



Effects of Foliar Application of Humic Acid and NPK Fertilisers on the Soil Ion Important Growth Indices of Black Mustard (*Brassica nigra* L.)

Keefah AL-Garallaa^{1*} and Richard L. Harkess²

¹Department of Medical Biotechnology, AL-Qasim Green University, College of Biotechnology, Iraq

²Department of Plant and Soil Sciences, Mississippi State University, 117 Dorman, Mississippi State, United States

Author Designation: ¹Asistant Professor, ²Professor

*Corresponding author: Keefah AL-Garallaa (e-mail: keefah@biotech.uoqasim.edu.iq).

©2026 the Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>)

Abstract Mustard—specifically the *Brassica nigra* L. variety—is a crop of industrial significance, as its seeds are renowned for containing between 41% and 48% high-quality oil. Amidst global climate change, there is an urgent need to utilize humic acid to enhance mustard growth. In this context, a field experiment was conducted in Babylon Governorate, Iraq, during the 2024–2025 growing season to investigate the effects of compound fertilizer (NPK) and organic fertilizer (humic acid) on the growth and productivity of black mustard, employing a Randomized Complete Block Design (RCBD) with three replicates. Using variance analysis and means comparison with the LSD test at a probability level of 0.05, the results showed that the foliar application of humic acid had a significant impact on the growth parameters of black mustard. A 3x3 two-factor experiment was conducted. Adding a balanced NPK complex fertilizer (20:20:20) was the first factor. In two batches, the first two weeks following germination and the second when blooming starts, at concentrations of (0, 30, or 60) kg/dunum. . After placing the fertilizer in the furrows approximately 10 cm beneath the plant and covering it with dirt, the plant was watered. Spraying three different quantities of organic fertilizer (humic acid) (0, 2, or 4) ml.l-1 was the second factor. It was observed from the results that adding NPK complex fertilizer and organic fertilizer (Humic acid) has a significant effect on the characteristics of vegetative growth, as is evident from the fact that the levels of NPK complex fertilizer and spraying with organic fertilizer (Humic acid) have a significant effect on the productive characteristics of the plant The experiment's conclusion is that the 60 kg overlap treatment is the most efficient way to feed the black mustard plant under the given circumstances, and it produced the best outcomes in terms of enhancing the plant's vegetative and productive qualities. 1 dunam-1 NPK with three 2 ml sprays.l-1 of organic fertilizer (Humic acid), which increased the features of vegetative development and delivered the greatest rate of mustard number. Plant-1 and seed count. Mustard-1 and seed weight. Plant-1 and the amount of seed yield per dunum. application of 45 ppm humic acid with 60/kg – per dunum (per 2500 square meters) would be the best option to maintain better growth, yield and quality in black mustard.

Key Words Organic Compounds, Growth, Development and Production, and NPK

INTRODUCTION

The Brassicaceae family includes the annual herbaceous plant known as black mustard (*Brassica nigra* L.). This plant is most likely endemic to southern Mediterranean Europe, North Africa, and Asia, while its precise natural range is unknown [1]. There are several species in the Brassica family, including *B. juncea* (leaf mustard), *B. elongata* (elongated mustard), *B. nigra* (black mustard), *B. rupestris* (brown mustard), and *B. tournefortii* (Asian mustard). In addition, to the cabbage, the cabbage, mustard, and leaf [2].

As a source of edible oil and seeds, it has been brought to regions beyond of its original continents, including America and Australia. Black mustard seeds are also widely utilized in the food, beverage, pharmaceutical, cosmetic, and personal care industries. Additionally, the black black was also commonly used as a black [3]. Until the 1950s, black mustard was the world's largest source of spicy mustard, but it was then overtaken by the more yielding, pungent brown mustard. Since mustard meal and water were widely employed to make plaster and mustard baths to treat

rheumatism, arthritis, and skin conditions. May Enhance Cardiovascular Health: Rich in antioxidants such as kaempferol, carotenoids, isorhamnetin, and other vital plant ingredients, mustard seeds may protect the body from various diseases and injuries. Additionally, these flavonoids may support cardiovascular health [4]. A black mustard plant typically has a persistent taproot, huge lower leaves, smaller top leaves, and a stem that has a few fine hairs on it. The seeds are round, 1-1.6 mm in diameter, and dark brown to virtually black in hue. Mustard black includes essential oils, phenolic chemicals known for their broad antioxidant properties [4]. Additionally, this plant is highly suited for agricultural and industrial applications due to its capacity to thrive in a variety of agro-ecological settings, including disturbed soil and relatively low temperatures [5]. Additionally, it is anticipated that black mustard output would increase significantly due to the growing usage of its seeds in the food and beverage, pharmaceutical, healthcare, and cosmetic industries. [6]. Other than that, mustard plant growth and development are affected by different soils types. Soils have greatly different in texture, chemical composition and color depends on the particles size of mineral component and the number of organic matters. Leaf mustards are the plants that easy to grow and require less attention. However, Mustard favors a sunny location with temperature about 27°C and fertile soils [7]. There are many nutrients that are necessary in growing of plants including nitrogen (N), phosphorus (P) and potassium (K). Potassium is a crucial nutritional source for leaf mustards since it helps the plants grow taller and heavier [8]. However, nitrogen is one of the main essential elements that plants need for healthy growth, development, and yield; it is thought to be a vital component of protein, nucleic acid, chlorophyll, and some significant enzymes [9]. Additionally, regular plant growth and development as well as the production of several metabolic intermediates depend on phosphorus (P) being supplied at an adequate nutritional level. [10]. Phosphorus is essential for plants, but crop species and soil phosphorus availability determine how crops react to phosphorus fertilizers. [11]. Humic acids have the capacity to boost the soil's ability to retain nutrients by binding to sodium, which helps plants tolerate high concentrations of this element and protects against toxicity and osmotic issues [12]. Humic acid enhances the plant's ability to absorb nutrients, including calcium, potassium, phosphorus, and magnesium from the soil. Additionally, it is crucial in reducing the negative effects of applying foliar fertilizers to the soil. [13].

Generally, the seeds of *Brassica* are an important portion of the plant which includes a vast range of natural antioxidants such as essential oils, flavonoids, phenolic acids, Glucosinolates, Isothiocyanate, and many other precious phenolic compounds. The goal of the current study was to determine how various NPK and humic acid concentrations affected the vegetative growth and yield components of mustard in a field setting. may offer a more effective and convenient way to enhance mustard growth and development [14].

METHOD

Soil Preparation

Black mustard *Brassica nigra* L. were used in this study. The research was conducted in a field of Babylon city during the 2022-2023 season, south of Baghdad city, to study the effect of adding NPK fertilizer to the soil and spraying with organic fertilizer (Humic Aljohara) (Table 1) on the growth and yield of black mustard plant. After preparing the land by plowing, smoothing and leveling, it was divided into 75 cm wide ditches with a distance of 1 m between each ditch. The seeds were planted on 10/15/2022 in holes in the upper third of the ditch and on the sides with a distance of 50 cm between holes. 3 seeds were placed in each hole, which resulted in one plant in each hole after two weeks of germination. The components of humic acid were: Organic Matter 25%, water Soluble Potassium Oxide (K₂O) 6%, Humic acid + Fulvic acid 21%, and (pH) 5.7 Table 1.

Experiment Design and Seeds Germination

The experimental unit included two plots; each unit was 2.5 m long, 6.25 m² in area, and 20 plants per unit. The first factor in a factorial experiment (3x3) was the addition of balanced NPK fertilizer (20:20:20) at levels of 0,30,60 kg/dunum in two batches, the first two weeks after germination and the second at the beginning of flowering. The fertilizer was placed in furrows about 10 cm below the plant, covered with soil, and watered after fertilization. The second factor was spraying with three concentrations of organic fertilizer (Humic Aljohara) at 0,2,4 mL.L⁻¹ (noting that the producing company's advice was 250-300 ml per 100 liters) three times with 12 days between sprays. After adding a spreading agent (soap) at a concentration of 0.01% by volume to lower the surface tension of water molecules and accomplish total wetting, spraying started on November 20, 2024. Control plants were sprayed with water only. A 5-liter hand sprayer was used for the spraying process.

Statistical Analysis

Three replicates of the experiment were carried out using a Randomized Complete Block Design (RCBD). Analysis of variance was used to assess the results, and the Least Significant Difference (LSD) test was used to compare averages at a probability threshold of 0.05.4). Plant height was measured, and the number of branches, total leaves, and fruit (mustard) per plant were calculated two weeks before harvest. Harvest began on January 10, 2023. The total seed yield per dm was calculated according to the following equation:

$$\text{Total yield (kg/dm-1)} = \frac{\text{Yield of experimental unit (kg)}}{\text{Area of experimental unit (m}^2\text{)}} \times 2500 \text{ m}^2$$

Table 1: Organic Fertilizer Components (Humic Aljohara) Produced by Mil-Tar, Konak- izmir/ Turkey

Organic Matter	25%
Water Soluble Potassium Oxide (K ₂ O)	6%
Humic acid + Fulvic acid	21%
(PH)	5.7

All the comparisons were made at the 5% level of significance. Measurement of growth parameters were collected (plant height, no. branches, no. leaves, no. seeds, weight of seeds, and amount yield). Vegetative growth was recorded at the end of the growing season for all plants.

RESULTS AND DESICCATION

Vegetative Growth Characteristics of Mustard

The results of Table 2 show that vegetative growth traits were significantly impacted by the addition of NPK fertilizer. The average plant height, number of branches, and number of leaves per plant were all highest at the 60 kg.dun-1 level, with 134.78 cm, 10.98 branches, and 41.69 leaves, respectively. This greatly surpassed the control treatment, which produced the lowest averages for these traits—99.42 cm, 8.27 branches, and 33.00 leaves, respectively—at the 30 kg.dun-1 level. This is due to the role of these major elements—nitrogen, phosphorus, and potassium—in plant growth and the optimal performance of its vital functions in respiration and photosynthesis. These findings are in line with those of Sahay *et al.*, who found that adding NPK fertilizer to the soil significantly increased the number, area, branch length, and root length of black mustard (*Brassica nigra*). They are also in line with the findings of Kumar *et al.* [15], who found that adding NPK fertilizer to the soil significantly increased the number of branches and plant height of Indian mustard (*Brassica juncea*). The organic fertilizer (Humic Aljohara) had a substantial effect on these features, as the concentrations of 2 and 4 ml. In terms of plant height, branch count, and total number of leaves per plant, L-1 outperformed the control treatment. At 132.95 cm, 10.58 branches, and 40.42 leaves per plant, respectively, the concentration of 4 ml.L-produced the highest rate of plant height, number of branches, and total leaves per plant. In these aspects, it was therefore noticeably better than the control therapy and the concentration of 2 ml.L-1. With 103.33 cm, 8.42 branches, and 34.75 leaves, respectively, the control treatment had the lowest rates of these traits. The increase brought about by the addition of Humic Aljohara may be explained by the beneficial effects of humic acids, organic materials, and nutrients on plant growth. These effects include improving cell division and elongation, boosting the production of plant enzymes within the cells, and increasing the permeability of cell membranes. These findings align with those of AL-Garallaa [16]. Results show that applying an organic fertilizer (humic acid) at a concentration of 4 ml/L-1 produced the highest rate of plant height and the total number of *Lavandula* sp. branches and leaves, outperforming both the comparison treatment and the concentration of 2 ml/L-1. On the other hand, the interaction between the two factors (NPK and Humic Aljohara) had a significant effect on the vegetative growth characteristics, as the interaction of adding NPK at a level of 60 kg/dunum-1 and spraying with organic fertilizer at a concentration of 4 ml/l-1 gave the highest average of plant height and the total number of branches and leaves per plant, which amounted to 153.73 cm, 12.40 branches and 44.20 leaves, respectively.

The comparison treatment gave the lowest average of these characteristics, which amounted to (84.67 cm, 7.20 branches and 28.33 leaves). Sonam and Moinuddin [17] Additionally, it was discovered that adding either of the organic manure, farmyard manure, or vermicompost poultry manure—with or without nitrogen—significantly increased the Indian mustard plant's height, number of branches, number of mustards, and seed output. However, Hadiyal *et al.* found that organic manure levels had a significant impact on growth characteristics, such as plant height at 60 DAS, 90 DAS, and harvest and the number of major and secondary branches per plant. Notably, the application of FYM 5.0 t/ha (M1) resulted in the greatest values of these growth indicators [18]. The delivery of plant nutrients, including micronutrients, the enhancement of the physical and biological characteristics of the soil, and the enhanced availability of these parameters might all be attributed to the use of organic manures. As a result, nutrients have a favorable effect on the production of larger, thinner-walled cells as well as their contribution to cell division and elongation, which enhances vegetative development and eventually raises plant height and the number of primary and secondary branches per plant. Nevertheless, Kansotia *et al.*, Yadav *et al.* and De and Sinha [19,20]. Similar outcomes were discovered. Humic acid influences root development, which can lead to shoot growth, as it enhances soil porosity [21]. However, according to Lin and Yeh [22], potassium is a major osmotic that promotes leaf growth and is involved in the elongation of plant cells. Furthermore, potassium is widely recognized as a nutrient that is critical for plant osmoregulation, turgor maintenance, cell growth, and stomatal function [23]. The leaves get wider as the potassium content is increased. In addition, the data revealed that untreated leaf mustard had the lowest mean when compared to leaf mustard treated with nitrogen fertilizers. This finding was corroborated by Maereka *et al.* [24], which demonstrated that the application of nitrogen fertilizers in mustard rape increased the size of the leaves. Furthermore, phosphorus is regarded as an essential nutrient for plant growth and development, according to Khan *et al.* [25]. According to Hawrylak *et al.* [26], phosphorus is a crucial element that influences plant growth from the cellular level to the total plant level, including plant height. Overall, the findings also demonstrate that there is a notable difference in plant height between the camper with high nitrogen, phosphate, and potassium fertilizers and the control (Figure 1).

Productive Characteristics of Mustard

Table 3 shows that the levels of NPK compound fertilizer had a significant effect on plant productivity traits, as the 30 and 60 kg/dun-1 and 60 kg/dun-1 levels outperformed the control treatment. However, the highest average number of mustard seeds per plant was 125.13 seeds, the number of mustard seeds was 10.42, the seed weight was 46.91 g, and the seed yield per dunum was 375.31 kg. This was achieved at the 60 kg/dun-1 level, outperforming the 30 kg/dun-1 level

Table 2: The Effect of Adding (NPK) Fertiliser and Spraying with Humic Acid on Some Vegetative Characteristics of Black Mustard

Number of leaves (leaf. plant-1)	Total number of branches (branches plant-1)	Plant height (cm)	Fertiliser concentrations NPK((kg d-1)	Effect of compound fertilizer (NPK)
33.00	8.27	99.42	0	
38.22	9.33	122.13	30	
41.69	10.98	134.78	60	
2.83	1.12	9.61	LSD0.05	
Concentrations Humic Aljohara (mL L-1)				
34.75	8.42	103.33	0	Effect of Humic Aljohara
37.73	9.58	119.67	2	
40.42	10.58	132.95	4	
2.81	1.08	9.04	LSD0.05	
Interaction effect				
Number of leaves (leaves plant-1)	Total number of branches (branches plant-1)	Plant height (cm)	Concentrations Humic Aljohara (mL L-1)	Compound fertiliser levels (NPK) Kg.A -1
28.33	7.20	84.67	0	0
33.40	8.47	103.60	2	
37.27	9.13	110.00	4	
36.73	8.67	109.20	0	30
38.13	9.13	122.07	2	
39.80	10.20	135.13	4	
39.20	9.40	117.27	0	60
41.67	11.13	133.33	2	
44.20	12.40	153.73	4	
4.34	1.63	16.24	LSD0.05	

Table 3: Effect of NPK Fertilizer Addition and Humic Acid Spraying on Black Mustard Seed Yie

Seed yield (Kg A-1)	Seed weight gm pl-1	Number mustard seeds-1	Number mustard pl-1	Fertilizer concentrations NPK)(Kg.A -1)	Effect of compound fertilizer (NPK)
300.51	37.56	8.36	95.47	0	
346.32	43.29	9.41	106.89	30	
375.31	46.91	10.42	125.13	60	
23.33	1.71	0.88	6.92	LSD0.05	
(Concentrations Humic Aljohara) mL L-1					
313.31	39.16	8.31	97.13	0	Effect of Humic Aljohara
339.84	42.48	9.54	111.96	2	
368.99	46.12	10.33	118.440	4	
22.08	1.67	0.82	6.88	LSD0.05	
Interaction Effect					
Seed yield (Kg A-1)	Seed weight gm pl-1	Number mustard seeds-1	Number mustard pl-1	concentrations Humic Aljohara (MI L-1)	Compound fertilizer levels (NPK) Kg.A -1
281.76	35.22	9.67	159.40	0	0
301.36	37.67	10.40	166.67	2	
318.40	39.80	11.00	170.33	4	
326.64	40.83	10.13	167.80	0	30
345.76	43.22	11.89	178.20	2	
366.56	45.82	12.20	184.67	4	
331.52	41.44	11.13	174.07	0	60
372.40	46.55	12.33	201.00	2	
422.00	52.75	13.80	210.33	4	
34.51	3.13	1.22	10.73	LSD0.05	

and the control treatment, which yielded the lowest average for these traits. The explanation for these considerable improvements may be related to the effect of compound fertilizer in promoting vegetative development, which enabled the plant to perform its biological tasks appropriately, which was reflected in the productivity indices of mustard. These results are congruent with the results of Sahay *et al*, (2015) and Kumar *et al*, (2016), who confirmed that significant increases in the production characteristics of black mustard and Indian mustard, respectively, occurred when NPK fertilizer was given to the soil. The number of mustards/plant-1 (125.13 mustards), number of mustard

seeds/plant-1 (10.42 seeds), seed weight/plant-1 (46.91 g), and amount of seed yield per dunum (375.31 kg) were all at their highest levels when 4 mL L-1 of organic fertilizer (Humic Aljohara) was sprayed, which had a significant impact on the plant production characteristics. While the control treatment offered the lowest rate of these characteristics, equal to 97.13 mustards, 8.31 seeds, 39.16 g, and 313.31 kg. This is due to the role of humic, fulvic acids, and potassium in the organic fertilizer in improving vegetative growth, increasing the process of food production and plant growth, and its positive impact on the quantitative characteristics of the crop. The quantitative parameters of the



Figure 1: Pictures of Mustard which had been used in Experiment

crop was significantly impacted by the combination of NPK compound fertilizer and organic fertilizer (Humic Aljohara), as demonstrated by the combination of 60 kg, dunum-1 NPK and spraying with 2 ml. L-1 of organic fertilizer (Humic Aljohara) produced the most mustard seeds per plant. Mustard-1, weight of seeds, plant-1. Additionally, there were 210.33 mustards, 13.80 seeds, 52.75 g, 1055 g, and 422.00 kg of seed production per donum. With 159.40 mustards, 9.67 seeds, 35.22 g, and 704.40 kg, the comparator treatment had the lowest rate of these traits. Sánchez *et al.* [27].

found that adding nitrogen to Indian mustard improved its yield components. Stated differently, as nitrogen levels increased to 120 kg/ha, 60, 120, and 180 kg/ha, the improvement in plant growth and yield components was reflected in seed and stover yields, which increased by 70.09, 127.69, and 116.83%, respectively, over the control treatment [28]. Humic acid is a natural, bioavailable organic matter. It has a great effect on plant growth and quality [29]. For cationic micronutrients, humic acid has long been regarded as a natural chelate [30]. According to Sanchez *et*

al. [27], adding humic acid may improve Fe absorption by chelating free Fe and preventing its immobilization. A stimulant of bacterial activity is a stimulator of bacterial activity. P and total N content were improved by this biologically elevated activity [31]. Numerous components included in humic acid promote nutrient availability, which influences plant growth [32]. Numerous components found in humic acid enhance soil fertility and make nutrients more accessible by retaining them on mineral surfaces, which influences plant growth and productivity [33-34].

CONCLUSIONS

The present study aimed to evaluate the effect of fertilization (NPK and humic acid) on vegetative growth, yield and quality of black mustard plants in order to identify alternative sources for better growth and seed productivity under natural conditions.

This experiment leads us to the following conclusion: The interaction treatment of 60 kg is the most efficient way to feed black mustard plants in the conditions of this experiment, and it produced the best results in enhancing the plant's vegetative and productive qualities. Donum-1 NPK with three 2 ml sprays. L-1 of organic fertilizer (Humic Aljohara), which produced the greatest quantity of mustard seeds per plant and enhanced the vegetative development characteristics. seed weight, plant-1. plant-1, as well as the amount of seed produced per donum. All of the study's examined parameters revealed statistically significant modification when NPK fertilizer and humic acid were combined as a therapy. The highest seed yield (422.00), seed weight (52.75), number of mustard seeds (13.80), and number of mustard plants (210.33) were determined by the interaction effect between humic acid at 4 and NPK at 60. In a similar vein, the interaction between humic acid (4 mg/L) and NPK (60 kg/Donum) produced the greatest number of leaves (44.20 leaf/plant), total number of branches (12.40), and plant height (153.73 cm) when compared to the control treatment. Future research should also focus on figuring out how using more effective fertilizers affects the quality of black mustard.

REFERENCES

- [1] Thomas J. *et al.* *Handbook of Herbs and Spices*. Cambridge, England: Woodhead Publishing Limited, 2012.
- [2] Bischoff K.L. "Glucosinolates." In *Nutraceuticals: Efficacy, Safety and Toxicity*, pp. 551–554. Academic Press, 2016. <https://doi.org/10.1016/B978-0-12-802147-7.00040-1>.
- [3] Singh S.M. *et al.* "Effect of varying rectangularities, nitrogen and varieties on yield and yield attributes of mustard." 1985.
- [4] Bagchi G.D. and Srivastava G.N. "Spices and flavoring crops: Fruits and seeds." 2003.
- [5] Angelova V. and Ivanov K. "Bio-accumulation and distribution of heavy metals in black mustard (*Brassica nigra* Koch)." *Environmental Monitoring and Assessment*, vol. 153, no. 1, 2009, pp. 449–459.
- [6] Rahman M. *et al.* "Brassicaceae mustards: Traditional and agronomic uses in Australia and New Zealand." *Molecules*, vol. 23, no. 1, 2018, pp. 231.
- [7] Toosi A.F. "Production ecology of *Brassica juncea* (L.) Czern. var. ensabi." University of Malaya, Malaysia, 2010.
- [8] Pervez M.A. *et al.* "Effect of nitrogen levels and spacing on growth and yield of radish (*Raphanus sativus* L.)." *International Journal of Agriculture and Biology*, vol. 6, no. 3, 2004, pp. 504–506.
- [9] Oke M. *et al.* "Effects of phosphorus fertilizer supplementation on processing quality and functional food ingredients in tomato." *Journal of Agricultural and Food Chemistry*, vol. 53, no. 5, 2005, pp. 1531–1538.
- [10] De B. and Sinha A.C. "Oil and protein yield of rapeseed (*Brassica campestris* L.) as influenced by integrated nutrient management." *SAARC Journal of Agriculture*, vol. 10, no. 2, 2012, pp. 41–49.
- [11] Wang Z. and Li S. "Effects of nitrogen and phosphorus fertilization on plant growth and nitrate accumulation in vegetables." *Journal of Plant Nutrition*, vol. 27, no. 3, 2004, pp. 539–556.
- [12] Stevenson F.J. *Humus Chemistry: Genesis, Composition, Reactions*. John Wiley and Sons, 1994.
- [13] Sahay S. *et al.* "Modulation in growth, photosynthesis and yield attributes of black mustard (*B. nigra* cv. IC247) by interactive effect of wastewater and fly ash under different NPK levels." *Cogent Food & Agriculture*, vol. 1, no. 1, 2015, pp. 1087632.
- [14] Hartwigsen J.A. and Evans M.R. "Humic acid seed and substrate treatments promote seedling root development." *HortScience*, vol. 35, no. 7, 2000, pp. 1231–1233.
- [15] Prakash S. and Hinata K. "Taxonomy, cytogenetics and origin of crop brassicas: A review." 1981.
- [16] Kumar S. *et al.* "Effect of organic and inorganic sources of nutrients on growth and yield attributing characters of mustard crop (*Brassica juncea* L.)." *International Journal of Chemical Studies*, vol. 6, no. 2, 2018, pp. 2306–2309.
- [17] Al-Garallaa K. "Phytochemical and biological strategies to improve essential oils content in lavender." 2021.
- [18] Sonam L. and Moinuddin Brujel K. "Influence of different organic and inorganic sources of nitrogen on growth, yield and oil content of Indian mustard (*Brassica juncea* L.) Czernj & Cosson." *Journal of International Academic Research for Multidisciplinary*, vol. 3, no. 11, 2015, pp. 28–32.
- [19] Hadiyal J.G. *et al.* "Response of Indian mustard (*Brassica juncea* L.) to different levels of organic manures and bio-fertilizers." *Journal of Pharmacognosy and Phytochemistry*, vol. 6, no. 4, 2017, pp. 873–875.
- [20] Yadav S.S. *et al.* "Response of taramira (*Eruca sativa*) to varying levels of FYM and vermicompost under rainfed conditions." 2013.
- [21] Kansotia B.C. *et al.* "Effect of vermicompost and inorganic fertilizers on growth, yield and quality of Indian mustard." *Journal Soil and Crop*, vol. 15, no. 1, 2005, pp. 163.
- [22] Katalinić V. *et al.* "Insight in the phenolic composition and antioxidative properties of *Vitis vinifera* leaves extracts." *Croatian Journal of Food Science and Technology*, vol. 1, no. 2, 2009, pp. 7–15.
- [23] Lin C.Y. and Yeh D.M. "Potassium nutrition affects leaf growth, anatomy, and macroelements of *Guzmania*." *HortScience*, vol. 43, no. 1, 2008, pp. 146–148.
- [24] Shabala S. "Regulation of potassium transport in leaves: From molecular to tissue level." *Annals of Botany*, vol. 92, no. 5, 2003, pp. 627–634.
- [25] Maereka E.K. *et al.* "Effect of nitrogen fertilization and timing of harvesting on leaf nitrate content and taste in mustard rape (*Brassica juncea* L. Czern.)." *Journal of Food, Agriculture and Environment*, vol. 5, no. 3–4, 2007, pp. 288.

- [26] Khan A. *et al.* "Response of fodder maize to various levels of nitrogen and phosphorus." *American Journal of Plant Sciences*, vol. 5, no. 15, 2014, pp. 2323–2329.
- [27] Hawrylak-Nowak B. *et al.* "Mechanisms of selenium-induced enhancement of abiotic stress tolerance in plants." In *Plant Nutrients and Abiotic Stress Tolerance*, pp. 269–295, 2018.
- [28] Sánchez-Sánchez A. *et al.* "Improvement of iron uptake in table grape by addition of humic substances." *Journal of Plant Nutrition*, vol. 29, no. 2, 2006, pp. 259–272.
- [29] Ali M.H. *et al.* "Variation in yield, oil and protein content of rapeseed (*Brassica campestris*) in relation to levels of nitrogen, sulphur and plant density." *Indian Journal of Agronomy*, vol. 41, no. 2, 1996, pp. 41–42.
- [30] Noroozisharaf A. and Kaviani M. "Effect of soil application of humic acid on nutrients uptake, essential oil and chemical compositions of garden thyme (*Thymus vulgaris* L.) under greenhouse conditions." *Physiology and Molecular Biology of Plants*, vol. 24, no. 3, 2018, pp. 423–431.
- [31] Varanini Z. and Pinton R. "Humic substances and plant nutrition." In *Progress in Botany: Structural Botany, Physiology, Genetics, Taxonomy, Geobotany/Fortschritte der Botanik: Struktur, Physiologie, Genetik, Systematik, Geobotanik*, pp. 97–117. Berlin, Heidelberg: Springer Berlin Heidelberg, 1995.
- [32] Busato J.G. *et al.* "Changes in labile phosphorus forms during maturation of vermicompost enriched with phosphorus-solubilizing and diazotrophic bacteria." *Bioresource Technology*, vol. 110, 2012, pp. 390–395.
- [33] Akinci S. *et al.* "The effect of humic acid on nutrient composition in broad bean (*Vicia faba* L.) roots." *Notulae Scientia Biologicae*, vol. 1, no. 1, 2009, pp. 81–87.
- [34] Abdel-Razzak H.S. and El-Sharkawy G.A. "Effect of biofertilizer and humic acid applications on growth, yield, quality and storability of two garlic (*Allium sativum* L.) cultivars." 2013.