Al-Muthanna J. For Agric Sci Online ISSN:2572-5149

Print ISSN: 2226-4086

Vol. 13 , Issue 1. 2026

https://muthjas.mu.edu.iq/ http://doi.org/10.52113/mjas04/13.1/46

Response of Two Oat (*Avena sativa* L.) Varieties to Foliar Spray Concentrations of Humic Acid

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Abstract

The experiment was carried out during the winter growing season of 2022–2023 in a farmer's field at Al-Zubair district, Basra, Iraq. The study aimed to evaluate the response of two oat varieties (Al-Shifa and Genzania) to four foliar spray concentrations of humic acid (0, 2, 4, and 6 mL L^{-1}, designated as H1, H2, H3, and H4, respectively) applied at the tillering and pre-flowering stages. A factorial experiment was conducted using a Randomized Complete Block Design (RCBD) with three replications. The results revealed that increasing humic acid concentrations significantly improved growth and yield traits. The highest concentration (H4, 6 mL L^{-1}) achieved the maximum values for plant height (91.51 cm), flag leaf area (22.42 cm^2), number of tillers (461.2 m^{-2}), number of panicles (449.8 m^{-2}), grains per panicle (32.12), 1000-grain weight (49.36 g), and grain yield (3.367 Mg ha^{-1}). Among the varieties, Al-Shifa outperformed Genzania, recording the highest plant height (86.22 cm), grains per panicle (39.03), 1000-grain weight (45.81 g), and grain yield (2.959 Mg ha^{-1}). The interaction between factors significantly influenced grain yield, with the combination of Al-Shifa and 6 mL L^{-1} of humic acid producing the highest yield.

Keywords**:** *Avena sativa* L., Foliar application, Growth traits, Oat varieties, Organic fertilizer, Yield components

Introduction

Oat (*Avena sativa* L.) belongs to the Poaceae family and is an annual winter crop cultivated as a dual-purpose crop for both grain and forage production. Oat is an estimated 9.34 million hectares (22.14 million tons) globally (US Dept of Agriculture, 2019). Oats stand out among cereals due to their exceptional nutritional profile, characterized by elevated levels of unsaturated fatty acids, proteins, antioxidants, B vitamins, and essential minerals such as calcium, magnesium, and sodium. It can be incorporated with wheat flour for use in bread production. Oat also has a significant amount of dietary fiber, which is important in lowering body fat, blood glucose and cholesterol. In addition, oat has a special soluble fiber called beta-glucan (Mayer, 2017).

The cultivar is among the most important factors contributing to the success of the production process and improving oat productivity and expanding its cultivation depends largely on selecting cultivars that are well adapted to local environmental conditions. Varieties vary in their growth habit, yield and yield components and in their reaction to different agronomic treatments, especially rate of fertilization. This requires an understanding of the performance of varieties in a range of environmental and management situations. Humic acid is an organic acid which occurs naturally as a result of the biological decomposition of organic matter in the soil. Effectively used to improve plant growth and productivity. Its significance is attributed to its direct effects, including the stimulation of physiological processes within the plant, improved nutrient availability, and the regulation of hormonal activity. Humic acid also indirectly enhances the physical and chemical attributes of the soil and the activity of beneficial microorganisms in the root zone that is reflected positively on plant growth (Al-Taey et al., 2019).

Many research studies have proven that foliar application of humic acid can enhance vegetative growth and yield and minimize the need for chemical fertilizers. This approach can help lower production costs while minimizing the environmental impacts associated with excessive use of mineral fertilizers. (Al-Taey and Majid). Considering the above, this study was undertaken to assess the reaction of two varieties of oats to various rates of foliar application of humic acid and to specify the impacts of this treatment on some of the plant growth parameters, yield and yield components, to identify the best treatment to increase the productivity in local environmental condition.

Materials and Methods

Field of Experiment

The field experiment was conducted in the agricultural field of a local farmer in AlZubair approximately 20 km west of the center of Basra in the winter season 2022-2023. The study aimed to investigate the response of two varieties of oats (Alshifa and Genzania) when grown at various levels of Humic acid (H1, H2, H3, and H4, at 0, 2, 4, and 6 mL L^{-1}, respectively). Humic acid was applied as a foliar spray at two growth stages: tillering and pre-flowering. The experiment was conducted using a Randomized Complete Block Design (RCBD) with three replications. Treatments were arranged in a factorial experiment, resulting in a total of 24 experimental units.. Sowing was carried out on November 15, 2022, for all experimental units. The plots were irrigated immediately after planting, while subsequent irrigations were applied as needed. All standard crop management practices were performed in accordance with the recommended agronomic guidelines. Superphosphate fertilizer was applied before sowing at a rate of 100 kg ha^{-1} (46% P_2O_5). Nitrogen fertilizer in the form of urea (46% N) was applied to all experimental units at a rate of 100 kg ha^{-1} in two equal split applications: the first after seedling emergence and the second at the stem elongation stage (Al-Abadi, 2010).

Application of Humic Acid Treatments

Humic acid treatments were applied by foliar spraying using aqueous solutions prepared according to the concentrations specified in the study, whereas the control treatment was sprayed with water only. Spraying was made at two growth phases, namely tillering and pre-flowering, while ensuring that the same volume of spray solution was applied to each experimental unit to guarantee accurate comparison among treatments.

Studied Traits

- Plant height (cm) at physiological maturity
- Flag leaf area (cm^2)
- Number of tillers (m^2)
- Number of panicles (m^2)

- Number of grains (grains panicle^{-1})
- 1000-grain weight (g)
- Grain yield (t ha^{-1})

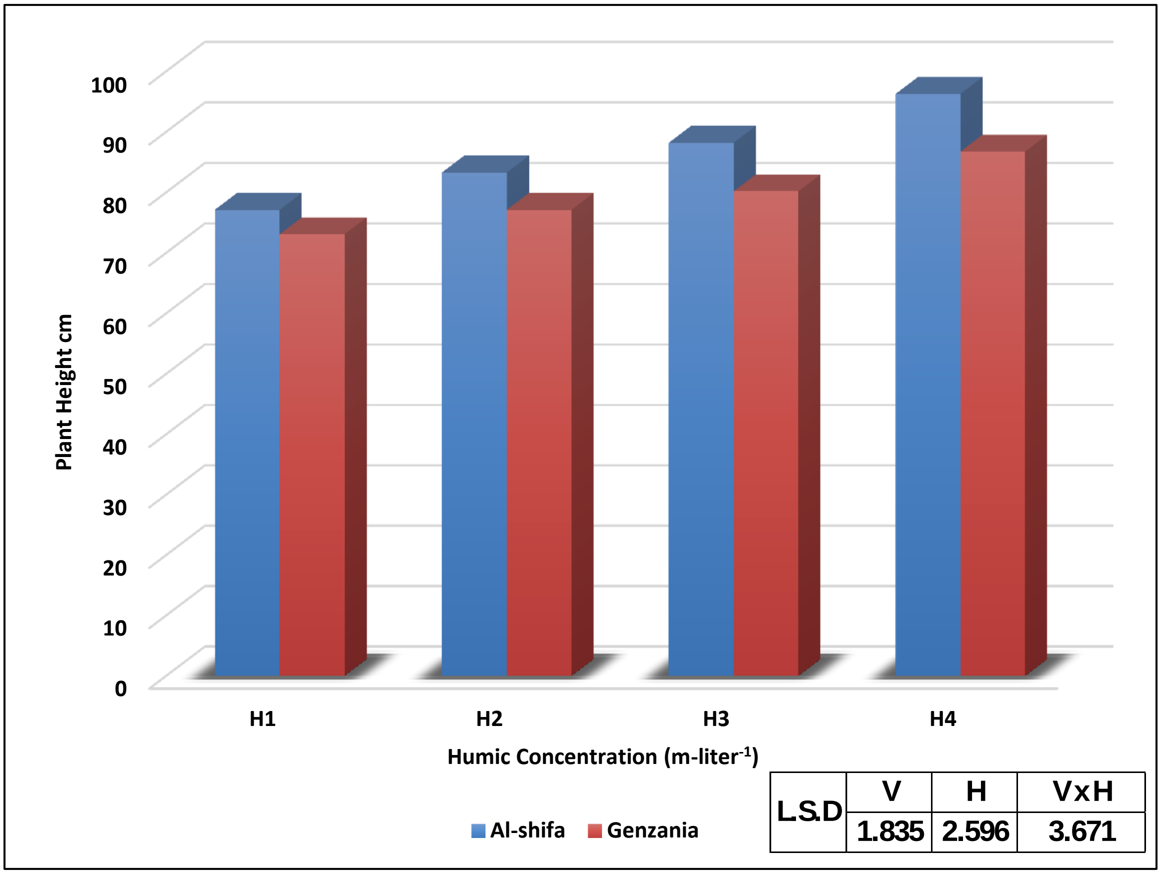
Statistical Analysis

The data were statistically analyzed using analysis of variance (ANOVA), and treatment means were compared using the Least Significant Difference (LSD) test at a 0.05 probability level, (AlRawi and Khalaf Allah 1980).

Results and Discussion

1. Plant Height (cm)

The results shown in Figure (1) indicate that, the foliar application levels of Humic acid significantly affected the height of the plants. Plant height showed a gradual increase with increasing concentrations of humic acid. The highest concentration (H4) recorded the maximum mean plant height of 91.51 cm, which was 21.85% greater than that of the lowest concentration (H1), which resulted in the minimum plant height of 75.10 cm.The increase in plant height with higher levels of humic acid may be attributed to the role of humic substances in enhancing the availability of essential soil nutrients and improving their uptake by plants. They also exhibit effects similar to plant growth regulators such as auxins and cytokinins, which stimulate cell division and cell elongation, thereby promoting vegetative growth and increasing plant height. (Canellas & Olivares, 2020). Humic acid also increases the efficiency of photosynthesis and induces physiological. The results shown in Figure (1) indicated a significant effect of the varieties on plant height. Mean plant height ‘Alshifa' was 86.22 cm while Genzania had the lowest value of 79.28 cm. The difference could be due to genetic variation among the cultivars or physiological differences. Variation might be linked to differences in endogenous levels of the plant hormones auxins and gibberellins, which promote elongation and expansion of cells. The findings obtained are in accordance with those of May et al. (2018), and Alrubaiee et al. (2019) who also found significant differences between the various oat varieties, in this trait.



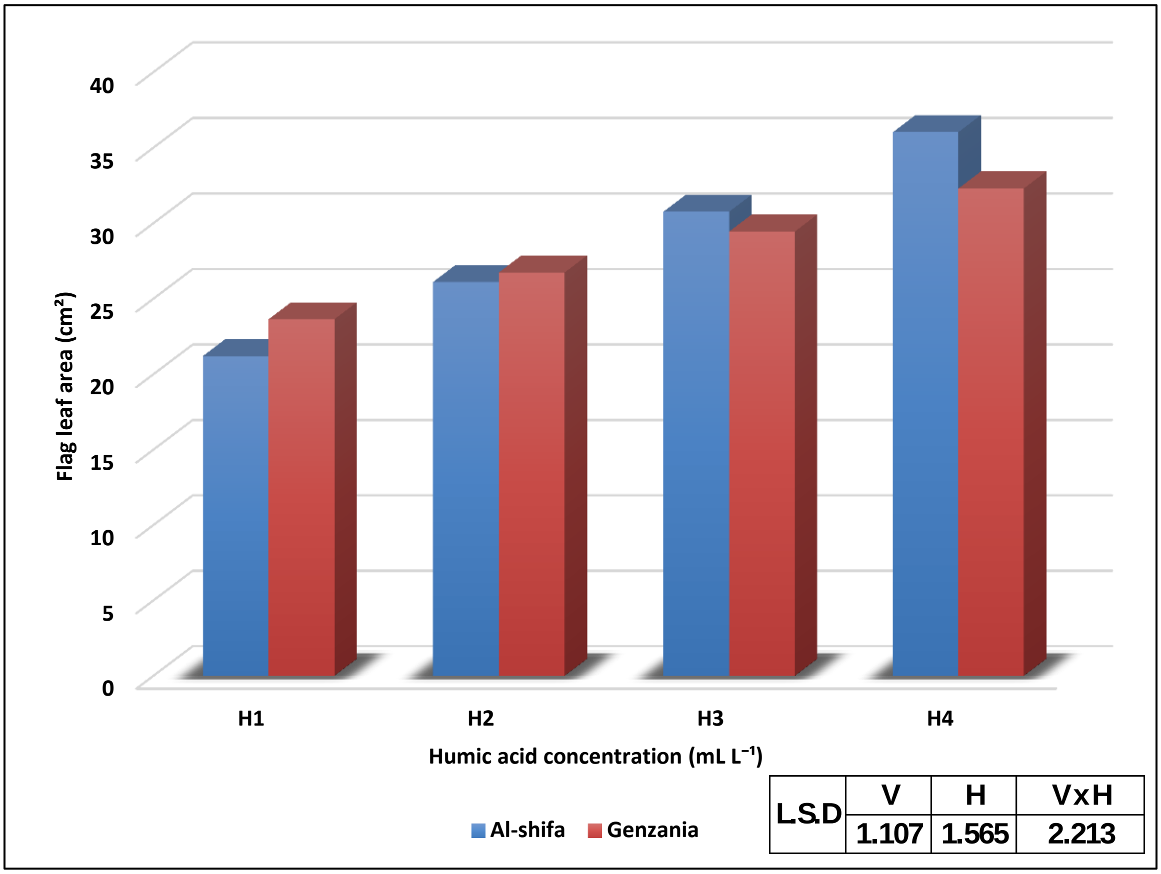
L.S.D	V	H	VxH
	1.835	2.596	3.671

Figure (1). Impact of foliar application of varying levels of Humic acid fertilizer on plant height (cm) of two oat varieties.

2. Flag Leaf Area (cm²)

It was observed that flag leaf area did not differ significantly among the three spray treatments of the crop, with the H4 (foliar spray) treatment having the highest mean value of 34.16 cm², but the H1 (control) treatment had the least mean value of 22.42 cm^2 as shown in the results presented in Figure (2). The humic acid may have influenced this increase by increasing the efficiency of nutrient uptake and improving the water holding capacity of the soil, which improves its cell division and expansion in the leaf tissues and subsequently increases the flag leaf area. These results are consistent with Al-Alawi and Al-Nadawi (2017) and Al-Nadawi et al. (2017) who stated that applying organic fertilizers had a significant effect on wheat flag leaf area as compared to the unfertilized treatment.

The results of Figure (2) also suggest that the interaction effect among the levels of humic acid application and varieties was significant for flag leaf area. The cultivar Al-shifa had the maximum mean flag leaf area (36.03cm^2) in treatment H4 while the lowest mean flag leaf area (21.20cm^2) was recorded with the same cultivar under treatment H1. The significance of this interaction might be due to differences in the utilization of enhanced nutrient availability provided by humic acid application, causing different responses among varieties in higher humic acid concentrations (Abd El-Mageed et al., 2023). The findings obtained in this study are consistent with Shahryari and Mollasadeghi (2020) who found the response of cereal crops to humic fertilizer varies according to the variety, resulting in a significant interaction effect between the variety and application levels.



L.S.D	V	H	VxH
	1.107	1.565	2.213

Figure (2). Impact of foliar application of variant levels of Humic acid fertilizer on Flag Leaf Area (cm^2) of two oat varieties.

3.

Number of Tillers (m^{-2})

The findings given in the figure (3) showed that the application rates of humic acid had significant effects on tillers. The number of tillers gradually increased by increasing in humic acid concentration, treatment H4 had the highest mean 461.2 tillers. m^{-2} while H1 had the lowest mean of 381.2 tillers m^{-2}. The increased number of tillers after humic acid treatment could be explained by the increased nutrient uptake, especially of nitrogen, which is crucial for the initiation of tillering and vegetative growth. Humic acids contribute to the stimulation of cell division and the promotion of lateral bud formation due to their physiological activity, which is similar to that of plant growth regulators, leading to an increase in tiller number ,(Canellas & Olivares, 2020). In addition, humic acid improves root system development and enhances the efficiency of water and nutrient absorption, which supports the initiation and growth of new tillers (Nardi et al., 2021).

Al-shifa variety also showed clear superiority over Genzania in the number of tillers, recording 421.4 tillers m^{-2}, whereas Genzania produced the lowest mean value 411.3 tillers m^{-2}. This difference may be attributed to genetic variation between the two varieties in their tillering capacity and nutrient use efficiency. Varieties differ in their physiological activity and responsiveness to growth-promoting substances, resulting in significant differences in tiller production (Rouphael and Colla, 2022).

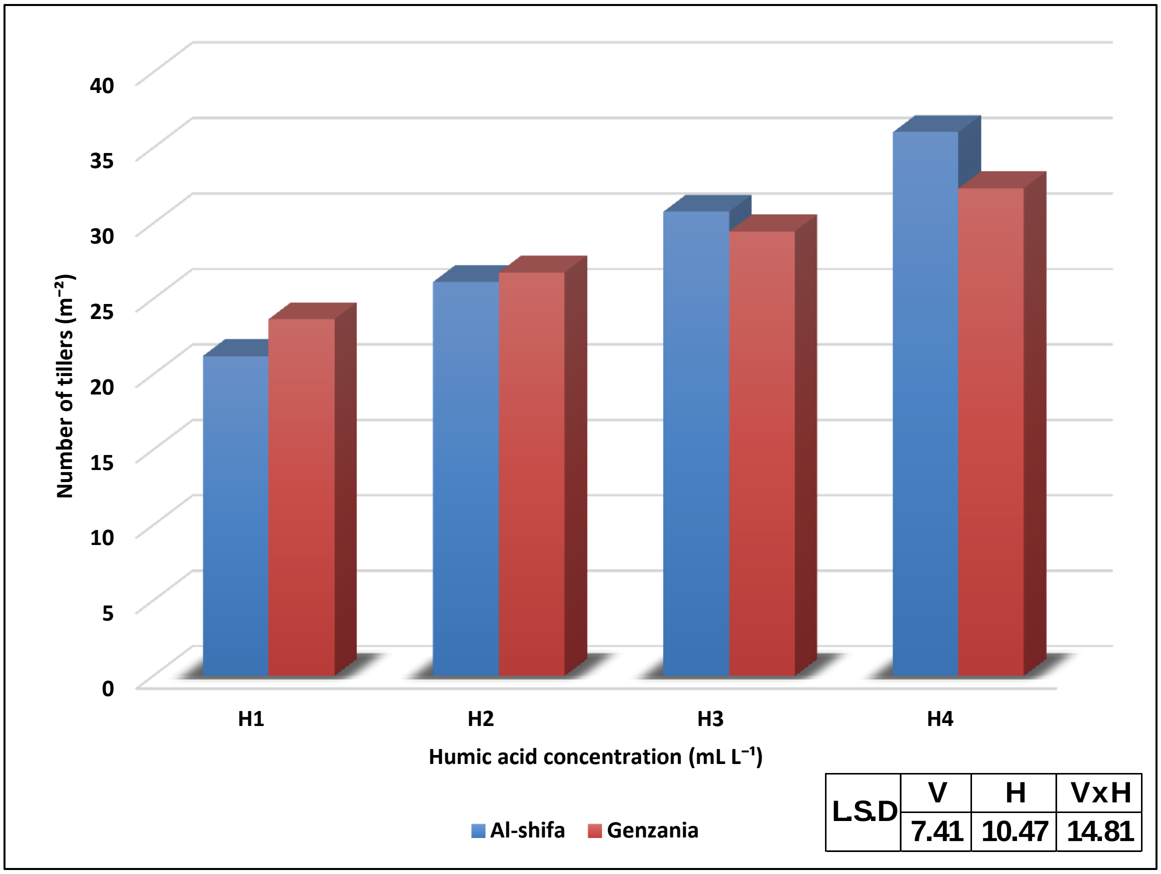


Figure (3). Impacts of foliar application of different levels of Humic acid fertilizer on the Number of Tillers m^{-2} in two oat varieties.

4.

Number of Panicles (m^{-2})

The results presented in Figure 4 indicate that the levels of foliar application of humic acid differed significantly in their effect on the number of panicles. Concentration H4 was superior and produced the highest number of panicles, reaching 449.8 panicles m^{-2}, compared with the control treatment (H1), which recorded 345.9 panicles m^{-2}. The increasing number of panicles may be attributed to the improved availability of nutrients, which enhanced photosynthetic products and consequently increased the flag leaf area. This promoted the initiation and development of tiller primordia and improved their survival, resulting in a larger count of panicles per unit area. This result was consistent with the findings reported by (Al-Hassan ,2017 and Mahato and Kafle ,2018).

Al-shifa variety showed superiority by recording the highest number of panicles, reaching 418.1 panicles m^{-2}, representing an increase of 10.34% over Genzania, which recorded the lowest mean value of 378.9 panicles m^{-2}. This variation among cultivars may be attributed to genetic differences that determine the tillering ability of each variety and its subsequent capacity to convert tillers into fertile panicles through the production of greater amounts of photosynthates (Al-Azzawi et al., 2018). These responses are influenced by a range of morphological and physiological characteristics that vary according to genetic constitution. The superior performance of Al-shifa may be related to its highly tillering growth habit. Regarding the interaction effect, Al-shifa under treatment H4 produced the maximal number of panicles, 487.5 panicles m^{-2}, whereas Genzania under the control treatment (H1) had the lowest number, 345.4 panicles m^{-2} (Figure 4). The significant interaction may be attributed to the individual and combined effects of both factors on this parameter.

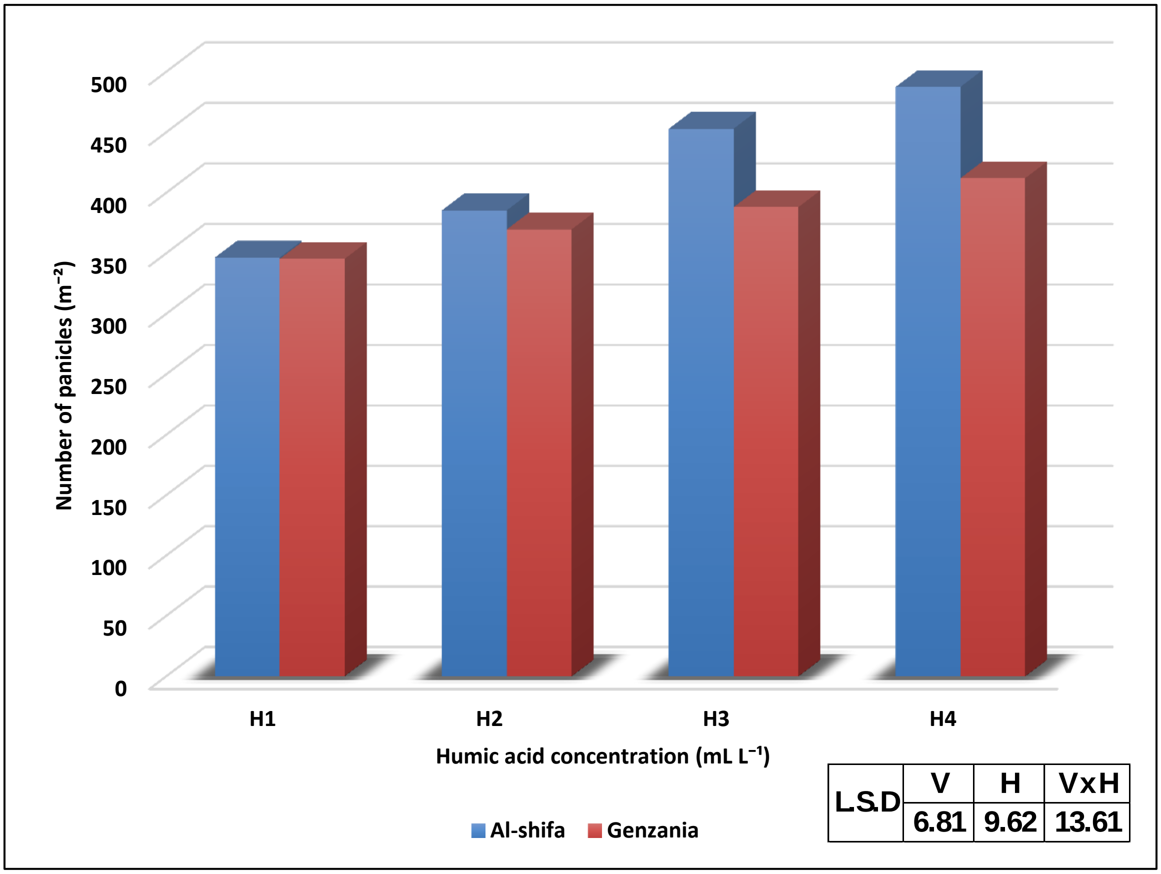


Figure (4). Influence of foliar application of different levels of Humic acid fertilizer on the Number of Panicles m^{-2} in two oat varieties.

5.

Number of Grains per Panicle

The results shown in figure (5) suggest that the treatment H4 was the most effective in producing the higher number of grains per panicle with 44.86 grains $panicle^{-1}$ which is an improvement of 39.66% over the rest of the treatments including the control (H1) which produced the lower number of grains per panicle with 32.12 grains $panicle^{-1}$. The increase could be explained due to the application of humic acid that increased the availability and uptake of the essential nutrients and vegetative growth. This improvement was realized in terms of photosynthetic assimilates generated by the source organs (leaves) and these assisted in providing the sink (developing grains) with nutrients. These results indicate that there may be a partial substitution of mineral fertilization with organic fertilizers because of their positive effect of this parameter. The present findings corroborate the outcomes of Uma Devi et al. (2014) who found higher number of grains per panicle in oat under application of different types of organic fertilizers. There was a wide variation in the number of grains per panicle among varieties. Al-shifa produced the highest number of grains, with a mean of 39.03 grains panicle^{-1}, whereas Genzania recorded the lowest mean value of 38.14 grains panicle^{-1}. These outcomes conform to those of Al-Hajooj and Anis (2018) and Alrubaiee et al. (2019), who indicated that variation among cultivars in this trait is attributable to the fact that the number of grains per inflorescence is a quantitative trait positively associated with both genetic and environmental factors.

The results shown in Figure (5) also revealed that Al-shifa under treatment H4 had the maximal number of grains per panicle 46.09 grains panicle^{-1}, whereas the same cultivar under treatment H1 produced the lowest number, 31.64 grains panicle^{-1}. The availability of nutrients during the stages of panicle initiation and development appears to have had a positive effect on increasing the number of florets per panicle and the number of potential grain sites. Floret development occurs during the period between stem elongation and flag leaf emergence, during which competition for carbohydrates takes place between the main stem and developing florets. Adequate and balanced nutrient availability during this critical period reduces such competition (Davidson and Chevalier, 1992). Moreover, nutrient availability before flowering enhances the readiness of a larger number of florets for successful fertilization and grain formation by promoting the development of floral organs.

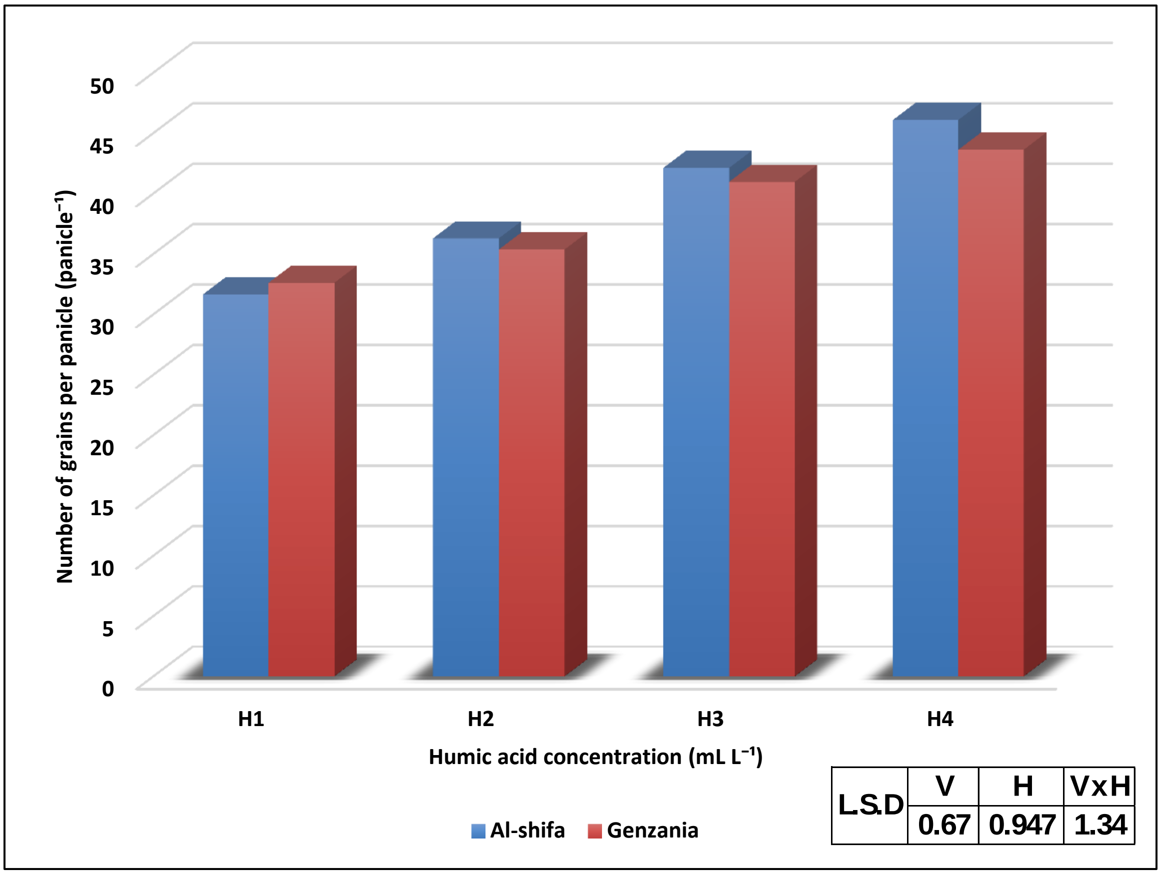


Figure (5). Effect of foliar application of different levels of Humic acid fertilizer on the Number of Grains per panicle in two oat varieties.

6.

1000-Grain Weight (g)

The results presented in Figure (6) indicate that treatment H4 was superior, recording a 1000-grain weight of 49.36 g, representing an increase of 21.72% over the control treatment (H1), that produced the least value of 40.55 g. This increase may be attributed to the vital role of humic substances as bio stimulants, which enhance vegetative growth and improve grain filling through better nutrient absorption and regulation of metabolic processes within the plant. These findings are parallel to those reported by Arjumend et al. (2015), who demonstrated that the application of humic acids resulted in a significant increase in grain weight.

Figure (6) also shows the superiority of Al-shifa, which produced the highest 1000-grain weight of 45.81 g, whereas Genzania recorded the lowest value of 44.50 g. The differences between varieties may be attributed to variation in their efficiency in utilizing photosynthetic assimilates, which enhanced the translocation and accumulation of nutrients in the grains and consequently increased grain weight. These findings are in agreement with those reported by Al-Halfi and Faleh (2017), who confirmed that varieties differ in their responses to bio stimulants according to their genetic efficiency. In addition, 1000-grain weight is considered a highly heritable trait compared with many other yield components and quantitative traits in plants.

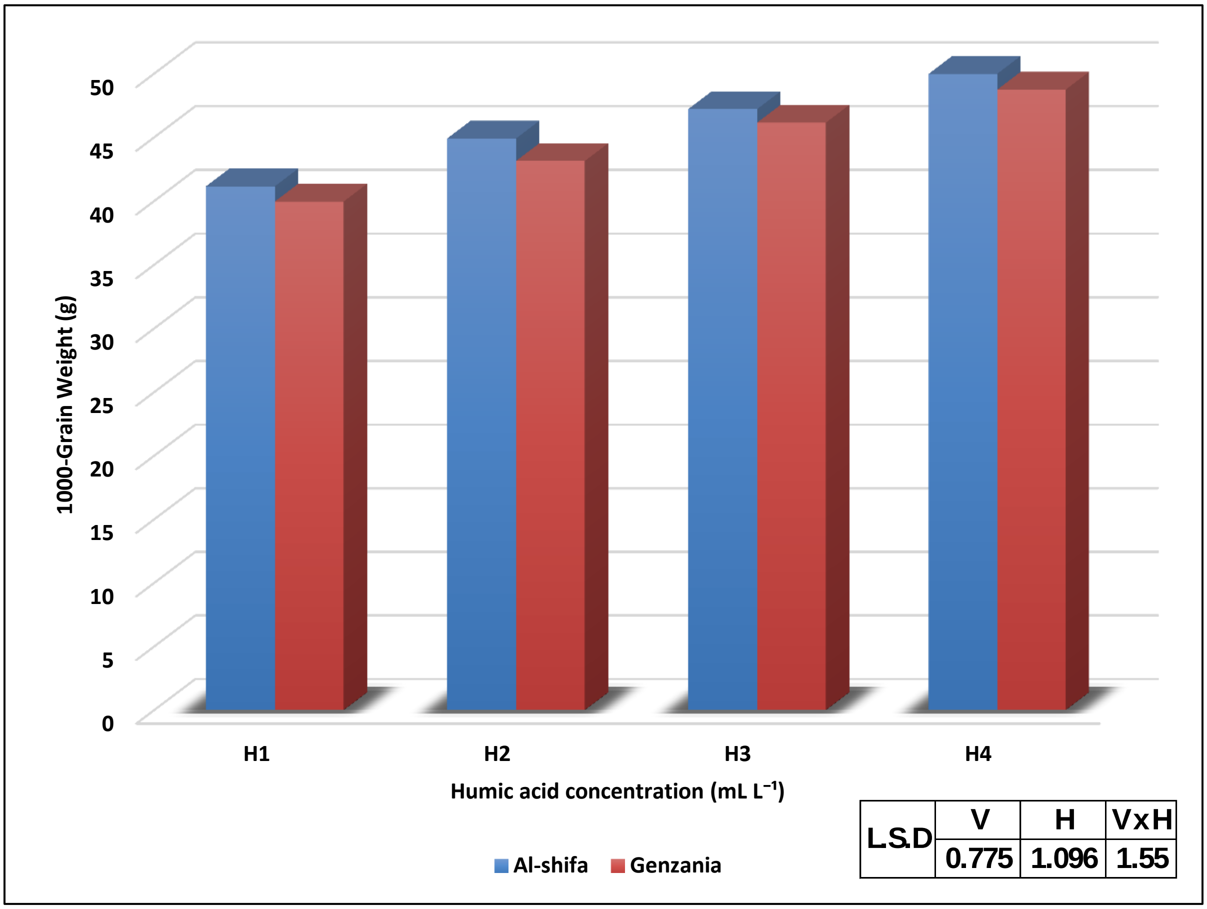
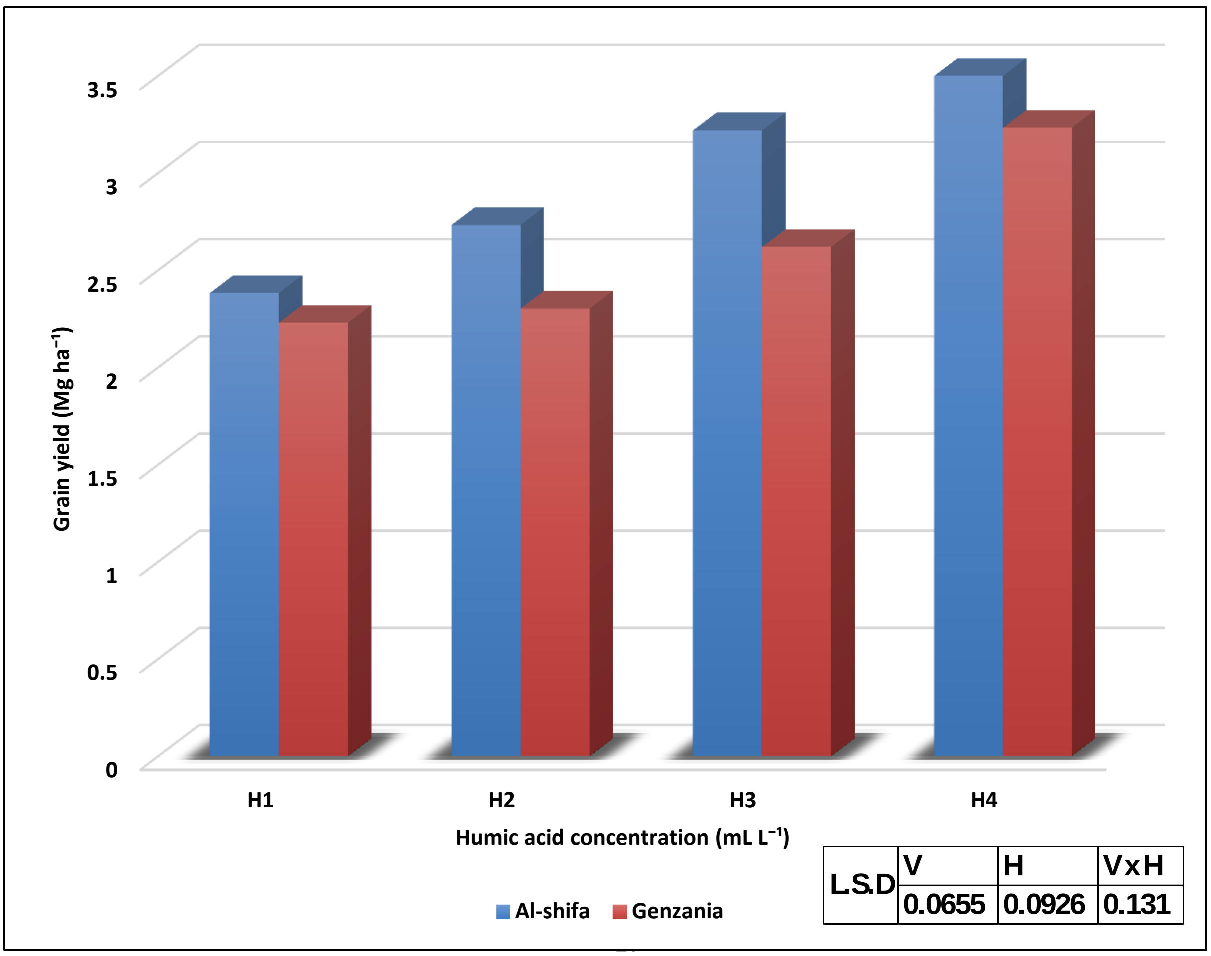


Figure (6). Impact of foliar application of different levels of Humic acid fertilizer on 1000-grain weight (g) of two oat varieties.

7.

Grain Yield (Mg ha^{-1})

The findings presented in Figure (7) show that treatment H4 was superior, recording a grain yield of 3.367 Mg ha^{-1}, representing an increase of 45.94% compared with the control treatment (H1), which produced the lowest yield of 2.307 Mg ha^{-1}. The higher yield in the humic acid treatment compared to the other treatments could be explained by the increase in yield components like the number of panicles per unit area and the number of grains per panicle. The present results are consistent with the findings of Arjumend et al. (2015), who reported that humic acids improve nutrient use efficiency and help in the metabolic function of the plant, resulting in increased productivity. The results also show varieties to be significantly different. The highest grain yield of 2.959 Mg ha^{-1} was obtained from al-shifa while the lowest yield of 2.597 Mg ha^{-1} was obtained from Genzania. This variation among cultivars is due to the difference in yield components which conforms to the findings of Al-Hajooj and Anis (2018) and Alrubaiee et al. (2019) who found significant differences in grain yield among oat varieties. The results presented in Figure (7) showed a differential response of cultivars to fertilizer treatments. Al-shifa under treatment H4 achieved the maximal grain yield, reaching 3.500 Mg ha^{-1}, whereas Genzania under the control treatment (H1) had the lowest yield of 2.230 Mg ha^{-1}.



L.S.D	V	H	VxH
	0.0655	0.0926	0.131

Figure (7). Impact of foliar application of different levels of Humic acid fertilizer on grain yield (Mg ha^{-1}) of two oat varieties.

Conclusion

The results revealed that the combination of humic acid application with Al-shifa was superior in most growth and yield traits of oat. This indicates the positive role of humic acid in improving growth efficiency and increasing productivity, in addition to the genetic efficiency of Al-shifa in responding to the studied factors.

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