	0.00±0.00
PD3	VC-S/VC-L	T7	49.60±0.59	39.90±0.57	9.70±0.37
	VC-L/VC-L	T8	37.00±0.73	34.50±0.67	2.50±0.13
	Ct	T9	7.50±0.82	7.50±0.82	0.00±0.00

Source: Original data.

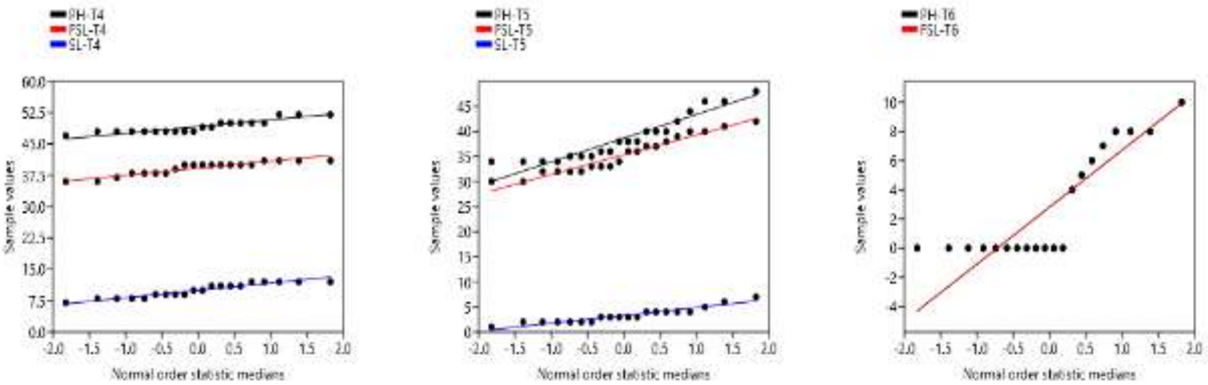
The ANOVA test confirmed the reliability of the results as well as the presence of variance in the set of recorded experimental data (F>Fcrit, p<0.001).

The distribution of data values for each parameter (20 values for each data series) was analyzed and displayed in graphic form (normal probability plot). In the case of the PD 1 planting date (March 6), the distribution of the data series by variants is represented in Figure 2 (a, b, c), under statistical safety conditions, assessed on the basis of the correlation coefficient (r=0.874 for PH-T1, r=0.843 for FSL-T1, r=0.845 for SL-T1, in fig. 2 a; r=0.956 for PH-T2, r=0.969 for FSL-T2, r=0.902 for SL-T2 in fig. 2 b; r=0.863 for PH-T3 and for FSL-T3, in fig. 2 c). In the case of the PD 2 planting date (March 13), the distribution of the data series by variants is represented in figure 3 (a, b, c), under statistical safety conditions, assessed on the basis of the correlation coefficient (r= 0.919 for PH-T4, r=0.934 for FSL-T4, r=0.957 for SL-T4 in Fig. 3 a, r=0.947 for PH-T5, r=0.974 for FSL-T5, r=0.949 for SL-T5 in Fig. 3 b; r=0.863 for PH-T6 and for FSL-T6 in fig. 3 c). In the case of the PD 3 planting date (March 20), the distribution of the data series by variants is represented in figure 4 (a, b, c), under statistical safety conditions, assessed on the basis of the correlation coefficient (r=836 for PH-T7, r=0.899 for FSL-T7, r=0.966 for SL-T7 in fig 4a; r=0.966 for PH-T8, r=0.973 for FSL-T8, r=0.853 for FS-T8 in fig 4b; r=0.862 for PH-T9 and for FSL-T9 in fig 4 c).



A b c

Fig. 2. The graphic distribution for the data series of the plant samples (PD1), *Liatris spicata* species
Source: Original figure, based on the data.



A b c

Fig. 3. The graphic distribution for the data series for the plant samples (PD2), *Liatris spicata* species
Source: Original figure, based on the data.

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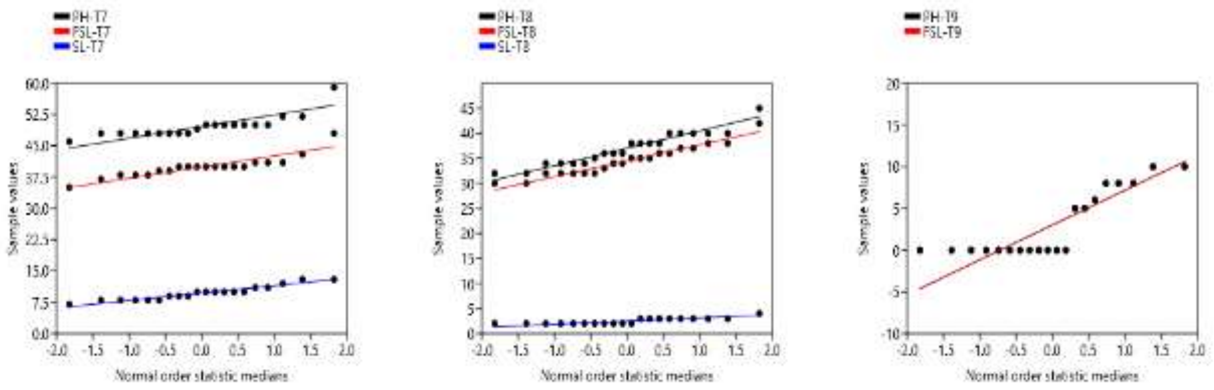

A b c

Fig. 4. The graphic distribution for the data series for the plant samples (PD3), *Liatris spicata* species
Source: The original figure, based on the data.

The variation in the interdependence of the evaluated parameters was highlighted by regression analysis. Thus, the variation of FSL in relation to PH was described by equation (1) under conditions of R^2=0.997, p<0.001, F=1262.9. The variation of FS in relation to PH was described by equation (2) under conditions of R^2=0.968, p<0.001, F=91.854. The variation of FS in relation to FSL was described by equation (3) under conditions of R^2=0.862, p=0.00264, F=18.688.

$$FSL = -0.01046 \cdot PH^2 + 1.38 \cdot PH - 2.148 \quad (1)$$
$$SL = 0.01046 \cdot PH^2 - 0.3803 \cdot PH + 2.148 \quad (2)$$
$$SL = 0.02596 \cdot FSL^2 - 0.9776 \cdot FSL + 5.577 \quad (3)$$

where: FSL - floral stem length;
PH – plant height;
SL – spike length.

Based on the PCA, the distribution diagram of the variants (T1 to T9) was obtained in relation to the values of the evaluated parameters (as biplot), generated by the date of planting and the fertilization applied, Figure 5.

The independent positioning of the variants T3 (PD1 Ct), T6 (PD2 Ct) and T9 (PD3 Ct) was found, which recorded the lowest values for the parametrically evaluated.

The variants T2 (PD1 VC-L/VC-L), T5 (PD2 VC-L/VC-L) and T8 (PD3 VC-L/VC-L) were associated with FSL.

The variants T1 (PD1 VC-S/VC-L), T4 (PD2 VC-S/VC-L) and T7 (PD3 VC-S/VC-L) were positioned associated with SL. PC1 explained 92.907% of variance, and PC2 explained 7.093% of variance.

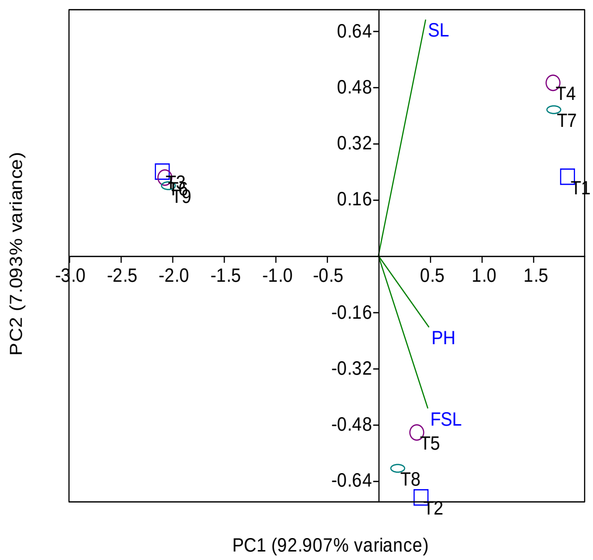

Fig. 5. PCA diagram, correlation, regarding the distribution of variants in the *Liatris spicata* species, in relation to evaluated parameters
Source: The original figure, based on the data.

The cluster analysis led to the dendrogram in Figure 6, under statistical safety conditions (Coph.corr=0.974). A high level of similarity was recorded between the T6 and T9 variants (SDI=0.52326), followed by the T6 and T9 variants (SDI=0.70711).

These variants were included in a cluster with the lowest values for the evaluated floral quality parameter. In the cluster with high values (quality flowers) the variants T1, T4 and T7 were included, within which a high level of similarity was recorded between the

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variants T4 and T7 (SDI=0.86891).

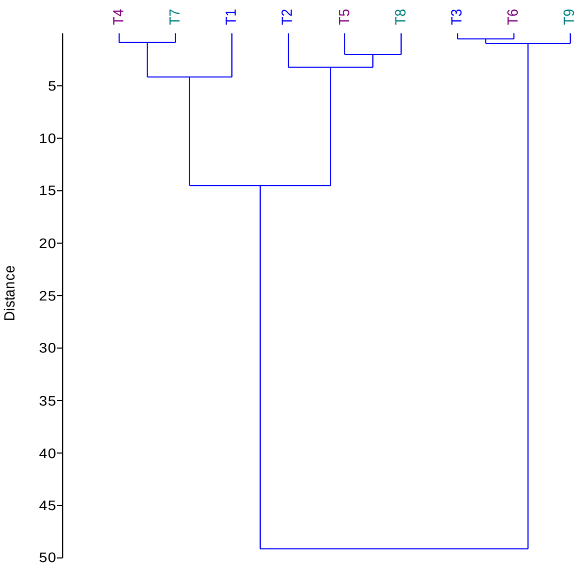


Fig. 6. Dendrogram for the classification of variants based on similarity in generating the values of the parameters studied in *Liatris spicata*
Source: Original figure.

Regression analysis was used to evaluate the variation of SL in relation to PH and FSL. Equation (4) was obtained, as a general type relationship, which described the variation of the flower quality parameter considered in the study (SL), and the values of the coefficients of the equation for the three planting dates, as study cases in the analysis of regression, and statistical safety parameters, are presented in Table 2. The graphic distribution of the variation of SL in relation to FSL and PH on the three considered experimental variants are presented in Figures 7 (T1), 8 (T4) and 9 (T7). The ANOVA test led to obtaining the values of the statistical safety parameter (p), corresponding to equation (4) in relation to each analysis performed (T1, T4 and T7). According to the p values, statistical certainty was recorded for *x* ($p<0.001$) and *y* ($p<0.001$) in the case of variants T1 and T7, respectively for *x* ($p<0.001$), *y* ($p<0.001$), x^2 ($p= 0.0016$), y^2 ($p=0.0042$), and *xy* ($p=0.00077$), in the case of the T4 variant.

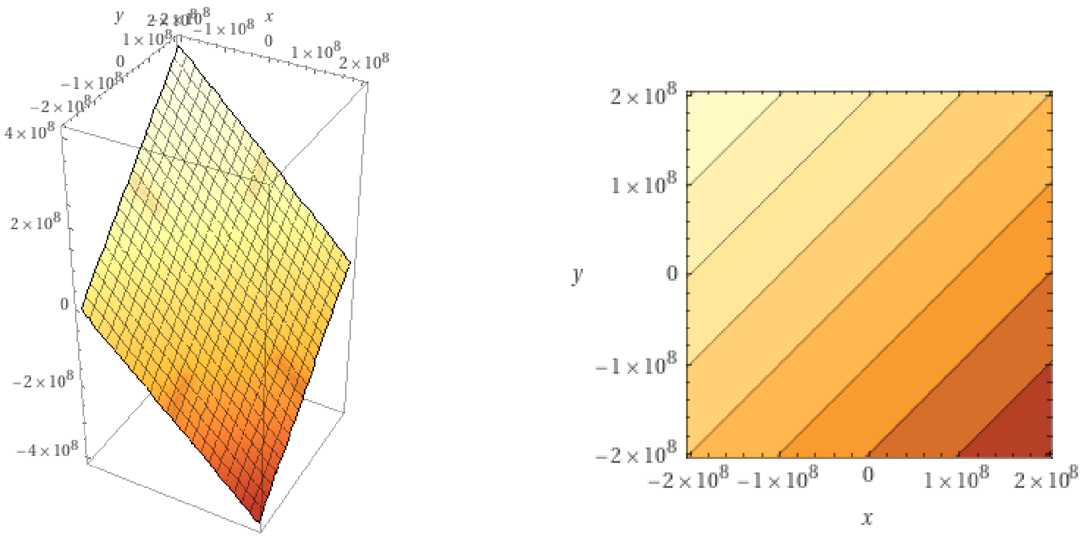
$$SL = ax^2 + by^2 + cx + dy + exy + f \qquad (4)$$

where: SL – the length of the spike-type inflorescence; *x* – floral stem length (FSL); *y* – plant height (PH); a, b, c, d, e, f – coefficients of the equation (4), Table 2.

Table 2. The values of the coefficients of equation (4), in relation to PH and FSL parameters on experimental variants

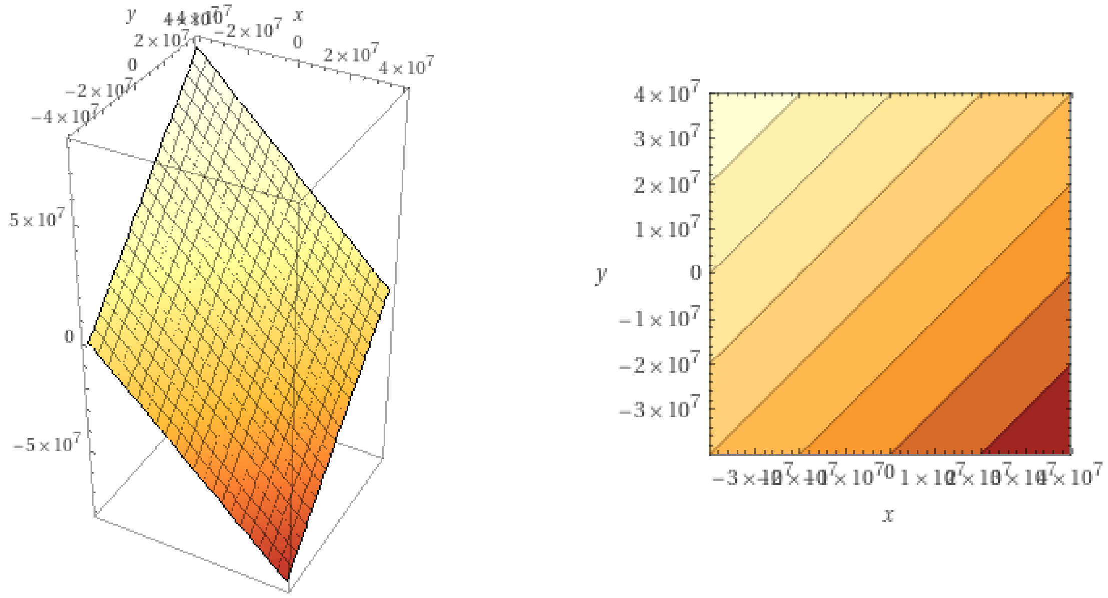
coefficients of equation (4)	Values of the coefficients on the analyzed experimental variants		
	T1	T4	T7
a	-7.72124E-17	3.58323E-15	-4.52357E-16
b	-1.43183E-16	3.06353E-15	2.74626E-16
c	-1	-1	-1
d	1	1	1
e	2.45865E-16	-6.67804E-15	-4.64266E-17
f	0	0	0

Source: Original data.



a b

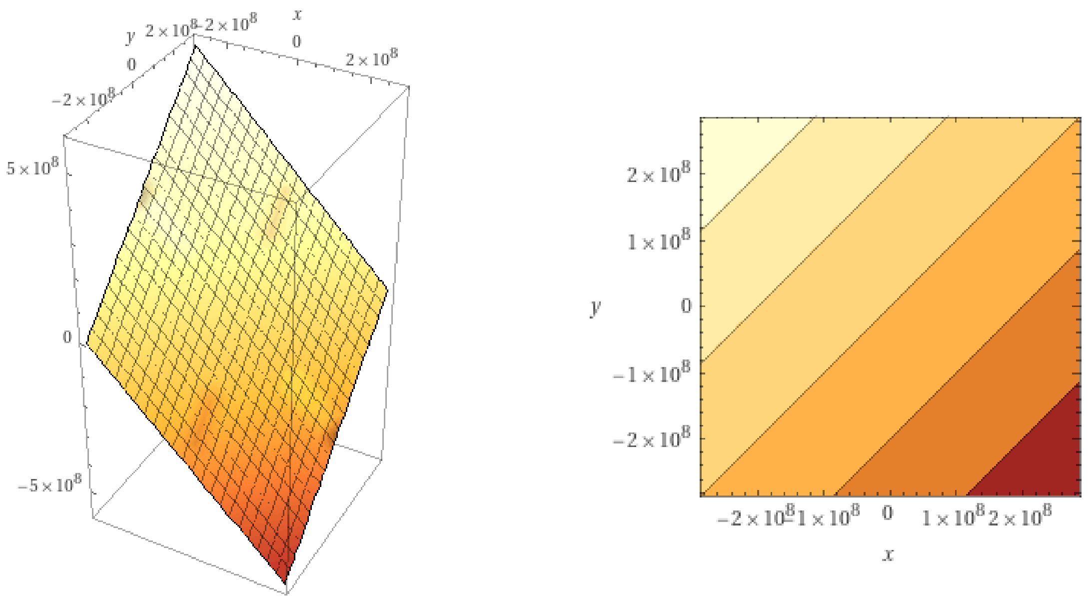
Fig. 7. Distribution of SL values in relation to FSL (x-axis) and PH (y-axis), in the case of variant T1; a – 3D model; b – model in the form of isoquants, plane format
Source: original graphs.



a b

Fig. 8. Distribution of SL values in relation to FSL (x-axis) and PH (y-axis), in the case of variant T4; a – 3D model; b – model in the form of isoquants, plane format

Source: original graphs.



a b

Fig. 9. Distribution of SL values in relation to FSL (x-axis) and PH (y-axis), in the case of variant T7; a – 3D model; b – model in the form of isoquants, plane format

Source: original graphs.

Green spaces are important in urban ecosystems, and have complex functionality, aesthetic, emotional, ecological, social, etc. [16, 20, 36].

Liatris spicata (L.) Wild., was present together with other species of perennial herbaceous plants (29 species and varieties), in the framework of a design study of perennial landscapes in urban areas (Shanghai and Hangzhou), in which the importance of the species was analyzed by their typology and the way of arrangement (six studied models) on the perception of people's gaze and aesthetic preferences [36. Similar studies, regarding the floristic diversity in urban gardens and green spaces (Zurich, Switzerland) have identified and reported the presence of the species *Liatris spicata* in some gardens [12].

Liatris spicata was taken into account, in a study that included 31 plant species, in order to evaluate the behavior of plants in conditions of combined stress, specific to the conditions of green spaces along roads and streets, in cold and humid climate conditions (eg. Norway) [23]. The authors reported considerable differences between the adaptation of the tested plant species to the study conditions, and the species *Liatris spicata* 'Floristan Weiss' was among the species with a high survival rate in the study conditions.

Also, *Listris spicata* was considered in a study, together with other species, regarding the impact of conscious, intentional and programmed plantings of wild flowers, on native plant species in urban and peri-urban habitats, and *Liatris spicata* obtained 3.1 points in Species Impact Index [21].

The relationship and response of Liatris plants in relation to climatic and cultivation factors have been addressed in some studies. Shoot formation in *Liatris spicata* was studied in relation to the soil temperature and the time of planting, respectively the photoperiod in which the plants grew, and it was found that the temperature but also the photoperiod influenced the growth and development of the Liatris plants, especially in the first 35 days of vegetation [9].

Moe and Berland (1986) [28] reported the favorable influence of low temperature during the storage period of Liatris corms on the flowering time and the number of shoots. Also, the authors found the favorable influence of gibberellic acid (GA3, 500 ppm) on the development of flowers and the number of flower shoots, by reducing the time until flowering and increasing the number of flower shoots on the corm, important aspects for practice.

Interest in Liatris was also presented from the perspective of obtaining essential oils. In a study on eight plant species, including Liatris, several components were detected, and the Germacrene D component was reported as a major component in Liatris samples, in a proportion of 24% [24].

The specificity of this study, regarding the qualitative assessment of Liatris flowers based on some vegetative and floral parameters, led to obtaining numerical data, as effective values of the parameters determined in relation to influencing factors (planting date, fertilizers), as well as data in the form of equations, diagrams and graphic models (3D or isoquants), which can be useful in other studies. At the same time, the study models used can be adapted to other species of ornamental plants with similar attributes, in order to optimize their cultivation.

CONCLUSIONS

Liatris plants responded differently to the time of planting (three planting dates; PD1, PD2, PD3) and applied fertilization (vermicompost in solid and liquid form; VC-S, VC-L, VC-S/VC-L) and led parametrically variable floral quality, especially in terms of spike length (SL).

The PCA and cluster analysis facilitated the generation of diagrams and dendrograms by which the assimilation of the considered parametric variants was quantified, as well as the degree of similarity of the nine variants in the generation of answers with the closest value, under conditions of statistical certainty.

Through the regression analysis, models in the form of equations, and 3D and isoquant graphic models were obtained, which described the behavior of Liatris plants under the study conditions with statistical certainty.

The obtained results confirm the fact that the quality of the flowers can be directed by the cultivation technology (planting date, fertilization in the present study), in relation to their intended use.

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