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Response of *Canna indica* L. to *Azospirillum* Bio-fertilizer, Date Palm Residues and Their Effect on Vegetative and Floral Growth

Eabdallah Yasin[1], Mateen Yilmaz AL-Bayati[2], Kareema A. AL-Fatlawi[3]

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ABSTRACT

Background: The global trend at present is to utilise organic fertilisers of various types and sources to minimise the adverse effects of chemical fertilisers as much as possible. Bio-fertilization is a biotechnology-based fertilization method that helps plants to receive even more nutrients, the method is important in enhancing the efficiency of photosynthesis by fixing nitrogen in the atmosphere and producing growth-stimulating compounds.

Methods: The experiment was conducted in the lath house of the Department of Horticulture and Landscape Design, College of Agricultural Engineering Sciences, University of Baghdad-Iraq, during the 2024-2025 growing season. The soil of *Canna indica* L. plants were inoculated with three levels of *Azospirillum* bacteria (0, 50 and 100 g pot^{-1}) and three levels of Date Palm residues (0, 4 and 8 g pot^{-1}) to determine their effects on vegetative and floral growth.

Result: The addition of *Azospirillum* bacteria at 100 g pot^{-1} resulted in a significant increase in most vegetative and floral growth characteristics and in the number of rhizomes. This treatment increased plant height, number of leaves, leaf area, main stem diameter, number of shoots, fresh weight, number of flowers, flower diameter, flowering period and number of rhizomes. The application of date palm residues at 8 g pot^{-1} also significantly increased most vegetative and floral growth traits and the number of rhizomes, including plant height, number of leaves, leaf area, stem diameter, number of shoots, fresh weight, number of flowers, flower diameter, flower stalk length, flowering period and number of rhizomes.

Key words: *Azospirillum*, Bacteria, Bio-fertilizer, *Canna indica* L., Date palm residues, Ornamental plant.

INTRODUCTION

Canna indica L. is an Ornamental plant, which is a species of the family cannaceae and is categorized as true bulbous dicotyledonous plant, it is characterized by its leaf of green color and its elongated foliage and its yellow flowers that are shaped like trumpeting, which have facilitated its wide use in landscaping both in public places and in the garden of individual homes (Al Batal, 2010). The plant grows very fast and vigorously and has leaves of oblong like ovate blades, being very firm in texture, the flowers can be in full leaf all year round, with the intensity during the summer months and have a wide variety of colors that which is widely used in decorative garden arrangements, propagation is mainly done by rhizomes in spring, among other ways of propagating by vegetative division and seed propagation, as well as that *C. indica* is traditionally planted in the garden and on the urban squares because of its flexibility and it is highly tolerant to a wide range of environmental factors (Al Dabaa *et al.,* 1992). Bio-fertilization is a biotechnology-based fertilization method that helps plants to receive even more nutrients, the method is important in enhancing the efficiency of photosynthesis by fixing nitrogen in the atmosphere and producing growth-stimulating compounds, the use of the *Azospirillum* bacteria-based bio-fertilizers is viewed as a good addition to the chemical one, which improves the physical structure and chemical composition of the soil, moreover, these microorganisms enhance the formation of endogenous plant hormones such as auxins, gibberellins, ethylene and cytokinins that control the process of growth and development (Contreras-Angulo *et al.*, 2019; Al-Fatlawi *et al.*, 2021). In addition, bio-fertilizers have phosphate compounds that play a vital role in transferring energy to cells and thus vegetative growth, curbing nutrient deficiencies in soil and curbing soil contamination by

[1]Department of Biology, College of Education for Women, University of Kirkuk, Iraq.
[2]Department of Horticulture and Landscape Design, College of Agriculture, University of Kirkuk, Iraq.
[3]Department of Horticulture and Landscape Design, College of Agricultural Engineering Sciences, University of Baghdad, Iraq.

Corresponding Author: Mateen Yilmaz AL-Bayati, Department of Horticulture and Landscape Design, College of Agriculture, University of Kirkuk, Iraq. Email: uk_mateen@uokirkuk.edu.iq
ORCIDs: https://orcid.org/0009-0008-5480-9792, https://orcid.org/0000-0002-8427-3633, https://orcid.org/0009-0006-3798-907X

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excessive fertilization with chemicals (Macik *et al.*, 2020). It has been proven by numerous studies that the use of *Azospirillum* improves the proliferation of the root system in the rhizosphere, which leads to the enhancement of water and nutrient absorption. This is directly translated into better vegetative performance, floral traits and the general development of the plant (Gureeva and Gureev, 2023). The researchers indicated that the use of *Azotobacter* at 5 mL L^{-1} on *Chrysanthemum coronarium* L. altered the yield of flowers by increasing it significantly (Kruti *et al.*, 2023). Similarly, (Pukhram *et al.*, 2023) also indicated that *Azospirillum* and *Azotobacter* used together yielded significant vegetative growth and flowering characteristics enhancement of gladiolus (*Gladiolus hybridus* Hort.), which showed the positive synergistic impacts of bio-fertilizer mixtures. The date palm residues are the agricultural by-products produced as a result of the growth of Date Palm, which can be converted into organic fertilizers using a particular processing method to generate beneficial soil supplements as well as mitigate environmental pollution, it has been estimated that about 2.5-2.9 million tons of such residues have been collected, processed and recycled into products of bio-fertilizers, it is these materials that are high in cellulose and hemicellulose, as well as possessing a high water-retention ability, which helps in enhancing the soil structure, earlier studies have indicated that date palm-derived fertilizers used as soil amendments with ornamental crops like carnation led to the enhancement of the level of vital nutrients, including iron, potassium, copper and manganese (Sajeed, 2024). Additionally, (Padhiyar *et al.*, 2017) indicated that the growth of chrysanthemum in a medium made with cocopeat, vermicompost and bio-compost was an important factor that accelerated the growth of the chrysanthemum in terms of plant height, the number of branches, the fresh and dry biomass, flower diameter, flowering and the number of flowers. Similarly, (Arunesh *et al.*, 2020) challenged the use of a mixture of vermicompost, coir pith and garden soil (1:1:1) as the growth medium in enhancing most vegetative and floral traits of *Gerbera jamesonii*. This study aimed to determine the role of bio-fertilizers such as *Azospirillum* and their interaction with the Date Palm residues by accelerating their decomposition and reflecting this interaction on some growth and flowering characteristics of the *C. indica* L.

MATERIALS AND METHODS

During the 2024-2025 growing season, the experiment was carried out in the Department of Horticulture and Landscape Design's lath house at the College of Agricultural Engineering Sciences, University of Baghdad-Iraq. Uniform-sized bulbs were planted in plastic pots with a diameter of 30 cm, each containing 7 kg of a soil mixture composed of sand, clay and silt (Table 1). The planting soil was inoculated with three levels of *Azospirillum* bacteria (0, 50 and 100 g pot^{-1}) and three levels of date palm residues (0, 4 and 8 g pot^{-1}), using three replicates, each replicate consisting of three pots. Colonies belonging to *Azospirillum* bacteria were isolated using the dilution and plate counting method described by (Kathryn *et al.*, 2005). They were counted and Modified Ashby's Medium was used, which consists of the following compounds:

Glucose	K_2HPO_4	$MgSo_4$	NaCl	K_2SO_4	$CaCO_3$	Agar
20 gm	0.5 gm	0.2 gm	0.2 gm	0.1 gm	5 gm	15 gm

A preventive program was applied using a fungicide (PREVICUR) and an insecticide (CONFIDOR) via soil irrigation at a concentration of 1 ml L^{-1} of water, weekly, to protect the plants from fungal and insect infections. The experiment was arranged according to a randomized complete block design (RCBD). We used the least significant difference (LSD) test to compare the means, with a significance level set at 5% (Sahuqi and Wahib, 1990). Data were recorded for the following traits (measurements were taken at the appearance of color in the first flower on the plant) (Al-Bayati and Salih, 2021).

- **Vegetative traits**

Plant height (cm), number of leaves (leave $plant^{-1}$), leaf area (cm^2), stem diameter (mm), number of branches (branch $plant^{-1}$) and fresh weight of vegetative growth (g).

- **Floral and bulb traits**

Number of flowers (flower $plant^{-1}$), flower diameter (cm), flower stalk diameter (mm), flower stalk length (cm), flowering duration (days) and number of bulbs (bulbs $plant^{-1}$).

RESULTS AND DISCUSSION

Effect of inoculation with *Azospirillum* bacteria, date palm residues and their interaction on the vegetative and floral growth traits of *Canna indica* L.

Table 2(A) indicates that the statistically significant impact of *Azospirillum* application at the rate of 100 g pot^{-1} on all the parameters of vegetative growth assessed was statistically significant. The height of the plants was 45 cm, the number of leaves per plant was 10, the main stem diameter was 16 mm, the leaf area was 75 cm^2 and the number of bulbs and shoots was 6 per plant compared to

Table 1: Some physical and chemical properties of the growth medium.

Soil properties	Results of analogs
% Sand	43.2
% Silt	2.16
% Clay	8.92
Plt	7.27
Ec	5.79
Arrange enteral	9.1
Calcium	2.17
N	3.2
P	6.29
K	32.6

the control treatment. Regarding the effect of Date Palm residues on the vegetative traits of *C. indica* L., it has been shown from the Table 2(B) a significant increase was observed in all the traits that were measured. The height of the plants grew to 84 cm, the number of leaves per plant was 9, the total area of the leaf increased to 88 cm^2, the stem diameter was 20 mm, the shoot count was 4 per plant and the fresh mass of the vegetative parts was 70 g, in comparison with untreated plants. In terms of floral and bulb characteristics, when Date Palm residue was added, all traits of interest were significantly improved.

Table 3(A) showed that the number of flowers was 5 per plant, the flower diameter was 8 mm, the flower stalk diameter was 7 mm, the stalk length was 45 cm, flowering was extended to 4 days and the bulbs were 8 per plant. Regarding the effect of Date Palm residues on the vegetative traits of *C. indica* L., it has been shown from the Table 3(B) a non-significant in all the traits that were measured except for the flower stalk length trait, which yielded 45 cm compared to the control treatment. The *Azospirillum* inoculation and date palm residue application interaction revealed a strong synergistic effect on all the growth and flowering traits under research. Table 2-3(C) showed that In particular, the joint treatment of 100 g pot^{-1} *Azospirillum* with 8 g pot^{-1} Date Palm residues resulted in the significant increases in the height of the plant, the number of leaves, the leaf area, the stem diameter, the number of shoots and the mass of fresh vegetative matter, the relative changes of which were 94.5, 9.5, 81.0, 18.0, 5.0 and 72.0, respectively. Similarly, floral traits, such as the number of flowers, flower diameter, flower stalk diameter, flower stalk length, flowering duration and the bulb number, increased by 5, 8.5, 7.0, 44, 4.0 and 6.5, respectively.

These beneficial microorganisms are able to cause growth in vegetation and floration because of their presence in the rhizosphere, where they can reduce soil

Table 2: Effect of *Azospirillum* inoculation and the date palm residues on vegetative growth traits of *Canna indica* L.

A- Effect of *Azospirillum*

Treatment	Studied characteristics					
	Plant height (cm)	Number of leaves	Leaf area (cm^2)	Stem diameter (mm)	Number of shoots	Fresh weight of vegetative growth (g)
Azo0	60	4	45	10	3	40
Azo1	90	8	56	14	5	62
Azo2	45	10	75	16	6	74
LSD % 5	15	6	30.1	0.6	3.0	34

B- Effect of the date palm residues

Treatment	Studied characteristics					
	Plant height (cm)	Number of leaves	Leaf area (cm^2)	Stem diameter (mm)	Number of shoots	Fresh weight of vegetative growth (g)
DP0	46	2	32	11	2	35
DP1	80	7	75	16	3	52
DP2	84	9	88	20	4	70
LSD %5	12.33	7.0	26.11	0.9	2.0	15.0

C- Interaction between *Azospirillum* and date palm residues

Treatment		Studied characteristics					
		Plant height (cm)	Number of leaves	Leaf area (cm^2)	Stem diameter (mm)	Number of shoots	Fresh weight of vegetative growth (g)
Azo0	DP0	62	3	38.5	10.5	2.5	35.5
	DP1	77.5	5	44.0	12.5	3.5	38.5
	DP2	79.5	6	48.5	13.5	4.0	58.5
Azo1	DP0	70	5.5	60.1	13.0	3.0	36.5
	DP1	80.5	7.5	73.5	15.5	4.0	65.1
	DP2	80.5	8.5	80	17.0	4.5	71.0
Azo2	DP0	74.10	6.5	71.5	15.0	3.5	55
	DP1	88.5	8.0	72	17.0	4.5	65.5
	DP2	94.5	9.5	81.0	18.0	5.0	72.0
LSD % 5		22.3	10.4	12.42	10.4	6.7	17.4

contamination and enhance soil quality by releasing enzymes and other necessary nutrients. On top of that, *Azospirillum* is involved in the degradation of ACC (1-aminecyclopropane-1-carboxylate) and this results in the regulation of the level of ethylene within the plant. The interaction of the synthesis of growth-regulating compounds, including auxins and cytokinins and the interaction of these compounds with gibberellins and indole-3-acetic acid promotes growth of roots and general plant vigor (Khalaf, 2013; Majoul and Haneen, 2018; Gul *et al.*, 2019; Al-Fatlawi and Al-Bayati, 2021). This is consistent with his findings (Gayathri and Aiswariya, 2020; Abdullah and Hasan, 2020; Tabasi *et al.*, 2024; Devi *et al.*, 2025; Iraiyanban *et al.*, 2025 and Maity *et al.*, 2025). This enhanced growth of roots in turn results in greater germination rates, higher root biomass and greater uptake of nutrients in the soil, maybe due to the process of nitrogen and phosphorus being released through the breakdown of Date Palm residues. This improves nutrient supply to vegetative growth and flowering. This is consistent with the findings of both (Khalaf, 2013; Shaker, 2022; Al-Taie, 2024; Kumari *et al.*, 2026). In addition, bio-fertilizers can also generate hydrolytic enzymes like amylase to decompose organic matter and develop organo-mineral complexes with the micronutrients to increase bioavailability to plants (Tamboli *et al*, 2012; Rajera *et al.*, 2017; Al-Bayati *et al.*, 2023). The synthesis of auxin-like compounds further promotes apical dominance, cell division and cell elongation, which leads to higher plant height and better vegetative growth (Coniglio *et al.*, 2019; Ibrahim, 2022). The high level of growth of the plants used in the experiment with Date Palm residues can also be explained by the high level of organic matter in the growth medium, as a factor that makes the soil fertile and improves its physical, chemical and biological characteristics. These remnants provide both the necessary macronutrients (nitrogen,

Table 3: Effect of *Azospirillum* inoculation and date palm residues on floral and bulb traits of *Canna indica* L.

A- Effect of *Azospirillum*

Treatment	Studied characteristics					
	Number of flowers (flowers plant^{-1})	Flower diameter (cm)	Flower stalk diameter (mm)	Flower stalk length (cm)	Flowering duration (days)	Number of bulbs (bulbs plant^{-1})
Azo0	2	5	5	40	3	4
Azo1	4	8	7	42	3	5
Azo2	6	9	7	43	4	6
LSD % 5	4.22	3.55	2.24	10.11	1.11	2.29

B- Effect of date palm residues

Treatment	Studied characteristics					
	Number of flowers (flowers plant^{-1})	Flower diameter (cm)	Flower stalk diameter (mm)	Flower stalk length (cm)	Flowering duration (days)	Number of bulbs (bulbs plant^{-1})
DP0	2	4	4	22	2	5
DP1	3	7	6	30	3	6
DP2	5	8	7	45	4	8
LSD %5	3.14	4.55	5.4	12.11	2.40	3.11

C- Interaction between *Azospirillum* and date palm residues

Treatment		Studied characteristics					
		Number of flowers (flowers plant^{-1})	Flower diameter (cm)	Flower stalk diameter (mm)	Flower stalk length (cm)	Flowering duration (days)	Number of bulbs (bulbs plant^{-1})
Azo0	DP0	2	4.5	4.5	26.0	2.5	4.5
	DP1	3	6.0	5.5	32	2.5	5.0
	DP2	4	7.5	5.5	33.5	3.0	5.5
Azo1	DP0	2.5	5.5	5.5	30.1	3.0	5.0
	DP1	3.5	7.5	6.5	31.0	3.5	6.0
	DP2	4.5	8.0	6.5	34.0	4.0	6.0
Azo2	DP0	3.5	6.5	6.5	31.0	3.5	6.0
	DP1	4.5	8.0	7.0	40.2	3.5	6.5
	DP2	5	8.5	7.0	44	4.0	6.5
LSD % 5		6.22	7.4	8.44	12.11	6.11	7.88

phosphorus and potassium) and the micronutrients, leading to an increase in microbial activity in the rhizosphere, as a result, its uptake of nutrients, photosynthesis and production of assimilates in leaves are improved, which results in better vegetative growth (Abu-Dahi and Al-Younis, 1988; Abdulrahman, 2019; Al-Bayati and Salih, 2021). This is consistent with what he found (Kavvadias *et al.*, 2024). The mentioned floral characteristics improvement related to Date Palm residue application could be explained by the improved root system development, the intensified nutrient acquisition of the soil solution and the availability of proteins, organic compounds, nitrogenous substances and plant growth regulators, which facilitate flower bud formation and flower reproductive development. The findings agree with those that have been recorded in earlier research (Giorgi *et al.*, 2010; Pader *et al.*, 2007), This is consistent with what he found (El Janati *et al.*, 2022; Burezq and Davidson, 2023; Kumari *et al*., 2025).

CONCLUSION

It can be concluded that *Azospirillum* inoculation at 100 g pot^{-1} significantly enhanced all vegetative and floral traits, as well as the number of bulbs. The application of Date Palm residues at 8 g pot^{-1} also showed a significant improvement in all vegetative and floral traits and bulb number. The interaction between *Azospirillum* at 100 g pot^{-1} and Date Palm residues at 8 g pot^{-1} exhibited a synergistic effect, resulting in significant enhancement of all vegetative and floral traits, as well as the number of bulbs.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

Experiment on plants, not animals.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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