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SCIENTIFIC ARTICLE

Growth regulators and mineral fertilizers effect on morphometric indicators and decorative qualities of *Zinnia elegans* varieties

Nikolai Vasilyevich Smolin [1]*, Alexander Vasilyevich Ivoilov [1], Viktor Vladimirovich Volgin [1], Natalia Vasilyevna Potapova [1], Alexander Nikolaevich Nikolskiy [1], Julia Nikolaevna Nedayborshch [1], Ilya Vladimirovich Potapov[1]

[1] Mordovia Ogarev State University, Department of Agronomy and Landscape Architecture, Saransk, Russia.

Abstract

Growth regulators had a significant effect on the morphometric parameters of graceful zinnia, among which the most effective was Epin-extra. Being treated twice with epibrassinolide, zinnia plants had a more saturated color range. Zircon (a drug from the group of hydroxycinnamic acids), as it turned out, had a lesser effect on morphometric parameters than Epin-extra. The Mechta (in English translation as Dream). Further in the text this name will be used) variety turned out to be more resistant to unfavorable weather conditions and in comparison with the Oranzhevyy korol' (in English translation as Orange King). Further in the text this name will be used variety, it more easily tolerated recurrent cold and droughts during the growing season. In addition, the Dream variety turned out to be more even in height and in the formation of lateral flowering shoots, which is important to create ornamental flower compositions. The use of growth regulators and mineral fertilizers increased zinnia visual perception. Among the varieties, the variety Dream had the most preferable decorative qualities.

Keywords: diameter of inflorescences, Epin-extra, number of inflorescences, plant height, Zircon.

Resumo

Reguladores de crescimento e adubos minerais efeito nos indicadores morfométricos e nas qualidades decorativas das variedades *Zinnia Elegans*

Os reguladores de crescimento tiveram efeito significativo nos parâmetros morfométricos da zínia graciosa, dentre os quais o mais eficaz foi o Epin-extra. Sendo tratadas duas vezes com epibrassinolídeo, as plantas de zínia apresentaram uma gama de cores mais saturada. O Zircon (um produto do grupo dos ácidos hidroxicinâmicos) teve um efeito menor nos parâmetros morfométricos do que o Epin-extra. O Mechta (em tradução inglesa como Dream), que ao longo do texto este nome será usado para esta variedade, foi a mais resistente a condições climáticas desfavoráveis, quando comparado com o Oranzhevyy korol' (em tradução inglesa como Orange King), que mais adiante no texto esse nome será usado para a variedade que tolerou facilmente ao frio recorrente e as secas durante o período de crescimento. Além disso, a variedade Dream revelou-se mais uniforme em altura e na formação de rebentos de floração lateral, o que é importante para criar composições de flores ornamentais. O uso de reguladores de crescimento e fertilizantes minerais aumentou a percepção visual da zínia. Entre as variedades, a variedade Dream apresentou as qualidades decorativas mais preferidas.

Palavras-chave: Epin-extra, altura da planta, diâmetro das inflorescências, número de inflorescências, Zircon.

Introduction

Morphobiometric features are one of the fundamental qualities in the visualization of ornamental plants. When choosing plants for a flower garden, it is necessary to take into account the biological characteristics of plants, their decorative appearance and flowering continuity.

Zinnia elegans is one of those plants that is often used in urban landscaping to create floral arrangements. Zinnia is perfectly combined both with other ornamental annuals, and in solo plantings (Ziobro and Usova, 2016; Konstantinova, 2017). This plant fits perfectly into the modern trend of the natural garden with a minimum of maintenance. At the same time, zinnia graceful is suitable for growing in containers and pots, as well as for cutting to create bouquet arrangements (Javid et al.; 2005 Loyola et al., 2019). Zinnia graceful is a heliophyte and is resistant to high soil temperatures and low air humidity. Zinnia is

*Corresponding author: smolin89@mail.ru

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a typical short-day plant (Kim et al., 2009; Safdar et al., 2016; Toscano and Romano, 2021; Marković et al., 2022).

However, this plant does not tolerate prolonged drought, as a result of which it loses its decorative appearance (the leaves lose their turgor, the inflorescences become small, and faded in color). Zinnia is also very sensitive to low temperatures and its growing season ends with first autumn frosts beginning (Ahmad and Dole, 2014).

The refined appearance of ornamental plants is ensured, first of all, by their healthy habit and picturesque spectrum of colors. Unfortunately, in urban environment, ornamental plants are significantly affected by biotic and abiotic stresses. Therefore, both growing and planting seedlings in landscape compositions, a number of specialists (Kuzovkova et al., 2015; Zeb et al., 2017; Sedaghathoor and Zakibakhsh-Mohammadi, 2019; Karimi et al., 2019; Ali et al., 2021; Mohamed et al., 2022) recommend to use growth regulators in order to neutralize the effect of unfavorable stress factors in the juvenile period of plant development. Having been transplanted from a greenhouse, the dug seedlings are significantly stressed.

To accelerate growth and development, improve decorative features, and increase plant defenses against diseases, drugs of various functional effects, namely biostimulants (orbioregulators) are used, which have a protective function that increases the plant organism's resistance to different functional stresses effects (Majkowska-Gadomska*et* et al., 2017; El-Nashar and Hassan, 2020; Smolin et al., 2020).

It has been proven that bioregulators increase the viability of seeds, seedlings and cuttings of ornamental crops, stimulate the growth of vegetative mass, improve the absorption and distribution of nutrients in the plant, increase the antioxidant capacity of plant tissues, thereby helping to increase resistance to stress and, ultimately, improve ornamental flower quality (Parađiković et al., 2019).

The scientific task of modern ornamental plant growing is to increase the resistance of plants to stress factors, the inclusion of additional protective functions of the plant organism through the use of biostimulants. Currently, studies of biostimulants effect on annual flower crops are fragmented and do not reveal the essence of the problem of comparative study of various varieties of a number of flower-decorative annuals. The reaction of decorative annuals to the application of mineral fertilizers and growth regulators in the European part of Russia was not studied, which served as the starting point of our research. The objective of this research was to determine the effect of mineral fertilizers and growth regulators on morphometric indicators and decorative qualities of zinnia.

Materials and Methods

In 2017-2019 a three-factor small-plot field experiment was carried out to study the effect of growth regulators and mineral fertilizers on morphometric parameters (height, diameter of inflorescences and their number) and decorative qualities of two varieties of graceful zinnia. The research was carried out in the botanical garden of the Mordovia State University (latitude: 54°11′01″ S, longitude: 45°10′29″ W, altitude: 173 m).

The experiment was carried out on leached chernozem with heavy loamy texture. Humus content varied from 6.0 to 6.5%, P_2O_5 from 168 to 179 mg kg^{-1}, K_2O from 215 to 235 mg kg^{-1}. The pH value of salt extract is 5.8-6.2. Saturation degree of soils with bases is high (86.4-88.4%).

During crop growing season, weather conditions varied significantly in different years of research (Table 1).

Table 1. The mean air temperature (°C) and total rainfall (mm) in 2017-2019 vegetation as compared to the long term mean (LTM = 1980-2000).

Year	Month, decade											
	May			June			July			August		
	I	II	III	I	II	III	I	II	III	I	II	III
Mean air temperature (°C)												
Long term mean	12.0	13.7	14.6	15.5	17.4	18.4	18.5	19.4	19.0	18.6	17.4	16.4
2017	12.9	10.4	13.0	12.4	15.8	16.6	16.0	19.9	20.2	20.4	19.1	17.7
2018	15.5	17.3	14	12.3	15.9	22.7	22.9	21.9	21.4	20.9	19.5	18.7
2019	15.2	16.8	17.1	19.8	18.8	19.0	16.6	18.0	18.0	14.5	18.9	15.5
Total rainfall (mm)												
Long term mean	13	16	15	14	24	17	30	22	18	18	19	16
2017	7	21	20	23	19	12	73	16	15	5	1	9
2018	9	4	5	17	3	0	13	6	17	5	0	2
2019	8	2	6	6	2	31	26	25	32	14	35	3

The experiment was carried out by the split plots' method in six replicates. The first factor included the study of two growth regulators by Nest-M manufacturing company (Moscow): Epin-extra (active ingredient is brassinosteroids) in a dose of 1.0 mL per 5 liters of water (concentration the active ingredient $5*10^{-3}$ %) and Zircon (active ingredient is hydroxycinnamic acids) in a dose of 1.0 mL per 10 liters of water (concentration the active ingredient 10^{-2}%). Spraying was carried out twice during the growing season (the first spraying after planting, the second during after 30 days in the bud-formation period). Plants treatment with drugs, according to the experimental schemes, was carried out with a knapsack sprayer in the evening. Control plots were treated with water.

During "B" factor the effect of mineral fertilizers was studied. As an experimental variant without fertilization, Azophoska (nitrogen-phosphorus-potassium fertilizer) ($N_{16}P_{16}K_{16}$) was applied with 15 g m^{-2} dose before planting. The final dose of fertilizers per standard hectare, as is customary in modern agriculture, was $N_{24}P_{24}K_{24}$ kg ha^{-1}.

As "C" factor for the comparative study, two varieties of graceful zinnia were taken: Dream and Orange King.

The plants decorative assessment was carried out during the period of mass flowering according to a generalized method (Khokhlacheva, 2012). Data were collected on plant height; number of leaf per plants, bud diameter at mature stage. The inflorescences diameter of plants was measured by the projective light method (Bochkova and Khokhlacheva, 2015). A cross in millimeters (two lines - horizontally (*x*-axis) and vertically (*y*-axis)) was painted on a white surface and, with the help of projection light, the diameter of the superimposed flower was marked in two directions. The average value was taken as a basis for measure. The zero point was first taken along the *x*-axis, then the flower was shifted, and the values along the *y*-axis were also noted from zero. Ten mature bud from each plant were measured and then average it after that mean was calculated. The total length from base of the branch to terminal node of flower was taken as stalk length. The number of leaves and plant height were calculated as an average of 10 plants from each replicates.

Data were analyzed using statistical package STATISTICA 12 and significant difference among the treatment means was determined by the Duncan's Multiple Range test (DMRT) at 5% level of significance. In addition, error bar represents the standard error at 5% level of significance.

Results and Discussion

The strict evenness of blossom plants gives a special appeal to flower beds and creates a continuous (like a carpet) picture with an even stalk height. Zinnia ornamental plants, leveled in height, are often used in continuous flower arrangements.

Exquisite observations of zinnia growth and development showed that experimentally grown zinnia plants, due to their considerable height (61-89 cm), were not suitable for use in continuous flower arrangements (Table 2).

Table 2. Influence of growth regulators, mineral fertilizers on the height of zinnia plants, on phenological stages (average over 3 years).

Variant			Plant height, cm		
Growth regulator (A factor)	Fertilizer (B factor)	Variety (C factor)	During bud-formation period (June 28-30)	During flowering period (July 31)	During seeds ripening period (August 30-31)
Without growth regulator (control)	Without fertilization	Orange king	29^{a}	37^{a}	61^{a}
		Dream	30^{ab}	38^{b}	65^{b}
	$N_{24}P_{24}K_{24}$	Orange king	34^{c}	42^{c}	70^{c}
		Dream	37^{d}	44^{d}	74^{c}
Epin-extra	Without fertilization	Orange king	34^{c}	42^{c}	72^{c}
		Dream	37^{cd}	43^{c}	76^{cd}
	$N_{24}P_{24}K_{24}$	Orange king	41^{de}	50^{de}	85^{de}
		Dream	44^{e}	54^{e}	89^{e}
Zircon	Without fertilization	Orange king	32^{ab}	40^{bc}	68^{bc}
		Dream	35^{c}	42^{c}	74^{c}
	$N_{24}P_{24}K_{24}$	Orange king	39^{de}	47^{d}	76^{cd}
		Dream	41^{de}	49^{de}	79^{d}

Means in each column in each factor followed by the same superscript letters are not significantly different according to DMRT at $P < 0.05$

Ornamental design of a flower garden requires decorative annuals with a lower stem (Zeb et al., 2017). In the control option, during seeds ripening period the height of zinnia plants was 61 cm in the Orange King variety and 65 cm in the Dream variety average over three years. With Epin-extra applying it increased to 72 and 76 cm, respectively.

The action of Zircon gave an increase in the plants' height by 7 cm in the Orange King variety and by 6 cm in the Dream variety compared to the control. Fertilizers use led to an increase in the height of zinnia stem by 9 cm an average in the variant without growth regulators and by 11 cm with their applying. In general, the Dream variety turned out to be more uniform in height than the Orange King variety, which is the preferred quality for the use of zinnia in monospecific plantings of summer flower-garden.

An important decorative feature is the number of flowers per plant, which ensures a continuous flowering cycle of the culture. The subsequence and duration of zinnia bloom ensures the presence of lateral shoots growing from the main stem. Some zinnia varieties have a large number of flowering shoots of the second and third orders, while others have fewer (Mahroof et al., 2017).

Being analyzed the Dream cultivar plant height it had a more branched main stem than the Orange King cultivar. Accordingly, the Dream variety was superior to the Orange King variety in the number of inflorescences. The use of fertilizers increased by 3.8-4.6 the number of zinnia inflorescences (Figure 1).

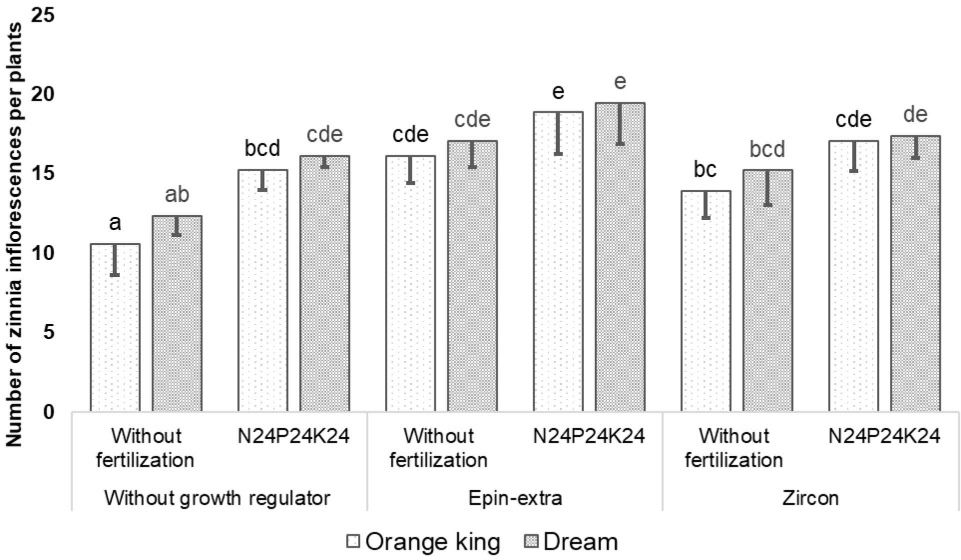

Figure 1. The influence of growth regulators and fertilizers on the number of zinnia inflorescences, on average for three years. Means in each column followed by the same superscript letters are not significantly different according to DMRT at P <0.05. Vertical bars indicate SD (n=3).

On average, for three years, the use of Epin-extra provided additional formation from 4 to 6 lateral stems and inflorescences on them. Zircon provided an increase of 2.5-3.0 additional lateral flowering branches. The highest increase in generative branching (19.5) was noted in zinnia of the Dream variety with variant of Epin-extra and fertilizers use, which is 78% higher than in control plants.

An important decorative feature is the shape and size of the inflorescence. The larger the size of the flower, the more attractive the look of the flower-garden is. Studies of the diameter of zinnia inflorescence showed that the Dream cultivar was distinguished by more voluminous and larger inflorescences. On average, over three years, the diameter of the inflorescence in this variety was 10.7 cm in the control plants (Figure 2), while in the Orange King variety it was only 9.6 cm.

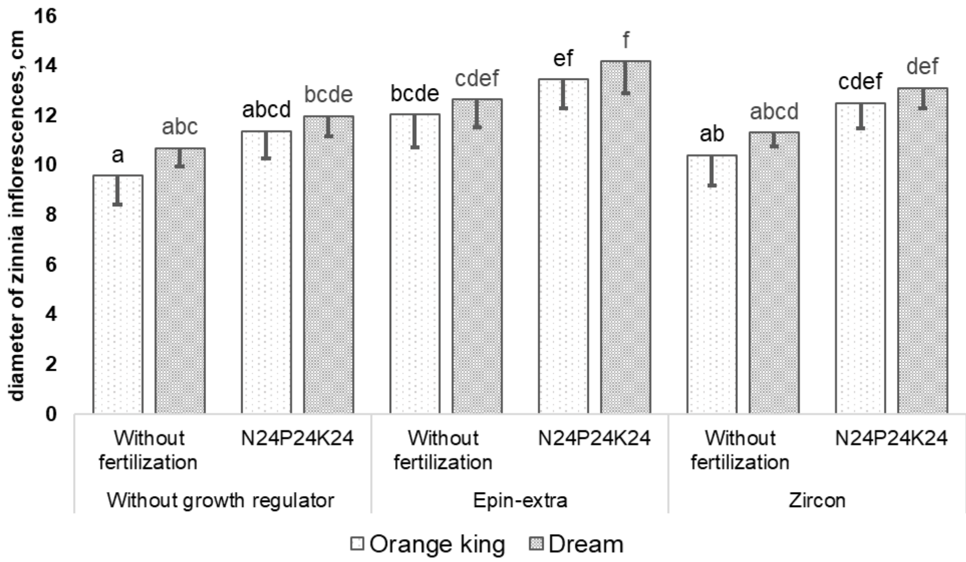

Figure 2. Influence of growth regulators, mineral fertilizers on the diameter of zinnia inflorescences, on average over three years. Means in each column followed by the same superscript letters are not significantly different according to DMRT at P <0.05. Vertical bars indicate SD (n=3).

Growth regulators use significantly increased the size of the zinnia inflorescence. The plantings treatment with Epin-extra contributed to an increase in inflorescence diameter by 2.1 cm, both without fertilization and with the application of $N_{24}P_{24}K_{24}$-dose fertilizers. The application of Zircon turned out to be less effective compared to Epin-extra. The excess of inflorescence diameter with the use of Zircon was 0.7 cm on average for three years. With the application of fertilizers this parameter was 1.1 cm.

Fertilizers also had a positive effect on the diameter of graceful zinnia inflorescence. The application of Azophoska at $N_{24}P_{24}K_{24}$-dose without growth regulators use provided an increase in the diameter of zinnia inflorescence by 1.5 cm. The same increase in the diameter of the inflorescence was noted with the application of fertilizers together with the use of Epin-extra. The increase in the diameter of the zinnia inflorescence with Zircon application was 1.9 cm.

Analysis of variance of these sizes of zinnia inflorescence diameter showed that the effect of all three factors under study was significant. Significant interaction between the factors of application of growth regulators and fertilizers was noted.

Ornamental crops grown in open field from seedlings are often exposed to stress factors of a biotic and an abiotic nature. Plants grown by seedlings do not immediately adapt to the soil and climatic conditions of outdoor bed. There is a period of adaptation or “hardening” of seedlings, during which the mechanisms of stress resistance to the adverse effects of an open urbanized environment are activated in plants. The number of unfavorable abiotic factors is territories gas contamination, recurrent cold snaps, lack of light and excess moisture in cloudy and rainy weather (Smirnova and Kochetov, 2015).

The assessment of the decorativeness of zinnia for a number of characteristics showed that both varieties had approximately the same total score (Table 3).

Table 3. Decorative assessment of zinnia graceful varieties.

Feature	Variety	Feature assessment according to a five-point system	Conversion factor depending on the feature significance	Feature assessment according to a hundred-point system
Inflorescence color	Orange king	5	2	10
	Dream	5		10
Resistance of inflorescences to unfavorable meteorological conditions	Orange king	4	3	12
	Dream	5		15
Inflorescence shape	Orange king	5	1	5
	Dream	5		5
Doubling	Orange king	5	3	15
	Dream	5		15
Peduncle (length and strength)	Orange king	4	3	12
	Dream	4		12
Bloom abundance	Orange king	5	3	15
	Dream	5		15
Bush (shape, decorativeness)	Orange king	4	1	4
	Dream	4		4
Originality	Orange king	5	1	5
	Dream	4		4
Plant condition (variety uniformity)	Orange king	4	3	12
	Dream	5		15
Total:	Orange king	-	-	90
	Dream			95

The total score for the Orange King variety was 90 points, for the Dream variety was 95 points. We noted only higher scores for the Dream variety in the resistance of inflorescences to unfavorable meteorological conditions and plant uniformity. The Orange King variety turned out to be visually more original, but this indicator has a certain subjectivity.

Conclusions

Double treatment of zinnia graceful plantings with Epin-extra provided additional formation from 4 to 6 lateral stems and inflorescences on them. Zircon provided an increase of 2.5-3.0 additional lateral flowering branches. The use of growth regulators significantly increased the size of the zinnia inflorescence. The treatment of plantings with Epin-extra contributed to an increase in inflorescence diameter by 2.1 cm, both without fertilization and with the application of $N_{24}P_{24}K_{24}$-dose fertilizers. The application of Zircon turned out to be less effective compared to Epin-extra.

Author Contribution

NVS: research orientation, suggestions, monitoring the experiment, preparation of the manuscript. **AVI, ANN:** monitoring the entire experiment, statistical analysis, preparation of the manuscript. **VVV, NVP, JNN, IVP:** sample preparation, monitoring the experiment, suggestions on manuscript preparation.

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