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MODELS FOR DESCRIBING FLOWER SIZE AND FLOWERING TIME IN CHRYSANTHEMUMS

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Abstract

The study evaluated the vegetation and quality parameters associated with chrysanthemum flowers. Four cultivars of chrysanthemums were studied, cultivated in protected conditions: 'Yellow Snowdon', 'Tom Pearce', 'Palisade' si 'Avignon'. Shoots height (SH) and shoots number (SN) were evaluated as vegetative parameters that express the vegetation state of the plants; the determinations were made at the beginning of August - T1 and at the beginning of September - T2. Flowers diameter (FD) and flowering time (FT) were also evaluated as floral quality indices. The 'Yellow Snowdon' and 'Palisade' cultivars had high shoot height, with significant differences (LSD5%, LSD1%). Regarding the number of shoots, significant differences were registered for the cultivars 'Tom Pearce', 'Palisade', 'Avignon' (LSD5%, LSD1%). Flowers dimension (FD), as a quality parameter, showed significant differences for the cultivars 'Palisade' (LSD0.1%), 'Yellow Snowdon' and 'Tom Pearce' (LSD1%, LSD5%). Longer flowering time was recorded for the 'Avignon' cultivar (58 days) and shorter for the 'Yellow Snowdon' cultivar (52 days). The regression analysis facilitated the obtaining of some equations, as models that described the variation of FD and FT in relation to vegetative parameters (SH and SN), in statistical safety conditions (p <0.001). It was found that a number of 2.223 shoots (SN-T1), respectively 2.765 shoots (SN-T2), provided large flowers. The height of the shoots of 27.191 cm (SH-T1) and 91.816 cm (SH-T2) showed optimal values in relation to the flowering time (FT).

Key words: *chrysanthemum, flower size, flowering time, model, vegetative indices*

INTRODUCTION

In the category of ornamental plants, chrysanthemums (*Chrysanthemum* L.) have special importance, aesthetic, popular and cultural in different areas around the world, but also a great economic importance [37], [24], [28].

Chrysanthemums are used for ornamental purposes most often as cut flowers, but also as potted flowers and garden flowers [39]. As a result, different genotypes of chrysanthemums have been studied and characterized in this regard for the production of cut flowers [34].

Some studies have evaluated different varieties of chrysanthemums in relation to growing systems and conditions, water regime, daylength and temperature [19], [36], [28] and flower quality indices [23], [13].

Due to the importance of chrysanthemums, these ornamental plants have been studied in relation to different growing substrates, mulches and organic fertilization [34], organic and conventional cultivation systems [24], aeroponic culture [5].

Plant growth and flower quality in chrysanthemums have been studied in relation to different nutrients, mineral nutrition and nutrient management [38], [40], [6], [1], [29]. Studies have also been conducted on the influence of fertilizer resources with controlled release of nutrients, or some bioactive substances on chrysanthemums [17], [13].

The cultivation of chrysanthemums has also been studied in relation to resistance to diseases and pathogens, in order to obtain quality ornamental plants [38].

Given the food resource requirements of humans, some studies have evaluated chrysanthemums as a sources of minerals and functional foods (minerals, antioxidants etc.) for human nutrition [30], and as a germplasm resource for medicinal purposes and for teas [33], [43].

Chrysanthemums also have different meanings, and special symbolism. Chrysanthemum flowers are present as elements and symbols in the cultural life of many peoples [33].

Chrysanthemums have been cultivated in China since the 15th century BC. An ancient Chinese city was named Chu-Hsien, in translation "Chrysanthemum City" [27].

As a result of the significance of chrysanthemums, cultural and artistic manifestations of these flowers have been dedicated in different areas of the world ("Sapporo Chrysanthemum festival" (2020), "Kasama Chrysanthemum festival" (2021) in Japan; "Chrysanthemum festival" every year in Tongxiang, China etc.).

In Romania, Teodorescu (2010) [38] mentions "Chrysanthemum festival", organized every autumn, in Targoviste, but there are other events associated with these flowers.

The present study evaluated four varieties of chrysanthemum in order to model the behavior of some flower quality parameters in relation to vegetative parameters.

MATERIALS AND METHODS

The study evaluated the behavior of some chrysanthemum cultivars in relation to vegetative and flower quality parameters and used regression analysis to find models to describe flower parameters. Four cultivars were analyzed: 'Yellow Snowdon' (lemon-yellow colour), 'Tom Pearce' (red colour), 'Palisade' (white colour) and 'Avignon' (pale-pink colour), Figure 1.

The experiments were organized in a protected space (greenhouse), on two experimental cycles, in different years, in relation to the chrysanthemums biology (experimental cycle I - ExpCI, experimental cycle II - ExpCII).

Fig. 1. Image from the experimental conditions, and the studied chrysanthemum cultivars
Source: Original image, from experimental field.

Vegetative parameters were studied that express the vegetation state of the plants and influence the quality of the chrysanthemums flowers: shoots height (SH) and shoots number (SN). During the vegetation period, the determination of the vegetative parameters was made at two plants evolutionary moments, at the beginning of August (T1) and at the beginning of September (T2), in both experimental cycles.

Chrysanthemums are ornamental plants with flowers. Flower quality was assessed by flower diameter (FD). The determination was made in early October (ExpCI and ExpCII).

To assess flowering time (FT), the beginning of flowering and the end of flowering were monitored, and the flowering time in days (FT) was calculated.

The data obtained were analyzed by Variance analysis, Correlation analysis, Cluster analysis, Regression analysis. For the interpretation of the results and the differences between the studied chrysanthemum cultivars, as well as in relation to the average of the experiment (control variant), the limits of significance of the differences (LSD), cophenetic coefficient (Coph. corr.), correlation coefficient (r), and regression coefficient (R^2) were calculated and used.

The calculation module from EXCEL, PAST software [12] and Wolfram Alpha (2020) [41] were used.

RESULTS AND DISCUSSIONS

Physiological parameters, such as shoots height (SH) and shoots number (SN), were determined at two different times in relation to the biology and vegetation cycle specific to chrysanthemums. Thus, determinations were made at the beginning of August - T1 and at the beginning of September - T2, on the two experimental cycles (Experimental cycle I - ExpCI, Experimental cycle II - ExpCII). The height of the shoots (SH) at the moment T1 registered values between 25.16 cm for the 'Palisade' cultivar and 31.40 cm for the 'Avignon' cultivar (ExpCI), respectively 24.65 cm for the 'Palisade' cultivar and 32.00 cm for the 'Avignon' cultivar (ExpCII), Table 1. The Variance analysis highlighted the significance of the differences between the varieties, in conditions of statistical safety for the 'Palisade' and 'Avignon' cultivars (LSD5%, LSD1%).

The evaluation made at the time of T2 showed values of shoots height between 82.19 cm for the 'Tom Pearce' cultivar and 98.42 cm for the 'Yellow Snowdon' cultivar (ExpCI), respectively 92.45 cm for the 'Palisade' cultivar and 102.25 cm for the 'Yellow Snowdon' cultivar (ExpCII), Table 2. The Variance analysis highlighted the significance of the differences between the cultivars for 'Yellow Snowdon' and 'Tom Pearce' (LSD5%).

Table 1. The height of the shoots in the studied chrysanthemum cultivars (T1)

Cultivars	ExpCI			ExpCII		
	Average value (cm)	Relative value (%)	Differences	Average value (cm)	Relative value (%)	Differences
Control	28.06	100.00	-	28.58	100.00	-
'Yellow Snowdon'	27.48	97.93	-0.58	28.35	99.20	-0.23
'Tom Pearce'	28.20	100.50	0.14	29.35	102.69	0.77
'Palisade'	25.16	89.67	-2.90°	24.65	86.25	-3.93°°
'Avignon'	31.40	111.90	3.34*	32.00	111.97	3.42*
LSD values	LSD5%=2.31; LSD1%=3.36; LSD0.1%=5.04			LSD5%=2.54; LSD1%=3.70; LSD0.1%=5.54		

Source: original data, resulted from our experiments.

Table 2. The height of the shoots in the studied chrysanthemum cultivars (T2)

Cultivars	ExpCI			ExpCII		
	Average value (cm)	Relative value (%)	Differences	Average value (cm)	Relative value (%)	Differences
Control	90.47	100.00	-	93.63	100.00	-
'Yellow Snowdon'	98.42	108.79	7.95*	102.25	109.21	8.62*
'Tom Pearce'	82.19	90.85	-8.28°	86.40	92.28	-7.23°
'Palisade'	92.40	102.13	1.93	92.45	98.74	-1.18
'Avignon'	88.90	98.26	-1.57	89.99	96.11	-3.64
LSD values	LSD5%=6.47; LSD1%=9.41; LSD0.1%=14.11			LSD5%=6.35; LSD1%=9.24; LSD0.1%=13.86		

Source: original data, resulted from our experiments.

The number of shoots (SN) at T1 recorded values between 2.40 for the 'Palisade' cultivar and 3.90 for the 'Avignon' cultivar (ExpCI), respectively 2.71 for the 'Tom Pearce' cultivar and 3.63 for the 'Avignon' cultivar (ExpCII), Table 3. The Variance analysis highlighted the significance of the differences between the cultivars, in conditions of statistical safety for the 'Tom Pearce', 'Palisade' and 'Avignon' cultivars (LSD5%, respectively LSD1%).

The evaluation made at the time of T2 showed values of the number of shoots between 2.97 for the 'Palisade' cultivar and 4.32 for the 'Avignon' cultivar (ExpCI), respectively 3.20 for the 'Palisade' cultivar and 4.25 for the 'Avignon' cultivar (ExpCII), Table 4. The Variance analysis highlighted the significance of the differences between the cultivars for 'Tom Pearce', 'Palisade' and 'Avignon' (LSD1%, LSD5%).

Table 3. Number of shoots in the studied chrysanthemum cultivars (T1)

Cultivars	ExpCI			ExpCII		
	Average value (no)	Relative value (%)	Differences	Average value (no)	Relative value (%)	Differences
Control	2.95	100.00	-	3.12	100.00	-
'Yellow Snowdon'	3.00	101.69	0.05	3.24	103.85	0.12
'Tom Pearce'	2.51	85.08	-0.44	2.71	86.86	-0.41°
'Palisade'	2.40	81.36	-0.55°	2.89	92.63	-0.23
'Avignon'	3.90	132.20	0.95^{**}	3.63	116.35	0.51^{**}
LSD values	LSD5%=0.46; LSD1%=0.67; LSD0.1%=1.01			LSD5%=0.33; LSD1%=0.49; LSD0.1%=0.72		

Source: original data, resulted from our experiments.

Table 4. Number of shoots in the studied chrysanthemum cultivars (T2)

Cultivars	ExpCI			ExpCII		
	Average value (no)	Relative value (%)	Differences	Average value (no)	Relative value (%)	Differences
Control	3.63	100.00	-	3.64	100.00	-
'Yellow Snowdon'	4.15	114.33	0.52	3.80	104.39	0.16
'Tom Pearce'	3.08	84.85	-0.55°	3.30	90.66	-0.34
'Palisade'	2.97	81.82	-0.66°	3.20	87.91	-0.44°
'Avignon'	4.32	119.01	0.69^{*}	4.25	116.76	0.61^{**}
LSD values	LSD5%=0.54; LSD1%=0.73; LSD0.1%=1.09			LSD5%=0.42; LSD1%=0.60; LSD0.1%=0.91		

Source: original data, resulted from our experiments.

The diameter of the flowers (FD), determined in early October, registered values between 8.31 cm for the 'Tom Pearce' cultivar and 13.66 cm for the 'Palisade' cultivar (ExpCI), Table 5, respectively 8.56 cm for the 'Yellow Snowdon' cultivar and 12.31 cm for the 'Palisade' cultivar (ExpCII), Table 6.

Table 5. Flower diameter in the studied chrysanthemum cultivars, ExpCI

Cultivars	Average value (cm)	Relative value (%)	Differences
Control	10.19	100.00	-
'Yellow Snowdon'	9.18	90.09	-1.01°
'Tom Pearce'	8.31	81.55	-1.88°°
'Palisade'	13.66	134.05	3.47^{***}
'Avignon'	9.63	94.50	-0.56
LSD values	LSD5%=0.89; LSD1%=1.27; LSD0.1%=2.14		

Source: original data, resulted from our experiments.

The Variance analysis highlighted the significance of the differences between the cultivars, in statistical safety conditions for 'Yellow Snowdon' (LSD5%), 'Tom Pearce' (LSD1%), and 'Palisade' (LSD0.1%) in the case of ExpCI, respectively for 'Yellow Snowdon', 'Tom Pearce' (LSD1%), and 'Palisade' (LSD0.1%) in the case of ExpCII.

Table 6. Flower diameter in the studied chrysanthemum cultivars, ExpCII

Cultivars	Average value (cm)	Relative value (%)	Differences
Control	9.86	100.00	-
'Yellow Snowdon'	8.56	86.81	-1.30°°
'Tom Pearce'	8.83	89.55	-1.03°°
'Palisade'	12.31	124.85	2.45^{***}
'Avignon'	9.74	98.78	-0.12
LSD values	LSD5%=0.65; LSD1%=0.93; LSD0.1%=1.36		

Source: original data, resulted from our experiments.

In order to evaluate the flowering time (FT), the data regarding the beginning and the end of the flowering were recorded, and the values obtained for FT are presented in the form of a graphical diagram, Figure 2.

A longer flowering time was recorded for the 'Avignon' cultivar and a shorter flowering time for the 'Yellow Snowdon' and 'Palisade' cultivars. The 'Palisade' cultivar showed a constant regarding FT, while the other cultivars showed variability in relation to the experimental cycle.

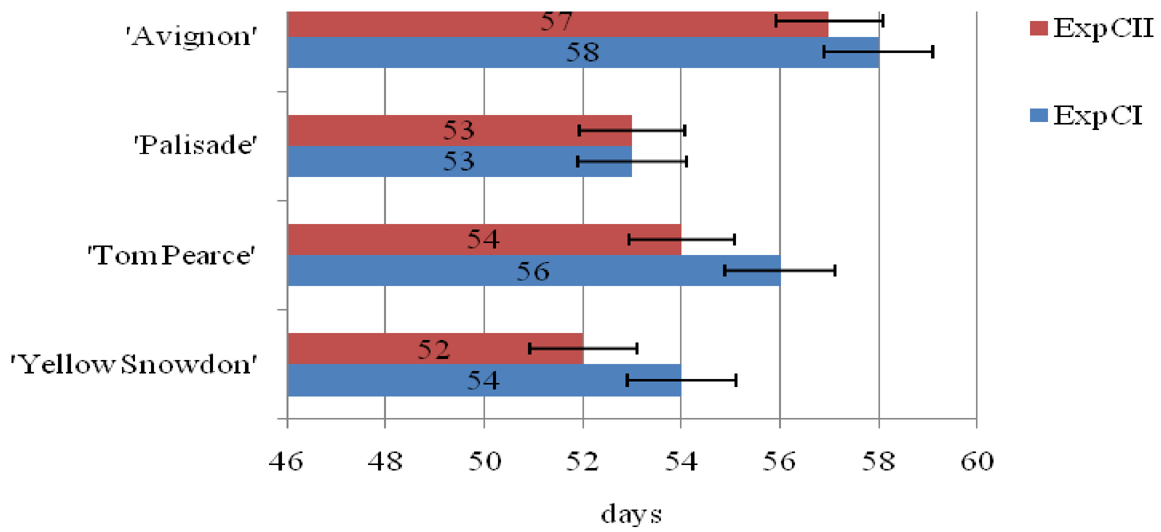

Fig. 2. Flowering time (FT) diagram for the studied chrysanthemum cultivars
Source: original graph, generated based on experimental data.

The cluster analysis that took into account FD and FT led to the diagram in Figure 3, in statistical safety conditions, Coph.corr = 0.893 (ExpCI), respectively Coph.corr = 0.799 (ExpCII).

The 'Tom Pearce' (TP) and 'Yellow Snowdon' (YS) cultivars showed a high level of similarity (SDI = 2.181, for ExpCI; SDI = 2.02181 for ExpCII). The two cultivars were associated in the diagram with the 'Avignon' (Avi) cultivar, the three cultivars being grouped in a cluster. The 'Palisade' (Pal) cultivar was placed in a separate position.

Correlation analysis revealed very strong correlation levels between FT and SH-T1 (r = 0.965) under ExpCI conditions, and between SN-T1 and SN-T2 (r = 0.964) under ExpCII conditions.

Strong correlations were recorded between SN-T1 and SH-T1 (r = 0.885), respectively between SN-T1 and SN-T2 (r = 0.892) under ExpCI conditions.

Moderate correlations were recorded between FT and SN-T1 (r = 0.761) under ExpCI conditions, respectively between FT and SH-T1 (r = 0.743) under ExpCII conditions. Other correlations of lower intensity were also recorded.

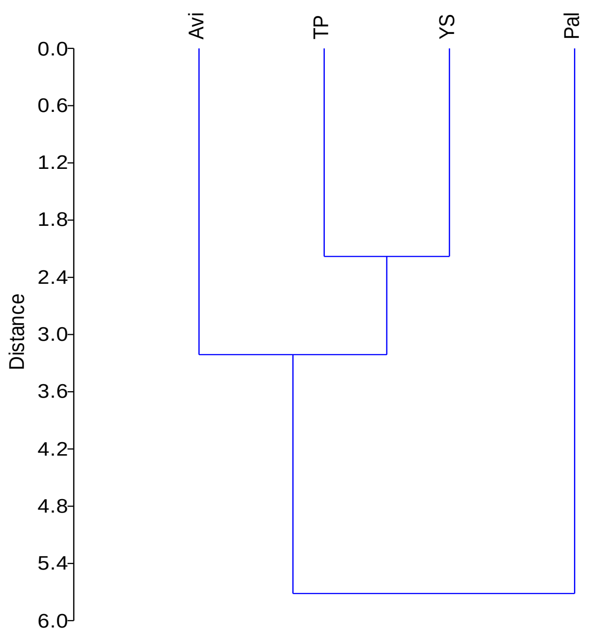

Fig. 3. Dendrogram of the group of chrysanthemum cultivars studied based on Euclidean distances, in relation to FD and FT
Source: original graph, generated based on experimental data.

Regression analysis was used to evaluate the variation of FD and FT in relation to vegetative parameters in the studied chrysanthemum cultivars.

The variation of the flower diameter (FD) for the chrysanthemums studied cultivars, on the two experimental cycles, in relation to shoots number (SN-T1 and SN-T2) was described by the equation (1), in statistical safety conditions ($R^2 = 0.978$, $p < 0.001$).

The graphical representation of the FD variation in relation to vegetative parameters (SN-T1, x-axis, and SN-T2, y-axis) is presented graphically in 3D form (Figure 4), and in isoquants form (Figure 5).

Based on the values of the coefficients of equation (1), the optimal values for x (SN-T1) and y (SN-T2) were calculated in relation to the flower diameter (FD). The values of x_{opt} = 2.223 and y_{opt} = 2.765 were found.

$$FD = ax^2 + by^2 + cx + dy + exy + f \qquad (1)$$

where: FD - flower diameter;
x – SN-T1 – shoots height at T1 determination;
y –SN-T2 – shoots number at T2 determination;
a, b, c, d, e, f – coefficients of the equation (1);
a= -1.4986899;
b= 8.8506251;
c= 13.5567693;
d= 6.9468557;
e= -21.2598468;
f= 0.

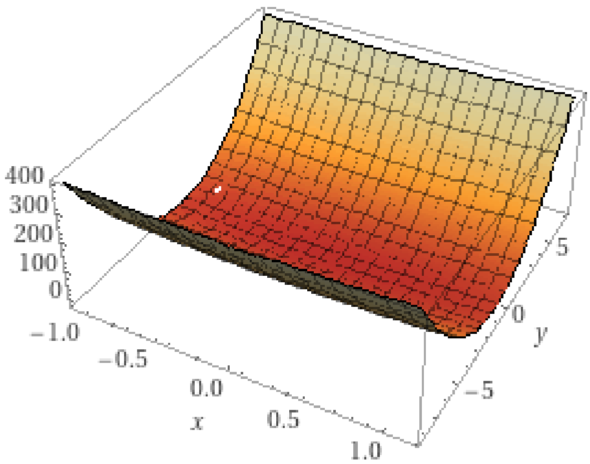

Fig. 4. 3D graphical representation of FD in relation to SN-T1 (x-axis) and SN-T2 (y-axis) on the two experimental cycles (ExpCI, ExpCII)
Source: original graph, generated based on experimental data.

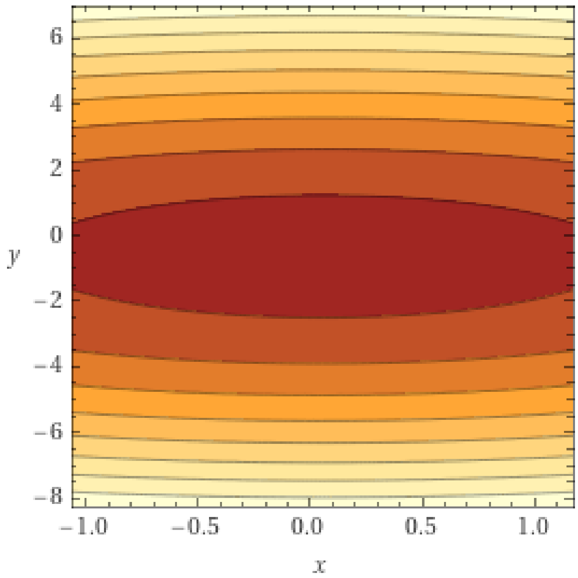

Fig. 5. Flower dimension (FD) graphical representation in the form of isoquants in relation to SN-T1 (x-axis) and SN-T2 (y-axis) on the two experimental cycles (ExpCI, ExpCII)
Source: original graph, generated based on experimental data.

From the graphic analysis, as well as of the obtained values, it was found the high importance of SN-T2 in the variation of FD in the studied chrysanthemum cultivars. This suggests the importance of controlling the number of shoots through specific maintenance works, but also the water and nutrients supply for the purpose of proper plant nutrition.

The variation of the flower size in chrysanthemums, the studied cultivars, on the two experimental cycles (flower diameter - FD) in relation to shoots height (SH-T1) and shoots number (SN-T1), was described by equation (2), in statistical safety conditions (R^2=0.986, p<0.001).

The graphical representation of the FD variation in relation to vegetative parameters (SH-T1, x-axis and SN-T1, y-axis) is represented graphically in 3D form in the Figure 6, and in the form of isoquants in the Figure 7.

Based on the values of the coefficients of equation (2), the optimal values for x (SH-T1) and y (SN-T1) were calculated in relation to the flower diameter (FD). The values of x_{opt} = 30.109 cm and y_{opt} = 3.793 were found.

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

where: FD - flower diameter
x – SH-T1 – shoots height at T1 determination;
y –SN-T1 – shoots number at T1 determination;
a, b, c, d, e, f – coefficients of the equation (2);
a= -0.2136185;
b= -2.8130313;
c= 5.4156014;
d= -37.7753417;
e= 1.9634209;
f= 0.

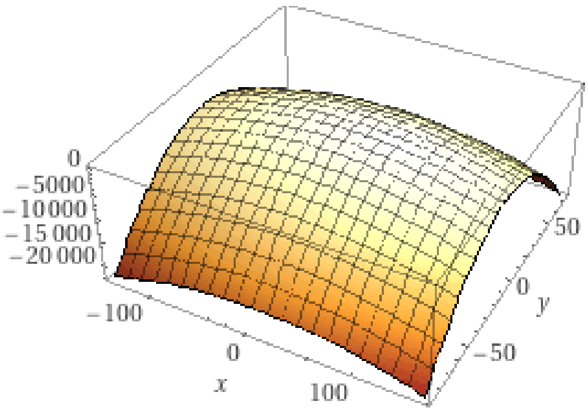

Fig. 6. 3D representation of FD in relation to SH-T1 (x-axis) and SN-T1 (y-axis) on the two experimental cycles
Source: original graph, generated based on experimental data.

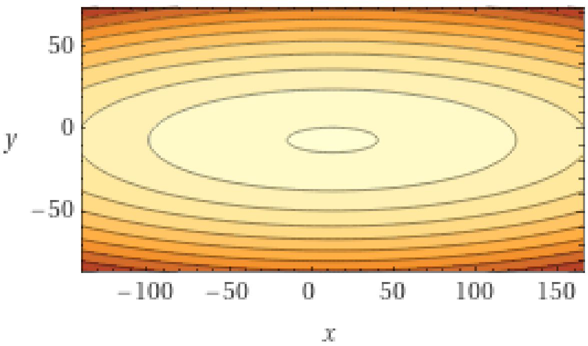

Fig. 7. Representation in the form of isoquants of FD in relation to SH-T1 (x-axis) and SN-T1 (y-axis) on the two experimental cycles
Source: original graph, generated based on experimental data.

The variation of the flowering time (FT) in relation to the values of the vegetative parameters (SH-T1 and SH-T2) was described by equation (3), in statistical safety conditions (R^2=0.999, p<0.001).

The graphical representation of the FT variation in relation to vegetative parameters (SH-T1, x-axis and SH-T2, y-axis) is rendered graphically in 3D form in Figure 8, and in the form of isoquants in Figure 9.

$$FT = ax^2 + by^2 + cx + dy + exy + f \qquad (3)$$

where: FT - flowering time in relation to vegetative parameters SH;
x – SH-T1 – shoots height at T1 determination;
y –SH-T2 – shoots number at T2 determination;
a, b, c, d, e, f – coefficients of the equation (3);
a= 0.1760536;
b= 0.0212712;
c= 3.7200560;
d= 0.0311723;
e= -0.1447952;
f= 0.

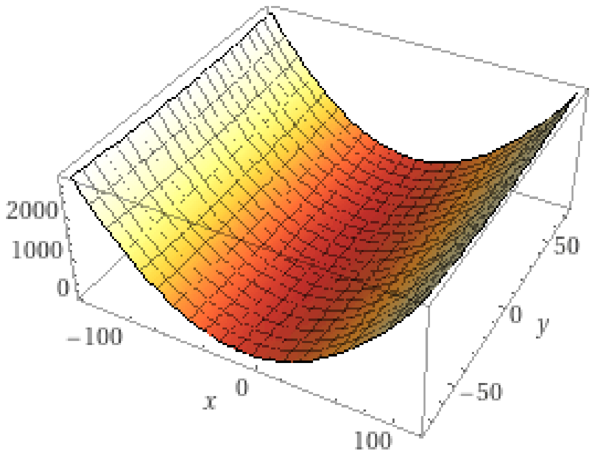

Fig. 8. 3D graphical representation of FT in relation to SH-T1 (x-axis) and SH-T2 (y-axis) on the two experimental cycles
Source: original graph, generated based on experimental data.

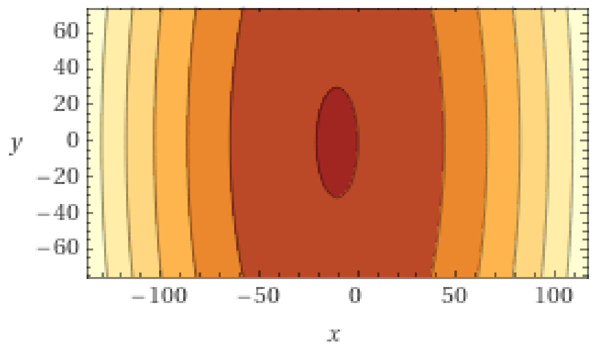

Fig. 9. Flowering time (FT) representation in the form of isoquants in relation to SH-T1 (x-axis) and SH-T2 (y-axis) on the two experimental cycles
Source: original graph, generated based on experimental data.

Based on the values of the coefficients of the equation (3), the optimal values for x (SH-T1) and y (SH-T2) were calculated in relation to the flowering time (FT). The values x_{opt} = 27.191 cm and y_{opt} = 91.816 cm were found.

From the FD and FT analysis in relation to SN and SH (T1 and T2; ExpCI, ExpCII), values were found for physiological parameters, figure 10, which suggest the need to control the number of shoots; fewer shoots provide large flowers.

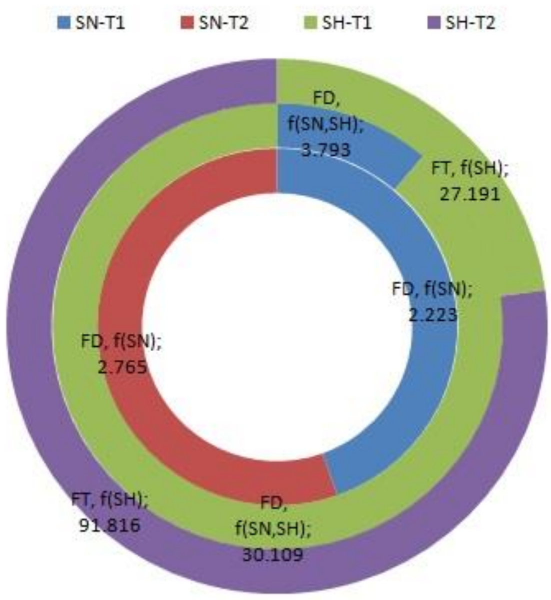

Fig. 10. Graphic distribution of optimal SN and SH values in relation to FD and FT for the studied chrysanthemum cultivars
Source: original graph, generated based on experimental data.

Also, maintenance works are needed to ensure water and nutrients in relation to the growing substrate, for the normal growth and development of plants.

The status of plant development is important; water supply and nutrients, as well as plant protection are needed to obtain vigorous shoots, which will provide large and quality flowers.

A small number of shoots and the vigorous development of the shoots ensure quality flowers and a longer flowering time.

For monitoring plants in relation to pathogens, non-destructive methods are recommended for rapid assessment, with a high level of safety, in order to estimate the attack on the leaves or plants and the decision to intervene with adequate treatments [9], [10], [21], [39]. Also, for the characterization and comparative analysis of different plant genotypes, non-destructive methods and imaging analysis is very useful [32].

Many models have been studied and developed in relation to crops plants [31], but ornamental plants have a high economic value and a high importance for the market [4]; [7], [41], and the modeling of these plants is also important [26], [25], [15].

By knowing their behaviour, some chrysanthemum genotypes can also occupy an important niche as garden plants in urban ecosystems [3], [2], [22], [11], studied in relation to various anthropogenic or natural factors of influence [14].

Interest to modeling, in chrysanthemums plants research, has also been found in other studies, in relation to stem elongation [18], the growth of chrysanthemum crops [20], the structure and response of plants to influencing factors [8], [16].

The present study, through the approach and the obtained results, contributes to the development of the information base and approach in the cultivation of chrysanthemums, in relation to the quality of the flowers and the flowering period.

CONCLUSIONS

The regression analysis facilitated the finding of equations as models to describe the variation of FD and FT in relation to vegetative parameters (SH and SN) for the four varieties of chrysanthemums studied.

Based on the coefficients of the equations obtained, it was possible to find the optimal values for vegetative parameters in relation to FD and FT, for the study conditions. This approach can be adapted to other study conditions, varieties of chrysanthemums, or ornamental plants.

The values obtained for vegetative parameters, in relation to the flowers dimension (FD), or the flowering time (FT), recommend the need for specific care works for chrysanthemums, in order to obtain quality flowers and a longer period of flowering.

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