Available online freely at www.isisn.org

Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 202219(2):1243-1250. **OPEN ACCESS**

Evaluation of the impact of nutritional treatments on the biochemical and physiological factors in Eryngium planum

Masoud Radmanesh

Department of agriculture and Plant breeding, Islamic azad university, Zanjan, **Iran**

***Correspondence:** Masoud_rad0000000@yahoo.com **Received 02-05-2022, Revised: 19-06-2022, Accepted: 21-06-2022 e-Published: 23-06-2022**

Nutrition is an essential factor in plants' growth and the chemical composition of medicinal herbs. Using natural fertilizers can enhance the performance and medicinal properties of plants. The present experiment was conducted to evaluate the influence of nutritional treatments on the biochemical and physiological factors in Eryngium planum in a greenhouse in Talesh using a randomized complete block design over three iterations in 2020-2021. The studied treatments included 1. The control treatment, 2. Recommended chemical fertilizer, 3. 500mg/l humic acid fertilizer, 4. 800mg/l humic acid fertilizer, and 5. Chemical and humic acid fertilizers. Results revealed significant differences between the fertilizer treatments at 1% and 5% significance levels in terms of all the studied traits. The highest values for the traits of plant height, wet and dry plant weight, number of grains, number of umbels, weight per 1000 grains, essential oil percentage, linalool percentage, and gamma-terpinene percentage were observed in the chemical and humic acid fertilizers and the recommended chemical fertilizer treatments. The recommended chemical treatment fertilizer led to a 35%, 23%, and 52% increase in the traits of wet weight, dry weight, and weight per 100 grains, while the chemical and humic acid fertilizers treatment yielded the higher essential oil and linalool percentages at 0.28 and 53.67, respectively. Results suggested that the use of the recommended chemical fertilizer led to the highest values in many qualitative and quantitative traits, but the humic acid fertilizer had a favorable performance as an alternative for the recommended chemical fertilizer.

Keywords: Eryngium planum, biochemical and physiological factors, nutritional treatments

INTRODUCTION

Medicinal plants are among the important sources of pharmaceuticals that have been long used by humans and are increasing in importance. Currently, around 80% of the developing countries are using medicinal herbs in their primary healthcare services (Gedif & Hahn, 2002). According to WHO, the medicinal plant trade will amount to over five billion dollars by 2050 (Gholamin and Khayatnezhad 2020, Karasakal, Khayatnezhad et al. 2020, Bi, Chen et al. 2021, Hou, Li et al. 2021, Huang, Wang et al. 2021). The use of natural ingredients from medicinal plants instead of synthetic additives that have side effects has recently become more popular (Paradiso et al., 208). Eryngium planum, also known as the blue eryngo or Eryngium caucasicum Trautv is a species native to the north of Iran and is among the medicinal herbs with little-known potential (Gholamin and Khayatnezhad 2020, Jia, Khayatnezhad et al. 2020, Chen, Khayatnezhad et al. 2021, Liu, Wang et al. 2021, Li, Khayatnezhad et al. 2022). This plant has various horticultural and medicinal applications and is among the medicinal herbs used as a Diuretic, painkiller, appetite stimulant, and antioxidant. This plant goes by the Persian name of “Shesh Shakh”, and is known as “Zoolang” in Mazandaran, “Shishak” in Shahsavar, and “Sjousjakh” in Ramsar which is the local phrase for “Shesh Shakh.” it is also called Chouchagh or Anar chouchagh in Gilan and "Qarsana Masdas" in Arabic. Some also called it Biveza(Gholamin and Khayatnezhad 2020, Karasakal, Khayatnezhad et al. 2020, Si, Gao et al. 2020, Cheng, Hong et al. 2021, Guo, She et al. 2021, Sun, Lin et al. 2021). Many medicinal thorns that include over 10 species are called Qarsana in Iranian traditional medicine, but when used as an absolute term, it refers to this fragrant plant. Chouchaq contains an abundance of compounds such as folic acid and limonene, which is why it can improve iron deficiency anemia significantly (Lima et al., 2004 and 2014). Fertilizer management is an important factor in the success of medicinal herb cultivation. Using bio-fertilizers in the cultivation of the plants seeking to remove or significantly reduce chemical inputs and improve soil fertility and plant growth and quality is of utmost significance (Gholamin and Khayatnezhad 2020, Khayatnezhad and Gholamin 2020, Ma, Ji et al. 2021, Ma, Khayatnezhad et al. 2021, Peng, Khayatnezhad et al. 2021). The presence of adequate nutrition in the soil plays an essential part in the yield of medicinal plants and crops (Dadvand Sarab et al., 2009)/ most producers have turned to chemical fertilizers to increase the agricultural production per unit area, assuming that the more fertilizer they use, the greater the yield will be (Khayatnezhad and Gholamin 2020, Gholamin and Khayatnezhad 2021, Shi, Khayatnezhad et al. 2021, Wang, Shang et al. 2021, Tao, Cui et al. 2022, Wang, Khayatnezhad et al. 2022). These fertilizers harm the physio-chemical properties of soil over the long term, distress the roots of the plants because of the reduced soil permeability, and will eventually result in a reduced yield. On the other hand, they reduce the quality of agricultural products and cause environmental problems and groundwater pollution (Mehrafarin et al., 2011). The use of chemical fertilizers causes ecological damages in many cases, which increases the production costs in turn (Khayatnezhad and Gholamin 2021, Li, Mu et al. 2021, Ren and Khayatnezhad 2021, Yin, Khayatnezhad et al. 2021, Zhang, Khayatnezhad et al. 2021). Therefore, it appears necessary to use inputs that meet the nutritional needs of the plants while improving the ecological aspects of the system and reducing environmental risks (Ahmad et al., 2013). Moreover, using biological and organic fertilizers increases the medicinal quality of the medicinal plants, which is why many herbal medicine companies prefer herbal compounds obtained from biodynamic or organic cultivation (Khayatnezhad and Gholamin 2021, Sun and Khayatnezhad 2021, Wang, Ye et al. 2021, Zhu, Liu et al. 2021, Wang, Ma et al. 2022). Today's organic agriculture cares about the quality and sustainability of the products just as much as the production quantity. Still, chemical fertilizers cannot be abruptly cast aside from the agricultural systems since sustainable agriculture entails food security and adequate income. In this regard, not only does the use of organic and chemical fertilizers together reduces the use of chemical fertilizers, but it also reduces the environmental pollution, improves the physical features of soil, and increases their absorbance by the plants (Khayatnezhad and Nasehi 2021, Xu, Ouyang et al. 2021, Zhang, Khayatnezhad et al. 2022). Higher consumption of the inputs –specifically chemical fertilizers- is among the essential components of increasing agricultural yield; however, the increased consumption of chemical fertilizers over the recent decades has led to severe environmental problems. On the other hand, the risk of negative impacts resulting from the excessive use of chemical fertilizers and toxins on the quality and quantity of the active ingredients in medicinal plants has led many pharmaceutical companies to prefer herbal compounds obtained from biodynamic or organic cultivation (Gewaily et al., 2006). Thus, other fertilizer sources that have lower costs and destructive effects on the environment would be better substitutes for these fertilizers. Non-chemical (biological and organic) fertilizers are among the healthy, convenient, and cheap available fertilizing sources that have been considered in sustainable systems (Nehvi et al., 2009). Among the ecologically sound fertilizers, humic acid is an organic acid that has no destructive impacts on the environment and improves the physical, chemical, and biological structure of the soil while leaving significant positive impacts on the qualitative and quantitative agricultural crops due to its hormonal compounds (Zhao, Wang et al. 2021, Zheng, Zhao et al. 2021, Zhu, Saadati et al. 2021). Humic acid is a natural organic polymer compound generated as a result of decay in peat, lignin, and organic matter in the soil which increases crop quality and yield (Ghorbani et al., 2010).

The hormonal effects and improved absorption of the nutrients which increase yield –especially when put under stress- are among the other impacts of humic acid resulting from humus and other natural resources and growth-stimulate bacteria (Gzik, 1996). Sensei et al. (2006) believed that as a part of the organic matter in the soil, humics result from the chemical, physical, and biological transformations of the biological molecules and are classified into the three categories of humic acid, fulvic acid, and humin based on their solubility. Humic acid makes up the majority of humics(Abdi 2021, Alizadeh 2021, Karasakal 2021, Karasakal 2021, Mohammadzadeh 2021, Radmanesh 2021). Nowadays, increasing agricultural production is cost-convenient thanks to the use of acid humic which is used directly in the soil or through spraying (Gad El-Hak et al., 2012). Spraying humic acid on green tea plant is reported to have resulted in increased plant height, stem diameter, number of secondary branches, wet and dry leaf and branch weight, number of fruits, wet and dry sepal weight, grain yield, and total anthocyanin content (Chamani et al.,1391). Research on organic cultivation aimed at clean production with favorable yield has gained more importance due to the importance of medicinal herbs in ensuring public health. The evaluation of various plant nutrition systems is thus necessary. The present experiment was conducted to evaluate the impact of nutritional treatments on the biochemical and physiological factors in Eryngium planum medicinal herb in Talesh County.

MATERIALS AND METHODS

The present study was carried out to evaluate the influence of nutritional treatments on the biochemical and physiological factors in Eryngium planum in a greenhouse in Talesh using a randomized complete block design over three iterations in 2020-2021. The studied treatments included 1. The control treatment, 2. Recommended chemical fertilizer, 3. 500mg/l humic acid fertilizer, 4. 800mg/l humic acid fertilizer, and 5. Chemical and humic acid fertilizers. For this purpose, pots with a height of 30cm and a diameter of 30cm were selected and filled with soil from a farm, and 10 Eryngium planum seeds were cultivated in each pot in March 2021. After the first two leaves emerged, three plants were kept in each pot after thinning. The fertilizer treatments were applied after the emergence of the first four leaves. Fertilizer treatments were applied over four stages and at 10-day intervals. The humic acid treatment was applied through a solution in the irrigation water with concentrations of 500 and 800 mg/l and was sprayed over four stages. The humic acid used in the present study contained 15% humic acid and 2% folic acid. Drop care was observed throughout the growing season. At the full flowering stage, one plant was harvested from each pot and the other two were kept in the pot for grain yield purposes. The present study examined the traits of plant height, wet and dry plant weight, number of grains, number of umbels, weight per 1000 grains, essential oil percentage, linalool percentage, and gamma-terpinene percentage. The statistical analysis conducted in the study included variance analysis and simple correlation coefficients using SPSS-16 and MSTAT-C and Minitab-15 software.

RESULTS AND DISCUSSION

Table 1 demonstrates the results of variance analysis. Results revealed significant differences between the fertilizer treatments at 1% and 5% significance levels in terms of all the studied traits, which was consistent with the results of Gardner et al. (1985), Scott et al. (1988), and Rezvani Moghaddam et al. (2013).

Results of comparing the mean values of the studied traits (Table 2) indicated that treatment with chemical and humic acid fertilizers resulted in the highest plant height at 40.49cm which was 46.73% higher than the control plants (Table 2). The use of humic acid and chemical fertilizer together seems to have simulated growth and increase plant height through the faster release of nutritional elements. Moreover, since the microorganisms in biofertilizers can increase the permeability of the root cells and stomatal resistance through the section of various plant hormones, they appear to have positive impacts on the general growth and water relations of the plants (Rezvani Moghaddam et al., 2013). The correlation between the evaluated traits under the influence of various fertilizer treatments indicated that plant height has a positive and significant relationship with the traits of dry plant weight, number of grains, weight per 1000 grains, and linalool percentage (Table 3).

In terms of the dry and wet plant weight, the recommended chemical fertilizer treatment yielded the highest mean values of 60.92 and 5.87 gr/plant while the control treatment yielded the lowest mean values of 39.98 and 4.52 gr/plant, respectively. Results also indicated that treatment with the recommended chemical fertilizer resulted in a 35% increase in wet and 23% increase in dry weight compared to the control treatment (Table 2). Among the reasons for the increased wet plant weight, one can mention the provision of better physiological conditions for the plant to absorb nutritional elements and suitable environmental conditions for adequate access to nutritional elements as a result of using other studied fertilizers (Karimijalilehvandi et al., 2017). On the other hand, the dry plant weight increased as a result of using humic acid compared to the control treatment. Humic acid fertilizer appears to improve plant growth alongside other growth factors such as indole butyric acid, indole acetic acid, gibberellic acid, macro and microelements, vitamins, and amino acids (Shahbaz et al., 2015). The correlation coefficients of the studied traits under the influence of fertilizer treatment indicated that wet plant weight had significant relationships with the number of umbels, weight per 100 grains, and essential oil percentage. Dry plant weight was also revealed to have significant relationships with the number of umbels, number of grains, weight per 1000 grains, and gamma-terpinene percentage (Table 3). In terms of the number of umbels and grain, treatment with recommended chemical fertilizer had the best results averaging 11.9 and 90.70, while the control treatment had the lowest results at an average of 7.5 and 60.58, respectively (Table 3). Al-Khayyat (2014) and Amran (2014) reported similar results for the two plants of Pelargonium graveolens and Rosmarinus officinalis. Treatment with the recommended chemical fertilizer yielded the highest weight per 100 grains at an average of 7.27gr, which indicated a 52% increase compared to the control treatment. Overall, the presence of adequate nutrients in the soil improves the nutritional state of the plant, the efficiency of photosynthetic conversion of material into dry material, and –as a result- grain number and weight (Mukesh et al., 2013). The growth of grains as important economic storage includes a set of growth stages including cell division and storage and storage of photosynthetic material. Higher grain weight and weight per 100 grains are due to the increased photosynthetic material, which was probably because of the impact of the growth hormones present in the humic acid treatment on cell division (Vijayanand et al., 2014). The significance of a medicinal herb depends on the active ingredients produced in its medicinal parts, and vastly different results have been reported regarding the influence of nutrients on the composition of essences in medicinal plants. A nutrient resource can increase some essential oils and reduce the others. Results of the present study indicated that the essential oil and linalool percentages were the highest in the treatment with recommended chemical fertilizer followed by chemical and humic acid fertilizers at 0.28% and 83.67%, respectively (Table 2) which is consistent with the results of Mostafa (2015) in the case of fennel, Badran et al. (2007) in the case of cumin, El-Gate et al. (2012) in the case of Indian Fennel, and Dadkhah (2012). A significant and positive relationship was observed between the number of umbels and the traits of weight per 1000 grains, the number of grains, and essential oils (Table 3).

Table 1: Results of analysis of variance of evaluated traits s

Source	df	Mean of Squares								
		Plant height	Fresh plan t weight	Dry weight of the plant	Number of umbrellas	Number Of seeds	Weight of 1000 seeds	Percentage Of essential	Percentage of linalool	Percentage of gamma-terpinene
Replication	2	2.077	0.143	$9.01E^{-5}$	0.07	0.007	0.0005	$6.09E^{-7}$	0.002	0.01
Fertilizer treatment	7	136**	165.3**	0.749**	8.642**	469.6**	2.761**	0.004**	22.94**	0.295**
Error	14	0.803	0.248	0.027	0.084	1.701	0.024	$6.94E^{-5}$	2.608	0.014
C. V %		2.73	0.99	3.07	2.92	1.66	2.45	3.49	3.21	2.33

* and ** Significantly at $p < 0.05$ and < 0.01, respectively.

Table 2: Comparison of the mean of the evaluated traits under the influence of fertilizer treatments

fertilizer treatments	Plant height	Fresh plant weight	Dry weight of the plant	Number of umbrellas	Number of seeds
Control (no fertilizer)	21.57[d]	39.98 [d]	4.52 [c]	7.50 [d]	60.58 [c]
Chemical fertilizer	35.29[b]	60.92 [a]	5.87 [a]	11.90 [a]	90.70 [a]
Humic acid 500 mg/lit	32.26[c]	49.51 [c]	5.39 [b]	9.52 [c]	74.50 [b]
Humic acid 800 mg/lit	34.67[b]	50.19 [c]	5.40 [b]	9.57 [c]	75.15 [b]
Chemical fertilizer + humic acid 500 mg / liter	40.49[a]	51.15 [b]	5.57 [ab]	11.18 [b]	90.44 [ab]

Different letters indicate a significant difference using the test (Duncan).

Table 2 continue

fertilizer treatments	Weight of 1000 seeds	Percentage of essential	Percentage of linalool	Percentage of gamma-terpinene
Control (no fertilizer)	4.77 [d]	0.17 [c]	45.70 [c]	4.50 [b]
Chemical fertilizer	7.27 [a]	0.28 [a]	50.55 [ab]	5.24 [a]
Humic acid 500 mg/lit	6.14 [c]	0.21 [b]	50.54 [ab]	5.15 [a]
Humic acid 800 mg/lit	6.31 [c]	0.22 [b]	50.18 [b]	5.20 [a]
Chemical fertilizer + humic acid 500 mg / liter	6.96 [b]	0.23 [b]	53.67 [a]	5.24 [a]

Different letters indicate a significant difference using the test (Duncan).

Table 3: Correlation coefficients of the evaluated traits under the influence of fertilizer treatments

	1	2	3	4	5	6	7	8	9
Plant height 1	1								
Fresh plant weight 2	0.718	1							
Dry weight of the plant 3	.881*	.953*	1						
Number of umbrellas 4	0.867	.936*	.956*	1					
Number of seeds 5	.905*	0.87	.922*	.988**	1				
Weight of 1000 seeds 6	.917*	.932*	.983**	.987**	.974**	1			
Percentage of essential 7	0.716	.993**	.935*	.948*	.890*	.933*	1		
Percentage of linalool 8	.978**	0.624	0.818	0.814	0.869	0.857	0.615	1	
Percentage of gamma-terpinene 9	.936*	0.82	.950*	0.852	0.84	.923*	0.785	.891*	1

*, ** Significant at the level of five and one percent probability

In terms of the gamma-terpinene content, the control treatment had the lowest content at 4.5%, while the other treatments yielded similar results (Table 2). Gamma-terpinene content was revealed to have significant and positive relationships with plant height, dry plant weight, weight per 1000 grains, and linalool content (Table 3), which is consistent with the results of Hassan (2015).

CONCLUSION

In conclusion, one can infer that the use of humic acid and chemical fertilizer together increased the quality and quantity of Eryngium planum product compared to the control treatment (no fertilizer). Although chemical fertilizer had a greater impact, the global approach in medicinal plant production is more inclined to improve the active ingredients in terms of quality and quantity. Healthy nutrition of these plants through organic fertilizers such as acid humic appear to be the most consistent with the goal behind the production of medicinal herbs. Considering the irreparable damages that chemical fertilizers impose on the environment, the use of humic acid fertilizer can be a way to protect the environment and human health

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

ACKNOWLEDGEMENT

This paper was from my own master thesis.

AUTHOR CONTRIBUTIONS

Masoud Radmanesh conducted, planned, Analyzed the data, wrote manuscript and interpreted the results and involved in manuscript preparation. All authors read and approved the final version.

REFERENCES

Abdi, M. M. (2021). "Evaluation of spring bread wheat lines/varieties in international observation nurseries and yield trials in moderat region of Iran." Bioscience Research 18(3): 2127-2134.

Ahmad, I., R.U. Saquib, M. Qasim, M. Saleem, A. Khan and M. Yaseen. 2013. Humic acid and cultivar effects on growth, yield, vase life, and corm characteristics of gladiolus. Chılean J. Agrıc. Res. 73(4): 339-344.

Alizadeh, M. (2021). "Protein profile and seeds storage proteins changes in wheat genotypes under control and drought stress conditions." Bioscience Research 18(3): 2164-2169.

Badran, F.S., Aly, M.K., Hassan, E.A. and Shalatet, S.G., 2007. Effect of organic and bio-fertilization treatments on cumin plants. The Third Conference of Sustainable Agricultural Development, 12-14 November.

bi, d., d. chen, m. khayatnezhad, z. s. hashjin, z. li and y. ma (2021). "molecular identification and genetic diversity in hypericum l.: a high value medicinal plant using rapd markers markers." genetika-belgrade 53(1): 393-405.

chen, w., m. khayatnezhad and n. sarhadi (2021). "protok gena i struktura populacije kod allochrusa (caryophylloideae, caryophyllaceae) pomocu molekularnih markera." Genetika-Belgrade 53(2): 799-812.

Cheng, X., X. Hong, M. Khayatnezhad and F. Ullah (2021). "Genetic diversity and comparative study of genomic DNA extraction protocols in Tamarix L. species." Caryologia 74(2): 131-139.

Dadkhah, A., 2012. Effect of chemicals and biofertilizers on yield, growth parameters and essential oil contents of fennel (*Foeniculum vulgare* Miller.). Journal of Medicinal Plants and By-products, 1(2): 101-105.

El-Ghait, E.M.A., Gomaa, A.O., Youssef, A.S.M., Atiea, E.M. and Abd-Allah, W.H., 2012. Effect of sowing dates, bio, organic and chemical fertilization treatments on growth and production of Indian fennel under north Sinai conditions. Bulletin of Faculty of Agriculture, Cairo University, 63: 52-68.

El-Khyat, L.A.S., 2013. Effect of chemical and bio fertilizer on growth and chemical composition of rosemary plants. M.Sc. Thesis Faculty Agriculture, Moshtohor, Benha University.

Gad El-Hak, S.H., A.M. Ahmed and Y.M.M. Moustafa. 2012. Effect of foliar application with two antioxidants and humic acid on growth, yield and yield components of peas (Pisum sativum L.). J. Hort. Sci. Ornam. Plants 4(3): 318-328.

Gedif, T. & Hahn, H. J. (2002). Herbalists in Addis Ababa and Butajira, Central Ethiopia: Mode of service delivery and traditional pharmaceutical practice. Ethiopian Journal of Health Development, 16(2), 183-189.

Gholamin, R. and M. Khayatnezhad (2020). "Assessment of the Correlation between Chlorophyll Content and Drought Resistance in Corn Cultivars (Zea Mays)." Helix 10(5): 93-97.

Gholamin, R. and M. Khayatnezhad (2020). "Study of Bread Wheat Genotype Physiological and Biochemical Responses to Drought Stress." Helix 10(5): 87-92.

Gholamin, R. and M. Khayatnezhad (2020). "The effect of dry season stretch on Chlorophyll Content and RWC of Wheat Genotypes (Triticum Durum L.)." Bioscience Biotechnology Research Communications 13(4): 1829-1833.

Gholamin, R. and M. Khayatnezhad (2020). "The Study of Path Analysis for Durum Wheat (Triticum durum Desf.) Yield Components." Bioscience Biotechnology Research Communications 13(4): 2139-2144.

Gholamin, R. and M. Khayatnezhad (2021). "Impacts of PEG-6000-induced Drought Stress on Chlorophyll Content, Relative Water Content (RWC), and RNA Content of Peanut (Arachis hypogaea L.) Roots and Leaves." Bioscience Research 18(1): 393-402.

Guo, L.-N., C. She, D.-B. Kong, S.-L. Yan, Y.-P. Xu, M. Khayatnezhad and F. Gholinia (2021). "Prediction of the effects of climate change on hydroelectric generation, electricity demand, and emissions of greenhouse gases under climatic scenarios and optimized ANN model." Energy Reports 7: 5431-5445.

Gzik, A. 1996. Accumulation of proline and pattern of α-amino acids in sugar beet plants in response to osmotic, water and salt stress. Environ. Exp. Bot. 36(1): 29-38.

Hassan, E.A., 2015. Influence of mixed minerals Ores and seaweed liquid extract on growth, yield and chemical constituents of dill (*Anethumgraveolens*, L.) plants. Middle East Journal of Applied Sciences, 5(3): 751-758

Hernandez, O.L., A.C. Garcia, R. Huelva, D. Martínez-Balmori, F. Guridi, N.O. Aguiar, F.L. Olivares and L.P. Canellas. 2015. Humic substances from vermicompost enhance urban lettuce production. Agron. Sustain. Dev., 35:225-232.

Hou, R., S. Li, M. Wu, G. Ren, W. Gao, M. Khayatnezhad and F. Gholinia (2021). "Assessing of impact climate parameters on the gap between hydropower supply and electricity demand by RCPs scenarios and optimized ANN by the improved Pathfinder (IPF) algorithm." Energy 237.

Huang, D., J. Wang and M. Khayatnezhad (2021). "Estimation of Actual Evapotranspiration Using Soil Moisture Balance and Remote Sensing." Iranian Journal of Science and Technology-Transactions of Civil Engineering 45(4): 2779-2786.

Jia, Y., M. Khayatnezhad and S. Mehri (2020). "population differentiation and gene flow in erodium cicutarium: a potential medicinal plant." Genetika-Belgrade 52(3): 1127-1144.

Jones, C.A., J.S. Jacobsen and A. Mugaas. 2004. Effect of humic acid on phosphorus availability and spring wheat yield. Fertilizer Facts, No. 32, Montana State University.

Karasakal, A. (2021). "Analysis of An Indoor Amount of Environmental Tobacco Smoke (ETS) with Quantified Particulate Matter." Bioscience Biotechnology Research Communications 14(2): 708-713.

Karasakal, A. (2021). "Gladiolus vegetative, floral, and yield characteristics in response to corm size and gibberellic acid." Bioscience Research 18(4): 3272-3279.

Karasakal, A., M. Khayatnezhad and R. Gholamin (2020). "The Durum Wheat Gene Sequence Response Assessment of Triticum durum for Dehydration Situations Utilizing Different Indicators of Water Deficiency." Bioscience Biotechnology Research Communications 13(4): 2050-2057.

Karasakal, A., M. Khayatnezhad and R. Gholamin (2020). "The Effect of Saline, Drought, and Presowing Salt Stress on Nitrate Reductase Activity in Varieties of Eleusine coracana (Gaertn)." Bioscience Biotechnology Research Communications 13(4): 2087-2091.

Karimijalilehvandi, T., Maleki Farahani, S. and Rezadzadeh, A., 2017. Effects of sowing date and chemical fertilizer on seed vigor and qualitative and quantitative characteristics of Lady's mantle (*Lallemantiaroyleana*Benth.). Iranian Journal of Medicinal and Aromatic plants Research, 33(1): 126-138.

Khayatnezhad, M. and F. Nasehi (2021). "Industrial Pesticides and a Methods Assessment for the Reduction of Associated Risks: A Review." Advancements in Life Sciences 8(2): 202-210.

Khayatnezhad, M. and R. Gholamin (2020). "A Modern Equation for Determining the Dry-spell Resistance of Crops to Identify Suitable Seeds for the Breeding Program Using Modified Stress Tolerance Index (MSTI)." Bioscience Biotechnology Research Communications 13(4): 2114-2117.

Khayatnezhad, M. and R. Gholamin (2020). "Study of Durum Wheat Genotypes' Response to Drought Stress Conditions." Helix 10(5): 98-103.

Khayatnezhad, M. and R. Gholamin (2021). "Impacts of Drought Stress on Corn Cultivars (Zea mays L.) At the Germination Stage." Bioscience Research 18(1): 409-414.

Khayatnezhad, M. and R. Gholamin (2021). "The Effect of Drought Stress on the Superoxide Dismutase and Chlorophyll Content in Durum Wheat Genotypes." Advancements in Life Sciences 8(2): 119-123.

Li, A., X. Mu, X. Zhao, J. Xu, M. Khayatnezhad and R. Lalehzari (2021). "Developing the non-dimensional framework for water distribution formulation to evaluate sprinkler irrigation." Irrigation and Drainage 70(4): 659-667.

Li, W., M. Khayatnezhad and A. Davarpanah (2022). "Statistical Analysis of Treated Flow-Back Water Measurements: An Industrial Insight for a Shale Reservoir." Geofluids 2022.

Lima PR, Sousa de Melo T, Bezerra Carvalho KMM, Anne de Castro Brito G, Rao VS, Santos FA (2014) 1,8-cineole (eucalyptol) ameliorates cerulein-induced acute pancreatitis via modulation of cytokines, oxidative stress and NF-κB activity in mice. Life Sciences 92:1195-1201

Lima, R.J.C., Moreno, A.J.D., Diniz, E.M., Oléa, R.S.G., Sasaki, J.M., Mendes Filho, J., Freire, P.T.C., Pontes, F.M., Leite E.R. and Longo, E., 2004. Characterization of a crystal grown from OcimumBasilicum leaves and branches. Crystal Research and Technology, 39(10): 864-867.

Liu, S., Y. Wang, Y. Song, M. Khayatnezhad and A. A. Minaeifar (2021). "Genetic variations and interspecific relationships in Salvia (Lamiaceae) using SCoT molecular markers." Caryologia 74(3): 77-89.

Ma, A., J. Ji and M. Khayatnezhad (2021). "Risk-constrained non-probabilistic scheduling of coordinated power-to-gas conversion facility and natural gas storage in power and gas based energy systems." Sustainable Energy Grids & Networks 26.

Ma, S., M. Khayatnezhad and A. A. Minaeifar (2021). "Genetic diversity and relationships among Hypericum L. species by ISSR Markers: A high value medicinal plant from Northern of Iran." Caryologia 74(1): 97-107.

Mohammadzadeh, S. (2021). "Effect of mineral nutrient solutions on secondary metabolites of German chamomile in Hydroponics system." Bioscience Research 18(4): 3143-3151.

Mostafa, G.G., 2015. Improving the growth of fennel plant grown under salinity stress using some biostimulants. American Journal of Plant Physiology, 10(2): 77-83.

Mukesh, T.S., Sudhakar, T.Z., Doongar, R.C., Karuppanan, E. and Jitendra, C., 2013. Seaweed sap as alternative liquid fertilizer for yield and quality improvement of wheat. Journal Plant Nutrition, 36(1): 192-200.

Paradiso VM., Summo C., Trani A. and Caponio F. An effort to improve the shelf life of breakfast cereals using natural mixed tocopherols. Journal of Cereal Science. 2008. 47: 322-330.

Peng, X., M. Khayatnezhad and L. J. Ghezeljehmeidan (2021). "RAPD PROFILING IN DETECTING GENETIC VARIATION IN Stellaria L. (Caryophyllaceae)." Genetika-Belgrade 53(1): 349-362.

Radmanesh, M. (2021). "The Impact of Various Planting Timelines on the Makings of Harvested Wheat Grains Triticum aestivum of Cultivars in Lorestan Province of Iran." Bioscience Biotechnology Research Communications 14(2): 680-685.

Ren, J. and M. Khayatnezhad (2021). "Evaluating the stormwater management model to improve urban water allocation system in drought conditions." Water Supply 21(4): 1514-1524.

Rezvani Moghaddam, P., Aminghafori, A., Bakhshaie, S. and Jafari, L., 2013. The effect of organic and biofertilizers on some quantitative characteristics and essential oil content of summer savory (Satureja hortensis L.). Agroecology. 5(2), 105-112. (In Persian with English Abstract).

Senesi, N., T.M. Miano, M.R. Provenzano and G. Brunetti. 2006. Characterization, differentiation, and classification of humic substances by fluorescence spectroscopy. Soil Sci. 152: 259-271.

Shahbazi, F., Seyyed nejad, M., Salimi, A. and Gilani, A., 2015. Effect of seaweed extracts on the growth and biochemical constituents of wheat. International Journal of Agriculture and Crop Sciences, 8(3): 283-287.

Shi, B., M. Khayatnezhad and A. Shakoor (2021). "The interacting effects of genetic variation in Geranium subg. Geranium (Geraniaceae) using scot molecular markers." Caryologia 74(3): 141-150.

Si, X., L. Gao, Y. Song, M. Khayatnezhad and A. A. Minaeifar (2020). "Understanding population differentiation using geographical, morphological and genetic characterization in Erodium cicunium." Indian Journal of Genetics and Plant Breeding 80(4): 459-+.

Sun, Q., D. Lin, M. Khayatnezhad and M. Taghavi (2021). "Investigation of phosphoric acid fuel cell, linear Fresnel solar reflector and Organic Rankine Cycle polygeneration energy system in different climatic conditions." Process Safety and Environmental Protection 147: 993-1008.

Sun, X. and M. Khayatnezhad (2021). "Fuzzy-probabilistic modeling the flood characteristics using bivariate frequency analysis and alpha-cut decomposition." Water Supply 21(8): 4391-4403.

Tao, Z., Z. Cui, J. Yu and M. Khayatnezhad (2022). "Finite Difference Modelings of Groundwater Flow for Constructing Artificial Recharge Structures." Iranian Journal of Science and Technology-Transactions of Civil Engineering 46(2): 1503-1514.

Vijayanand, N., Sivasangari Ramya, S. and Rathinave, S., 2014. Potential of liquid extracts of Sargassum wightii on growth, biochemical and yield parameters of cluster bean plant. Asian Pacific Journal of Reproduction, 3(2): 150-155.

Wang, C., Y. Shang and M. Khayatnezhad (2021). "Fuzzy Stress-based Modeling for Probabilistic Irrigation Planning Using Copula-NSPSO." Water Resources Management 35(14): 4943-4959.

Wang, H., M. Khayatnezhad and N. Youssefi (2022). "Using an optimized soil and water assessment tool by deep belief networks to evaluate the impact of land use and climate change on water resources." Concurrency and Computation-Practice & Experience 34(10).

Wang, J., Q. Ye, C. Wang, T. Zhang, X. Shi, M. Khayatnezhad and A. Shakoor (2021). "Palynological analysis of genus Geranium (Geraniaceae) and its systematic implications using scanning electron microscopy." Caryologia 74(3): 31-43.

Wang, S., J. Ma, W. Li, M. Khayatnezhad and B. D. Rouyendegh (2022). "An optimal configuration for hybrid SOFC, gas turbine, and Proton Exchange Membrane Electrolyzer using a developed Aquila Optimizer." International Journal of Hydrogen Energy 47(14): 8943-8955.

Xu, Y.-P., P. Ouyang, S.-M. Xing, L.-Y. Qi, M. Khayatnezhad and H. Jafari (2021). "Optimal structure design of a PV/FC HRES using amended Water Strider Algorithm." Energy Reports 7: 2057-2067.

Yin, J., M. Khayatnezhad and A. Shakoor (2021). "EVALUATION OF GENETIC DIVERSITY IN Geranium (Geraniaceae) USING RAPD MARKER." Genetika-Belgrade 53(1): 363-378.

Zhang, H., M. Khayatnezhad and A. Davarpanah (2021). "Experimental investigation on the application of carbon dioxide adsorption for a shale reservoir."

Energy Science & Engineering 9(11): 2165-2176.

Zhang, J., M. Khayatnezhad and N. Ghadimi (2022). "Optimal model evaluation of the proton-exchange membrane fuel cells based on deep learning and modified African Vulture Optimization Algorithm." Energy Sources Part a-Recovery Utilization and Environmental Effects 44(1): 287-305.

Zhao, Y., H. Wang, W. Liang, M. Khayatnezhad and Faisal (2021). "GENETIC DIVERSITY AND RELATIONSHIPS AMONG SALVIA SPECIES BY ISSR MARKERS." Genetika-Belgrade 53(2): 559-574.

Zheng, R., S. Zhao, M. Khayatnezhad and S. A. Shah (2021). "Comparative study and genetic diversity in Salvia (Lamiaceae) using RAPD Molecular Markers." Caryologia 74(2): 45-56.

Zhu, K., L. Liu, S. Li, B. Li, M. Khayatnezhad and A. Shakoor (2021). "Morphological method and molecular marker determine genetic diversity and population structure in Allochrusa." Caryologia 74(2): 121-130.

Zhu, P., H. Saadati and M. Khayatnezhad (2021). "Application of probability decision system and particle swarm optimization for improving soil moisture content." Water Supply 21(8): 4145-4152.