Effect of growth regulators melatonin and salicylic acid on the growth of Cassia glauca under heavy metal stress

Mohammed Adnan Jwaad Alwash Janan k. Hussein

Department of Horticulture, College of Agriculture, Al-Qasim Green University, Babil, 51013, Iraq.

[2]E-mail: dr.janan77@agre.uoqasim.edu.iq

Abstract

The experiment was conducted in a private nursery in Babylon province during the 2024-2025 growing season, on one-month-age *Cassia glouca* seedlings, homogeneous in size, after being converted into pot with a diameter of 29 cm, to study the effect of two factors: the first factor: heavy elements (lead at a concentration of 300 mg/kg soil, cadmium at a concentration of 10 mg/kg soil) and the second factor: growth regulators (melatonin at a concentration of 50 mg/L, salicylic acid at a concentration of 100 mg/L). The experiment was conducted as a factorial experiment (4 × 4) using a complete randomized block design (R.C.B.D) with three replicates, where each replicate contained 16 treatments randomly distributed within each replicate. Four levels of heavy elements were used (lead Cadmium) and the levels were (0, 300, 10, (10+300 mg.kg^{-1} soil and symbolized by (M0, M1, M2, M3), also four levels were used for growth regulators (melatonin and salicylic acid) and the levels were (0, 50, 100, (100+50 mg.L^{-1}) and symbolized by (F0, F1, F2, F3) and the averages were compared using the least significant difference (L.S.D) test at the 0.05% level, the results showed the presence of significant differences when spraying with salicylic acid in some of the studied traits such as (number of branches 3.18 branches.plant^{-1}, chlorophyll content 47.14 (SPAD), and number of inflorescences 24.46 inflorescences.plant^{-1}), and salicylic acid did not show any significant differences In the rest of the studied vegetative and floral traits, melatonin acid did not show any significant differences in all the studied vegetative and floral traits. As for the heavy elements (lead and cadmium), they caused a significant decrease in all the studied vegetative and floral traits, where the effect of lead was recorded (number of branches 2.79 branches. plant^{-1}, leaf area 2152.09 cm^2, and chlorophyll content 45.19 SPAD)), percentage of dry matter 29.66%, number of inflorescences 18.71 inflorescences. plant^{-1}, number of florets per inflorescence 2.50 inflorescences. flower diameter 37.91 mm), and cadmium was also recorded (number of branches 2.60 branches. plant^{-1}, leaf area 2010.44 cm2, and chlorophyll content 45.06 SPAD)), dry matter percentage 30.18%,

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number of inflorescences 16.96 plant^{-1}, number of florets per inflorescence 3.00 florets per inflorescence, and floret diameter 36.49 mm). The results of bi- interaction between the studied factors showed significant differences in some studied traits such as (number of branches 4.87 plant^{-1}, leaf area 2659.05 cm^2, chlorophyll content in leaves 45.06 SPAD)), dry matter percentage 49.62%, number of inflorescences 24.19 plant^{-1}, number of florets per inflorescence 6.19 florets per inflorescence, and floret diameter 40.55 mm).

Keywords: Cassia plant, heavy element lead, heavy element cadmium, growth regulator melatonin, growth regulator salicylate.

Introduction

Cassia glauca belongs to the Fabaceae family. Cassia glauca is a relatively small flowering shrub. The flowers are a very bright color, and the leaves are green and compound. It usually flowering year-round, but is most intense in spring, summer, and fall. Butterflies are strongly attracted to this tree, which also lays its eggs on the shrub. It is native to tropical Asia and northeastern Australia. It grows well in desert conditions in full sun and high temperatures if watered. The single, golden flowers are borne on the ends of the branches for most of the year. The Egyptian cassia shrub does not tolerate frost, so it should not be planted in cold locations. If the plant is affected by low temperatures, it quickly recovers and begins flowering in the summer. Pruning is necessary if this plant is used as a flowering hedge, as a tall, single-stemmed tree, or as a plant screen on a support. If the plant is left alone, it will not bloom. It grows freely without pruning, becoming a large, slender tree with smooth, olive-green bark. The leaves are compound, evergreen, up to 35 cm long, with light green, oval leaflets. The long, pod-like fruits are formed shortly after flowering. The seeds are short, hard, and must be immersed in water to facilitate germination. This plant is sensitive to water accumulation around the roots, especially if grown in pots. It thrives in acidic to slightly alkaline soils rich in organic matter and nutrients. As a leguminous plant, it has the ability to fix atmospheric nitrogen, which enables the plant to provide its own nitrogen (Al-Nafie et al., 2023).

Heavy Metals

Heavy metals (HM) are elements with a high atomic weight and a density at least five times greater than that of water. Heavy metals are non-biodegradable, meaning they persist in the environment for more than 20 years. Among the most important types of stress that have adverse effects on growth and development is heavy metal stress. In addition, the biochemical and physiological responses of plants are affected by heavy metal toxicity, which can manifest through oxidative damage, ionic imbalance, osmotic stress, and metabolic imbalance in cells. Some heavy metals, such as zinc (Zn), iron (Fe), manganese (Mn), and copper (Cu), Cobalt (Co), molybdenum (Mo) and nickel (Ni) are essential for plant growth but can be toxic if present in excess amounts. On the other hand, cadmium (Cd), lead (Pb), mercury (Hg) and arsenic (As) are severely harmful to plant growth and are not essential for them. Soil pollution with heavy elements can occur due to both natural and human activities. (Jorjani and Karakaş, 2024).

Melatonin (N-acetyl-5-methoxytryptamine) is a naturally occurring, low-molecular-weight, multi-organic molecule found in all living organisms, including plants and animals. Since its discovery in plants, scientists have become increasingly interested in melatonin due to its diverse biological roles as a key plant regulator and its defensive roles in fluctuating environmental conditions, such as extreme temperatures, salinity, drought, heavy metals, ultraviolet radiation, and oxidative stress (Wei et al., 2018). It can be speculated that melatonin is inexpensive and safe for animals and humans, and its use as a bio stimulant could be a viable, feasible, and effective method for use in agriculture to reduce environmental stresses and improve food quality. Melatonin research has been published (Dawood et al., 2024). Salicylic acid is a plant growth regulator and regulates various functions in plants such as vegetative growth, photosynthesis, bud formation, seed germination, and senescence. In plant defense, salicylic acid is an important component. When plants are grown under abiotic stresses such as heat, drought, salinity, heavy metals, and cold stress, the performance of the plants is negatively affected. When salicylic acid is sprayed on such stressed plants, it activates several defensive enzymes in the plants that prevent the negative effects of such particular stressors. Salicylic acid not only reduces the negative effects of stress but also enhances plant growth and productivity (War et al., 2011). It is also used as a food preservative and bactericide. Salicylic acid is said to be naturally present in some plants and plays a key role in plant growth. It is used as a foliar spray on plants under both normal and stressed conditions to improve crop yield. Salicylic acid does not improve plant growth. Not only does it enhance plant production, but it also enhances plant resistance to salicylic acid pathogens (Mukhtar et al., 2024).

Given the limited research on heavy metals (lead and cadmium) and their effects on ornamental plants, despite their abundance in the air, water, and soil, and their constant emission from car exhausts, this study aimed to:

1. The effect of melatonin and salicylic acid, and the interaction between them, on vegetative growth and flower production in cassia plants.

2. To study the tolerance of cassia plants to heavy metal stress (lead and cadmium).

3. To study the extent to which melatonin and salicylic acid, and the interaction between them, help reduce the damage caused by heavy metal stress.

Materials and Methods

The experiment was conducted in a private nursery in Babylon Governorate, Al-Seha District, during the 2024-2025 growing season. It used uniformly sized Cassia glauca seedlings, approximately 50 cm tall and approximately one month old, after being transplanted into 29 cm diameter pots. A medium of compost and peat moss was used in the following ratio (1:3) to study the effect of melatonin and salicylic acid, and their interaction, on the vegetative growth and flower production of Cassia. It was also to determine Cassia glauca's tolerance to heavy metal stress and to study the effect of melatonin and salicylic acid, and their interaction, on reducing heavy metal stress. A soil and plant sample was taken for the experiment, and some chemical analyses were conducted before planting.

Table 1: Some physical and chemical properties of the study soil before planting

No.	traits	values
1	Soil saturation ratio per kg dry soil	0.37
2	Soil field capacity per pot (pot weight 10 kg dry soil)	2.8
3	Soil sand percentage (%)	93
4	Soil clay percentage (%)	3
5	Soil silt percentage (%)	6
6	Soil electrical conductivity (EC) ms/cm	2.70
7	Soil pH (pH)	6.4

8	Soil available nitrogen (ppm)	8.7
9	Soil available phosphorus (ppm)	0.143
10	Soil available potassium (ppm)	9.7
11	Soil total lead (ppm)	6.19
12	Soil available lead (ppm)	0.28
13	Soil total cadmium (ppm)	0.33
14	Soil available cadmium (ppm)	0.08
15	Soil lead content (ppm)	0.04
16	Soil cadmium content (ppm)	0.07
17	Soil cadmium content (ppm)	1.16
18	Soil cadmium content (ppm)	0.03

Experimental Implementation:

The experiment was conducted to study the effect of melatonin and salicylic acid on the growth and flowering of cassia plants. The experiment was also conducted to determine the tolerance of cassia plants to heavy metal stress. It was also to determine the effect of both melatonin and salicylic acid and their role in reducing the harmful effects of heavy metal stress according to the following treatments:

First Factor: Heavy Metal Stress (Lead Nitrate and Cadmium Nitrate)

Plants were irrigated with lead nitrate and cadmium nitrate, and the interaction between them was as follows:

1. Standard treatment without added contaminants, symbolized by M0.

2. Lead nitrate treatment at a concentration of 300 mg lead.kg^{-1} soil, symbolized by M1.

3. Cadmium nitrate treatment at a concentration of 10 mg cadmium.kg^{-1} soil, symbolized by M2.

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4- Treatment with lead nitrate and cadmium nitrate together at concentrations of 300 and 10 mg/kg of soil for lead and cadmium, respectively, designated M3.

The second factor: Growth regulators (anti-stress agents)

Melatonin and salicylic acid were used to reduce the damage caused by heavy metal stress on cassia plants. They were sprayed twice on the vegetative parts of the plants, with two months between each spray, as follows:

1- Control treatment without spraying, designated F0.

2- Spraying with melatonin at a concentration of 50 mg.L^{-1}, symbolized F1.

3- Spraying with salicylic acid at a concentration of 100 mg.L^{-1}, symbolized F2.

4- Spraying with melatonin and salicylic acid together at concentrations of 50 and 100 mg/L-1, respectively, symbolized F3.

Experimental Design

The experiment was conducted as a factorial experiment (4 x 4) using a complete randomized block design (R.C.B.D) with three replicates. Each replicate contained 16 treatments, with 4 seedlings per experimental unit. Thus, the total number of plants was 192. The means were compared using the least significant difference (LSD) test at the 0.05% level (Al-Rawi and Khalaf Allah, 2000).

Results and Discussion:

Vegetative Traits of Cassia

Number of Branches (Branch. $Plant^{-1}$)

The results of Table (2) for the number of branches trait showed significant differences when treated with growth regulators. Treatment F2 excelled, producing the highest number of branches per plant, reaching 3.18 branches per plant, compared to the standard treatment F0, which produced a number of branches per plant of 2.51 branches .plant-1

When treating cassia with heavy metals, the standard treatment M0 significantly excelled, producing the highest number of branches per plant, reaching 3.75 branches per plant, while the lowest number of branches per plant was in treatment M3, which reached 2.07 branches .plant-1

The results of the interaction between the two study factors also showed significant differences in the number of branches per plant trait. Treatment F2M0 excelled, producing the highest number of branches per plant, reaching 4.87 branches per plant, compared to treatment F0M3, which produced a number of The number of branches of the

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cassia plant reached 1.83 branches .plant-1The table also showed no significant differences in plant height between the interaction treatments (F1M1, F1M2, F2M1, F2M2, F3M1, and F3M2) and the control treatment, despite the addition of lead, cadmium, and lead + cadmium together to the soil. This was due to the effect of melatonin, salicylic acid, and melatonin + salicylic acid in reducing heavy metal stress on the cassia plant.

Table 2: The effect of melatonin and salicylic acids on the number of branches of the cassia plant under the influence of heavy metal stress (branch per plant).

Growth regulators (mg kg^{-1})		(Heavy element concentration (mg kg-1				average
		without adding (M0)	Lead (M1)	Cadmium (M2)	Lead + Cadmium (M3)	
		0	300	10	10+300	
(Without added (F0	0	3.11	2.65	2.46	1.83	2.51
(Melatonin (F1	50	3.62	2.67	2.53	2.33	2.79
Salicylic acid (F2)	100	4.87	3.08	2.92	1.86	3.18
Salicylic acid + Melatonin (F3)	100+50	3.42	2.75	2.50	2.28	2.74
LSD 5%		0.61				0.30
average		3.75	2.79	2.60	2.07	
LSD 5%		0.30				

Plant Leaf Area (cm2)

The results of Table (3) showed no significant differences in the leaf area of the plant when treated with growth regulators.When treating cassia plants with heavy metals, the M0 treatment significantly excelled, gave the highest leaf area of 2659.05 cm2, while the lowest leaf area of cassia plants was achieved with the M3 treatment, which reached 1793.80

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cm2.The results of the interaction between the two study factors also showed significant differences in the leaf area of the plant. Treatment F3M0 excelled, gave the highest leaf area of 2890.32 cm2, compared to treatment F3M2, which gave the lowest leaf area of cassia plants, which reached 1543.77 cm2. The table also showed no significant differences in leaf area between the interaction treatment (F1M2) and the control treatment (F0M0), despite the addition of cadmium to the soil. This was due to the contribution of melatoninic acid in reducing heavy metal stress (cadmium) on the cassia plant.

Table 3 - Effect of melatoninic and salicylic acids on the leaf area of cassia plants under heavy metal stress (cm²).

Growth regulators (mg kg-1)		(Heavy element concentration (mg kg-1				average
		without adding (M0)	Lead (M1)	Cadmium (M2)	Lead + Cadmium (M3)	
		0	300	10	10+300	
(Without added (F0	0	2646.60	2178.53	2058.21	1827.22	2177.64
Melatonin (F1)	50	2491.81	2080.49	2245.22	1762.18	2144.93
Salicylic acid (F2)	100	2607.48	2170.43	2194.54	1928.57	2225.25
+ Melatonin Salicylic acid (F3)	100+50	2890.32	2178.92	1543.77	1657.22	2067.56
LSD 5%		418.76				209.38
average		2659.05	2152.09	2010.44	1793.80	
LSD 5%		209.38				

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Chlorophyll content in leaves (SPAD)

The results of Table (4) showed significant differences in the chlorophyll content of plant leaves when treated with growth regulators. Treatment F2 gave the highest chlorophyll content in plant leaves, reaching 47.14, while treatment F3 gave the lowest chlorophyll content in cassia leaves, reaching 44.82.When treating cassia with heavy metals, the standard M0 treatment gave the highest chlorophyll content in plant leaves, reaching 49.62, while treatment M3 gave the lowest chlorophyll content in cassia leaves, reaching 43.66. The results of the interaction between growth regulators and heavy metals also showed significant differences in the chlorophyll content of plant leaves. Treatment F1M0 gave the highest chlorophyll content in plant leaves, reaching 50.87, compared to treatment F3M3, which gave the lowest chlorophyll content in cassia leaves, reaching 41.22.

The table also shows no significant differences in the chlorophyll content of plant leaves between the interaction treatments (F2M1 and F2M2) compared to the control treatment, despite the addition of lead and cadmium to the soil. This is due to the contribution of salicylic acid in reducing heavy metal stress on cassia plants.

Table 4 - Effect of melatonin and salicylic acid on chlorophyll content in cassia leaves under heavy metal stress (Spad).

Growth regulators (mg kg-1)		(Heavy element concentration (mg kg-1				average
		without adding (M0)	Lead (M1)	Cadmium (M2)	Lead + Cadmium (M3)	
		0	300	10	10+300	
(Without added (F0	0	48.83	46.78	44.41	43.13	45.79
Melatonin (F1)	50	50.87	43.06	44.46	44.76	45.79
Salicylic acid (F2)	100	49.76	46.50	46.77	45.54	47.14
Salicylic acid + Melatonin (F3)	100+50	49.02	44.42	44.62	41.22	44.82

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LSD 5%	2.39				1.20
average	49.62	45.19	45.06	43.66	
LSD 5%	1.20				

Percentage of Dry Matter (g)

The results of Table (5) showed no significant differences in the percentage of dry matter in plant leaves when treated with growth regulators.

When treating cassia plants with heavy metals, the standard M0 treatment significantly excelled, gave the highest percentage of dry matter in the leaves, reaching 31.43 g, while the lowest percentage of dry matter in cassia leaves was in treatment M1, reaching 29.66 g.

The results of the interaction between growth regulators and heavy metals also showed significant differences in the percentage of dry matter in plant leaves. Treatment F3M0 excelled, gave the highest percentage of dry matter in the leaves, reaching 32.17 g, while treatment F3M1 gave the lowest percentage of dry matter in cassia leaves, reaching 27.06 g. The table also showed no significant differences in the percentage of dry matter in plant leaves between the interaction treatments (F1M1, F1M2, F2M1, F1M3, F2M2, F2M3, F3M2, and F3M3) and the control treatment, despite the addition of lead, cadmium, and lead + cadmium together to the soil. This was due to the effect of melatonin, salicylic acid, and melatonin + salicylic acid in reducing heavy metal stress on cassia plants.

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Table 5: Effect of melatonin and salicylic acids on the percentage of dry matter in cassia plants.

Growth regulators (mg kg-1)		(Heavy element concentration (mg kg-1				average
		without adding (M0)	Lead (M1)	Cadmium (M2)	Lead + Cadmium (M3)	
		0	300	10	10+300	
(Without added (F0	0	30.71	30.35	29.43	28.07	29.64
Melatonin (F1)	50	31.19	30.28	30.09	29.88	30.36
Salicylic acid (F2)	100	31.66	30.98	30.16	29.71	30.62
Salicylic acid + Melatonin (F3)	100+50	32.17	27.06	31.03	31.23	30.37
LSD 5%		2.10				1.05
average		31.43	29.66	30.18	29.72	
LSD 5%		1.05				

The Effect of Growth Regulators on the Vegetative Traits of Egyptian Cassia

The results of the statistical analysis in Tables (2, 3, 4, 5) showed that melatonin at a concentration of 50 mg/L-1 did not show significant differences in vegetative growth traits (number of branches, leaf area, percentage of dry matter, and chlorophyll content in leaves). However, spraying with salicylic acid at a concentration of 100 mg/L-1 significantly excelled both traits (number of branches and chlorophyll content in leaves). The improvement in vegetative traits resulting from spraying with salicylic acid may be due to its role in various plant functions. It is a cofactor for enzymes involved in a variety of processes, including flavonoids, plant hormone synthesis, and the xanthophyll cycle. Salicylic research by El-Shanhorey and Hassan, (2021).

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The Effect of Heavy Metals on the Vegetative Traits of Cassia Egyptian

The results of Tables (2, 3, 4, and 5) show that adding the heavy metals lead and cadmium to the soil had an impact on the vegetative characteristics of cassia plants. Adding lead at a concentration of 300 mg kg-1 soil and cadmium at a concentration of 10 mg kg-1 soil to the soil resulted in a significant decrease in vegetative characteristics (number of branches, leaf area, chlorophyll content, and dry matter percentage). This may be due to the higher accumulation of toxic metals in leaves and roots, which invariably inhibits vital processes and metabolism, such as photosynthesis, inhibits some enzyme systems, and prevents the formation of proteins and chlorophyll (Nofal et al., 2022).

Interaction between growth regulators and heavy metals

The results of Tables (2, 3, 4, and 5) show that adding the heavy metals lead at a concentration of 300 mg kg-1 soil and cadmium at a concentration of 10 mg kg-1 -1 Soil to the planting soil had no significant effect on the vegetative traits (number of branches, leaf area, and percentage of dry matter) of cassia plants due to the addition of melatonin at a concentration of 50 mg.L-1, which has a role similar to the effect of the auxin indole-3-acetic acid (IAA) in promoting cell division and elongation, delaying leaf senescence, stimulating carbon metabolism, and preserving the integrity of cell membranes and chlorophyll pigment from decomposition under stress conditions (Gong et al., 2017). The results of Tables (2, 3, 4, 5) also showed that the addition of heavy elements lead at a concentration of 300 mg.kg-1 soil and cadmium at a concentration of 10 mg.kg-1 soil to the planting soil had no significant effect on the vegetative traits (number of branches, chlorophyll content, and percentage of dry matter) of cassia plants due to the addition of melatonin. Salicylic acid at a concentration of 100 mg/L-1 plays an important role in contributing to reducing heavy metal stress and enhancing growth, as spraying with salicylic acid improves the absorption of nutrients, enhances the photosynthesis process, which leads to increased carbohydrate accumulation, and thus increases overall growth and cell elongation (Chauhan et al., 2025).

Floral Traits of Cassia

Number of Inflorescence.plant-1 (Inflorescence. Plant-1)

The results of Table (6) showed significant differences in the number of inflorescence.plant-1 when treated with growth regulators. Treatment F2 excelled, producing the highest number of inflorescence.plant-1, reaching 24.64 inflorescences. Plant-1, while treatment F1 produced the lowest number of inflorescence.plant-1, reaching 14.23 inflorescences. Plant-1.

When treating cassia with heavy metals, the standard M0 treatment significantly excelled, producing the highest number of inflorescence.plant-1, reaching 24.19 inflorescences. Plant-1, while the lowest number of inflorescence.plant-1 was in treatment M3, reaching 15.58 inflorescences. Plant-1. The results of the interaction between the two study factors also revealed significant differences in the number of inflorescence.plant-1. Treatment F2M0 excelled, producing the highest number of inflorescence.plant-1, reaching 29.67 inflorescence.plant-1, compared to treatment F1M3, which produced the lowest number of inflorescence.plant-1, reaching 11.33 inflorescence.plant-1.The table also showed no significant differences in flowering time between the interaction treatments (F2M1, F2M2, F2M3, F3M1, and F3M2) and the control treatment, despite the addition of lead, cadmium, and lead + cadmium to the soil. This is due to the contribution of salicylic acid and melatonin + salicylic acid in reducing heavy metal stress on the cassia plant.

Table: 6 - The effect of melatonin and salicylic acid on the number of inflorescences of cassia plant under the influence of heavy element stress (inflorescence.plant-1).

Growth regulators (mg kg-1)		(Heavy element concentration (mg kg-1				average
		without adding (M0)	Lead (M1)	Cadmium (M2)	Lead + Cadmium (M3)	
		0	300	10	10+300	
Without added ((F0	0	26.67	15.67	11.67	11.67	16.42
Melatonin (F1)	50	16.77	15.17	13.67	11.33	14.23
Salicylic acid (F2)	100	29.67	24.33	21.17	22.67	24.46
+ Melatonin	100+50	23.67	19.67	21.33	16.67	20.33

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Salicylic acid (F3)						
LSD 5%		9.35				4.67
average		24.19	18.71	16.96	15.58	
LSD 5%		4.67				

Number of florets per inflorescence (flower.flower-1)

The results of Table (7) showed significant differences in the number of florets per inflorescence when treated with growth regulators. Treatment F3 excelled, producing the highest number of florets per inflorescence, reaching 4.46 florets.flower-1, compared to treatment F2, which produced the lowest number of florets per inflorescence of the cassia plant, reaching 2.39 florets.flower-1.

When treating the cassia plant with heavy metals, the standard treatment M0 significantly excelled, producing the highest number of florets per inflorescence, reaching 6.19 florets.flower-1. The lowest number of florets per inflorescence of the cassia plant was in treatment M1, which reached 2.50 florets.flower-1. The results of the interaction between the two study factors also revealed significant differences in the number of florets per inflorescence. Treatment F3M0 excelled, producing the highest number of florets per inflorescence, reaching 10.00 florets per inflorescence, compared to treatment F2M3, which produced the lowest number of florets per inflorescence of the cassia plant, reaching 1.83 florets per inflorescence.

The table also showed no significant differences in the number of inflorescences between the interaction treatment (F1M3) and the control treatment, despite the combined addition of lead and cadmium to the soil. This was due to the contribution of melatonin to reducing heavy metal stress on the cassia plant.

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Table 7: Effect of melatonin and salicylic acid on the number of florets per inflorescence of the cassia plant under the influence of heavy metal stress (flower.inflorescence-1).

Growth regulators (mg kg-1)		(Heavy element concentration (mg kg-1				average
		without adding (M0)	Lead (M1)	Cadmium (M2)	Lead + Cadmium (M3)	
		0	300	10	10+300	
(Without added (F0	0	6.33	3.11	4.33	2.44	4.05
Melatonin (F1)	50	4.78	2.17	2.50	4.72	3.54
Salicylic acid (F2)	100	3.67	1.89	2.17	1.83	2.39
Salicylic acid + Melatonin (F3)	100+50	10.00	2.83	3.00	2.00	4.46
LSD 5%		2.15				1.08
average		6.19	2.50	3.00	2.75	
LSD 5%		1.08				

4-3-4 Floret Diameter (mm)

The results of Table (8) showed no significant differences in the floret diameter of the plant when treated with growth regulators.

When treating cassia plants with heavy metals, the M0 treatment significantly excelled, producing the largest floret diameter in the plant, reaching 40.55 mm, while the smallest floret diameter for cassia plants was in the M2 treatment, reaching 36.49 mm.

The results of the interaction between the two study factors also showed significant differences in the floret diameter trait in the plant. The F0M0 treatment excelled, producing the largest floret diameter in the plant, reaching 41.94 mm, compared to the

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F3M2 treatment, which produced the smallest floret diameter in cassia plants, reaching 33.65 mm. The table also showed no significant differences in flowering time between the interaction treatments (F2M3, F2M3) and the control treatment, despite the combined application of lead and cadmium to the soil. This was due to the contribution of salicylic acid in reducing heavy metal stress on cassia plants.

Table 8 - Effect of melatonin and salicylic acid on cassia flower diameter under heavy metal stress (mm).

Growth regulators (mg kg-1)		(Heavy element concentration (mg kg-1				average
		without adding (M0)	Lead (M1)	Cadmium (M2)	Lead + Cadmium (M3)	
		0	300	10	10+300	
(Without added (F0	0	41.94	39.01	36.82	36.94	38.68
Melatonin (F1)	50	39.28	37.69	37.49	37.72	38.05
Salicylic acid (F2)	100	40.12	37.53	38.00	38.70	38.59
Salicylic acid + Melatonin (F3)	100+50	40.85	37.39	33.65	35.70	36.90
LSD 5%		4.14				2.07
average		40.55	37.91	36.49	37.27	
LSD 5%		2.07				

The effect of growth regulators on the floral characteristics of Egyptian cassia

The results of Tables (6, 7, and 8) for spraying melatonin and salicylic acid showed that the melatonin treatment at a concentration of 50 mg/L-1 had no significant effect on the floral characteristics studied (number of inflorescences, number of florets per inflorescence, and floret diameter). Salicylic acid treatment at a concentration of 100 mg/L-

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1 had a significant effect in Table (6), which represents the number of inflorescences. These positive effects may be due to the role of salicylic acid in increasing the plant's content of internal hormones such as gibberellins, auxins, and cytokinins, thus increasing cell division and elongation, and ultimately enhancing plant growth and development. Alternatively, this result may be due to the role of salicylic acid in improving vegetative growth, which leads to increased nutrient absorption. It also enhances photosynthesis in the plant, leading to increased carbohydrate biosynthesis, leading to higher differentiation and stimulation of flowers (El-Shanhorey and Hassan, 2021).

Effect of heavy elements on the floral characteristics of Egyptian cassia plants

The results of Tables (6, 7, 8) showed that adding the heavy elements lead and cadmium to the soil had an effect on the floral characteristics of cassia plants. Adding lead at a concentration of 300 Adding cadmium at a concentration of 10 mg kg-1 to the soil led to a significant decrease in floral traits (number of inflorescences, number of florets per inflorescence, and inflorescence diameter). This is due to the toxicity caused by lead when added to the soil. This may also be due to the increased accumulation of toxic metals in leaves and roots, which inhibits vital processes and metabolism, such as photosynthesis, inhibits some enzyme systems, and prevents the formation of proteins and chlorophyll, thus reducing the accumulation of carbohydrates, which leads to reduced floral traits (Nofal et al., 2022). Furthermore, adding cadmium at a concentration of 10 mg kg-1 to the soil led to a significant decrease in floral traits (number of inflorescences, number of florets per inflorescence, and inflorescence diameter). This decrease may be due to reduced photosynthesis and transpiration resulting from the closure of stomata and reduced carbon dioxide entry into plant tissues due to cadmium toxicity. It may also be attributed to an imbalance in plant activity. Enzymes and inhibition of cell division, negatively affecting plant growth (Almuwayhi, 2021).

Interaction between growth regulators and heavy metals

The results of Tables (6, 7, and 8) show that adding the heavy metals lead at a concentration of 300 mg kg-1 soil and cadmium at a concentration of 10 mg kg-1 soil to the planting soil had no significant effect on the floral characteristics (number of inflorescences and number of florets per inflorescence) of cassia plants. This was due to the addition of melatonin at a concentration of 50 mg L-1, which has been shown to be a hormone with dual roles in plants, such as

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promoting growth and protecting against abiotic stresses (M. Imran et al., 2021). Melatonin improves cell elongation and water content in buds and leaves, reduces osmotic stress, and enhances the activities of antioxidant enzymes. Melatonin also interacts directly with many reactive oxygen species, neutralizing them before they are released. It can cause cell injury and can increase the activities of internal antioxidant enzymes, thus improving the cells' intrinsic defense systems. Melatonin also improves photosynthesis, the most vital physiological mechanism directly linked to plant growth and dry matter production, whose activities depend primarily on the condition of the stomata and water movement through the conducting tissues (Ahsan et al., 2025). Tables 6, 7, and 8 show that adding the heavy elements lead at a concentration of 300 mg kg-1 soil and cadmium at a concentration of 10 mg kg-1 soil to the planting soil had no significant effect on the floral traits (number of inflorescences and flower diameter) of cassia plants due to spraying with salicylic acid at a concentration of 100 mg L-1, which is a phenolic compound that enables plants to survive under difficult soil and environmental conditions. It improves vegetative growth, leading to increased nutrient uptake. It also enhances photosynthesis in plants, leading to increased biosynthesis. For carbohydrates (Suri and Tohidloo, 2019). This leads to an increase in the number of flowers. The use of salicylic acid can also increase auxin levels, and thus flower growth (El-Shanhorey and Hassan, 2021). Conclusion: The use of melatonin did not affect all the studied traits, but salicylic acid significantly affected some studied traits, such as (number of branches, chlorophyll content, and number of inflorescences). However, salicylic acid did not significantly affect some traits, such as leaf area, percentage of dry matter, number of inflorescences per inflorescence, and inflorescence diameter. Therefore, it is recommended to use salicylic acid in conjunction with a study using other growth regulators to combat heavy metal stress (lead and cadmium).

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Department of Horticulture and Landscape Engineering, College of Agriculture.

Al-Qasim Green University, Iraq.

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