



Effect of vermicompost extract and foliar nutrition with mannitol and riboflavin B₂ on some vegetative growth traits of Myrtle seedlings (*Myrtus communis* L.)

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Received: May 27, 2025	Abstract The experiment was conducted in the shade house of the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Kerbala, from 1/3/2024 to 1/7/2024 to study the effects of vermicompost extract, mannitol, and riboflavin B ₂ on vegetative growth traits of Myrtle seedlings. A randomized complete block design (R.C.B.D) with three replications was used. The factors included vermicompost extract at two concentrations (0 and 2 ml L ⁻¹), mannitol spray at three concentrations (0, 2, and 4 g L ⁻¹), and riboflavin spray at three concentrations (0, 50, and 100 mg L ⁻¹). Results showed that vermicompost extract at concentration (2 ml L ⁻¹) significantly improved seedling height (25.770 cm), diameter (3.076 mm), number of leaves (424.244 leaf seedling ⁻¹), leaf area (3.767 cm ²), dry leaf weight (7.656 g), and dry vegetative weight (18.281 g). Mannitol at concentration (4 g L ⁻¹) showed outperformed effects with means of 31.922 cm, 4.097 mm, 540.444 leaf seedling ⁻¹ , 4.461 cm ² , 9.406 g, and 21.983 g, respectively. Riboflavin at concentration (100 mg L ⁻¹) also enhanced growth traits, recording averages of 25.322 cm, 3.113 mm, 425.256 leaf seedling ⁻¹ , 3.741 cm ² , 7.650 g, and 18.316 g respectively. The dual interaction of vermicompost and mannitol most improved vegetative traits, followed by mannitol and riboflavin, while vermicompost with riboflavin had limited effect. The triple intervention achieved the best results, indicating the efficiency of the combined use of the three factors.
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Introduction

Myrtle (*Myrtus communis* L.), belongs to the family Myrtaceae. It is a perennial plant and one of the most important green hedge species, comprising approximately 150 genera and more than 5500 naturally cultivated species worldwide [1,2]. Myrtle is widely distributed across the Mediterranean region, the Middle East, South America, Australia, and Iraq [3]. It is commonly cultivated as an ornamental shrub in gardens and parks [4], and is well suited as a green fence due to its prunability and ability to be shaped. The pruned branches are traditionally used in religious ceremonies, placed on graves, and used in

floral arrangements during weddings and other occasions [5,6]. Essential oils are extracted from the glandular tissues found in the leaves, flowers, and fruits of the plant. These oils, known as “angel water,” are characterized by a pleasant aromatic scent and serve as a natural defense mechanism against herbivores and insect pests. Additionally, myrtle oil is utilized in the production of perfumes and cosmetic products [7,8,9].

In recent decades, there has been a trend towards the use of various types of organic fertilizers (animal and plant), vermicompost tea is of great importance in improving vegetative traits, as it increases the effectiveness of many enzymes, especially those responsible for oxidation and reduction reactions within the plant, and thus positively affects the process of photosynthesis [10].

Mannitol is a form of sugar alcohols, which are products of photosynthesis in the form of carbohydrates. It plays an important role in cell division and elongation, especially in the growing tips of the plant, and thus increases protein and carbohydrates, which is reflected in improving growth indicators. It is called a sugar alcohol because of its chemical composition, as it is formed when the aldehyde group CHO is reduced to the ketone group OH CH₂, and then it is converted into a secondary sugar alcohol, as one type of sugar alcohol is formed from each sugar belonging to the aldose, as mannitol is formed from D-mannose [11].

Vitamins are organic compounds with a low molecular weight, differing from fats, carbohydrates, and proteins in that they are not used for tissue building or energy generation. However, they are essential for the majority of metabolic processes and are considered necessary for the proper functioning of metabolism. They are also crucial for ensuring the activity of many enzymes. The addition of vitamins to plants stimulates growth by activating certain enzymatic reactions, regulating factors that affect several physiological processes, and protecting the plant from the harmful effects of high temperatures [12]. Riboflavin, in particular, is involved in the structure of several enzyme cofactors required for enzymes involved in oxidation and reduction reactions. Since riboflavin is a yellow-orange compound, the enzymes working with these compounds are referred to as flavin or yellow enzymes [13].

It was reported by [14] that foliar application of mannitol on pepper plants led to a significant increase. The treatment with mannitol at a concentration of 30 g L⁻¹ outperformed most growth traits, including plant height (60.34 cm), number of branches (7.33 branch plant⁻¹), and dry weight of the shoot system (461.0 g plant⁻¹), compared to the lowest values observed in the control treatment. It was found by [15] that foliar spraying of rose bush plants with riboflavin at three concentrations resulted in significant effects. (0, 30, and 60 mg L⁻¹) led to a significant increase in vegetative growth indicators, including plant height, stem diameter, number of leaves, leaf area, and dry weight of both leaves and shoot system, at the concentration of 60 mg L⁻¹. In light of the above, the aim of the research was to determine the response of *Myrtus communis* plants to the study factors and their impact on vegetative growth indicators. The study also sought to identify the optimal concentrations of vermicompost, mannitol, and riboflavin to improve



vegetative growth indicators and to determine the best binary and ternary interactions between the study factors to achieve optimal vegetative growth.

Materials and Methods

The study was conducted in the shade of the Department of Horticulture and Landscape Engineering, College of Agriculture, University of Kerbala, from March 1, 2024 to July 1, 2024. The study aimed to investigate the role of vermicompost extract and foliar feeding with mannitol and riboflavin B₂ on some vegetative growth traits of *Myrtus communis* L. seedlings. Selected 270 seedlings, 8 months old, were and as homogeneous as possible in size and vegetative growth. They were grown in sandy soil and planted in black plastic polyethylene bags with a capacity of 1.25 kg. These bags were then transferred on February 20, 2024, to two anvils with a capacity of 10 kg of soil. The experiment was implemented according to a randomized complete block design (R.C.B.D.) based on a factorial experiment arrangement with three factors. The first factor included the addition of vermicompost extract at two concentrations (0 and 2) ml L⁻¹, while the organic vermicompost extract was added. 4 times between each addition 15 days starting from 1/3/2024 until 15/4/2024. While the second factor included mannitol spray treatments at three concentrations (0, 2 and 4) g L⁻¹, while the third factor included riboflavin spray treatments at three concentrations as well (0, 50 and 100) mg L⁻¹, with three replicates, each containing 90 seedlings 5 seedlings per experimental unit, as the seedlings were sprayed 4 times until completely wet between each spray 15 days from 1/3/2024 until 15/4/2024. The seedlings were watered one day before spraying to increase the plants' efficiency in absorbing the sprayed material, as humidity plays a role in the process of cell swelling and stomata opening, in addition to the fact that watering before spraying reduces the concentration of solutes in the leaf cells, which increases the penetration of the spray solution ions into the leaf cells [16], Spraying was carried out in the early morning with hand sprayer (2 L size), and 1 cm³ of the detergent (Al-Zahi) was added to each concentration to reduce the surface tension of water droplets and ensure complete wetting of the plant parts. All necessary maintenance operations, including irrigation and weeding, were conducted uniformly across all treatments and replications as needed. The final measurements were taken at the end of the study, on 1/7/2024.

Data recorded

Average increase in seedling height (cm)

The increase in height was measured by calculating the difference in stem height before and after the study treatments. A graduated measuring tape was used to measure from the soil surface to the top of the main stem. The average increase in height for each experimental unit was then calculated for each treatment and replication.

Average increase in seedling diameter (mm)

The increase in stem diameter was measured before and after the study treatments at a point 5 cm above the soil surface using a digital caliper (Vernier). The average increase in diameter for each experimental unit was then calculated for each treatment and replication.

Average increase in the number of leaves (leaf seedling⁻¹)

The number of leaves per seedling was counted before and after the experiment treatments, the average number of leaves for each experimental unit was then calculated for each treatment and replication.

Leaf area (cm²)

The leaf area for each treatment and replication was calculated using the ImageJ software on the Windows 7 operating system [17].

Dry weight of leaves (g seedling⁻¹)

The dry weight of the leaves was calculated by separating the leaves from the dry shoot system and weighing them using a sensitive balance for each experimental unit of the study treatments.

Dry weight of the shoot system (g seedling⁻¹)

The dry weight of the shoot system was determined by separating it from the root system at the crown region. The shoot system was placed in perforated paper bags and dried in an electric oven at 70°C until a constant weight was achieved, then weighed using a precision balance for each experimental unit [18].

Statistical analysis

After collecting and tabulating the data related to the study, it was statistically analyzed using by randomized complete blocks designing (R.C.B.D), And using the least significant difference (L.S.D_{0.05}) test was used to compare and separate the means [19]. this is done by statistical analysis software GenStat12.

Results and Discussion

Plant height (cm)

The results (table 1) showed that the concentrations of vermicompost extract, mannitol and riboflavin significantly affected the average increase in seedling height. It was noted that the vermicompost extract treatment at a concentration of (2 ml L⁻¹) recorded the highest average of 25.770 cm, while the control treatment (0 ml L⁻¹) recorded the lowest average of 22.007 cm, with an increase percentage of 17.099%. It was also found that spraying with mannitol had a significant effect on this trait, as the concentration (4 g L⁻¹) achieved the highest average of 31.922 cm, while the control treatment (0 g L⁻¹) recorded the lowest average of 16.244 cm, with an increase percentage of 96.515%. It was also noted that spraying with riboflavin had a significant effect, as the treatment (100 mg L⁻¹) achieved the highest average of 25.322 cm, compared to the control control treatment (0 mg L⁻¹) which recorded the lowest average of 22.689 cm, with an increase percentage of 11.604%.

Two-way interaction between the study factors showed a significant effect on the average increase in seedling height, as the highest interaction was recorded in the treatment with 2 ml L⁻¹ vermicompost extract and 4 g L⁻¹ mannitol, with an average of 33.622

cm, while the control treatment for both factors (0 ml L⁻¹ vermicompost extract + 0 g L⁻¹ mannitol) gave the lowest average of 14.400 cm, with an increase percentage of 133.486%. The results also showed a significant interaction between vermicompost extract and riboflavin, as the highest interaction was recorded in the treatment of 2 ml L⁻¹ vermicompost extract with 100 mg L⁻¹ riboflavin with an average of 27.333 cm., while the control treatment for both factors (0 ml L⁻¹ vermicompost extract + 0 g L⁻¹ riboflavin) recorded the lowest interaction, with an average of 20.933 cm with an increase percentage of 30.573%. As for the interaction between mannitol and riboflavin, the treatment 4 g L⁻¹ mannitol and the treatment 100 mg L⁻¹ riboflavin, gave the highest interaction with an average of 33.800 cm², while the lowest interaction was recorded with the control treatment (0 g L⁻¹ mannitol + 0 g L⁻¹ riboflavin) with an average of 15.167 cm², with an increase percentage of 122.852%. While the triple interaction between vermicompost extract, mannitol and riboflavin did not show a significant effect on the rate of increase in seedling height.

Table (1): Effect of vermicompost extract, spraying with mannitol, riboflavin and their interaction on the average increase in seedling height (cm)

Vermicompost extract concentrations (m L ⁻¹)	Mannitol concentrations (g L ⁻¹)	Riboflavin concentrations (mg L ⁻¹)			Vermicompost extract × Mannitol
		0	50	100	
0	0	13.333	14.333	15.533	14.400
	2	20.200	21.400	22.600	21.400
	4	29.267	29.600	31.800	30.222
2	0	17.000	17.867	19.400	18.089
	2	24.400	25.600	26.800	25.600
	4	31.933	33.133	35.800	33.622
L.S.D _{0.05}		N.S.			0.2949
Means (Riboflavin)		22.689	23.656	25.322	Means (Vermicompost extract)
L.S.D _{0.05}		0.2085			
Vermicompost extract × Riboflavin					
0		20.933	21.778	23.311	22.007
2		24.444	25.533	27.333	25.770
L.S.D _{0.05}		0.2949			0.1703
Mannitol × Riboflavin					Means (Mannitol)
0		15.167	16.100	17.467	16.244
2		22.300	23.500	24.700	23.500
4		30.600	31.367	33.800	31.922
L.S.D _{0.05}		0.3612			0.2085

Average increase in seedling diameter (mm)

The results (Table 2) showed significant differences between the concentrations of vermicompost extract, mannitol and riboflavin in the average increase in seedling diameter. It was observed that the vermicompost extract treatment at a concentration of (2 ml L⁻¹) achieved the highest average of 3.076 mm, while the control treatment (0 ml L⁻¹) recorded the lowest average of 2.504 mm, with an increase percentage of 22.843%. Significant differences were also observed between the mannitol spray concentrations, as the concentration (4 g L⁻¹) achieved the highest average of 4.097 mm, while the control treatment (0 g L⁻¹) recorded the lowest average of 1.666 mm, with an increase percentage of 145.918%. Spraying with riboflavin also had a significant effect on this trait, as the treatment (100 mg L⁻¹) achieved the highest average of 3.113 mm, compared to the control treatment (0 mg L⁻¹) which recorded the lowest average of 2.517 mm and with an increase percentage of 23.678%.

The two-way interactions between the study factors showed a significant effect on the average increase in seedling height, as the highest interaction was recorded in the treatment with 2 ml L⁻¹ vermicompost extract and 4 g L⁻¹ mannitol, with an average of 4.508 mm, while the control treatment for both factors (0 ml L⁻¹ vermicompost extract + 0 g L⁻¹ mannitol) gave the lowest average of 1.491 mm, with an increase percentage of 202.347%. The results also showed a significant interaction between vermicompost extract and riboflavin, as the highest interaction was achieved in the treatment of 2 ml L⁻¹ vermicompost extract with 100 mg L⁻¹ riboflavin, with an average of 3.383 mm, while the control treatment for both factors (0 ml L⁻¹ vermicompost extract + 0 g L⁻¹ riboflavin) recorded the lowest interaction, with an average of 2.291 mm, with an increase percentage of 47.664%. As for the interaction between mannitol and riboflavin, it had a significant effect on this trait, as the spraying treatment with mannitol at a concentration of 4 g L⁻¹ with the treatment with riboflavin at a concentration of 100 mg L⁻¹ gave the highest interaction of 4.720 mm. 4.720 mm, while the lowest interaction was in the control treatment (0 g L⁻¹ mannitol + 0 g L⁻¹ riboflavin) with an average of 1.516 mm, with an increase percentage of 211.345%. The results also showed a significant three-way interaction between the factors on the average increase of this trait, as the concentration of 2 ml L⁻¹ vermicompost extract, 4 g L⁻¹ mannitol and 100 mg L⁻¹ riboflavin gave the highest interaction of 5.020 mm, while the control treatment (0 ml L⁻¹ vermicompost extract + 0 g L⁻¹ mannitol + 0 g L⁻¹ riboflavin) gave the lowest interaction of 1.323 mm, with an increase percentage of 279.440%.

Table (2): Effect of vermicompost extract, spraying with mannitol, riboflavin and their interaction on the average increase in seedling diameter (mm)

Vermicompost extract concentrations (m L ⁻¹)	Mannitol concentrations (g L ⁻¹)	Riboflavin concentrations (mg L ⁻¹)			Vermicompost extract × Mannitol
		0	50	100	
0	0	1.323	1.490	1.660	1.491
	2	2.260	2.300	2.450	2.336
	4	3.290	3.350	4.420	3.686
2	0	1.710	1.873	1.940	1.841
	2	2.550	2.900	3.190	2.880
	4	3.970	4.536	5.020	4.508
L.S.D 0.05		0.0113			0.0065
Means (Riboflavin)		2.517	2.741	3.113	Means (Vermicompost extract)
L.S.D 0.05		0.0046			
Vermicompost extract × Riboflavin					
0		2.291	2.380	2.843	2.504
2		2.743	3.103	3.383	3.076
L.S.D 0.05		0.0065			0.0037
Mannitol × Riboflavin					Means (Mannitol)
0		1.516	1.681	1.800	1.666
2		2.405	2.600	2.820	2.608
4		3.630	3.943	4.720	4.097
L.S.D 0.05		0.0080			0.0046

Average increase in the number of leaves (leaf seedling⁻¹)

The results (Table 3) showed significant differences between the concentrations of vermicompost extract, mannitol and riboflavin in the average increase in the number of leaves, as the treatment with vermicompost extract at a concentration of (2 ml L⁻¹) was superior, giving the highest average of 424.244 leaf seedling⁻¹, while the control treatment (0 ml L⁻¹) recorded the lowest average of 363.889 leaf seedling⁻¹, with an increase percentage of 16.586%. Significant differences were also observed between the spray concentrations of mannitol, as the concentration (4 g L⁻¹) achieved the highest average of 540.444 leaf seedling⁻¹, while the control treatment (0 g L⁻¹) recorded the lowest average of 249.256 leaf seedling⁻¹, with an increase percentage of 116.822%. Spraying with riboflavin had a significant effect on this trait, as the treatment (100 mg L⁻¹) achieved the highest average of 425.256 leaf seedling⁻¹, compared to the control treatment (0 mg L⁻¹) which recorded the lowest average of 361.322 leaf seedling⁻¹, with an increase percentage of 17.694%.

The results indicated that the two factors interaction among the study factors had a significant effect on the average of this trait, as the treatment with vermicompost extract at a concentration of 2 ml L⁻¹ and mannitol at a concentration of 4 g L⁻¹ gave the highest interaction with an average of 586.600 leaf seedling⁻¹, while the lowest interaction was in the control treatment (0 ml L⁻¹ vermicompost extract + 0 g L⁻¹ mannitol) with an average of 219.244 leaf seedling⁻¹, with an increase percentage of 167.555%. The results also showed a significant interaction between vermicompost extract and riboflavin, the results also showed a significant interaction between the vermicompost extract and riboflavin, as the highest interaction was observed in the treatment of 2 ml L⁻¹ vermicompost extract with 100 mg L⁻¹ riboflavin with an average of 470.600 leaf seedling⁻¹, while the control treatment for both factors (0 ml L⁻¹ vermicompost extract + 0 g L⁻¹ riboflavin) recorded the lowest interaction, with an average of 338.644 leaf seedling⁻¹, with an increase percentage of 38.965%. As for the interaction between mannitol and riboflavin, it had a significant effect on this trait, as the treatment of spraying mannitol at a concentration of 4 g L⁻¹ with the treatment of riboflavin at a concentration of 100 mg L⁻¹ gave the highest interaction, with an average of 600.200 leaf seedling⁻¹, while the lowest interaction was in the control treatment (0 g L⁻¹ mannitol + 0 g L⁻¹ riboflavin) with an average of 222.100 leaf seedling⁻¹ with an increase percentage of 170.238%. The results also showed a significant three-way interaction between the factors on the average increase of this trait, as the treatment of vermicompost extract at a concentration of 2 ml L⁻¹ with the treatment of mannitol at a concentration of 4 g L⁻¹ and riboflavin at a concentration of 100 mg L⁻¹ gave the highest interaction with an average of 672.800 leaf seedling⁻¹, while the control treatment for the factors under study gave the lowest interaction with an average of 210.000 leaf seedling⁻¹, with an increase percentage of 220.380%.

Table (3): Effect of vermicompost extract, spraying with mannitol, riboflavin and their interaction on the average increase in the number of leaves (leaf seedling⁻¹)

Vermicompost extract concentrations (m L ⁻¹)	Mannitol concentrations (g L ⁻¹)	Riboflavin concentrations (mg L ⁻¹)			Vermicompost extract × Mannitol
		0	50	100	
0	0	210.000	222.200	225.533	219.244
	2	364.400	383.400	386.600	378.133
	4	441.533	513.733	527.600	494.289
2	0	234.200	301.200	302.400	279.267
	2	386.400	397.600	436.600	406.867
	4	531.400	555.600	672.800	586.600
L.S.D _{0.05}		0.3674			0.2121
Means (Riboflavin)		361.322	395.622	425.256	Means (Vermicompost extract)
L.S.D _{0.05}		0.1500			
Vermicompost extract × Riboflavin					



0	338.644	373.111	379.911	363.889
2	384.000	418.133	470.600	424.244
L.S.D _{0.05}	0.2121			0.1225
Mannitol × Riboflavin				Means (Mannitol)
0	222.100	261.700	263.967	249.256
2	375.400	390.500	411.600	392.500
4	486.467	534.667	600.200	540.444
L.S.D _{0.05}	0.2598			0.1500

Leaf area (cm²)

The results (Table 4) showed significant differences between the concentrations of vermicompost extract, mannitol and riboflavin in the average increase in leaf area, as the treatment with vermicompost extract at a concentration of (2 ml L⁻¹) was superior, giving it the highest average of 3.767 cm², while the control treatment (0 ml L⁻¹) recorded the lowest average of 3.463 cm², with an increase percentage of 8.778%. The results also showed significant differences between the spray concentrations of mannitol, as the concentration (4 g L⁻¹) achieved the highest average of 4.461 cm², while the control treatment (0 g L⁻¹) recorded the lowest average of 2.545 cm², with an increase percentage of 75.284%. Spraying with riboflavin also had a significant effect on this trait, as the treatment (100 mg L⁻¹) achieved the highest average of 3.741 cm², compared to the control treatment (0 mg L⁻¹) which recorded the lowest average of 3.507 cm², with an increase percentage of 6.672%.

The results showed that the two factors interaction between the study factors had a significant effect on the average of this trait, as the treatment with vermicompost extract at a concentration of 2 ml L⁻¹ and mannitol at a concentration of 4 g L⁻¹ gave the highest interaction of 4.631 cm², while the lowest interaction was achieved in the control treatment of both factors (0 ml L⁻¹ vermicompost extract + 0 g L⁻¹ mannitol) with an average of 2.406 cm², with an increase percentage of 92.477%. The results showed a significant interaction between vermicompost extract and riboflavin, as the highest interaction was achieved when treating with vermicompost extract at a concentration of 2 ml L⁻¹ with riboflavin at a concentration of 100 mg L⁻¹ with an average of 3.832 cm², while the control treatment for both factors (0 ml L⁻¹ vermicompost extract + 0 g L⁻¹ riboflavin) recorded the lowest interaction with an average of 3.298 cm² with an increase percentage of 16.191%. As for the interaction between mannitol and riboflavin, it had a significant effect on this trait, as the spraying treatment with mannitol at a concentration of 4 g L⁻¹ with the treatment of riboflavin at a concentration of 100 mg L⁻¹ gave the highest interaction of 4.580 cm², while the lowest interaction was achieved in the control treatment of both factors (0 g L⁻¹ mannitol + 0 g L⁻¹ riboflavin) with an average of 2.461 cm² with an increase percentage of 86.103%. The results also showed a significant three-way interaction between the factors in the average increase of this trait, as the treatment of vermicompost extract at a concentration of 2 ml L⁻¹ with the treatment of mannitol at a concentration of 4 g L⁻¹ and riboflavin at a concentration of 100 mg L⁻¹ gave the highest interaction

of 4.736 cm², while the control treatment gave the lowest interaction of 2.297 cm² with an increase percentage of 106.181%.

Table (4): Effect of vermicompost extract, spraying with mannitol, riboflavin and their interaction on the average leaf area (cm²)

Vermicompost extract concentrations (m L ⁻¹)	Mannitol concentrations (g L ⁻¹)	Riboflavin concentrations (mg L ⁻¹)			Vermicompost extract × Mannitol
		0	50	100	
0	0	2.297	2.375	2.547	2.406
	2	3.414	3.686	3.978	3.693
	4	4.183	4.266	4.425	4.291
2	0	2.625	2.655	2.770	2.683
	2	3.983	3.986	3.991	3.986
	4	4.544	4.615	4.736	4.631
L.S.D 0.05		0.0032			0.0018
Means (Riboflavin)		3.507	3.597	3.741	Means (Vermicompost extract)
L.S.D 0.05		0.0013			
Vermicompost extract × Riboflavin					
0		3.298	3.442	3.650	3.463
2		3.717	3.752	3.832	3.767
L.S.D 0.05		0.0018			0.0010
Mannitol × Riboflavin					Means (Mannitol)
0		2.461	2.515	2.658	2.545
2		3.698	3.836	3.984	3.839
4		4.363	4.441	4.580	4.461
L.S.D 0.05		0.0023			0.0013

Dry weight of leaves (g seedling⁻¹)

The results (Table 5) showed that the concentrations of vermicompost extract, mannitol and riboflavin significantly affected the average increase in dry weight of leaves, as the treatment with vermicompost extract at a concentration of (2 ml L⁻¹) was superior, giving it the highest average of 7.656 g seedlings⁻¹, while the control treatment (0 ml L⁻¹) recorded the lowest average of 6.933 g seedlings⁻¹, with an increase percentage of 10.428%. The results also showed significant differences between the mannitol spray concentrations, as the concentration (4 g L⁻¹) achieved the highest average of 9.406 g seedlings⁻¹, while the control treatment (0 g L⁻¹) recorded the lowest average of 5.594 g seedlings⁻¹, with an increase percentage of 68.144%. Riboflavin spraying also had a significant effect on this trait, the concentration (100 mg L⁻¹) achieved the highest average of 7.650 g seedlings⁻¹, compared to the control treatment (0 mg L⁻¹) which recorded the lowest average of 6.961 g seedlings⁻¹, with an increase percentage of 9.898%.

The results showed that the two factors interaction between the factors had a significant effect on the average increase in leaf dry weight, as the treatment with vermicompost

extract at a concentration of 2 ml L⁻¹ with mannitol treatment at a concentration of 4 g L⁻¹ gave the highest interaction of 9.944 g seedling⁻¹, while the lowest interaction was achieved with the control treatment of both factors (0 ml L⁻¹ vermicompost extract + 0 g L⁻¹ mannitol) with an average of 5.433 g seedling⁻¹, and with an increase percentage of 83.029%. While the results showed an insignificant interaction between vermicompost extract and riboflavin on this trait. As for the interaction between mannitol and riboflavin, it had a significant effect on this trait, as the treatment of spraying mannitol at a concentration of 4 g L⁻¹ with the treatment of riboflavin at a concentration of 100 mg L⁻¹ gave the highest interaction of 9.900 g seedlings⁻¹, while the lowest interaction was reached in the control treatment for both factors (0 g L⁻¹ mannitol + 0 g L⁻¹ riboflavin) with an average of 5.400 g seedlings⁻¹, with an increase percentage of 83.333%. The results also showed a significant three-way interaction between the factors in the average increase of this trait, as the treatment of vermicompost extract at a concentration of 2 ml L⁻¹ with the treatment of mannitol at a concentration of 4 g L⁻¹ and riboflavin at a concentration of 100 mg L⁻¹ gave the highest interaction with an average of 10.400 g seedlings⁻¹, while the control treatment of these factors gave the lowest interaction with an average of 5.200 g seedlings⁻¹ with an increase percentage of 100%.

Table (5): Effect of vermicompost extract, spraying with mannitol, riboflavin and their interaction on the average dry weight of leaves (g seedling⁻¹)

Vermicompost extract concentrations (m L ⁻¹)	Mannitol concentrations (g L ⁻¹)	Riboflavin concentrations (mg L ⁻¹)			Vermicompost extract × Mannitol
		0	50	100	
0	0	5.200	5.400	5.700	5.433
	2	6.200	6.500	6.800	6.500
	4	8.400	8.800	9.400	8.867
2	0	5.600	5.767	5.900	5.756
	2	6.800	7.300	7.700	7.267
	4	9.567	9.867	10.400	9.944
L.S.D _{0.05}		0.1269			0.0733
Means (Riboflavin)		6.961	7.272	7.650	Means (Vermicompost extract)
L.S.D _{0.05}		0.0518			
Vermicompost extract × Riboflavin					
0		6.600	6.900	7.300	6.933
2		7.322	7.644	8.000	7.656
L.S.D _{0.05}		N.S.			0.0423
Mannitol × Riboflavin					Means (Mannitol)
0		5.400	5.583	5.800	5.594
2		6.500	6.900	7.250	6.883

4	8.983	9.333	9.900	9.406
L.S.D _{0.05}	0.0897			0.0518

Dry weight of the shoot system (g seedling⁻¹)

The results (Table 6) indicated that the concentrations of vermicompost extract, mannitol and riboflavin significantly affected the average increase in the dry weight of the shoot system, as the treatment with vermicompost extract at a concentration of (2 ml L⁻¹) was superior, giving the highest average of 18.281 g seedlings⁻¹, while the control treatment (0 ml L⁻¹) gave the lowest average of 16.211 g seedlings⁻¹, with an increase percentage of 12.769%. The results also showed significant differences between the mannitol spray concentrations, as the concentration (4 g L⁻¹) achieved the highest average of 21.983 g seedlings⁻¹, compared to the control treatment (0 g L⁻¹), which recorded the lowest average of 13.155 g seedlings⁻¹, with an increase percentage of 67.107%. Riboflavin spraying also had a significant effect on this trait, as the concentration (100 mg L⁻¹) achieved the highest average of 18.316 g seedlings⁻¹, compared to the distilled water spraying treatment (0 mg L⁻¹) which recorded the lowest average of 16.188 g seedlings⁻¹, with an increase percentage of 13.145%.

The results showed that the two factors interaction between the factors had a significant effect on the average increase in the dry weight of leaves, as the treatment with vermicompost extract at a concentration of 2 ml L⁻¹ with mannitol treatment at a concentration of 4 g L⁻¹ gave the highest interaction with an average of 23.555 g seedlings⁻¹, while the lowest interaction was achieved in the control treatment for both factors (0 ml L⁻¹ vermicompost extract + 0 g L⁻¹ mannitol) with an average of 12.655 g seedlings⁻¹, with an increase percentage of 86.131%. The results also showed a significant interaction between vermicompost extract and riboflavin spraying, as the highest interaction was achieved when treating with vermicompost extract at a concentration of 2 ml L⁻¹ with riboflavin treatment at a concentration of 100 mg L⁻¹ with an average of 19.166 g seedlings⁻¹, while the control treatment for both factors (ml L⁻¹ vermicompost extract + 0 g L⁻¹ riboflavin) recorded the lowest interaction with an average of 15.100 g seedlings⁻¹ with an increase percentage of 26.927%. As for the interaction between mannitol and riboflavin, it had a significant effect on this trait, as the treatment of spraying mannitol at a concentration of 4 g L⁻¹ with the treatment of riboflavin at a concentration of 100 mg L⁻¹ gave the highest interaction, with an average of 23.116 g seedlings⁻¹, while the lowest interaction was achieved in the control treatment for both factors (0 g L⁻¹ mannitol + 0 g L⁻¹ riboflavin) with an average of 12.150 g seedlings⁻¹, with an increase percentage of 90.255%. The results also showed a significant three-way interaction between the factors in the average increase of this trait, as the treatment of vermicompost extract at a concentration of 2 ml L⁻¹ with the treatment of mannitol at a concentration of 4 g L⁻¹ and riboflavin at a concentration of 100 mg L⁻¹ gave the highest interaction with an average of 24.400 g seedlings⁻¹, while the control treatment of these factors gave the lowest interaction with an average of 11.500 g seedlings⁻¹ with an increase percentage of 112.173%.

Table (6): Effect of vermicompost extract, spraying with mannitol, riboflavin and their interaction on the average dry weight of the shoot system (g seedling⁻¹)

Vermicompost extract concentrations (m L ⁻¹)	Mannitol concentrations (g L ⁻¹)	Riboflavin concentrations (mg L ⁻¹)			Vermicompost extract × Mannitol
		0	50	100	
0	0	11.500	12.700	13.766	12.655
	2	14.600	15.300	16.800	15.566
	4	19.200	20.200	21.833	20.411
2	0	12.800	13.866	14.300	13.655
	2	16.600	17.500	18.800	17.633
	4	22.433	23.833	24.400	23.555
L.S.D _{0.05}		0.1063			0.0613
Means (Riboflavin)		16.188	17.233	18.316	Means (Vermicompost extract)
L.S.D _{0.05}		0.0434			
Vermicompost extract × Riboflavin					
0		15.100	16.066	17.466	16.211
2		17.277	18.400	19.166	18.281
L.S.D _{0.05}		0.0613			0.0354
Mannitol × Riboflavin					Means (Mannitol)
0		12.150	13.283	14.033	13.155
2		15.600	16.400	17.800	16.600
4		20.816	22.016	23.116	21.983
L.S.D _{0.05}		0.0751			0.0434

The results indicate that the addition of vermicompost extract had a significant effect on the average of all studied vegetative growth parameters. This effect is attributed to the fact that vermicompost extract, when added to the soil, improves its physical and chemical properties. It reduces soil pH and increases the population of beneficial microorganisms that promote plant growth [20]. Consequently, this facilitates root penetration and branching, and enhances the availability of macro- and micronutrients, which in turn positively reflects on the increase in vegetative growth indicators [21]. The positive effect may also be attributed to the presence of organic and inorganic acids in the extract, which act as intermediates in the respiration process, thereby enhancing the activity of enzymes and hormones that contribute to an increase in the products of photosynthesis [22]. This ultimately stimulates cell division and enlargement, leading to the formation of new plant tissues and consequently increasing plant height and leaf area [23].

The application of vermicompost extract may have contributed to the increase in chlorophyll content in the leaves due to its high concentrations of nitrogen (N), magnesium (Mg), and iron (Fe), which are essential components of the chlorophyll molecule. This,

in turn, enhances the photosynthetic efficiency and the synthesis of carbohydrates, positively influencing vegetative growth parameters [24]. Moreover, the extract's content of macro- and micronutrients plays a vital role in stimulating various chemical processes by improving photosynthetic efficiency, enhancing carbohydrate biosynthesis, and promoting respiratory activity [25]. Or perhaps the improvement of vegetative growth characteristics is attributed to the fact that this extract contains potassium, which is also one of the main nutrients that play an important role in improving plant growth through its role in improving the photosynthesis process [26], in addition to its content of humic acid, which works to stimulate root respiration and growth and increase the absorption of essential elements such as manganese, phosphorus, potassium and calcium from the soil [27]. The increase in plant growth indicators such as plant height, stem diameter, number of leaves, and leaf area ultimately leads to a greater dry weight of the shoot system. These findings are consistent with the results reported by [28,29]. Similarly, these findings were consistent with [30,31,32,33].

The application of mannitol may have contributed to enhanced plant growth due to its effect on cell membrane permeability, as its small molecular size facilitates its penetration into the leaves and accumulation within plant tissues [34] (Serenella et al., 2002). This effect is likely attributed to the increased efficiency of the photosynthetic process and the accumulation of carbohydrates, which improved the nutritional status of the seedlings and positively influenced the secretion of plant hormones. These hormones play a crucial role in enhancing vegetative growth through cell division, elongation of the apical meristems, and branch extension. Additionally, they promote cell swelling and expansion by increasing the plant's ability to absorb water and nutrients, thereby improving vegetative growth traits [35,36]. The increase in seedling height also leads to a greater number of stem nodes, which is positively correlated with an increased number of leaves [37].

The results also showed that spraying plants with riboflavin had a significant effect on plant height. This is due to the fact that it is a component of the well-known enzymes FAD and FMN, which are important organic compounds responsible for oxidation and reduction processes, including nitrate reduction in plant cells as one of the steps in amino acid synthesis. This is a series of vital processes that lead to the formation of indole acetaldehyde, which is the intermediate compound that generates the auxin indole acetic acid, which works to elongate cells, increase plant height and diameter, and increase the number of plant leaves [38]. Riboflavin can also lead to an increase in leaf area and increased efficiency of photosynthesis, which positively affects plant height and leaf number, thus increasing vegetative growth indicators [39].

From the above, it can be concluded that the use of vermicompost extract, especially at a concentration of (2 ml L⁻¹), led to a clear improvement in most of the vegetative traits of myrtle seedlings. Additionally, foliar application with mannitol at a concentration of (4 g L⁻¹) further enhanced these traits, and riboflavin at a concentration of (100 mg L⁻¹) also contributed to improving growth. This is in addition to the effective interactions between these factors, which confirms the existence of a complementary effect between

them, highlighting the importance of using these treatments together to enhance the growth of myrtle seedlings.

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