Effect of Humic Acid on the Seed Germination, Plantlet and Seedling Growth of Summer Vegetables

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Article Info

ISSN (online): 3049-0588
Volume: 02
Issue: 04
July - August 2025
Received: 18-05-2025
Accepted: 21-06-2025
Published: 04-07-2025
Page No: 43-50

Abstract
The application of humic acid (HA) as a biostimulant in vegetable production has gained attention for its potential to enhance plant growth, soil health, and nutrient availability. This study investigated the effects of different HA concentrations (0, 4, 8, and 12 g/kg) on seed germination, seedling growth, and physiological parameters of cucumber, pumpkin, okra, brinjal (eggplant), and tomato under controlled conditions. Results indicated that HA application significantly influenced germination rates, plant height, leaf number, root development, and flowering patterns in a dose- and species-dependent manner. Lower HA concentrations (4 g/kg) improved germination speed in cucumber, pumpkin, and okra, whereas higher doses (12 g/kg) delayed germination or caused seedling mortality in okra and tomato. Root proliferation was enhanced across species, with the highest root numbers observed at 12 g/kg in cucumber and pumpkin. However, excessive HA (12 g/kg) adversely affected okra and tomato, leading to stunted growth or plant death. Brinjal seedlings showed moderate growth improvements with HA, while tomato seedlings exhibited delayed flowering under HA treatment. The findings suggest that optimal HA doses vary by crop species, with moderate concentrations (4–8 g/kg) generally promoting growth, while higher doses may induce stress. This study highlights the importance of tailored HA application strategies to maximize benefits in sustainable vegetable production.

DOI: https://doi.org/10.54660/GARJ.2025.2.4.43-50

Keywords: Humic Acid, Seed Germination, Summer Vegetables, Root Development, Sustainable Agriculture

Introduction

Humic acids play several important roles such as, increase soil physical and biochemical activities by improving structure, texture, water holding capacity (WHC), and microbial population [1, 2, 3] increase soil nutrients availability, especially micronutrients by chelating and co-transporting micronutrients to plants [4]. Humic acids also increase crop growth by increasing plant growth promoting hormones such as auxin and cytokine, which aid in stress resistance. Although high humic acid doses are associated with enhanced soil physical characteristics [5], humic acid application can have inconsistent results on yield, possibly due to the different humic acid biological origins [6].

Humic acid application has been reported to increase microbial population and activities [7, 8]. The external sources of HS are mostly commercially produced from soils, coal, lignite, and organic materials [5, 4].

The application of humic acid has been reported to have positive effects on the texture and structure of degraded soils [9, 4]. Soil structural stability has been attributed to increased adsorption of humic acid onto clay surfaces [10]. The application of potassium humate increased aggregate stability in both bulk loamy acidic and sodic soils in a controlled study [11].

The use of humic acid as a bio-stimulant in horticultural crops is rapidly gaining attention as a key sustainable practice. When integrated with other agricultural methods, humic acid has the potential to enhance crop productivity and system efficiency while simultaneously reducing the environmental footprint of farming. A range of humic acid-based formulations are available, offering promising applications as biologically active compounds within modern sustainable agriculture [12].

Vegetable crops, known for their high nutrient demands, require substantial inputs to maintain optimal growth. This has driven the exploration of organic alternatives that can partially or fully replace conventional fertilizers. Among these, humic acid stands out as a valuable option for promoting sustainable vegetable production. By improving soil health and helping maintain a balance of plant nutrients, humic acid contributes to a more resilient and efficient growing environment. Though humic acids are not classified as traditional fertilizers, since they do not directly supply nutrients in a defined chemical form, they play a crucial role in enhancing soil structure, microbial activity, and plant metabolism, ultimately supporting healthier and more productive crops [13].

As vegetable is one of the most important requirements to fulfil our dietary needs, so its increased production as well as to maintain its quality, the nutrients application and their availability to the plant play very important role. Application of artificial fertilizers and organic manures/supplements usually fulfill all the required major & minor nutrients necessary for plant growth. Beside all these, the use of Humic acid as a soil amending agent has been fully encouraged to boost the agricultural yield. The application of humic acid to vegetable crops has been shown to significantly enhance their quality. Various attributes, such as total soluble solids, total acidity, lycopene levels, and the nutritional content of key elements like nitrogen, phosphorus, potassium, calcium, and magnesium, improve in response to humic acid treatment [14]. Additionally, humic acid has been reported to increase protein content in cabbage [15], boost starch levels in potatoes [16], enhance mineral accumulation in potatoes [17], and improve fruit firmness in cucumbers [18]. Therefore, keeping in view the importance of humic acid in vegetable production, this study was focused to research on the effect of humic acid on the seed germination and seedling growth of different summer vegetables.

Material and Methods

A series of pot experiments were conducted to check the influence of different concentrations of humic acid on the seed germination and plantlet growth of Cucumber, Pumpkin and Okra as well as on seedling growth of Tomatoes and Eggplant, at horticultural nursery of Faculty of Agriculture Gomal University, Dera Ismail Khan. Different parameters related to seed germination and plantlet growth such as days to seed germination, plant height (cm), number of leaves per plant, Root length (cm), number of roots and parameters related to seedling growth such as increment in plant height, increment in leaves number, increment in root length (cm), increment in root number were studied.

Treatments

Four humic acid concentrations (0, 4, 8 & 12 g/kg) were prepared. Experiment was designed to Randomized Complete Block Design having total of 12 pots for each vegetable and total of 60 pots. Treatments details are as follows:

1. H_1: 0.0 g/kg humic acid (Control)
2. H_2: 4.0 g/kg humic acid
3. H_3: 8.0 g/kg humic acid
4. H_4: 12.0 g/kg humic acid

Methods

A mixture of river mud and clay soil was used as a potting mixture along with the assigned (0, 4, 8 and 12 g/kg) humic acid concentrations. Pot size (12x12 cm) having a capacity of accommodating 0.7 Kg of soil was used. Seeds of cucumber, pumpkin and okra were sown, whereas, the seedlings of Tomato & eggplant were transplanted to the assigned media. Soon after seed sowing and seedling transplant, the pots were irrigated and then regular irrigation and hoeing was carried out at regular interval. The plant growth and its destructive analysis were carried out after two months of seed sowing and seedling transplantation.

Results and Discussion

Cucumber

- **Days to Germination**
  The data showed that maximum days to cucumber seed germination (18 days) was recorded in pots under treatment H4, followed by H1 (18 days) and H3 (16 days). However, minimum days to cucumber seed germination (14 days) was noticed in pots under treatment H2 (Figure 1).
- **Plant height (cm)**
  The data showed that maximum plant height (24 cm) was noticed in H1, followed by H4 and H3 with 20 & 19 cm long plants, respectively. Minimum plant height (14 cm) was recorded in pots under treatment H2 (Figure 1).
- **Number of leaves**
  The data shown in Figure No.1, clearly indicates that maximum number of leaves (08) was recorded in pots under treatment H2, H3 and H4, while minimum leaves (05) were recorded in H1 (Figure 1).
- **Number of roots**
  The data showed that maximum number of roots (31) was recorded in pots under treatment H4, followed by H1 & H2 with 30 and 27 roots per plant, respectively. Whereas, minimum number of roots (22) was recorded in pots under treatment H3 (Figure 1).
- **Root length (cm)**
  The data showed that maximum root length (11 cm) was noticed in pots under treatment H3, trailed by H1 & H2 with 9 & 8 cm long roots, correspondingly. However, minimum root length (7 cm) was recorded in pots under treatment H4 (Figure 1).

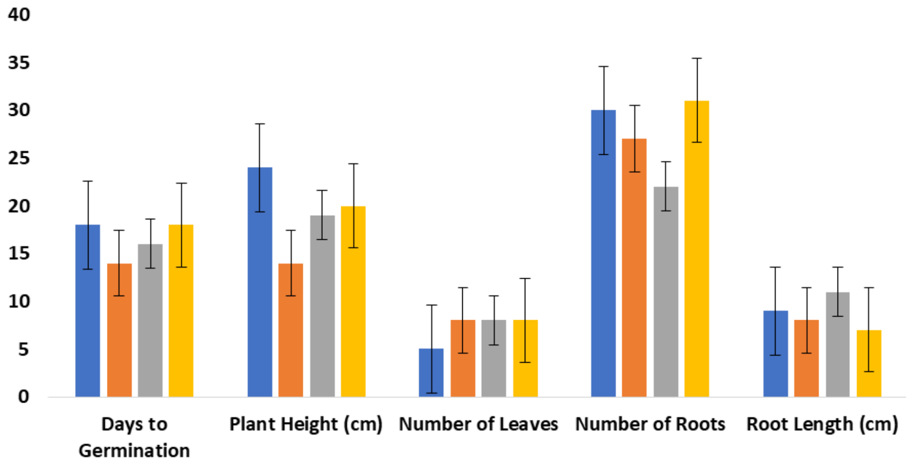

Fig 1: Effect of different concentration of humic acid on Cucumber vegetable.

Pumpkin

- **Days to Germination**
  The data shown in Figure 2, showed that maximum days to pumpkin seed germination (18) was recorded in pots under treatment H4, followed by H1 (16) days and H3 (16) days to seed germination. Minimum days to cucumber seed germination (14) was noticed in pots under treatment H2 (Figure 2).
- **Plant height(cm)**
  The data showed that maximum plant height (20 cm) was noticed in pots under treatment H4. It was followed by H1 and H3 which produce 19cm long plants each. Whereas, minimum plant height (14) was recorded in pots under treatment H2 (Figure 2).
- **Number of leaves**
  The data indicated that maximum number of leaves (8) was recorded in pots under treatment H2, H3 and H4. While, minimum number of leaves (5) was recorded in H1 (control) (Figure 2)
- **Number of roots**
  The data showed that maximum number of roots (31) was recorded in H4, followed by H1 and H2 with 27 and 30 roots respectively. Whereas, minimum number of roots (22) was recorded in pots under treatment H3 (Figure 2).
- **Root length (cm)**
  The data showed that maximum root length (11cm) was noticed in pots under treatment H3. It was followed by H1 and H2 with 9 and 8 cm long roots respectively. However, minimum root length (7 cm) was recorded in pots under treatment H4 (Figure 2)

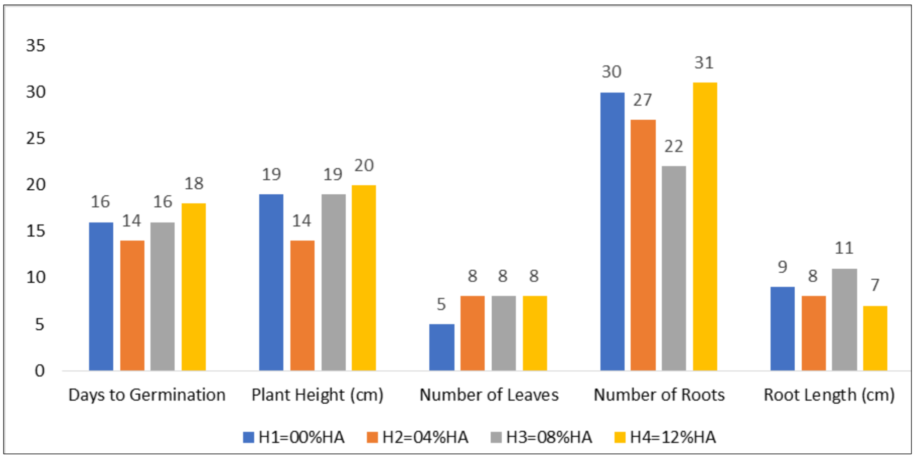

Fig 2: Effect of different concentration of humic acid on Pumpkin vegetable.

Okra

- **Days to Germination**
- The data showed that maximum day to pumpkin seed germination (10) was recorded in pots under treatment H4, followed by H1 and H3 taking 9 days to seed germination each. However, minimum days to cucumber seed germination (7) was noticed in pots under treatment H2 (Figure 3).
- **Plant height (cm)**
- The data showed that maximum plant height (16 cm) was noticed in pots under treatment H1 and H3 both. Minimum plant height (14) was recorded in H2. However, plant produced in pots under treatment H4 died off (Figure 3).
- **Number of leaves**
- The data indicates that maximum number of leaves (7) was recorded in pots under treatment H2. Followed by H1 and H3 with 6 and 3 number of leaves respectively. While, zero number of leaves were recorded in H4 (Figure 3).

- **Number of roots**
  The data presented in Figure 3 showed that maximum number of roots (43) was recorded in H1, followed by pots under treatment H3 and H2 with 33 and 30 roots, respectively. Whereas, plant produced in pots under treatment H4 was died off (Figure 3).

- **Root length(cm)**
  The data showed that maximum root length (33cm) was noticed in pots under treatment H3. It was followed by H1 and H2 with 11 and 10 cm, respectively. Whereas, plant produced in pots under treatment H4 died off (Figure 3)

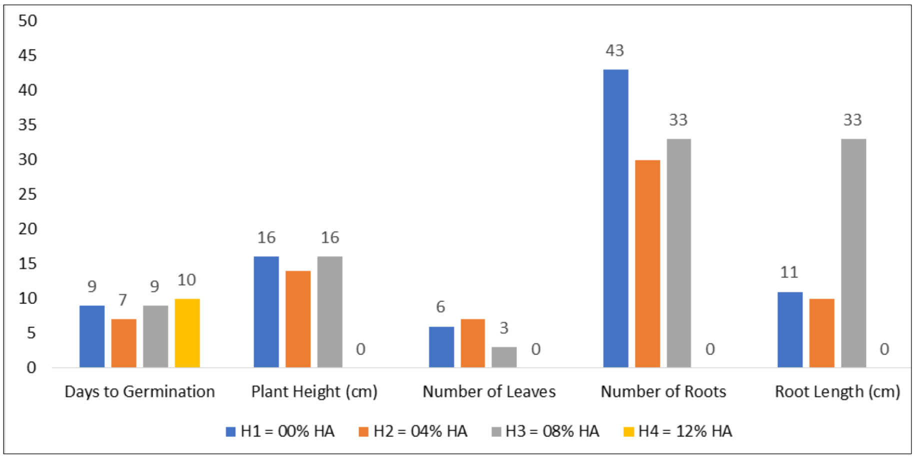

Fig 3: Effect of different concentration of Humic acid on Okra vegetable.

Brinjal seedling

Increment in plant height (cm)

The data obtained after two months of transplanting the seedlings that maximum increment in plant height (3 cm) was recorded in pots under treatment H2, whereas same increment in plant height (2 cm) was recorded in H1, H3 and H4 (Figure 4a).

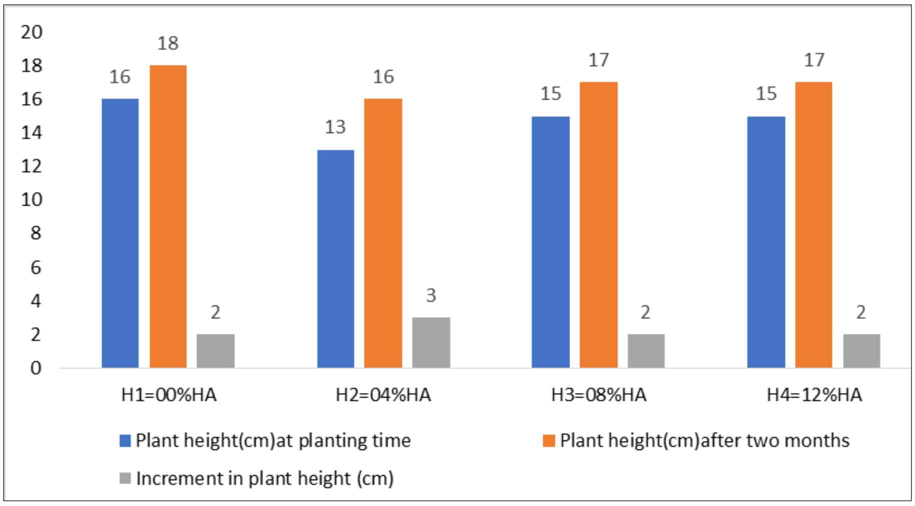

Fig 4 (a): Effect of different concentration of humic acid on Plant height (cm) of brinjal Seedling

Increment in number of leaves

The data regarding increment in leaf number showed that after two months only a single leaf was added in all the plants planted in H1, H2, H3 and H4, as shown in (Figure 4b).

Figure 4(b). Effect of different concentration of humic acid on number of leaves of brinjal Seedlings.

Increment in number of roots

The data presented in Figure 4(c), clearly showed that maximum increment in root number (12) was reported in H2, whereas H4, H3 and H1 produced an increase of 8, 7 and 6 roots, respectively.

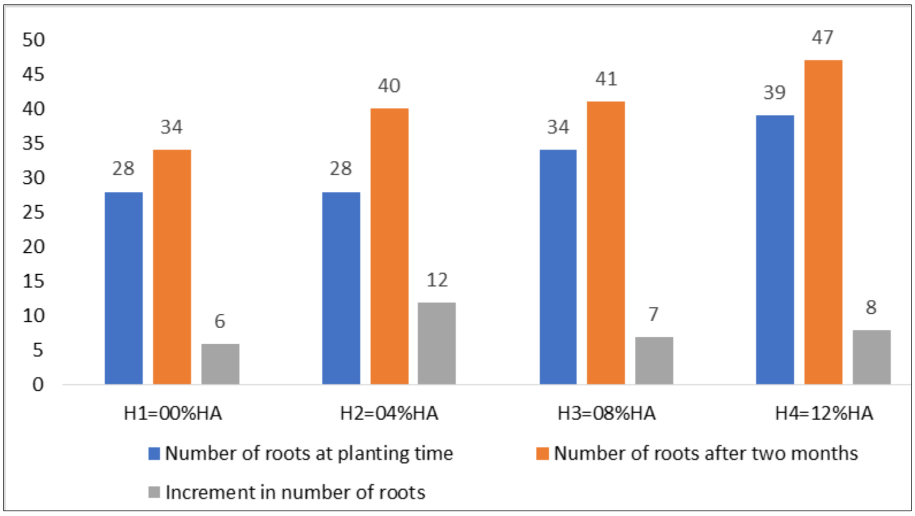

Fig 4(c): Effect of different concentration of humic acid on brinjal Seedlings.

Increment in root length (cm)

The result obtained after two months of seedling transplantation, clearly depicted that maximum increase in root length (8cm) was noticed in H4, followed by 6, 5 and 2 cm increase in H1, H2 and H3 respectively (Figure 4d).

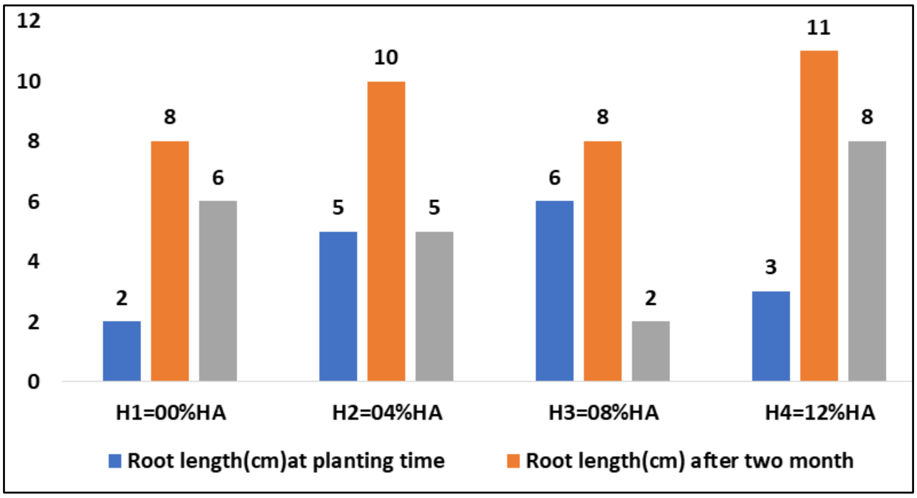

Fig 4(d): Effect of different concentration of humic acid on brinjal Seedlings.

Tomatoes Seedlings

- **Increment in plant height (cm)**
  The data obtained after two months of transplanting the seedlings that maximum increment in plant height (9cm) was recorded in H1, followed by H2 and H3 with 8 and 1 cm respectively. Whereas, plant produced in H4 died off (Figure 5a).
- **Increment in number of leaves**
  The data regarding increment in leaf number showed that maximum leaf number 15 was recorded in H3, followed by H4 and H1 with 12 and 6 number of leaves respectively, whereas minimum number of leaves 4 was noticed in H2 (Figure 5b).
- **Increment in Number of roots**
  The data shown in Figure 5(c) clearly showed that maximum increment in root number (16) was reported in H3, followed by H2 and H1 with 8 and 6 cm number of roots, where plant produced in H4 died off.
- **Increment in root length (cm)**
  The result obtained after two months of seedling transplantation, clearly depicted that maximum increase in root length (8cm) was noticed in H1, followed by 6, 5 and 4cm increase in H4, H2 and H3 respectively (Figure 5d).
- **Days to flowering**
  The data showed that maximum days to flowering was noticed in H2 and H3 both which is 18, while no or zero days to be flowering recorded in H1 as well as in H4 (Figure 5e).

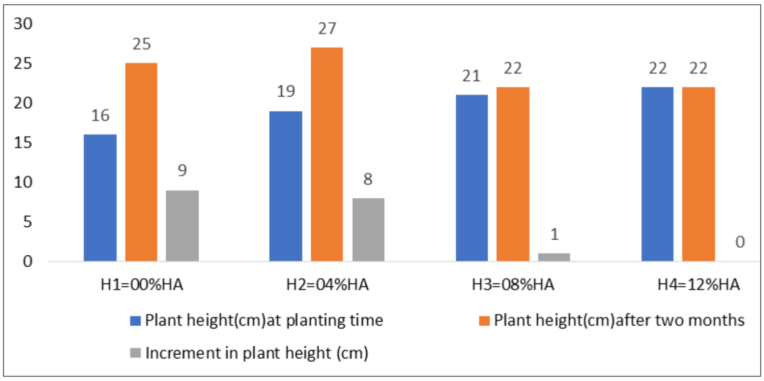

Fig 5(a): Effect of different concentration of humic acid on tomatoes seedlings.

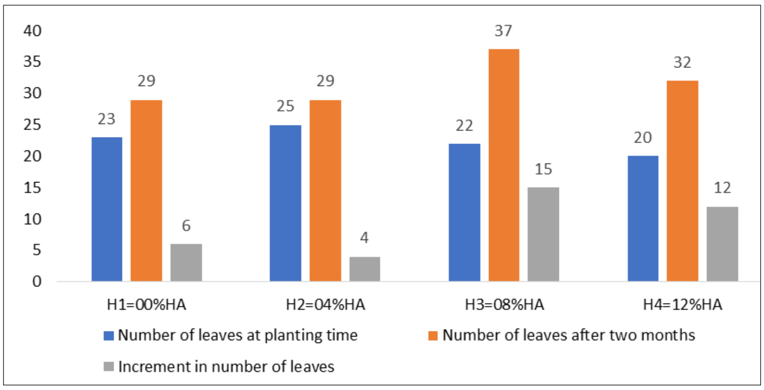

Fig 5(b): Effect of different concentration of humic acid on tomatoes seedlings.

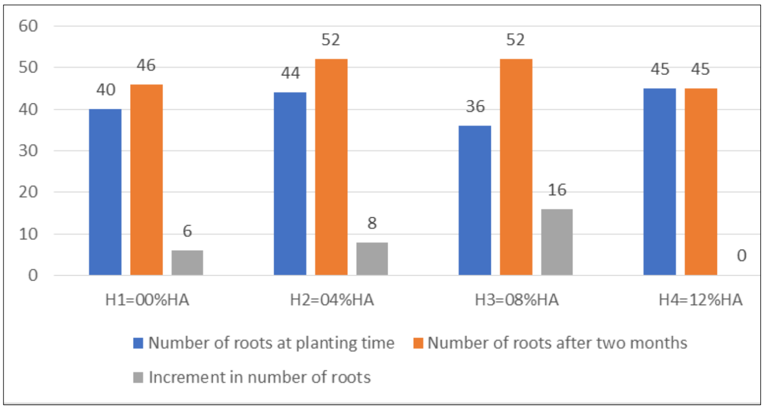

Fig 5(c): Effect of different concentration of humic acid on tomatoes seedlings.

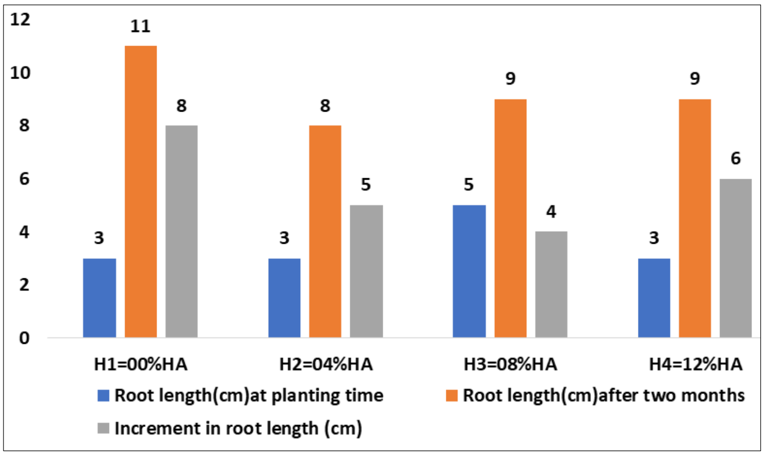

Fig 5(d): Effect of different concentration of humic acid on tomatoes seedlings.

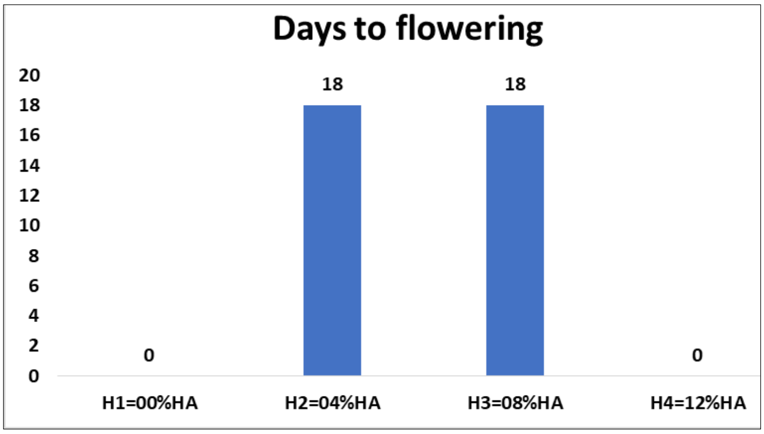

Fig 5(e): Effect of different concentration of humic acid on tomatoes seedlings.

Discussion

The experimental results demonstrate that humic acid (HA) treatments (H1, H2, H3, H4) significantly influence seed germination, plant growth, leaf development, root proliferation, and flowering patterns across multiple vegetable species (cucumber, pumpkin, okra, brinjal, and tomato). These findings align with previous research on humic acid's role in enhancing plant growth through improved nutrient uptake, root stimulation, and stress mitigation. In Cucumber & Pumpkin, maximum germination time (18 days) was observed in H4, while H2 exhibited the fastest germination (14 days). This suggests that lower HA concentrations (H2) may accelerate metabolic activity, whereas higher doses (H4) could delay germination due to osmotic stress or hormonal interactions. Similar results were reported by [19], where HA improved pumpkin germination under cadmium stress, indicating its role in mitigating abiotic stress. Whereas in Okra, H2 again showed the fastest germination (7 days), while H4 delayed it (10 days). However, H4-treated okra plants died post-germination, suggesting toxicity at higher HA levels. This contrasts with [20], who found that foliar HA enhanced okra germination and yield, indicating that application method and concentration are critical.

In cucumber and pumpkin, H1 (control) and H4 produced taller plants, whereas H2 had the shortest height but the highest leaf count. This indicates that HA may enhance shoot elongation in some treatments while promoting leaf proliferation in others. Okra showed stunted growth in H4, but H1 and H3 performed best, suggesting species-specific HA tolerance. [21] reported similar variability in okra cultivars, where HA improved growth in some genotypes but not others.

HA consistently enhanced root proliferation (e.g., cucumber H4: 31 roots; pumpkin H4: 31 roots), aligning with [22], who found HA stimulated root growth in tomatoes. However, root length varied, H3-treated plants had the longest roots, while H4 had the shortest, possibly due to nutrient competition or HA-induced changes in soil structure.

H1 (control) showed the highest height increment, but H3 had the most roots (16) and leaves (15). H4 plants died, reinforcing that excessive HA can be detrimental.

Delayed flowering in H2 and H3 (18 days) vs. no flowering in H1 and H4 suggests HA may modulate flowering hormones. [23] observed similar effects, where HA (14.4 kg/ha) improved tomato flowering and yield under heat stress.

Incremental growth was modest across treatments, but H2 had the highest root number (12), supporting [24], who found moderate HA concentrations improved eggplant seedling growth in low-nutrient conditions.

The results suggest that moderate HA doses (e.g., H2) enhance germination and root growth, while higher doses (H4) may inhibit growth or cause mortality, as seen in okra and tomato. This aligns with [25], who found 50 mg/L HA optimal for squash growth, beyond which benefits plateaued. Cucumber and pumpkin responded favorably to HA, whereas okra and tomato exhibited toxicity at higher doses. This variability mirrors [26], where HA improved okra yields only at 20 kg/ha, beyond which effects diminished.

HA should be tailored to crop species and growth stage as though actual yields can fluctuate due to climate conditions and various stress factors, indicating that further improvements cum investigations are possible [27] such as for instance, lower doses may benefit germination, while higher doses could enhance root development in mature plants and hence integrating HA with slow-release fertilizers as suggested by [28] could optimize nutrient uptake and reduce toxicity risks.

These findings align with previous research on humic acid's role in enhancing plant growth through improved nutrient uptake, root stimulation, and stress mitigation such as study by [29] who analyzed increased yield in Faba Bean, [30] recorded favorable results for plant height under humic acid treatment, [31] recorded improved number of leaves in onion.

Conclusion

Humic acid exhibits a dual role, enhancing growth at optimal concentrations while causing stress at excessive levels. The study corroborates prior research on HA’s growth-promoting effects but highlights critical thresholds for different species. Future studies should explore HA interactions with soil microbiota and stress conditions to refine application protocols for sustainable vegetable production.

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