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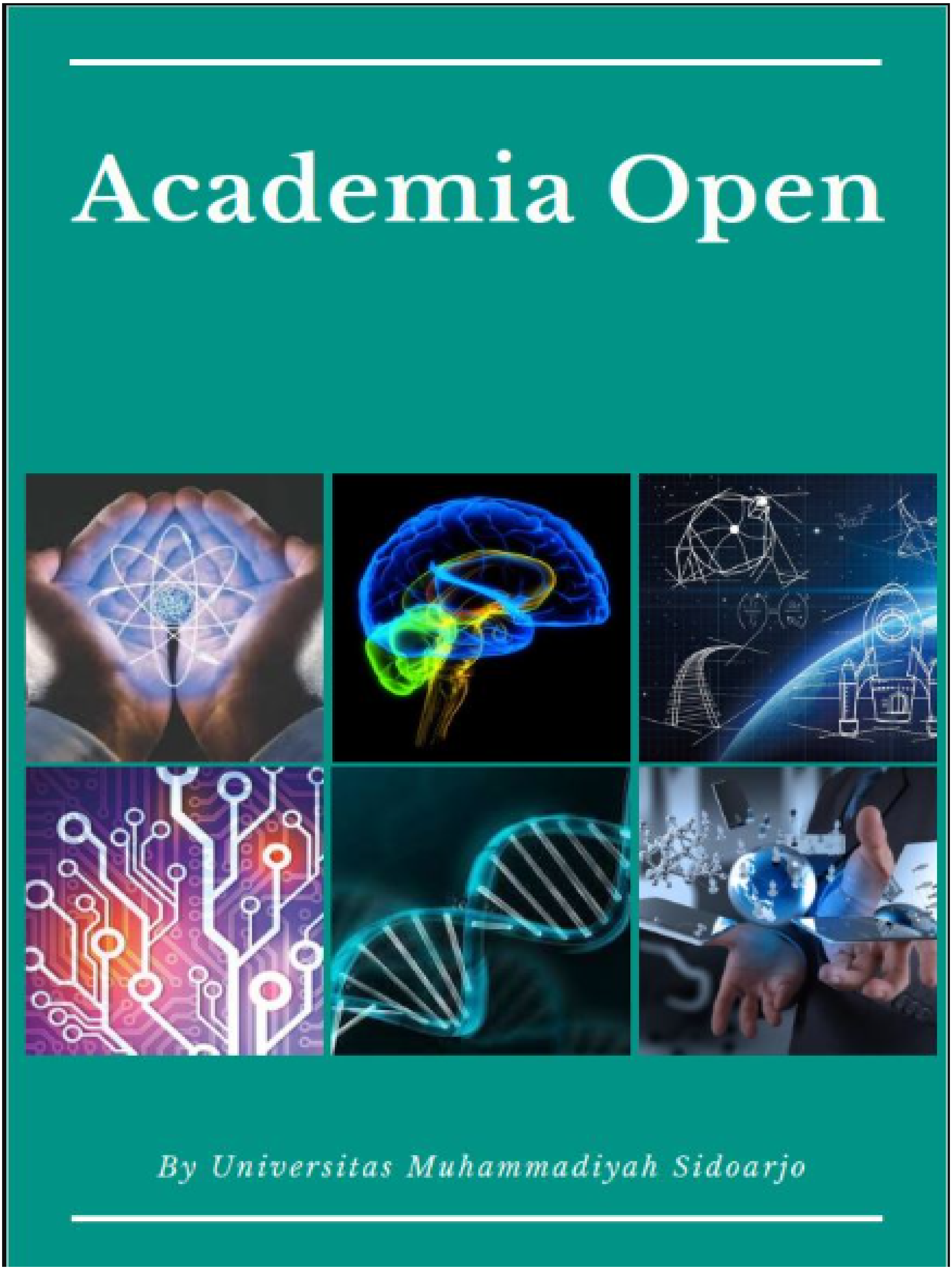

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Effect of Foliar Application of Nano-Fertilizers (Macro- and Micro) Nutrients on growth , Flowering and Bulbs Yield of Yellow Iris (Iris pseudacorus L.): Pengaruh Aplikasi Daun Pupuk Nano (Makro dan Mikro) terhadap Pertumbuhan, Pembungaan, dan Hasil Umbi Iris Kuning (Iris pseudacorus L.)

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Abstract

General Background The integration of nanotechnology into agriculture has introduced new fertilization strategies aimed at improving nutrient availability and crop productivity. **Specific Background** Ornamental bulbous plants such as *Iris pseudacorus L.* require balanced macro- and micro-nutrient supply to support flowering performance and bulb development. **Knowledge Gap** Despite increasing attention to nanofertilizers in horticulture, limited experimental information is available regarding the response of yellow iris to foliar applications of macro- and micronutrient nano-fertilizers at different concentrations. **Aims** This study evaluated the response of yellow iris to foliar spraying of nano-fertilizer containing macro- and micro-nutrients at concentrations of 0, 1, 2, 3, and 4 g L^{-1} under a randomized complete block design with three replicates. **Results** The findings showed that nano-fertilizer treatments did not significantly change most vegetative growth traits. However, application at 4 g L^{-1} accelerated flowering to 138 days and increased flower longevity to 15 days. The same treatment also produced higher bulb and bulblet formation with averages of 2.43 bulbs and 8.45 bulblets per plant, accompanied by increases in fresh bulb weight, bulblet weight, and bulb diameter. **Novelty** The study provides experimental evidence describing concentration-specific responses of yellow iris to foliar nano-fertilizer applications in relation to flowering behavior and bulb productivity. **Implications** These findings support the use of nano-fertilizer foliar spraying as a promising approach for improving reproductive performance and propagation capacity of ornamental iris cultivation.

Keywords: Nano Fertilizer, Iris Pseudacorus, Foliar Application, Flowering Traits, Bulb Yield

Key Findings Highlights

1. Foliar nano-nutrient treatment accelerated flowering time in yellow iris plants
2. Higher concentrations produced greater bulb and bulblet formation
3. Flower longevity increased under optimized nano-fertilizer spraying

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Introduction

Yellow iris (*Iris pseudacorus* L) is a winter-growing annual bulbous plant belonging to the family Iridaceae. It is well known for its bright yellow ornamental flowers and its high adaptability to wet environments and marshlands. The native range of *Iris pseudacorus L* extends across Europe, Western Asia, and North Africa; however, it has spread widely to many regions of the world due to its ornamental appeal and ecological applications **(Gallego-Téva et al., 2019)**. The plant grows to a height of (0.5-1.5) m and has linear bluish-green leaves that are long and fan-shaped from near the base of the plant. The flowers are large, golden yellow and appear from late spring to early summer. Each flower has 3 reflexed outer tepals and 3 erect inner tepals, which frequently have a brown or purplish center (**CABI, 2020)**.

The plant prefers wet and marshy soils as well as the banks of rivers and lakes. It is occasionally listed as an invasive species in areas not within its natural range, because of its rapid spread by bulbs and seed **(Smith et al., 2018)**. As well as its ornamental value, yellow iris has special properties in biological wastewater treatment; it is one of the most commonly selected plants for CWs since it can accumulate large amounts of heavy metals and other pollutants **(Zhang et al., 2014)**.

Nanotechnology application in agriculture is considered as one of the most promising modern approaches for enhancing crop productivity and sustainability. Among the different formulations of nano-based fertilisers, “super nano” is of significant interest since they carry essential macro- and micro-nutrients (including iron, zinc, copper and nitrogen) in the form of nanosized particles which have higher bioavailability and lower environmental losses **(Kah, 2018**).

Nitrogen is the central constituent of proteins and cytoplasm (protoplasm) and takes part in the enhanced biomass of plants as well as their reproductive functions. It is deemed an essential nutrient in the growth of crops within agricultural systems as it is involved in chlorophyll formation, increases photosynthesis efficiency, and plays a role in protein production and vitamin formation. Phosphorus is also involved in a variety of physiological functions such as energy metabolism, the biosynthesis of nucleic acid and lipid membrane, photosynthesis, respiration nitrogen fixation and enzymatic control**(Abdul Majeed et al., 2023)**. For these reasons, nano fertilizers have received increasing attention as an alternative to conventional crops owing to their low-cost and high shelf-life nature due to their degree of stability against different environmental conditions. They are involved in promoting vegetative growth and flowering in numerous plants and received a lot of attention in the past few years. Physicochemical properties of nano-fertilizers that account for their high functional efficiency include small particle size (1–100) nm for easy entry of nutrients through plant cell membranes, large specific surface area which can increase interaction with plant biomolecules, controlled and slow nutrient release rate that reduces losses and enhances fertilization efficiency, and better solubility ensuring uptake in both wet and dry conditions. Nano-carriers are typically fabricated from metal oxides, e.g., ZnO [6,7] and Fe_2O_3 ; or natural organic carriers: biopolymers chitosan or alginate functionalized by macromolecular NPKZnCuFe. **(Zhao et al., 2020**). They limit agricultural residues and environmental pollutants, being able to be taken up by plants through several routes such as roots (for soil application) and leaves (for foliar sprays). The NPs enter stomatal apertures or the cuticle, and there release nutrients stored in the NP slowly stimulating photosynthesis, protein and enzyme synthesis, cell division (mitosis), and stress tolerance (salt, drought, heat). It has been reported that the nano-fertilizers can increase efficiency of literatures between (30-50)%**(Naderi & Danesh-Shahraki, 2013)**. In recent times, a great deal of attention has focused on the application of nano-fertilizers like Super Nano for enhancing growth and flowering performance of bulbous plants including *Iris pseudacorus L.* given that they have demonstrated to be efficient in promoting nutrients use efficiency, productivity and reducing environmental pollutants **(Gallego-Tévar et al. (2019)** , yellow iris shows high physiological sensitivity to edaphic and mineral nutrient variability, thus we can conclude the same about nano-compounds on this vegetation, despite their experiments did not include these compounds, highlighting the interesting effect of advanced fertilization on vegetative and floral characteristics**(Mohamed & El-Sayed (2022).**observed in an Iris hollandica study, in which nano-fertilizers with iron, zinc, and copper led to increase of leaf number and length, stem diameter, bulb number and size, as well as flower number and size **Solanki et al. (2015)** suggested that the nano-fertilizers, namely zinc and iron oxides at suitable doses could significantly elevate photosynthesis, cell division and bulb formation processes, while excessive dose concentrations result in physiological inhibition resulting from the accumulation of nanoparticles in plant tissues **Fraceto et al. (2016)** were found to have superior absorption efficiency as compared to traditional fertilizers which benefit growth of different parts of the plants under wetter conditions, like *Iris pseudacorus L.* **Zhao et al. (2020**) also noted that low concentrations of nano-silver did not negatively affect vegetative growth, indicating the plant’s tolerance to nanoparticle exposure in water-saturated environments. **Ali & Mashkoor (2023)** studied the effect of bio-fertilizers combined with foliar application of nano-phosphate at(0, 1, and 2) mg L^{-1} on iris plants. The results showed that foliar spraying at 2 mg L^{-1} significantly improved vegetative traits, including plant height, leaf number, and dry weight, as well as most floral traits, such as days to flowering, flower diameter, flower longevity, and bulb number and diameter, compared with other treatments and the control. Similar findings were reported by **Ismail (2024)** in *Freesia hybrida* L., **Abdul Majeed et al. (2023)** in *Crocus sativus*, and **Lazar et al. (2024)** in *Petunia hybrida* L.

Materials and Methods

The study was conducted within the lath house facility of the Department of Horticulture and Landscape Design, College of Agriculture, University of Kirkuk, Iraq, throughout the 2024–2025 cultivation period, commencing on 16 November 2024. The study aimed to investigate the effect of foliar application of nano-fertilizers containing macro- and micro-nutrients at five concentrations (0, 1, 2, 3, and 4)g L^{-1} on growth ,flowering , bulb and bulblets yield of yellow iris (*Iris pseudacorus L.*). Two foliar sprays were applied, the first at the emergence of the third leaf and the second one month later.The experiment was designed as a Randomized Complete Block Design (RCBD) with three replicates and five plants per experimental unit. Lath house soil was prepared by clearing debris, plowing, leveling, removing shrubs, and smoothing the surface to ensure

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uniformity. Plants were grown in pots with a diameter of 15 cm and a capacity of 2 kg, filled with a mixed sandy soil, the physical and chemical properties of which are presented in Table 1. One bulb was planted per pot on 18 November 2024. Plants were irrigated manually using hand sprayers at ten-day intervals, with adjustments during rainfall periods or as needed. Foliar sprays were applied until the leaves were completely wetted, and weeding was performed whenever necessary.The recorded traits included vegetative growth traits (days to sprouting, plant height, length of the longest leaf, and number of leaves per plant), floral traits (days to flowering, flower diameter, diameter and length of the main flower stalk, and flower longevity), and bulb and bulblet traits (number of bulbs and bulblets per plant wet weight of bulbs and bulblets, and bulb diameter). All data were statistically analyzed using IBM

Type of Analysis	**Standard Unit**	**Value**
Nitrogen	mg. kg^{-1}	683.414
Phosphorus	mg. kg^{-1}	3.185
Potassium	mg. kg^{-1}	133.724
%$CaCO_3$	mg. kg^{-1}	28.210
pH	-	7.61
E.C.	dS. m^{-1}	0.920
TDS	g. kg-1	588.800
Sand	g. kg-1	70
Clay	g. kg-1	10
Silt	g. kg-1	20
Organic Matter	g. kg-1	0.966
Soil Texture		Loamy Sand

Table 1. **Table (1):** Physical and chemical analysis of the used soil before planting*
* Soil analysis was carried out in the soil laboratory of the Kirkuk Directorate of Agriculture.

SPSS version 20.0, and means were compared using Duncan’s Multiple Range Test (DMRT) at $p \leq 0.05$ to determine significant differences among treatments.

Results and Discussion

1-Vegetative Traits

Table 2 indicates that there were no significant differences among the means for the effect of foliar application of different concentrations of macro- and micro-nutrient nano-fertilizers on the vegetative traits of yellow iris (*Iris pseudacorus* L.). This finding is consistent with **Kah et al. (2018)**, who reported that nano-fertilizers may not exhibit a clear effect on vegetative growth in some plant species, except at specific concentrations stress-tolerant plants, such as iris, possess high nutrient uptake efficiency and are capable of absorbing essential elements even without external fertilization.

Nano-fertilizer (macro- and micro) nutrients concentration (g L^{-1})	**Sprouting Duration (days)**	**Plant Height (cm)**	**Number of Leaves per Plant**	**Length of the Longest Leaf (cm)**
0	**25.73a**	**61.32a**	**8.87a**	**56.27a**
1	**25.37a**	**61.69a**	**8.28a**	**59.19a**
2	**24.77a**	**62.85a**	**8.53a**	**51.90a**
3	**21.10a**	**64.07a**	**8.11a**	**52.56a**
4	**19.1a**	**68.22a**	**9.00a**	**55.16a**

Table 2. **Table(2): Effect of foliar application of different concentrations of macro- and micro-nutrient nano-fertilizers on vegetative traits of yellow iris (*Iris pseudacorus* L.)**
Means followed by the same letter within columns do not differ significantly based on Duncan’s Multiple Range Test (DMRT) at the 5% probability level ($p \leq 0.05$).

2-Floral Traits

Table (3) shows that foliar application of the nano-fertilizer at a concentration of 4 g L^{-1} significantly promoted early flowering, as flowering occurred after 138 days compared with plants subjected to the other treatments and the control. This treatment also showed a statistically significant increase in the number of days to flowering, exceeding the other concentrations and the control by 15 days. However, it had no significant effect on flower diameter, nor on the diameter and length of the main floral stalk. The advancement in flowering may be attributed to the role of micronutrients (such as zinc and iron) in activating enzymes responsible for the biosynthesis of flowering hormones**(Solanki *et al.*, 2015)**. In addition, **Mohamed and El-Sayed (2022)** reported that the extension of flower longevity is associated with enhanced photosynthetic efficiency and the stimulation of organic compound synthesis (e.g., carbohydrates), which contributes to prolonged flower lifespan. These findings are consistent with the report of **CABI (2020)**, which indicated that the lack of fertilizer effect on flower diameter may be due to this trait being more strongly governed by genetic factors than by nutritional status.

Nano-fertilizer (macro- and micro) nutrients concentration (g	**Flower diameter (cm)**	**Days to flowering (day)**	**Main floral stalk diameter (cm)**	**Main floral stalk length (cm)**	**Flower longevity on the plant (day)**

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L⁻¹)					
0	**7.81a**	**141.5a**	**0.41a**	**44.71a**	**7.89d**
1	**8.68a**	**140.47ab**	**0.43a**	**50.71a**	**8.45d**
2	**7.97a**	**139.53b**	**0.37a**	**46.72a**	**11.10c**
3	**7.72a**	**139.33b**	**0.33a**	**46.53a**	**12.50b**
4	**7.81a**	**138c**	**0.32a**	**46.68a**	**15a**

Table 3. **Table (3). Effect of foliar application of different concentrations of macro- and micronutrient nano-fertilizer on the floral traits of yellow iris (*Iris pseudacorus* L.)** Means followed by the same letter within a column do not differ significantly based on Duncan's Multiple Range Test (DMRT) at the 5% probability level ($p \leq 0.05$).

3-Bulbs and bulblets yield

Table (4) indicates that foliar application of the nano-fertilizer at a concentration of 4 g L⁻¹ resulted in a statistically significant increase in the number of bulbs and bulblets, as well as their fresh weight and bulb diameter, recording mean values of 2.43 bulbs, 8.45 bulblets, 9.72 g, 5.06 g, and 18.77 cm, respectively, compared with the control treatment. This improvement may be attributed to the role of nano-nitrogen and nano-phosphorus in stimulating bulb formation through enhancing cell division and the accumulation of storage compounds (such as starch) within the bulbs **(Zhao *et al.*, 2020)**. Furthermore, **Ali and Mashkoor (2023)** reported that nano-phosphorus enhances ATP synthesis, which is essential for the growth of storage organs, thereby contributing to increased fresh weight and diameter. According to**Naderi and Danesh-Shahraki (2013)**, nano-fertilizers improve nutrient use efficiency by (30–50)% compared with conventional fertilizers, which supports the observed increase in productivity.

Nano-fertilizer (macro- and micro-nutrients) concentration (g L⁻¹)	**Number of bulbs plant⁻¹**	**Number of bulblets plant⁻¹**	**wet weight of bulbs (g)**	**wet weight of bulblets (g)**	**Bulb diameter (cm)**
0	**1.00b**	**2.66b**	**4.91c**	**1.66b**	**14.75b**
1	**1.10b**	**3.37b**	**6.63b**	**2.43b**	**15.11b**
2	**1.43b**	**3.80ab**	**7.18b**	**2.59b**	**16.37ab**
3	**1.67b**	**3.67ab**	**7.16b**	**2.63b**	**16.28ab**
4	**2.43a**	**8.45a**	**9.72a**	**5.06a**	**18.77a**

Table 4. **Table (4). Effect of foliar application of different concentrations of macro- and micronutrient nano-fertilizer on bulb and bulblets yield traits of yellow iris (*Iris pseudacorus* L.).** Within each column, means followed by common letters are not significantly different ($p \leq 0.05$(according to Duncan's Multiple Range Test.

Conclusions

Based on the results of this study, it can be concluded that foliar application of the nano-fertilizer at a concentration of 4 g L⁻¹ significantly improved flowering traits. It accelerated the time to flowering, increased flower longevity on the plant, and enhanced the number of bulbs and bulblets per plant, as well as their wet weight and bulb diameter. These findings highlight the positive role of nano-fertilizers in promoting both floral and bulbous characteristics.

References

1. [1] L. S. Abdul Majeed, K. G. Al-Saad, and M. O. Mohammed, “Effect of Nano Fertilizers and Amino Acid of Tryptophan on Some Physiological Characteristics of Saffron Plant (Crocus sativus L.),” Kirkuk University Journal for Agricultural Sciences, vol. 14, no. 1, pp. 151–165, 2023.
2. [2] M. N. Ali and S. A. Mashkoor, “Efficiency of Bacterial Biofertilizers and Spraying with Nano-Phosphates on Vegetative and Root Growth Indicators of Iris Flowers,” IOP Conference Series: Earth and Environmental Science, vol. 1262, no. 4, p. 042060, 2023.
3. [3] M. N. Ali and S. A. Mashkoor, “Iris Flowering Traits Response to Bacterial Biofertilizers and Foliar Nano-Phosphates,” IOP Conference Series: Earth and Environmental Science, vol. 1262, no. 4, p. 042069, 2023.
4. [4] M. Ali and F. Mashkoor, “Nanofertilizers A Novel Way for Enhancing Nutrient Use Efficiency and Crop Productivity,” Environmental Science and Pollution Research, vol. 30, no. 7, pp. 17005–17025, 2023.
5. [5] CABI, “Iris pseudacorus Yellow Flag Iris,” Invasive Species Compendium, 2020.
6. [6] L. F. Fraceto et al., “Nanotechnology in Agriculture Which Innovation Potential Does It Have,” Frontiers in Environmental Science, vol. 4, p. 20, 2016.
7. [7] B. Gallego-Tévar, B. J. Grewell, and J. M. Castillo, “The Invasive Potential of the Wetland Ornamental Iris pseudacorus A Review,” Aquatic Botany, vol. 157, pp. 47–53, 2019.
8. [8] A. H. Ismail, “Physiological Role of Nano Chelated Micro-Elements and Cycocel on Active Chemical Compounds of Aromatic Oils of Freesia hybrida,” Master's thesis, University of Kirkuk, Iraq, 2024.
9. [9] M. Kah, R. S. Kookana, A. Gogos, and T. D. Bucheli, “A Critical Evaluation of Nanopesticides and Nanofertilizers Against Their Conventional Analogues,” Nature Nanotechnology, vol. 13, no. 8, pp. 677–684, 2018.
10. [10] H. I. Mohamed and M. A. El-Sayed, “Effect of Nanofertilizers on Plant Growth Yield and Biochemical Constituents of Agricultural Crops,” Agricultural Nanotechnology, vol. 5, no. 2, pp. 45–58, 2022.
11. [11] H. M. Mohamed and A. M. El-Sayed, “Effect of Nano-Fertilizers on Growth Flowering and Bulb Yield of Iris hollandica,” Journal of Horticultural Science, vol. 58, no. 3, pp. 201–210, 2022.

ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo

12. [12] M. R. Naderi and A. Danesh-Shahraki, “Nanofertilizers and Their Roles in Sustainable Agriculture,” International Journal of Agriculture and Crop Sciences, vol. 5, no. 19, pp. 2229–2232, 2013.
13. [13] C. S. Smith and S. R. Winslow, “Iris pseudacorus Yellow Flag Iris,” Invasive Species Compendium, 2018.
14. [14] P. Solanki, A. Bhargava, H. Chhipa, N. Jain, and J. Panwar, “Nanofertilizers and Their Smart Delivery System,” in Nanotechnologies in Food and Agriculture. Springer, 2015, pp. 81–101.
15. [15] J. Vymazal, “Constructed Wetlands for Wastewater Treatment Five Decades of Experience,” Environmental Science and Technology, vol. 45, no. 1, pp. 61–69, 2011.
16. [16] M. Wichtl, Herbal Drugs and Phytopharmaceuticals A Handbook for Practice on a Scientific Basis. Stuttgart: Medpharm Scientific Publishers, 2004.
17. [17] D. Q. Zhang et al., “Application of Constructed Wetlands for Wastewater Treatment in Developing Countries A Review of Recent Developments,” Journal of Environmental Management, vol. 141, pp. 116–131, 2014.
18. [18] L. Zhao, Y. Huang, H. Wang, and X. Wang, “Interaction of Nanomaterials with Plants Phytotoxicity and Defense Mechanisms,” Journal of Agricultural and Food Chemistry, vol. 68, no. 26, pp. 7291–7301, 2020.
19. [19] L. Zhao et al., “Application of Nanotechnology in Sustainable Agriculture Current Advances and Future Perspectives,” Environmental Science Nano, vol. 7, no. 5, pp. 1236–1260, 2020.

ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo