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Enhancing vegetative and root productions of four turnip genotypes through varied humic acid fertilizer levels

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Abstract. *Ullah H, Kiran M, Haq F, Waseem K, Nadeem MA, Ullah G, Farid A, Aziz T. 2023. Enhancing vegetative and root productions of four turnip genotypes through varied humic acid fertilizer levels. Cell Biol Dev 7: 67-74.* A meticulously designed pot experiment was conducted to investigate the intricate effects of varying Humic Acid (HA) fertilizer levels on the growth patterns of four distinct turnip genotypes. The trial encompassed an array of HA concentrations, from 0 to 120 Kg/ha, to discern their influence on the vegetative and root aspects of the turnip plants. The outcomes of this comprehensive study unveiled an undeniable impact of HA concentrations on virtually every facet of turnip growth and output. Notably, the pinnacle of performance across several critical parameters, including plant height, leaf area, canopy coverage, leaf count per plant, chlorophyll content in leaves, and both the fresh and dry weights of both leaves and roots, was achieved at the HA concentration of 60 kg/ha. Among the four turnip genotypes scrutinized, the Golden Bal genotype reacted favorably to the HA treatments. With a compelling total yield of 11.79 t/ha, the Golden Bal genotype emerged as a leader in productive response. A noteworthy revelation was the intricate interplay between the specific turnip genotypes and the HA concentrations employed. This interplay significantly affected numerous facets of vegetative development and yield-related attributes. The synergy observed between the moderate HA concentration of 60 Kg/ha and the Golden Bal genotype was particularly striking, resulting in a superior manifestation of various traits compared to alternate genotype-HA combinations. In essence, this research has effectively underscored the pivotal role of varying HA fertilizer levels in steering the trajectory of turnip production. The findings of this study bear valuable implications for optimizing agricultural practices to harness the full potential of turnip cultivation while emphasizing the need for a nuanced understanding of genotype-HA interactions in modern agronomic endeavors.

Keywords: Desi Faisalabad, Golden Bal, humic acid, purple top, turnip productivity, White Globe Vikima F1 (Denmark)

INTRODUCTION

Turnips (*Brassica rapa* L. ssp. rapa) are globally cultivated and cherished for their nutritional value and health benefits (Dejanovic et al. 2021). Packed with phytochemicals like glucosinolates, polyphenols, flavonoids, and phenolic acids, turnips possess antioxidant, enzyme-regulating, and apoptosis-controlling properties. Glucosinolates, sulfur-containing compounds, show promise in anticancer research, while polyphenols and flavonoids are known for their antioxidant prowess (Paul et al. 2019). Consuming turnips offers several health advantages, including liver protection against diabetes-related damage, hepatoprotective effects, and robust antioxidant support. These benefits stem from turnips' phytochemical makeup, effectively neutralizing harmful free radicals, guarding against oxidative damage, inflammation, and specific cancers. Turnips also exhibit potential in managing diabetes and regulating blood lipids. Beyond their nutritional and health perks, turnips serve as subjects of study in diverse domains. Genomic analysis of the turnip mosaic potyvirus (TuMV), a significant brassica crop pathogen, has unveiled its historical spread along Silk Road trade routes, aiding crop protection strategies (Kawakubo et al. 2021). Turnips also hold promise in phytoremediation, actively accumulating heavy metals from contaminated soil. Additionally, traditional medicine has utilized turnips to address various conditions, including headaches, chest complaints, rheumatism, and gonorrhea. Moreover, there have been reports of turnip-derived syrup associated with memory enhancement. The availability of nutrients significantly impacts plant growth, production, and the various components of plants (Etesami and Adl 2020). Increased nitrogen levels (N) have enhanced seed production, total dry matter, and harvested index in multiple genotypes of *B. napus* and *B. juncea* (Zou et al. 2020). Moreover, in canola and various other *Brassica* species, phosphorus (P) supplementation has a dual effect, enhancing P absorption and producing remarkable improvements in plant parts (Wang et al. 2021). Organic products, driven by philosophical choices, convictions, commercial needs, or consumer demands, exclude or prohibit conventional agricultural inputs commonly used in modern farming practices. In the context of plant growth, development, and the production of organic compounds, the content of macro- and microelements in the soil becomes enriched by applying organic fertilizers. Furthermore, utilizing these organic materials promotes human health and is economically advantageous, boosting farmers' income. The literature strongly supports the role of Humic Substances (HS) in promoting plant growth (Canellas and Olivares 2014). In a random-effects meta-analysis, Rose et al. (2014) found that applying HS from external sources resulted in an approximately 22% increase in shoot and root dry weights across various plant species. It is important to emphasize that plant responses to HS are highly dependent on factors such as plant species, developmental stage, application method and rate, HS source, and the prevailing management practices and environmental conditions. Through mitigating the adverse impacts of extreme soil stress, the constituents found in plants and soil play a pivotal role in fostering plant development, enhancing soil fertility and health, increasing plant yield, and improving nutrient availability. Organic manures lies an active group consisting of filvic and humic acids, which play a vital role in soil by facilitating interactions among various elements through chelation and complexation, thereby keeping them in bound forms (Rashad et al. 2022; Hanc et al. 2019). The crucial significance of the concentration of macro and microelements in the soil is enhanced by using organic fertilizers for plant growth, development, and the synthesis of organic compounds (Bhatt et al. 2019). Furthermore, the application of higher rates of organic manure, up to 40 m^3 per fed, resulted in the highest total yield of radish roots, increased levels of crude protein, nitrogen, phosphorus, and potassium, and the most substantial seed output (Gomez et al. 2021). Additionally, the utilization of organic materials poses no harm to human health. Another research demonstrated that applying organic compost enhances soil fertility in turnip plants while mitigating the detrimental effects of chemical fertilizers as the enrichment of soil with macro and microelements through the application of organic fertilizers plays a crucial role in facilitating plant growth, development, and the synthesis of organic compounds (Monfared et al. 2023). This research briefly explains the appropriate levels of HA for the effective growth and yield of four genotypes of turnip.

MATERIALS AND METHOD

During November 2012 to April 2022, four turnip genotypes' root production and vegetative growth were investigated in a pot experiment that explored the effects of various humic acid treatments. The pot size measurments were (Length: 45.72 cm and width: 30.48 cm, respectively). Factor A consisted of seven distinct humic acid treatments (HAT1: 0, HAT2: 20, HAT3: 40, HAT4: 60, HAT5: 80, HAT6: 100 and HAT7: 120 kg/ha, while Factor B comprised four different genotypes (V1: Desi Faisalabad, V2: Vikima F1 (Denmark), V3: Purple white top globe and V4: Golden Bal). Three of four geneotypes, V2, V3 and V4 were hybride varieties. The experiment followed a factorial Completely Randomized Design (CRD) with two components. Each treatment was administered three times in total. Pots were filled with sun-dried soil, and specific levels of Humic Acid (HA) and appropriate NPK dosages of 120:65:100 kg/ha were incorporated into the pots. During November, the tested turnip varieties' seeds were sown in containers. Four seeds were sown within each container in a manner of equal spacing. The pots were regularly irrigated, and the soil was kept adequately moist after seed sowing to ensure proper germination. Additional cultural tasks, such as timely weeding, providing water, spraying, and applying pesticides, were performed as necessary. After harvesting, different parameters were investigated, such as Height of Plant (HP), Canopy Cover Percentage (CCP), Number of Leaves on Plant (NLP), Leaf Area (LA), Chlorophyll Content (CC), Fresh Leaf Weight (FLW), Dry Leaf Mass (DLM), Fresh Root Weight (FRW), Dry Root Mass (DRM) and Total Yield (TY).

Statistical analysis

A thorough statistical analysis was conducted to ascertain the treatment combinations' significance on all the examined parameters. This analysis was conducted using the statistical software "Statistix Version 8.1".

RESULTS AND DISCUSSION

Height of Plant (HP)

The height of turnip plants is impacted by various levels of HA, genotypes, and their interactions, as depicted in Figure 1.A, which offers significant insights. As indicated by the findings in Figure 1.A, there were significant variations among all the humic acid treatments in terms of HP. The recorded values ranged from 22.70 to 17.52 cm. The turnip plant treated with HAT4 exhibited the tallest height of 22.70 cm, tracked by HAT3 (40 kg/ha), HAT7, HAT2, HAT5, and HATT6 with heights of 21.19 cm, 19.63 cm, 18.35 cm, 17.64 cm, and 17.90 cm, respectively. Among the treatments, HAT1 (0 kg/ha) exhibited the lowest HP results at 17.52 cm, and it is worth noting that all of these treatments displayed significant differences. As the Humic Acid (HA) levels increased, HP showed a positive response up to a certain threshold (60 Kg/ha). However, an inverse relationship emerged beyond this threshold, and higher HA levels had a detrimental effect on HP. Additionally, Rose et al. (2014) observed similar outcomes, reporting a 22% increase in plant shoot growth with the application of exogenous HA fertilizers. The HP displayed significant variation among different genotypes, as depicted in Figure 1.A. The height range of the turnip plants varied between 17.85 cm and 20.81 cm. Remarkably, the tallest plants, measuring 20.81 cm, were observed in (V4), followed by V3 (19.63), V2 (19.43), and V1 (17.85 cm) in height. In Figure 1.A, the evaluation of the interaction between turnip genotypes and HA levels revealed significant differences in HP. The observed heights ranged from 23.83 to 14.40 cm. The maximum HP of 23.83 cm was observed for HAT4 V4 , and this treatment displayed contrasting behavior. Similar findings, with HP of 18.67, 18.23, 18.10, and 17.63 cm, respectively, were observed in HAT5 V3, HAT6 V1, HAT2V2, and HAT5 V4. In contrast, the lowest HP response (14.40 cm) was observed in HAT1 V1, and the interactions exhibited distinct behavior. In terms of HP, all other treatments yielded inconsistent results.

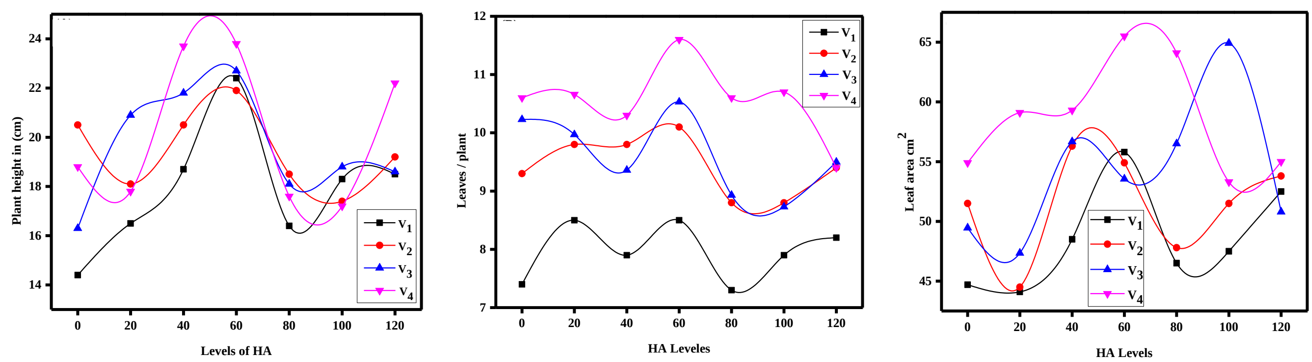
Number of Leaves/Plant (NLP)

The leaf count of turnip plants is influenced by different concentrations of HA, turnip genotypes, and their interactions, as depicted in Figure 1.B.. The data in Figure 1.B clearly demonstrates significant distinctions among all the Humic Acid (HA) treatments concerning the NLP, with values ranging between 10.17 and 9.02. HAT4 exhibited the highest NLP (10.17), followed by HAT2, HAT1, HAT3, HAT5 and HAT6, with 9.75, 9.38, 9.37, 9.12, and 9.05 NLP. All the treatments displayed statistically significant differences except for the smallest result regarding the NLP (9.02), observed in the HAT1. The response plant^{-1} to increasing levels of Humic Acid (HA) was initially positive, leading to taller plant growth until a certain HA level was reached. Beyond that point, further increments in HA had a detrimental effect, resulting in a decrease in the NLP (60 kg/ha). Similar findings were reported by Gutiérrez et al. (2011), who observed an increase in NLP in root crops with higher concentrations of HA. Regarding HP, significant variations were observed for multiple genotypes, as depicted in Figure 1.B. The NLP ranged from 10.58 to 8.01. Remarkably, the highest NLP (10.58) was exhibited by genotype (V4), followed by (V3) with 9.61 NLP, (V2) with 9.45 NLP, and (V1) with 8.01 NLP. Furthermore, Subedi et al. (2018) made an interesting discovery regarding the vegetative development of radish cultivars. In various aspects, including the NPL, Mino Early Long outperformed other radish cultivars, as found by the researchers. Figure 1.B revealed a significant pattern for the NPL concerning the interaction between HA levels and turnip genotypes. Plant 1 The maximum and minimum values of 11.60 and 7.30 of NLP were recorded for V4 to V1. The highest NPL (11.60) was notably observed in the HAT4 V4 treatment, which stood in stark contrast to the others, displaying a substantial divergence in behavior. HAT3 V2, HAT3 V3, and HAT5 V3 displayed remarkably similar results, with 9.86, 9.36, and 8.93 NLP, respectively. On the other hand, the lowest response for the NLP (7.30) was observed in the HAT1 V1 treatment, and the interactions exhibited distinct behavioral patterns. As for plant height, all other treatments yielded inconsistent results.

Leaf Area (LA)

The information presented in Figure 1.C holds significant importance in understanding the impact of different combinations of humic acid treatments and cultivars on turnips' LA (cm^2). The data from Figure 1.C clearly demonstrates substantial variations in LA among all the Humic Acid (HA) treatments. The maximum and minimum values for LA were observed to be ranged from 65.16 to 44.06 cm^2, respectively. The recorded values ranged from 65.16 to 44.06 cm^2. HAT4 exhibited the largest LA, measuring 65.16 cm^2, followed by HAT6 (64.92), HAT5 (64.1), HAT3 (59. 29), HAT7 (55.0), and HAT1 (54.9 cm^2). Conversely, the least LA (54.9 cm^2) was observed in HAT1 HAT2, and these treatments displayed noticeable distinctions. It was observed that increasing the levels of humic acid led to a corresponding increase in LA (cm^2) until a certain threshold (60 kg/ha) was reached. Beyond that point, further increments in humic acid had a negative impact, resulting in a decline in LA. These findings align with previous studies conducted by Ahmad et al. (2013), who also obtained similar results, indicating that higher levels of humic acid contribute to larger leaves in root vegetables.

Based on Figure 1.C, the LA exhibited significant variations among different genotypes. The range of LA was between 58.43 and 48.46 cm^2. Notably, (V4) recorded the highest LA data (58.43 cm^2), followed by V3 (54.18), V2 (51.46), and V1 (48.46 cm^2). In investigating the interaction between turnip genotypes and HA concentrations, Figure 1.C demonstrated prominent patterns concerning LA. The obtained data showed a maximum value of 65.16 cm2 and minimum value of 44.06 cm^2 for LA. Remarkably, within the HAT4 V4 treatment, the maximum LA reached 65.16 cm^2, signifying a profound interaction effect. Additional remarkable findings encompassed measurements of 54.95 cm^2, 53.75 cm^2, and 53.56 cm^2 within the HAT4V2, HAT7V2, and HAT4V3 treatments, respectively. Conversely, the most minimal LA response (44.06 cm^2) was observed in the HAT2V1 treatment, showcasing distinct behavioral patterns in these interactions. It is imperative to highlight that all other treatments yielded incongruous outcomes concerning LA.



A B C

Figure 1. Response of (A) HP, (B) NLP, and (C) LA towards different levels of HA

Canopy Cover (CC) %

Figure 2.A encompasses crucial data regarding the proportion of the turnip plant's CC affected by different concentrations of humic acid, genotypes, and their interactions. The data presented in Figure 2.A revealed that all of the Humic Acid (HA) treatments displayed significantly distinct CC. The recorded values ranged from 63.8 to 17.36 % %. The HAT4 treatment exhibited the highest CC (63.8 %), followed by HAT7, HAT6, HAT3, HAT5 , and HAT2 with (54.60), (54.6), (51.66), (51.6), and (46.96 %). Although HAT1 showed the lowest CC data (34.30 %), it is important to note that these treatments displayed noticeable differences. Observing the response of canopy cover to increasing HA levels, it was observed that the CC increased up to a specific HA concentration (60 Kg/ha), beyond which it began to decline, negatively impacting the CC. Ahmad et al. (2013), Ahmed et al. (2013) and Khan et al. (2018) conducted research that demonstrated the positive influence of humic acid on leaf area and vegetative development in radish. Similarly, Figure 2.A provides significant insights into the behavior of CC among various genotypes. The observed values ranged from 63.8 to 17.36 %. Notably, (V4) displayed the highest CC data (63.8 %), followed by V3 (46.96), V2 (33.83), and V1 (31.23 %). Concerning the interplay between turnip genotypes and HA levels, Figure 2.A disclosed marked patterns regarding the CC. The recorded data ranged between 63.8 and 17.36 %. Notably, the highest CC (63.8 %) was significantly observed in the HAT4V4 treatment, indicating a significant interaction. Comparatively similar results were obtained in HAT1 V2, HAT4 V1, and HAT3 V2, with percentages of 31.66, 31.23, and 30.76 %, respectively. On the other hand, the lowest response in terms of CC (17.36 %) was observed in the HAT1 V1 treatment, and these interactions exhibited substantially distinct behaviors. It is important to note that all other treatments yielded mediocre results regarding CC.

Leaf Chlorophyll Content (LCC)

The data in Figure 2.B is significant in elucidating the ramifications of varying HA levels, genotypes, and their interactions on the LCC of turnips. According to the data in Figure 2.B, all HA treatments displayed substantial variations in LCC from one another. The recorded statistics ranged from 61.80 to 30.0. The highest LCC (61.80) was observed in the HAT4 treatment, while the values for HAT3, HAT2, HAT7, and HAT6, an were 57.76, 57.33, 57.10, and 52.26, respectively. Despite the HAT1 treatment manifesting the lowest LCC values at 30.0, it is imperative to underscore the salient disparities observed among all these treatments. The association amid the escalation of HA levels and LCC unraveled a discernable trend, wherein it initially amplified the chlorophyll content up to a designated HA level of 60 kg/ha. However, beyond that threshold, the LCC began to decline, having a negative impact. This observation aligns with previous studies conducted by Ahmad et al. (2013) which also reported similar findings indicating that humic acid promotes increased development, enhanced leaf area, and elevated LCC of root vegetables. Based on Figure 2.B, the LCC exhibited significant variations among different genotypes. The range of LCC spanned from 61.80 to 30.0. Remarkably, (V4) registered the greatest LCC value of 61.80, succeeded by V3 (51.76), V1 (47.13), and V2 (46.10).

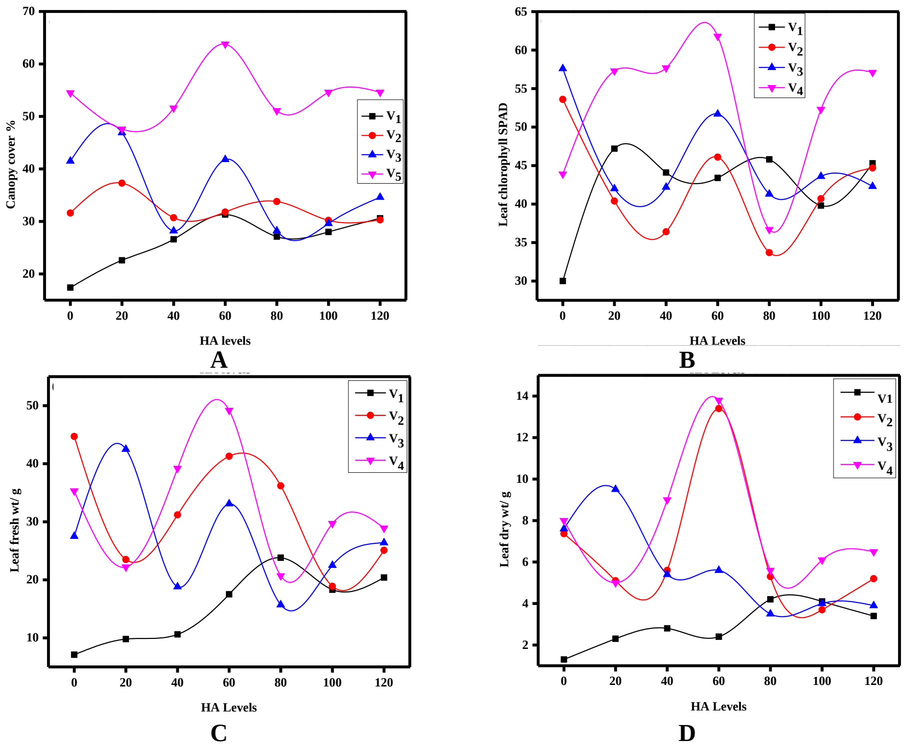


Figure 2. Impact of HA levels on (A) CC %, (B) LC, (C) LFW, and (D) LDW

Dongarwar et al. (2017) described similar findings, stating that the Japanese White variety had the highest observed LCC, followed by the variety Arka Nishant. It is important to note that the amount of chlorophyll in a leaf can vary depending on the leaf's type, size, and genotypic characteristics. Furthermore, a substantial pattern was observed for LCC when analyzing the interplay between HA levels and turnip genotypes, as illustrated in Figure 2.B. The data varied from maximum value of 61.80 to minimum valueof 30.0 for LCC. The highest LCC (61.80) was significantly observed in the HA4 V4 treatment, indicating a significant interaction among the factors. Comparatively, HAT7 V3, HAT3 V3, and HAT2 V3 treatments produced results of 42.23, 42.16, and 42.0, respectively. On the contrary, the HAT1 V1 interaction exhibited the least LCC response at 30.0, and these interactions demonstrated highly distinct behaviors from each other. Notably, all the other treatments resulted in mediocre outcomes in terms of LCC.

Leaf Fresh Weight (LFW)

The data provided in Figure 2.C regarding the number of Turnip LFW (g) and its relationship with various HA Levels, Genotypes, and their interaction holds significant importance. The data presented in Figure 2.C demonstrated substantial variations in LFW among the different Humic Acid (HA) treatments (g). The recorded values ranged from 49.16 to 7.09 grams. The highest LFW of 49.16 grams was observed in the HAT4, followed by values of 42.49, 41.33, 39.12, and 36.14 grams for the HAT2, HAT4 , HAT3, and HAT5, respectively. Conversely, the HAT1 exhibited the lowest results in terms of LFW, with a value of 7.09 grams. Significantly, each of these treatments exhibited notable statistical dissimilarities from one another. Vitally, all of these treatments manifested significant statistical distinctions from one another. The reaction of LFW in response to escalating HA levels revealed an intriguing pattern. Observations revealed an augmentation in LFW up to a particular HA level of 60 kg/ha. However, the LFW started to decline beyond that point, resulting in a negative impact. Furthermore, Figure 2.C displayed significant variations in LFW among different genotypes. The data showed maximum (49.16) and minimum (7.09) values for LFW, respectively. The (V4) exhibited the greatest LFW of 49.16 g, while V3 (42.49), V2 (41.33), and V1 (23.80). These discoveries maintain congruence with the investigations undertaken by Dongarwar et al. (2017) who ascertained that the Pusa Reshmi cultivar exhibited significantly superior maximum LFW in comparison to other cultivars (Mani and Anburani 2018). Figure 2.C elucidated substantial divergences in the LFW behavior when analyzing the interplay between HA concentrations and turnip genotypes. The observed data spanned a range from 49.16 g to 7.09 g. The HAT4 V4 treatment demonstrated the highest LFW of 49.16 grams, signifying a substantial interaction between the factors. Comparatively, HAT5 V1, HAT2 V2, and HAT6 V3 exhibited values of 23.80, 23.45, and 22.54 grams, respectively, which were noticeably similar. On the other hand, the lowest response in terms of LFW (7.09 g) was reported in the HAT1 V1 treatment, and these interactions displayed distinctly different behaviors. It is worth noting that all the other treatments yielded inconsistent results in terms of LFW.

Leaf Dry Weight (LDW)

Figure 2.D signifies critical data regarding the implications of varying HA concentrations, genotypes, and their influences on the LDW. The data provided in Figure 2.D clearly demonstrates significant variations in LDW among all the HA treatments. The maxium and minimum values of 13.79 and 1.28 g were LDW. The HAT4 treatment exhibited the highest LDW (13.79 g), followed by the HAT2, HAT3, HAT7, HAT6, and HAT5 treatments with 9.50, 9.0, 6.46, 6.10, and 5.55 grams, respectively. Conversely, the HAT1 treatment had the lowest data for LDW (1.28 g). Importantly, all of these treatments displayed noticeable differences from one another. The response of LDW to increasing HA levels revealed an interesting pattern. It was observed that HA enhanced LDW up to a specific HA level (60 kg/ha). However, there was a decline in LDW beyond that threshold, resulting in a negative impact. This observation is consistent with a previous study conducted by Esringü et al. (2016) demonstrating HA's positive effect on LDW in Walleriana and its overall beneficial impact (Ibrahim et al. 2016). Furthermore, as indicated in Figure 2.D, the LDW displayed significant variations among different genotypes. The range of data observed was from 13.79 to 1.28 g. Notably, (V4) exhibited the highest LDW (13.79 g), followed by V2 (13.35), V3 (9.50) and V1 (4.16 g). These findings are consistent with the investigations carried out by Abdel (2016), who reported analogous outcomes accentuating that the "Cheongdae" and "Chunha" radish cultivars demonstrated elevated LDW and greater percentages of dry matter in comparison to other cultivars. Figure 2.D unveiled substantial discrepancies in the LDW behavior when analyzing the interaction between turnip genotypes and humic acid concentrations. The data ranged from 13.79 to 1.28 g. Notably, the maximum LDW of 13.79 grams was significantly observed in the HAT4 V4 treatment, indicating a significant interaction among the factors. Comparatively, HAT4 V3, HAT3 V3, and HAT5 V2 exhibited LDW results of 5.60, 5.40, and 5.23 grams, respectively. On the other hand, the lowest response in terms of LDW (1.28 grams) was reported in the HAT1 V1 treatment, and these interactions displayed noticeably distinct behaviors. It is important to note that all the other treatments yielded inconsistent results regarding LDW.

Root Fresh Weight (RFW)

Figure 3.A provides crucial insights into the impact of different humic acid levels, genotypes, and their interactions on the RFW of turnip. The data presented in Figure 3.A clearly indicates substantial variations in RFW among the different HA treatments. The obtained results showed a maximum and minimum values of 161.35 and 11.74 g, respectively. The HAT4 treatment exhibited the highest RFW (161.35 g), followed by the HAT3, HAT5, HAT6, HAT2, and HAT7 treatments with 113.07, 86.18, 80.21, 77.13, and 66.42 grams, respectively. Conversely,

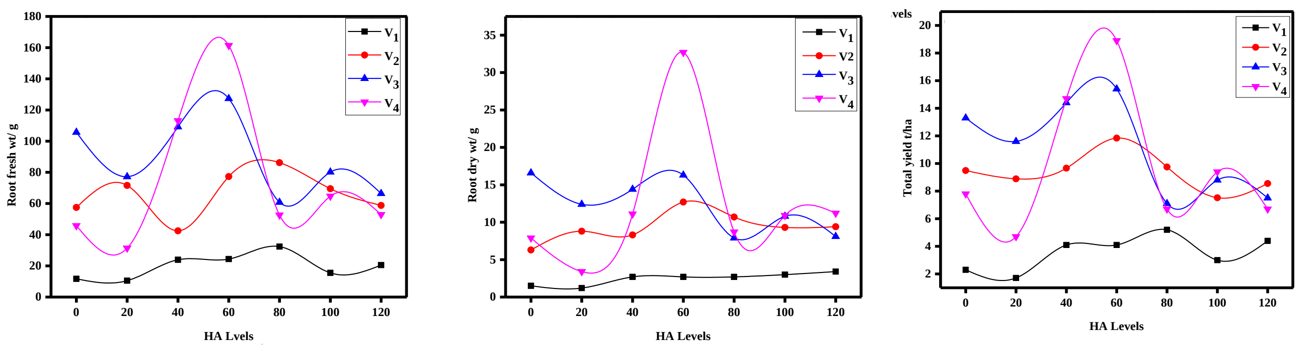
the HAT7 treatment recorded the lowest results for RFW (66.42 g). Importantly, all of these treatments displayed statistical differences from one another. Furthermore, the response of RFW to increasing HA levels revealed an interesting pattern. It was observed that up to a specific HA level (60 kg/ha), there was an enhancement in RFW. However, beyond that point, RFW began to decline, resulting in a negative impact. Similar findings have been reported in studies conducted by Heba et al. (2014) on sugar beet, and Shafeek et al. on Japanese. These studies support the observations made in Figure 3.A regarding the significant behavior of RFW across various genotypes. The data in Figure 3.A exhibited a range of 161.35 to 11.74 g for RFW. Notably, (V4) exhibited the highest RFW data (161.35 g), followed by V3 (127.28), V2 (86.18), and V1 (32.43 g). The interaction between HA concentrations and turnip genotypes, as depicted in Figure 3.A, revealed significant variations in the behavior of RFW. The data ranged from 161.35 to 10.48 g. Notably, the maximum RFW of 161.35 g was significantly observed in the HAT4 V4 treatment, indicating a significant interaction among the factors. Comparatively, HAT2 V3, HAT2 V3, and HAT4 V2 exhibited 71.63, 77.13, and 77.27 g, respectively, which were noticeably comparable. On the other hand, the lowest response in terms of RFW (10.48 g) was reported in the HAT2 V1 treatment, and these interactions displayed distinctly different behaviors. It is important to note that all the other treatments yielded inconsistent results in terms of RFW.

Root Dry Weight (RDW)

Figure 3.B provides crucial insights into the impact of different humic acid concentrations, genotypes, and their interactions on the RDW of turnip roots. The data presented in Figure 3.B clearly demonstrates significant variations in RDW among all the Humic Acid (HA) treatments (g). The maximumand minimum values of RDW were recorded from 32.67 to 1.51 g The HAT4 treatment exhibited the highest RDW (32.67 g), followed by the HAT3, HAT2 , HAT7 , HAT6 , and HAT5 treatments with 14.39 , 12.36 , 11.13 , 10.82 , and 10.7 grams, respectively. Conversely, the HAT2 treatment recorded the lowest results for RDW (10.7 g). Importantly, all of these treatments displayed statistical differences from one another. The response of RDW to increasing HA levels revealed an intriguing pattern. It was observed that up to a specific HA level (60 kg/ha), there was an increase in RDW. However, the RDW started to decline beyond that threshold, resulting in a negative impact. These findings align with similar observations made in studies conducted by Heba et al. (2014) on sugar beet. Furthermore, as indicated in Figure 3.B, the RDW displayed significant variations among different genotypes. The data ranged from 32.67 to 1.51 g. Notably, (V4) exhibited the highest RDW data (32.67 g), followed by V3 (14.39), V2 (12.76) and V1 (3.40 g). These findings further support the studies mentioned above and highlight the impact of genotypes on RDW. The interaction between turnip genotypes and HA concentrations, as depicted in Figure 3.B, revealed significant variations in the behavior of RDW. The data ranged from 32.67 to 1.51 g. Notably, the maximum RDW of 32.67 g was substantially observed in the HAT4 V4 treatment, indicating a significant interaction among the factors. Comparatively, HAT7 V2, HAT6 V2, and HAT2 V2 exhibited root dry weight results of 9.36, 9.32, and 8.80 g, respectively. On the other hand, the lowest response regarding RDW (1.19 g) was reported in the HAT2 V1 treatment, and these interactions displayed noticeably distinct behaviors. It is important to note that all the other treatments yielded inconsistent results in terms of RDW.

Total Yield (TY)

Figure 3.C presents invaluable information regarding the influence of different HA levels, genotypes, and their interactions on turnip TY (t/ha). The data presented in Figure 3.C clearly demonstrate the significant variations in average yields (t/ha) among the various HA treatments. The recorded maximum and minimum values for TY were ranged from 18.91 to 1.71 (t/ha). Notably, the HAT4 crop exhibited the highest TY of 18.91 t/ha, followed by the HAT3, HAT2 , HAT5, HAT6, and HAT7 crops with yields of 14.76, 11.56, 9.75, 9.36, and 8.55 t/ha, respectively. These results highlight the substantial differences in turnip TY among the different treatments. The obtained data indicated that HAT7 exhibited the lowest TY (8.55 t/ha), and it was evident that all of these treatments significantly differed. The response of TY to increasing HA levels showed a positive trend up to a specific HA level (60 kg/ha).



A B C

Figure 3. Effect of HA doses on (A) RFE, (B) RDW, and (C) TY

However, beyond that threshold, the total yield began to decline, negatively impacting the TY. Interestingly, the results demonstrated that adding organic manure significantly enhanced the total root output and the physical quality of the roots compared to the untreated control. This highlights the advantage of incorporating organic compost manure alongside fertilizers, surpassing the benefits of using fresh or dry manure alone. The total yield (t/ha) exhibited significant variations among several genotypes, as highlighted in Figure 3.C. The recorded data ranged from 18.91 to 1.71 tonnes per hectare (t/ha). Notably, (V4) achieved the highest TY (18.91 t/ha), followed by V3 (15.37), V2 (11.84) and V1 (5.22 t/ha). Regarding the interaction between HA concentrations and turnip genotypes, Figure 3.C revealed significant behavior about the TY. The data ranged from 18.91 to 1.71 t/ha. Remarkably, the highest TY of 18.91 t/ha was significantly observed in the HAT4 V4 treatment, indicating a significant interaction among the factors. Moreover, 7.52, 7.48, and 7.11 t/ha were also observed in the HAT6 V2, HAT7 V3, and HAT5 V3 treatments, respectively. Conversely, the HAT2 V1 interaction demonstrated the lowest response regarding TY, with a 1.71 t/ha value. It is important to note that these interactions exhibited statistically distinct behaviors. For the remaining treatments, the TY values fell within the intermediate ranges.

In conclusion, in light of the conducted investigation, many inferences can be derived. Firstly, using humic acid at a precise concentration of 60 Kg/ha greatly impacted turnip growth and yield. This intermediary level led to the utmost values in a myriad of growth parameters, encompassing plant height, leaf quantity per plant, leaf expanse, canopy coverage percentage, leaf chlorophyll content, root mass in both fresh and desiccated states, leaf weight when fresh or desiccated, and total yield per hectare.

Secondly, amidst the scrutinized turnip genotypes, the Golden Bal genotype demonstrated unparalleled performance across all gauged criteria. This particular genotype consistently outperformed its counterparts in terms of both vegetative and reproductive characteristics, unequivocally attesting to its superiority concerning growth and yield potential. Moreover, the interplay between humic acid concentrations and turnip genotypes significantly influenced growth and production outcomes. The amalgamation of the Golden Bal genotype with humic acid administered at 60 Kg/ha concentration consistently yielded the most favorable results across all measured parameters. This synergistic interrelation significantly augmented turnip growth and productivity.

Based upon these discerned outcomes, it is strongly advised to cultivate the Golden Bal turnip genotype while concurrently applying humic acid at the prescribed 60 kg/ha concentration to optimize yield within the distinct agroclimatic milieu of Dera Ismail Khan. This well-established combination has unequivocally showcased its profound effectiveness in fostering desirable growth attributes and maximizing the overall productivity of turnip cultivation.

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