



THE EFFECT OF MYCORRHIZA AND FOLIAR APPLICATION OF PLANT EXTRACTS ON THE GROWTH AND YIELD OF CUCUMBER UNDER PROTECTED CULTIVATION (*CUCUMIS SATIVUS*)

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Abstract

The experiment was conducted during 2023–2024 growing season in a plastic house at the research station in Al-Bandar, affiliated with the College of Agriculture, University of Al-Muthanna, on cucumber plants (*Cucumis sativus* L., cv. Sahara). The study aimed to investigate the effect of Mycorrhizal fungi and foliar spraying with licorice extract combined with yeast at concentrations of 0, 5, and 10 g L⁻¹ on the growth and yield of cucumber cultivated under greenhouse conditions. Three foliar sprays were applied during the growing season. A randomized completely block design (RCBD) with three replications was used, and means were compared using the least significant difference (LSD) test at the 0.05 probability level. The main results can be summarized as follows:

Plants treated with mycorrhizal fungi showed significant superiority in all studied traits. The concentration of 10 g L⁻¹ licorice extract combined with yeast was superior comparing with other treatments in terms of vegetative growth and yield parameters. Furthermore, the interaction between mycorrhizal fungi and 10 g L⁻¹ concentration of licorice extract combined with yeast recorded the highest values for plant height, number of leaves, leaf area, dry weight of vegetative growth, number of fruits, and total yield per plant, reaching 221.93 cm, 36.12 leaves, 40.72 dm², 117.49 g, 34.26 fruits, and 4.44 kg plant⁻¹, respectively .

DOI:-10.5281/zenodo.19448740

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INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the most important vegetable crops in Cucurbitaceae family. It is among the oldest cultivated vegetables by humans and ranks second after tomato in Europe. The cucumber is believed to have originated in India, where some wild varieties still exist, most of which bitter and inedible fruits. India also exports large quantities of cucumbers, especially very small-fruited types used for pickling (Eifediyi and Remison, 2010). Records from the Sumerians and Babylonians dating back to about 3000 B.C. mention cucurbits, including cucumber, indicating the interest of ancient Iraqis in cultivating these crops. The nutritional importance of cucumber lies in its content of carbohydrates, proteins, oils, vitamins B1, B2, and C, as well as mineral salts, particularly iron, calcium, and phosphorus (Al-Tahafi *et al.*, 2013). In Iraq, the cultivated area of cucumber reached 95,281 dunums in 2020, with a production of 242,614 tons (Central Organization for Statistics, 2021). With the increasing awareness of environmental issues, the excessive use of chemical fertilizers, herbicides, and pesticides, along with their rising costs, it has become necessary to improve the efficiency of fertilizer use and to search for alternative methods to enhance crop yield and quality. Many developed countries have shifted toward organic farming and minimizing the use of chemical compounds, as one of the goals of organic farming is to produce plants free from the toxic residues of pesticides and chemical fertilizers. Moreover, organic agriculture has both medium- and long-term effects on agro-ecosystems. This agricultural system aims to produce organic foods while creating ecological balance to overcome problems of soil fertility and pests.

The addition of organic residues to soil plays a major role in improving fertility and providing nutrients, in addition to enhancing soil chemical and physical properties such as cation exchange capacity, water-holding capacity, and the release of amino acid stimulants. Furthermore, bio-fertilizers such as mycorrhizal fungi and natural plant extracts have been utilized (Al-Jubouri *et al.*, 2017). Therefore, this study aims to evaluate the potential use of mycorrhizal fungi as a bio-fertilizer and yeast suspension, and to investigate their individual and combined effects on the growth and yield of cucumber under protected cultivation systems.

Materials and Methods

A field experiment was carried out during the winter growing season of 2022–2023 at the Second Agricultural Research Station of the College of Agriculture, University of Al-Muthanna, located in Al-Bandar, 3 km away from the city center of Al-Muthanna Governorate, Iraq (coordinates: 31.320705 N, 45.303067 E). The study aimed to investigate the effect of mycorrhizal fungi and yeast suspension on growth traits and yield of cucumber hybrid Sahara. Soil samples were collected from different sites at a depth of 0–30 cm, mixed thoroughly to ensure homogeneity, air-dried, ground, and sieved through a 2-mm mesh. A composite sample was taken for physical and chemical analyses, as presented in Table 1. The plastic house was prepared by leveling the soil, which was then divided into six ridges, each 56 m in length. Decomposed organic fertilizer was applied to all ridges. For fungal disease prevention, Ridomil fungicide was applied at a rate of 3 kg donum⁻¹. The spacing between ridges was 75 cm, and drip irrigation lines were placed along the ridge tops with 30 cm between planting hills. Three seeds were sown per hill, and plants were thinned to one per hill two weeks after germination. A distance of 90 cm was left at the entrance and end of each block. The experiment was conducted using a randomized completely block design (RCBD) with three replications and nine experimental units, involving two factors:

Factor 1 – Mycorrhizal fungi (M0: Without mycorrhiza inoculation, M1: Mycorrhiza applied to seeds at 5 g hill⁻¹). Factor 2 – Extract treatments: (T0: No application, T1: Foliar spray with licorice extract + yeast suspension at 5 g L⁻¹ each and T2: Foliar spray with licorice extract + yeast suspension at 10 g L⁻¹ each).

Table (1). Some chemical and physical properties of the soil sample before cultivation :

Property	Value	Unit
Soil reaction (pH)	7.68	
Electrical conductivity (ECe)	8.13	dS m ⁻¹
Organic matter%	0.4	%
Available nitrogen	18.9	mg N kg ⁻¹ soil
Available phosphorus	10	mg P kg ⁻¹ soil
Available potassium	195	mg K kg ⁻¹ soil
Soil fractions		
Texture		Sandy loam
Clay	19.1	%
Sand	48.2	%
Silt	32.7	%

Results and Discussion

Plant Height

It is evident from Table (2) that mycorrhizal inoculation significantly influenced plant height compared to the non-inoculated control. Plant height which treated with mycorrhiza reached 208.62 cm, compared with 179.86 cm control treatment. The increase in plant height may be attributed to the enhancement of root growth by mycorrhiza, which in turn improves the absorption of water and dissolved nutrients. This stimulates physiological activities within the plant, such as increased cell division and elongation, which positively affect plant height. These results are in agreement with those reported by Raheem and Issa (2018).

As shown in Table (2), significant differences were also observed among the treatments with licorice extract and yeast suspension. The highest plant height was recorded at the concentration of 10 g L⁻¹, reaching 206.31 cm, while the lowest was at 0 g L⁻¹ with 181.9 cm. This increase could be due to the hormonal nature of the extracts, since both licorice and yeast contain substances with growth regulator-like effects (auxins) and enzymes, particularly those that enhance Mg and K availability, which play a crucial role in stimulating cell division in the apical meristems. This ultimately reflects positively on plant height. These findings are consistent with Issa and Herby (2017), who reported similar effects in broad bean when using different concentrations of yeast suspension and licorice extract. Moreover, significant interactions were found between mycorrhizal inoculation and foliar spraying with plant extracts on plant height. The combined treatment T2M1 (mycorrhiza + licorice extract + yeast). It is also evident from Table (2) that there were significant interactions between mycorrhizal inoculation and foliar application of plant extracts on plant height. The highest value was recorded in treatment T2M1 (mycorrhiza + licorice extract and yeast suspension at 10 g L⁻¹), where plant height reached 221.93 cm, compared with the control treatment (M0T0), which recorded only 167.75 cm.

Table (2). Effect of mycorrhiza, plant extracts, and their interaction on plant height of cucumber under protected cultivation (cm).

Extracts \ Mycorrhiza	T2	T1	T0	Mycorrhiza Mean
M0	190.7	181.15	167.75	179.86
M1	221.93	207.9	196.05	208.62
Extracts Mean	206.31	194.52	181.9	
L.S.D. _{0.05}	TM= 15.430	M= 8.371	T=9.984	

Number of Leaves

The results presented in Table (3) indicate that mycorrhizal inoculation had a significant effect on the average number of leaves per plant. Mycorrhiza recorded the highest mean value (33.92 leaves plant⁻¹) compared to the control treatment (29.80 leaves plant⁻¹). This increase may be attributed to the ability of mycorrhiza to enhance the root surface area, thereby improving water and nutrient uptake. In addition, mycorrhiza stimulate the roots to produce plant hormones such as gibberellins and cytokinins, which are translocated to the aerial parts of the plant, leading to enhanced cell division and the initiation of leaf primordia, ultimately increasing the number of leaves. These findings are consistent with those reported by Saleh (2006) and Nzanza and Soundy (2012).

Furthermore, foliar application of licorice extract and yeast suspension also showed a significant effect on the number of leaves. The concentration of 10 g L⁻¹ produced the highest average number of leaves (35.47 leaves plant⁻¹) compared to 29.09 leaves plant⁻¹ in the control during the autumn season. Similarly, the concentration of 7.5 mL L⁻¹ gave the highest average of 34.18 leaves plant⁻¹ compared to 29.22 leaves plant⁻¹ in the control treatment. This increase can be explained by the presence of auxin-like substances in these extracts, which enhance the concentration of growth regulators within the plant, thereby promoting cell division and leaf initiation. These results agree with Hussein (2002) on cucumber and Al-Rawi (2004) on squash.

It is also evident from Table (3) that there were significant interaction effects between mycorrhiza and plant extracts on the number of leaves. The treatment T2M1 recorded the highest number of leaves (36.12 leaves plant⁻¹), compared to the control treatment which had only 27.45 leaves plant⁻¹.

Table (3). Effect of mycorrhiza, plant extracts, and their interaction on number of leaves of cucumber under protected cultivation (leaf plant⁻¹).

Extracts \ Mycorrhiza	T2	T1	T0	Mycorrhiza Mean
M0	32.25	29.7	27.45	29.8
M1	36.12	32.75	31.00	33.29
Extracts Mean	34.18	31.22	29.22	
L.S.D. _{0.05}	TM=3.021	M=1.005	T=2.987	

Leaf Area

Table (4) shows that mycorrhizal inoculation significantly affected leaf area. The highest leaf area was recorded in mycorrhiza-treated plants, reaching $37.92 \text{ dm}^2 \text{ plant}^{-1}$, which was significantly higher than the control treatment ($34.17 \text{ dm}^2 \text{ plant}^{-1}$). This increase may be attributed to the effect of mycorrhiza in enhancing the plant's ability to absorb water and nutrients through the roots, thereby increasing metabolic activities and consequently the leaf area. These results are consistent with Utobo *et al.*, 2011).

Additionally, foliar application of plant extracts, which contain amino acids and essential nutrients such as magnesium and iron, plays a critical role in cell division, cell expansion, chlorophyll synthesis, and other metabolic processes, all of which contribute to increasing leaf surface area. These findings agree with Hussein (2002), who reported significant effects of garlic extract on cucumber leaf area at different concentrations over two growing seasons.

Furthermore, significant interaction effects between mycorrhiza and plant extracts were observed on leaf area. The highest leaf area ($40.72 \text{ dm}^2 \text{ plant}^{-1}$) was recorded in the T2M1 treatment (mycorrhiza + 10 g L^{-1} licorice extract + yeast suspension), compared with the lowest value in the control (T0M0), which was $32.62 \text{ dm}^2 \text{ plant}^{-1}$.

Table (4). Effect of mycorrhiza, plant extracts, and their interaction on leaf area of cucumber under protected cultivation ($\text{dm}^2 \text{ plant}^{-1}$).

Extracts \ Mycorrhiza	T2	T1	T0	Mycorrhiza Mean
	M0	35.55	34.35	
M1	40.72	37.4	35.65	37.92
Extracts Mean	38.13	35.87	34.13	
L.S.D. _{0.05}	TM= 3.231	M=1.002	T=1.512	

Dry Weight of Vegetative Growth

The results in Table (5) indicate that mycorrhizal inoculation had a significant effect on the dry weight of the vegetative growth. The highest dry weight was recorded in mycorrhiza-treated plants (93.80 g), compared to the control treatment, which produced the lowest value (68.40 g). This increase may be attributed to the enhanced root surface area due to mycorrhizal inoculation, which improves water and nutrient absorption, thereby increasing photosynthetic efficiency, carbohydrate production, and dry matter accumulation in the vegetative parts. These results are consistent with Al-Kafaji *et al.*, (2018).

Foliar application of plant extracts also had a significant effect. The highest dry weight (102.11 g) was recorded at the concentration of 10 g L^{-1} , compared to 67.66 g in the control treatment. This effect may be due to the presence of essential nutrients in the extracts, which enhance leaf area (Table 4) and other physiological activities, thereby improving photosynthetic efficiency and carbohydrate accumulation in the vegetative growth. These findings agree with Najm (2005).

Moreover, significant interaction effects were observed between mycorrhiza and plant extracts on dry weight. The T2M1 treatment (mycorrhiza + 10 g L^{-1} licorice extract + yeast suspension) recorded the highest dry weight (117.49 g), while the lowest value was observed in the control treatment (T0M0), which produced only 55.43 g .

Table (5). Effect of mycorrhiza, plant extracts, and their interaction on vegetative dry weight of cucumber under protected cultivation (g).

Extracts \ Mycorrhiza	T2	T1	T0	Mycorrhiza Mean
	M0	86.73	63.04	
M1	117.49	84.04	79.89	93.80
Extracts Mean	102.11	73.54	67.66	
L.S.D. _{0.05}	TM=16.652	M=7.458	T= 9.311	

Number of Fruits

The results in Table (6) indicate that mycorrhizal inoculation had a significant effect on the number of fruits per plant. The highest value was recorded in mycorrhiza-treated plants, reaching $32.748 \text{ fruits plant}^{-1}$, whereas the control treatment produced the lowest number of fruits ($29.01 \text{ fruits plant}^{-1}$).

Foliar application of plant extracts also showed a significant effect. The highest number of fruits ($32.89 \text{ fruits plant}^{-1}$) was obtained at the concentration of 10 g L^{-1} , compared to $28.46 \text{ fruits plant}^{-1}$ in the control treatment. This increase may be attributed to the enhanced production of metabolic compounds in the leaves, and the

increased leaf number and leaf area (Tables 3 and 4), which stimulate root growth both in length and surface area, thereby improving water and nutrient uptake. Improved vegetative growth and increased nutrient translocation from leaves to fruits ultimately lead to an increased number of fruits. These findings are in agreement with those reported by Al-Abdullah (2008) and Ayotamuno *et al.*, (2007) on cucumber.

Significant interaction effects were also observed between mycorrhiza and plant extracts. The treatment T2M1 (mycorrhiza + 10 g L⁻¹ licorice extract + yeast suspension) recorded the highest number of fruits (34.26 fruits plant⁻¹), compared to the control treatment (T0M0), which produced the lowest number of fruits (26.99 fruits plant⁻¹).

Table (6). Effect of mycorrhiza, plant extracts, and their interaction on number of fruits of cucumber under protected cultivation (fruit plant⁻¹).

Mycorrhiza \ Extracts	T2	T1	T0	Mycorrhiza Mean
	M0	31.52	28.54	
M1	34.26	34.03	29.94	32.74
Extracts Mean	32.89	31.28	28.46	
L.S.D. _{0.05}	TM= 2.453	M= 0.981	T=1.467	

Total Yield per Plant

The results presented in Table (7) indicate a significant effect of mycorrhizal inoculation on cucumber yield under protected cultivation. Plants treated with mycorrhiza (M1) produced the highest average yield per plant (3.80 kg plant⁻¹), which was significantly higher than the control treatment, which produced the lowest yield (3.22 kg plant⁻¹). This increase can be attributed to the positive effects of mycorrhiza on plant height, number of leaves, leaf area, dry weight of vegetative growth, and number of fruits (Tables 3–6), all of which contributed to the improved total yield. These findings are consistent with those reported by Rahman *et al.*, (2004) and Al-Zahawi (2007). Foliar application of plant extracts also had a significant effect on total yield. The highest yield (4.03 kg plant⁻¹) was obtained at the concentration of 10 g L⁻¹, compared to 3.01 kg plant⁻¹ in the control treatment. This effect may be due to the essential nutrients in the extracts, which enhance photosynthetic efficiency, increase carbohydrate production, and facilitate translocation from the leaves to the fruits, thereby improving vegetative growth and fruit development, which ultimately increases total yield. These results are in agreement with Hussein (2002) and Omran (2004) on cucumber.

Significant interaction effects between mycorrhiza and plant extracts were also observed. The treatment T2M1 (mycorrhiza + 10 g L⁻¹ licorice extract + yeast suspension) produced the highest yield (4.44 kg plant⁻¹), while the lowest value was observed in the control treatment (T0M0) with 2.96 kg plant⁻¹.

Table (7). Effect of mycorrhiza, plant extracts, and their interaction on total yield of cucumber plant under protected cultivation (g plant⁻¹).

Mycorrhiza \ Extracts	T2	T1	T0	Mycorrhiza Mean
	M0	3.62	3.1	
M1	4.44	3.91	3.06	3.80
Extracts Mean	4.03	3.50	3.01	
L.S.D. _{0.05}	TM=0. 523	M= 0.131	T=0.302	

Conclusion from the results of this study, it can be concluded that the application of bio-fertilizers, specifically mycorrhizal fungi, significantly enhanced the vegetative growth and yield of cucumber grown under protected cultivation. Foliar application of plant extracts also contributed to the improvement of plant growth and yield. Based on the findings, it is recommended to use mycorrhizal fungi in combination with foliar application of licorice extract and yeast suspension at a concentration of 10 g L⁻¹ to achieve optimal vegetative growth and yield of cucumber under protected cultivation

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