

VEGETATIVE AND FLORAL PARAMETERS IN *Ranunculus asiaticus* L. GENOTYPE 'ELEGANCE STRIATO BIANCO' DESCRIPTION BY MATHEMATICAL METHODS

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ABSTRACT

Ornamental plants, through specific structural and architectural elements, or flowers, offer aesthetic value, with multiple benefits for people. Within ornamental plants, numerous alien species have found interest, and there has been a high probability and progress in the naturalization of these species. The present study aimed to describe some vegetative and floral parameters variation in *Ranunculus asiaticus* L., genotype 'Elegance Striato Bianco' through mathematical tools. The study was conducted during 2024 – 2025, in a protected space (greenhouse), within the Didactic Base of ULS "King Mihai I" from Timisoara. *Ranunculus* plants were grown in pots, on peat substrate (Klasmann TS 3 Fin 70L). Flowering was recorded during the months of March - April 2025. In relation to the purpose of the study, determinations were made regarding: plant height (PH, cm), leaf number (LN), leaf color intensity (LCI), flower stem height (FSH, cm), flower number (FN), flower height (FH, cm), flower diameter (FD, cm). The data series ($N = 48$) presented a normal distribution, in conditions of statistical safety ($p < 0.001$). The variation of floral quality parameters FN and FD in relation to plant parameters was described by polynomial equations in conditions of statistical safety. The convergent and divergent contribution of the parameters in the variation of the two floral quality parameters was recorded. The Venn diagram evaluated the logical relationships between the groups of elements of the floral parameters, in the description of the flowers of *Ranunculus asiaticus* L., genotype 'Elegance Striato Bianco'.

KEY WORDS: floral parameters, mathematical models, morphological characters, ornamental plants, quality, Venn diagram

INTRODUCTION

'Ornamental plants', as a generic term, refers to plants that have special plant architectures (individual plants or plant communities), or have beautiful flowers, which gives them ornamental value (Zheng *et al.*, 2021). Ornamental plants, through their diversity and specificity, offer aesthetic, ecosystemic, practical and cultural value, with

multiple benefits for people, in terms of emotional and physiological health, social interactions, and the economic component (Altman *et al.*, 2022; Rihn *et al.*, 2023; Di Gristina *et al.*, 2025; Saensouk *et al.*, 2025).

Commercial aspects related to ornamental plants have determined the frequent cultivation of alien species worldwide, with technological and economic implications, but also in terms of the higher probability of naturalization of these species (Dawes *et al.*, 2026).

Aesthetic value, from the perspective of the ornamental plant industry, is based on the implementation of innovative technologies, by defining new symbols as elements of progress, and by creating 'tangible assets' based on valuable symbols (Partap *et al.*, 2023). The size of floral elements and the balance and proportionality between floral parameters are important for the aesthetics of ornamental plants, and contribute to the beauty of ornamental plants through flowers (Guan *et al.*, 2025).

The complexity of flowering has been studied in ornamental flowering plants, in relation to genetic, hormonal and environmental factors, in order to understand the mechanisms underlying flowering (Erwin, 2007; Aizaz *et al.*, 2025). Through specific floral parameters (e.g. plant type, flower shape and color, fragrance, viability duration, stress tolerance, etc.) ornamental flowering plants are used in all occasions and events worldwide (Penna and Jain, 2023).

Various methods, tests and mathematical models have been used to evaluate the relationship of ornamental plants with climatic factors and growing conditions (Taib *et al.*, 2019). Environmental and technological factors influence the growth, productivity and quality of ornamental plants, in relation to their typology - ornamental plants with leaves, cut flowers, potted plants, etc. (Penna and Jain, 2023; Ibrahim *et al.*, 2024; Cai *et al.*, 2025).

Ranunculus asiaticus L. (Persian Buttercup), an ornamental geophyte, is included in the ornamental flowering plants. The species has been the subject of study in many articles, in terms of propagation, relationship with environmental factors, physiological functions, and production systems (Beruto *et al.*, 2019; Carillo *et al.*, 2019; Fusco *et al.*, 2023).

The present study used methods and mathematical models to describe floral parameters and flower size variation in *Ranunculus asiaticus* L., genotype 'Elegance Striato Bianco'.

MATERIAL AND METHOD

The study was conducted in a protected area, Figure 1, within the Didactic

Base of ULS “King Mihai I” from Timișoara, during 2024 – 2025. The aim of the study was to evaluate vegetative and floral quality parameters of ornamental ranunculus plants. The biological material was represented by the species *Ranunculus asiaticus* L., genotype 'Elegance Striato Bianco'.



FIG. 1. Aspects of the experiment

The ranunculus bulbs presented the caliber of size 2/3. The studied genotype presents white – pink flowers, height 30 – 50 cm. The plants are suitable for cultivation in full sun / partial shade conditions, with a sheltered position. The plants require loamy-sandy soil with good drainage. Planting density is approximately 90 bulbs / m².

To obtain the plants, the tuberized roots of *Ranunculus asiaticus* L. 'Elegance Striato Bianco', were hydrated for 8 hours in water. After hydration, the tuberized roots were placed in a well-drained, peat-based substrate. The Klasmann TS 3 Fin 70 L substrate was used, based on blond peat, partially decomposed (0 - 5 mm), containing microelements, hydrating agent, pH (H₂O) = 6.0. The planting of the tuberized roots was done on November 20, 2024. The beginning of emergence was recorded on December 12, 2024. Flowering was recorded during the months of March - April 2025.

In relation to the purpose of the study, determinations were made regarding: plant height (PH, cm), leaf number (LN), leaf color intensity (LCI), flower stem height

(FSH, cm), flower number (FN), flower height (FH, cm), flower diameter (FD, cm).

In relation to the objectives of the study, the PAST software v. 4.17 (Hammer *et al.*, 2001) was used to analyze the recorded data.

RESULTS AND DISCUSSIONS

Statistical analysis described the distribution of the data series (N = 48), with $r = 0.977$ (PH parameter), $r = 0.933$ (LN parameter), $r = 0.876$ (LCI parameter), $r = 0.984$ (FTH parameter), $r = 0.852$ (FN parameter), $r = 0.952$ (FH parameter), and $r = 0.983$ (FD parameter). The distribution of the data series, in relation to the median values, is presented graphically in Figure 2.

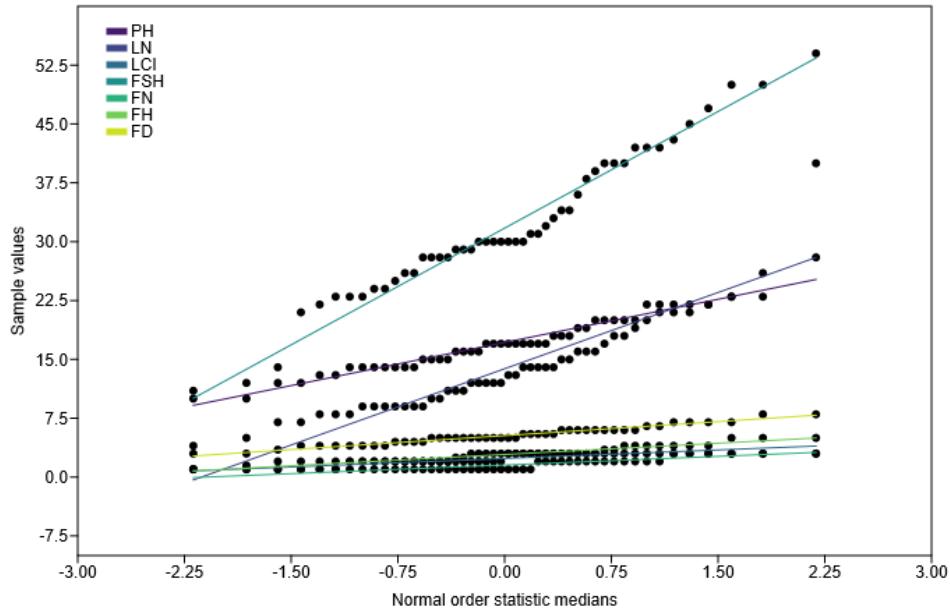


FIG. 2. Normal distribution of data series

The ANOVA test (Alpha = 0.05) confirmed the statistical reliability of the experimental data ($F > F_{crit}$), and the presence of variance in the data set (table 1).

Outlier test (Grubbs test) found a single outlier value, in the case of the LN parameter (value 40, row 4, $p < 0.001$), according to the recorded results (table 2).

TABLE 1. ANOVA Test results (Alpha=0.05)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	35386.96	6	5897.827	277.588	1.7E-125	2.126
Within Groups	6990.16	329	21.247			
Total	42377.12	335				

TABLE 2. Outliers test results

Statistical parameters	PH	LN	LCI	FSH	FN	FH	FD
	Grubbs test values						
G	3.035	4.152	1.955	2.309	2.044	2.275	2.341
p	0.069	<0.001	1.000	0.860	1.000	0.952	0.783

The studied genotype 'Elegance Striato Bianco', within the *Ranunculus asiaticus* L. species, is ornamental genotype, and is important for the density of the plants (the vegetal carpet through leaves and flowers), in relation to certain areas of land they occupy. At the same time, it is important for the length of the floral stem and the diameter of the flowers, when grown for cut flowers.

In the present study, the plants were grown in pots, but in relation to ornamental potential, the variation of the FSH parameter, and of the FN parameter and the FD parameter in relation to PH, LN and LCI, respectively the variation of the FD parameter in relation to all plant parameters, was evaluated.

Regression analysis indicated the variation of the FSH parameter in relation to PH, LN and LCI, in different combinations, as a direct and interaction effect, but under low statistical confidence conditions ($p > 0.05$).

In the case of flower number (FN), regression analysis described the variation of FN in relation to PH, LN, and LCI according to Equation (1), under conditions of statistical safety (table 3).

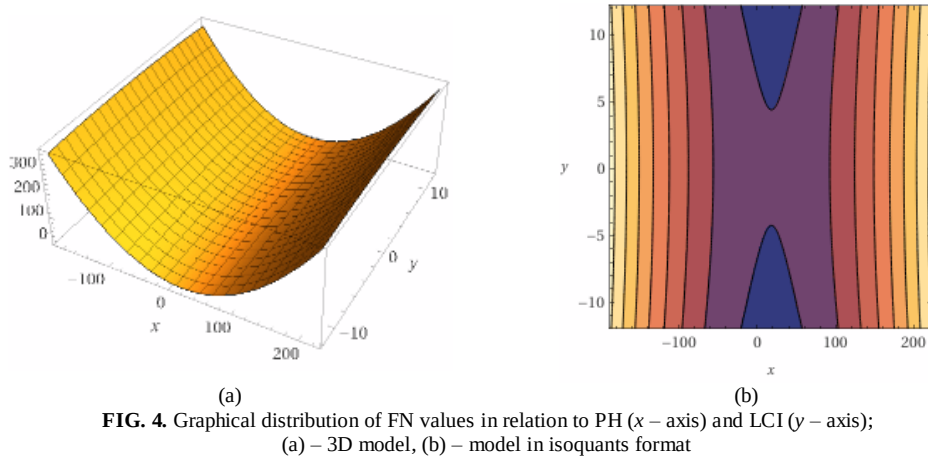
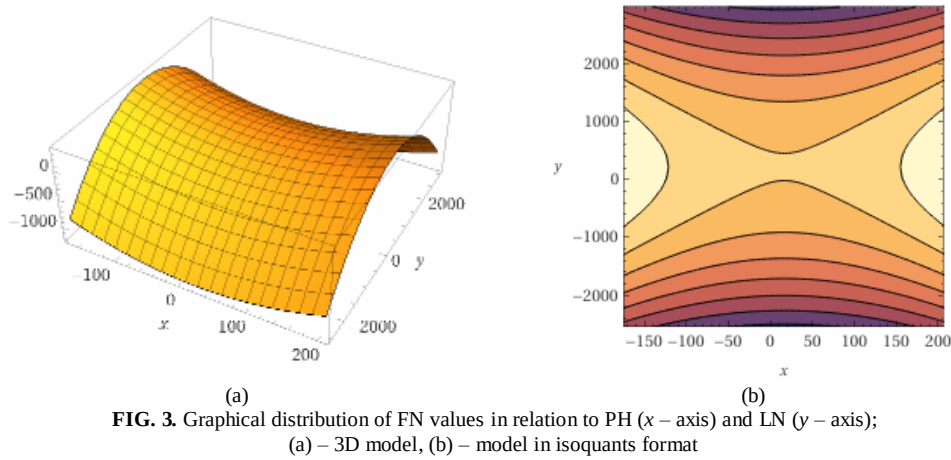
$$FN = a x^2 + b y^2 + c x + d y + e xy + f \quad (1)$$

where: FN – flower number; x and y – variables of Equation (1), according to Table 3; a, b, c, d, e, f – coefficients of Equation (1), according to table 3.

TABLE 3. Values of the parameters and statistical safety coefficients of Equation (1)

Variables	Coefficients of Equation (1)						Statistical safety parameters		
	a	b	c	d	e	f	Multiple R	F	p
$x = PH, y = LN$	0.009970	-0.000164	-0.316468	0.075413	-0.000171	2.948421	0.682	7.3021	<0.001
$x = PH, y = LCI$	0.008622	-0.104376	-0.296794	0.029602	0.001676	4.490507	0.503	2.8342	0.0271
$x = LN, y = LCI$	-0.001475	-0.210181	0.196145	1.045740	-0.034787	-0.908167	0.717	8.9080	<0.001

The values of the coefficients of Equation (1) (table 3) indicated divergent contribution of the parameters PH and LN, respectively PH and LCI (the two variables of the equation) in the formation and variation of the values of the FN parameter. The parameters LN and LCI presented convergent contribution in the formation and variation of the values of the FN parameter. Graphical models in 3D format and isoquants are presented in Figure 3, Figure 4, and Figure 5.



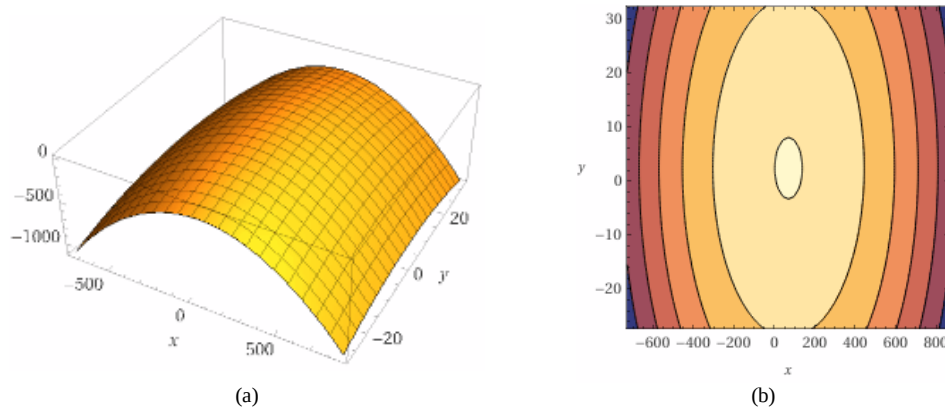


FIG. 5. Graphical distribution of FN values in relation to LN (x – axis) and LCI (y – axis);
(a) – 3D model, (b) – model in isoquants format

In the case of flower diameter (FD), regression analysis described the variation of FD in relation to plant parameters, according to Equation (2). In the case of some parameters, as variables in Equation (2), statistical reliability was recorded (Table 4).

$$FD = a x^2 + b y^2 + c x + d y + e xy + f \quad (2)$$

where: FD – flower diameter; x and y – Equation (2) variables (table 4); a, b, c, d, e, f – Equation (2) coefficients (table 4).

TABLE 4. Values of the parameters and statistical safety coefficients of Equation (2)

Variables	Coefficients of Equation (2)						Statistical safety parameters		
	a	b	c	d	e	f	Multiple R	F	p
x = PH, y = FSH	-0.004317	-0.000435	0.410325	0.239796	-0.008727	-2.848968	0.639	5.8217	<0.001
x = PH, y = FH	0.002024	-0.238293	-0.117445	2.281515	-0.005756	2.576320	0.609	4.9585	0.0012
x = LN, y = FSH	0.002051	-0.000711	-0.096090	0.122563	-0.000941	3.448126	0.659	6.4759	<0.001
x = LN, y = FH	0.001950	-0.351874	0.018104	3.308500	-0.044574	-0.025235	0.619	5.2279	<0.001
x = LCI, y = FSH	-0.084483	0.000186	-0.348635	-0.039449	0.039382	4.660711	0.664	6.6148	<0.001
x = LCI, y = FN	-0.472196	0.342501	3.197553	-0.775911	-0.475419	2.435435	0.521	3.1218	0.0174
x = LCI, y = FH	-0.154331	-0.188737	0.639698	1.456199	0.147055	1.223733	0.623	5.3356	<0.001
x = FSH, y = FN	-0.000674	0.331122	0.165129	-0.545667	-0.038537	2.513276	0.697	7.9645	<0.001
x = FSH, y = FH	-0.000143	-0.373413	0.040785	2.367982	0.009868	-0.194742	0.727	9.4488	<0.001
x = FN, y = FH	0.289858	-0.268747	-1.094903	2.522459	-0.179749	2.111774	0.671	6.8919	<0.001

Based on the coefficient values (table 4), it was found that in three cases of combinations of parameters, as variables in Equation (2), convergent action was recorded in the formation and variation of the FD parameter values (flower diameter)

in the studied ranunculus ornamental genotype 'Elegance Striato Bianco'. 3D models and in isoquant format are presented in Figure 6, Figure 7, and Figure 8.

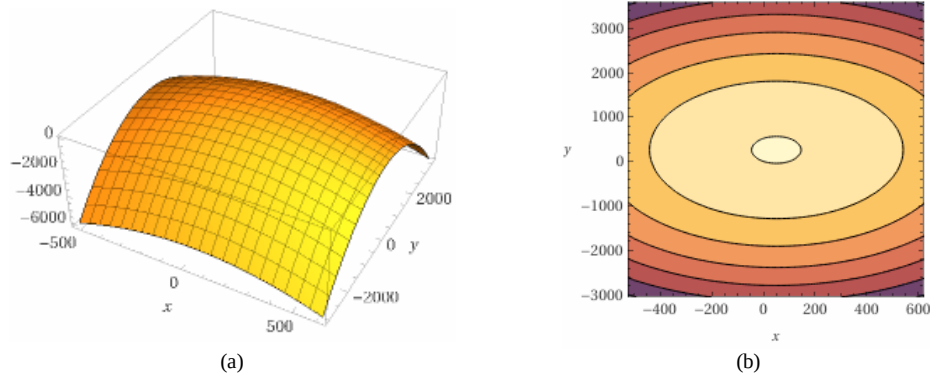


FIG. 6. Graphical distribution of FD values in relation to PH (x – axis) and FSH (y – axis); (a) – 3D model, (b) – model in isoquants format

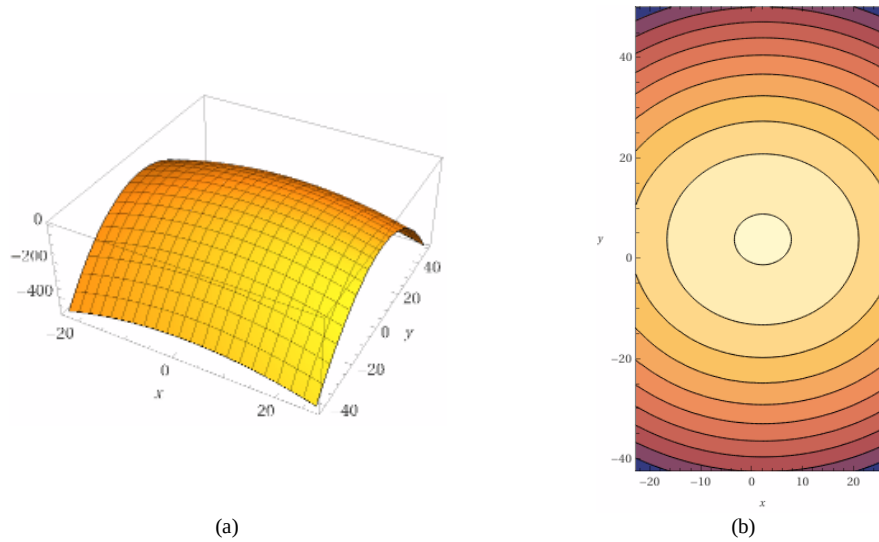


FIG. 7. Graphical distribution of FD values in relation to LCI (x – axis) and FH (y – axis); (a) – 3D model, (b) – model in isoquants format

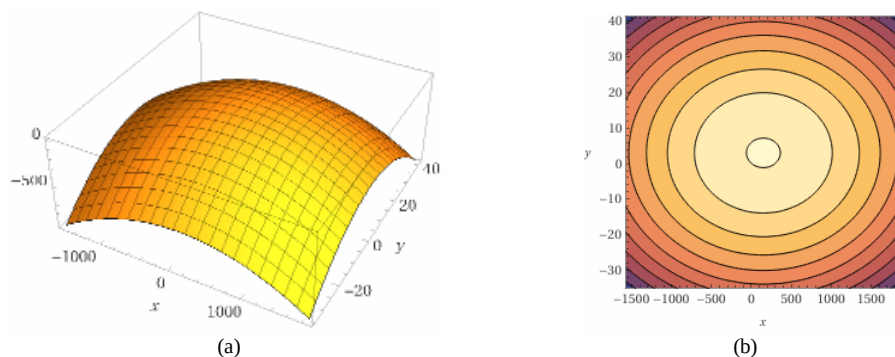


FIG. 8. Graphical distribution of FD values in relation to FSH (x – axis) and FH (y – axis);
(a) – 3D model, (b) – model in isoquants format

In seven cases of combinations of plant parameters, as variables in Equation (2), divergent action of the parameters in the formation and variation of flower diameter (FD) values was recorded in the studied ranunculus genotype 'Elegance Striato Bianco'. 3D and isoquant models are presented, selectively, in Figure 9, Figure 10, Figure 11 and Figure 12.

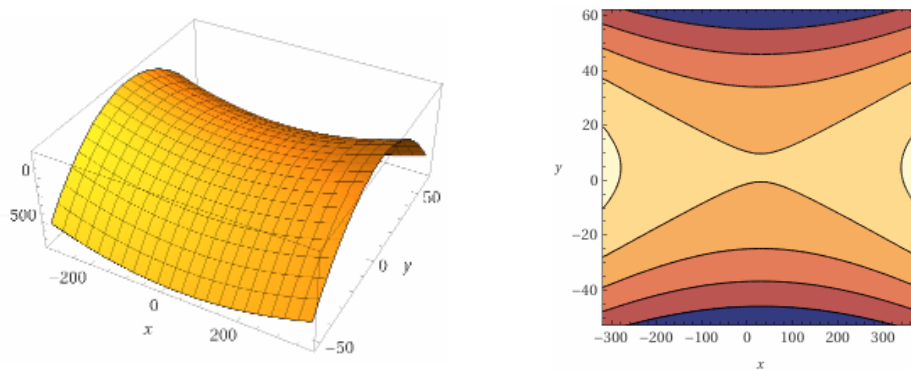


FIG. 9. Graphical distribution of FD values in relation to PH (x – axis) and FH (y – axis),
(a) – 3D model, (b) – model in isoquants format

In the graphic models, it was observed how the FD parameter recorded wide variation in relation to the parameters considered and their combinations in the regression analysis.

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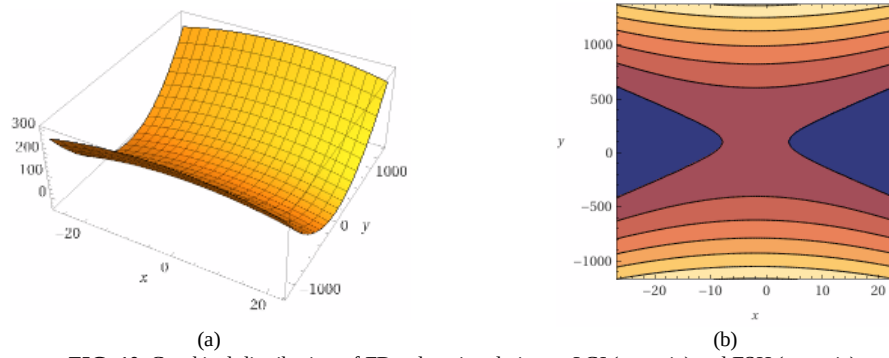


FIG. 10. Graphical distribution of FD values in relation to LCI (x – axis) and FSH (y – axis); (a) – 3D model, (b) – model in isoquants format

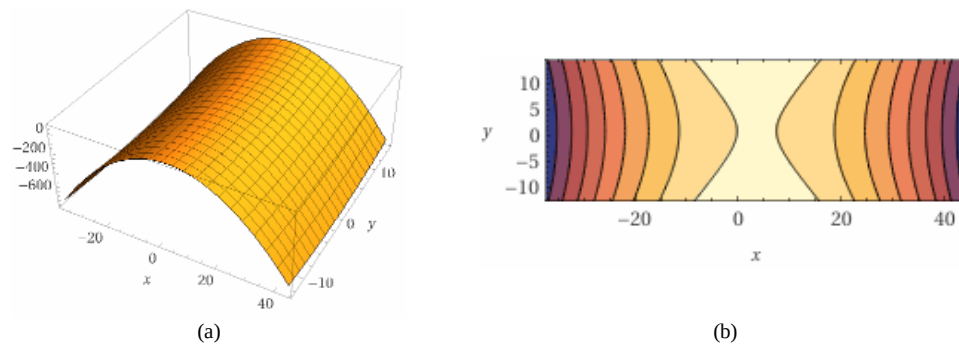


FIG. 11. Graphical distribution of FD values in relation to LCI (x – axis) and FN (y – axis); (a) – 3D model, (b) – model in isoquants format

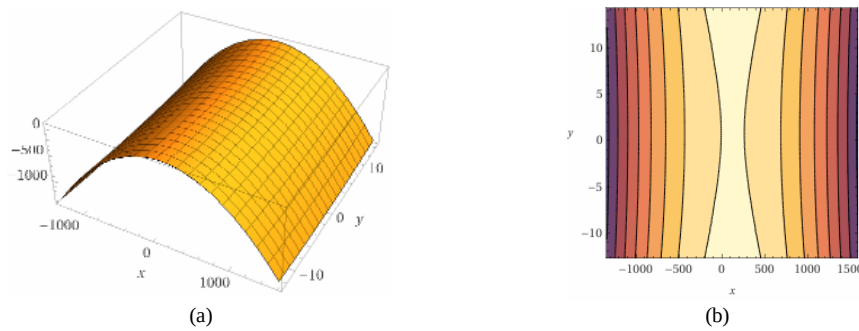


FIG. 12. Graphical distribution of FD values in relation to FSH (x – axis) and FN (y – axis); (a) – 3D model, (b) – model in isoquants format

The Venn diagram was used to evaluate the logical relationships between the groups of elements of the floral parameters, FSH, FN, FH, FD, in the description of the flowers of ranunculus, genotype 'Elegance Striato Bianco', Figure 13.

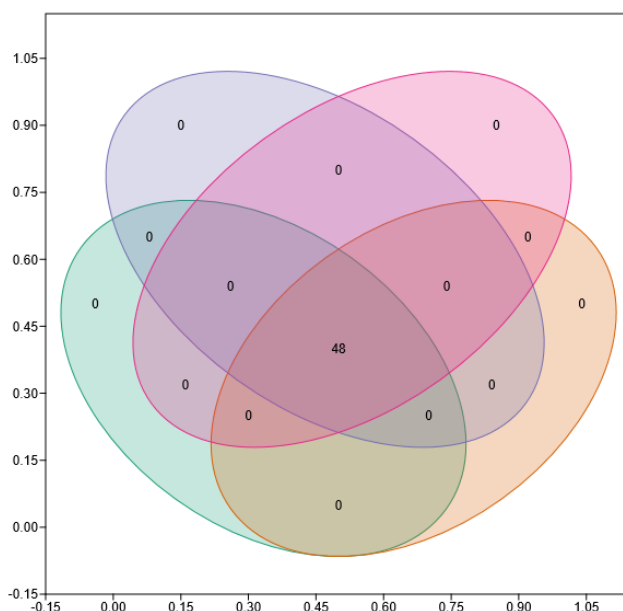


FIG. 13. Venn diagram based on floral parameters of the ranunculus genotype 'Elegance Striato Bianco'

The diagram illustrated the ellipses for the parameters considered (each ellipse represented a category of values), the differences (unique areas; the portions of the ellipses that did not overlap), and the intersection (middle area; the area where the ellipses overlapped and contained the values common to all parameters). In the present analysis, the intersection area included all 48 values, recorded for each parameter, which showed the harmonious development of the flowers, respectively of the floral parameters considered.

In studies of some plant species, the Venn diagram has been proposed as a tool and database for evaluating the structure and complexity of flowers (Herlinda *et al.*, 2021).

Venn diagrams have been considered valuable tools for visualizing

relationships between sets (parameters) and obtaining information in biological, medical, plant studies, bioinformatics, etc., due to their ease of interpretation (Heberle *et al.*, 2015; Gao *et al.*, 2021; Jia *et al.*, 2021; Yang *et al.*, 2024).

Venn diagrams have been used in studies and analyses of living organisms, ecosystems, society, and climate perspectives (Becker, 2024). Venn diagrams have been used for comparative analysis of wild fruits and vegetables in relation to perceived use (Jabeen *et al.*, 2024).

In the case of ornamental plants, Venn diagrams have been used to analyze and visualize differences and overlaps in the genetic base, metabolic products, or plant species and varieties at different stages of development (Zhou *et al.*, 2017). Pollinator attractiveness of ornamental plants from different nurseries was assessed using Venn diagrams (Sponsler *et al.*, 2020). Venn diagrams have been used to map the genetically determined floral architecture of some woody ornamental plants, such as *Prunus mume* (Li *et al.*, 2022).

The mathematical models obtained described the variation of floral parameters, of ornamental quality, in relation to plant parameters and highlighted the differentiated contribution (convergence and divergence) of the parameters to the formation and variation of the number of flowers and flower diameter.

CONCLUSIONS

The data series for vegetative and floral parameters of *Ranunculus asiaticus* L. plants, genotype 'Elegance Striato Bianco' presented normal distribution, without outlier values, except for the LN (leaf number) parameter with an outlier value ($p < 0.001$). The presence of variance was confirmed in the data set, under conditions of statistical safety.

Floral parameters, flower number (FN) and flower diameter (FD) presented differentiated variation in relation to plant parameters, according to regression analysis. Models were recorded that described the convergent action of some parameters (e.g. LN with LCI in the formation of the FN parameter; PH with FSH, LCI with FH, and FSH with FH in the formation of the FD parameter). In the other cases, the regression analysis showed divergent contribution of the parameters considered in the study to the formation of floral parameters (FN, FD). The results recommend the continuation and development of studies to decipher in more detail how vegetative parameters of plants capitalized on environmental conditions and influenced floral quality parameters.

The Venn diagram described the logical relationships between the groups of

elements of the floral parameters, FSH, FN, FH, FD, in the description of the flowers of ranunculus, genotype 'Elegance Striato Bianco', and the intersection area included all 48 values recorded for the parameters considered in the study.

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