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RESEARCH ARTICLE Agricultural Science Digest

Influence of Humic Acid and Clay Liquid on the Physicochemical Properties of Sandy Soil and the Vegetative Growth of *Moringa oleifera*

Afak Ibraheem Jumaa[1], Salah Mahdi Alibi[2], Raad Farhan Shahad[2], Hussein Abdul Hamid[2]

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ABSTRACT

Background: Sandy soils are characterized by poor structure, low water holding capacity and limited nutrient availability, which in turn have adverse effects on plant growth and productivity. Organic amendments, such as humic acid and clay liquid, have been proposed as environmentally friendly alternatives for enhancing the physicochemical properties of the soil and improving plant performance, especially for crops of high economic and nutritional value like *Moringa oleifera*.

Methods: In the present study, a factorial arrangement was utilized with a completely randomized block design statistical layout, using three replications for each treatment. Application of humic acid was performed at three concentrations consisting of 0, 5 and 10 mg L^{-1}. As for the clay liquid, applications were made at three levels of 0, 10 and 30 mL L^{-1}. Growth parameters recorded included plant height, number of leaves and branches, leaf area, root dry weight and shoot dry weight. Physical and chemical properties of sandy soil were also analyzed in selected series. Data obtained were subjected to ANOVA tests; meanwhile, treatment means were compared by the LSD test at probability level 0.05.

Result: The findings indicated a significant increase in vegetative growth with humic acid treatment, with the maximum recorded at 10 mg L^{-1}. Clay liquid at 30 mL L^{-1} increased branching, leaf area and biomass. The interaction effect of humic acid at 10 mg L^{-1} with clay liquid at 30 mL L^{-1} gave a better result for most factors related to growth, such as shoot and root dry weight, showing a significant synergy effect between humic acid and clay liquid in showing a significant synergy effect between humic acid and clay liquid in enhancing the vegetative growth of *Moringa oleifera* of Moringa oleifera. The soil pH, electrical conductivity and nutrient content increased with the application of treatments.

Key words: Clay liquid, Humic acid, *Moringa oleifera*, Sandy soil, Soil fertility, Vegetative growth.

INTRODUCTION

Moringa oleifera, often known as moringa or the “Miracle Tree,” is a rapidly growing species belonging to the family Moringaceae (Villegas-Vazquez *et al*., 2025). Native to the Indian subcontinent, *Moringa oleifera* is widely cultivated in tropical and subtropical regions, including Africa, the Middle East and South America (Gopalakrishnan *et al*., 2016). Moringa is known for its extraordinary nutritional profile and therapeutic properties. Its leaves are especially rich in vitamin C, vitamin A, calcium, iron and antioxidants such as catechin and quercetin, which help reduce oxidative stress (Villegas-Vazquez *et al*., 2025). Seeds have also been shown to be effective in cleaning water, removing harmful contaminants Dandesa *et al*. (2023). Given the high nutritional value, the moringa has been recognized as a strategic crop in combating malnutrition. It also contributes to environmental, stability through applications in improving the Earth’s fertility and water purification Gutirrez *et al*. (2024). Successful container cultivation of the moringa requires the right soil choice, as the plant grows deep roots and is sensitive to waterlogging. Studies have shown that *Moringa oleifera* grows best in the well-dried sandy soil Kumar *et al*. (2023). These soil types promote better growth, leaf production and accumulation of biomass than soil. Moreover, mineral transformations in agriculturally exploited soils particularly involving mica-can influence nutrient dynamics and soil structure, affecting plant development Shahad *et al*. (2021). An ideal soil mixture includes sandy soil, peat moss and medium joints of perlite or compost (2: 1: 1), which ensures adequate drainage and organic materials (Ewetola and Adebayo, 2019). Humic acid is a naturally occurring organic matter derived from the degradation of plant and animal residues. It is rich in carboxylic and phenolic groups, providing high cation

[1]Department of Desertification Combat, College of Agricultural Engineering Sciences, University of Baghdad, Baghdad, Iraq.
[2]Department of Soil and Water Resources Sciences, College of Agriculture, University of Al-Qadisiyah, Al-Diwaniyah 58001, Iraq.

Corresponding Author: Raad Farhan Shahad, Department of Soil and Water Resources Sciences, College of Agriculture, University of Al-Qadisiyah, Al-Diwaniyah 58001, Iraq.
Email: raad.farhan@qu.edu.iq

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exchange capacity, improving nutrient availability, enhancing soil conditions and supporting microbial activity (Manna and Siddique, 2025; Al-Zaydi and Al-Jibouri, 2025). This has been shown to improve botanical growth in different plant species, including Catharanthus roseus, especially in sandy soil (Shahad and Hamid, 2025). Sidhdharth *et al*. (2022) reported that the height, leaf number and biomass of the Moringa plant increased significantly due to Humic Acid application. The clay liquid is a traditional but effective change, especially beneficial for poor soil of nutrients or nutrients (Lehmann and Kleber, 2015). It consists of fine collaidal particles and dissolved minerals that increase water retention, soil structure and micronutrient accessibility in the rizosphere. Class rich in montmorillonite or kaolinite are especially effective for improving moisture protection and nutrition dynamics and it was found that the extract of soil water led to the promotion of botanical growth and dried tolerance Alaboz *et al*. (2022). Several studies have reported that the combined application of humic acid and soil has an impact on biophysical properties and plant productivity. Such combinations represent an environmentally friendly alternative for synthetic fertilizer, especially in the cultivation of medicinal plants such as the Moringa. Although previous studies have examined the effects of humic acid or clay amendments separately, limited information is available regarding their combined application on sandy soil properties and the vegetative growth of *Moringa oleifera,* particularly under Iraqi environmental conditions. Therefore, the present study aimed to evaluate, the individual and interactive effects of humic acid and clay liquid, on improving sandy soil characteristics and enhancing. The growth performance of Moringa oleifera seedlings. The experiment was conducted in a nursery located in Al-Diwaniyah municipality, Iraq, under a green polymer cover (Saran) that provided about 25% light reduction. The study was conducted from October 2024 to August 2025 to find the effect of humic acid and clay liquid on the physical and chemical properties of sandy soil and the growth of *Moringa oleifera*.

MATERIALS AND METHODS

This study was carried out in a nursery. This experiment was conducted at the Nursery of the Department of Soil Sciences, College of Agriculture, University of Al-Qadisiyah, Iraq in the province of Iraq. underneath a green polymer roofing (Saran) with a light intensity reduction of 25%. This test started on October 1, 2024, in an attempt to assess the impacts of humic acid as well as clay liquid on the physicochemical parameters of sandy soil as well as the growth of *Moringa oleifera*. Moringa seedlings were planted on November 15, 2024, inside plastic pots measuring 25 cm in diameter, 24 cm in height, with a weight of 5 kg of a 1:1 (w/w) combination of river Zamiyah soil and peat moss, with a single plant per container. The experiment comprised two main factors: humic acid at three concentrations (0, 5 and 10 mg L^{-1}) and clay liquid applied as a foliar spray at three concentrations (0, 10 and 30 mL L^{-1}).

The first application of both humic acid and clay liquid was made on November 22, 2024, with the second application following 21 days later. A 3×3 factorial arrangement was used in an RCBD, with three replications, according to the method of Al-Rawi and Khalaf (2000). Each replication consisted of nine treatment combinations and each treatment was applied to three pots; thus, a total of 81 pots were used. Data were subjected to ANOVA and treatment means were separated using the LSD test at a probability level of 0.05. The statistical analysis was run using GenStat software, version 12.1 (VSN International, 2009).

Plant height was determined by using a tape measure up to the top of the plant. Leaves and branches were recorded per plant and their average was determined based on each treatment unit. Leaf area was determined by the method proposed by Schneider *et al*. (2012). in which three fully expanded leaves per plant were scanned using a flatbed scanner and image analysis was conducted using Digitizer software. Roots were carefully washed to remove soil, separated from the shoots, placed in perforated paper bags, air-dried for 10 days and then oven-dried at 45°C until constant weight to determine root dry weight. Shoots were separated from the root system, air-dried and oven-dried at 45°C until constant weight to determine shoot dry weight using a precision balance AOAC (2016).

RESULTS AND DISCUSSION

Soil physical and chemical properties

The result of the soil physical and chemical properties is shown in Table 1. The soil textural analysis revealed a sandy loam soil with a relatively high sand component (780 g kg^{-1}), along with a low amount of silt (108 g kg^{-1}) and clay (112 g kg^{-1}). The pH was measured to be 7.20, indicating it to be a neutral soil, suitable for most plants due to its ability to provide adequate nutrients. The electrical conductivity was found to be 2.20 dS m^{-1}. The available cations of calcium, magnesium, sodium and potassium were measured to be 250, 180, 50 and 100 mg kg^{-1}, respectively, values that were within the normal limits for a sandy loam soil. The total calcium carbonate was found to

Table 1: Some soil physical and chemical properties.

Parameter	value	Unit
Soil texture	Sandy loam	-
Sand fraction	780	$g.kg^{-1}$
Silt fraction	108	$g.kg^{-1}$
Clay fraction	112	$g.kg^{-1}$
pH	7.20	-
(EC)	2.20	$dS.m^{-1}$
($CaCO_3$)	266	$g.kg^{-1}$
(Ca^{2+})	250	PPM
(Mg^{2+})	180	PPM
(Kz^{+})	100	PPM
(Naz^{+})	50	PPM

be 106 g kg^{-1}. The improvement of soil physical and biological conditions through organic and biological practices is supported by similar findings on the improvement of the ecosystem of the soil by legumes in cropping systems, as revealed by Sharma *et al*. (2023); Al-Silmawy (2025).

Plant height

Fig 1 on plant growth indicators revealed that humic acid and clay liquid significantly influenced the vegetative growth of Moringa oleifera. Fig 1 revealed that the use of humic acid resulted in a remarkable increase in plant height. There was an increase in the mean height of the plant from 71.11 cm at 0 mg L^{-1} to 78.11 cm at 10 mg L^{-1}. The difference between the two concentrations, that is, 5 and 10 mg L^{-1}, was remarkable and the difference between the control and the highest treatment was above the least significant difference for interaction at 6.408. This resulted in a statistically significant difference. These findings are in conformity with previous works that have shown the positive influence of humic substances on nutrient uptake, root and vegetative growth (Khalil *et al*., 2019; El-Sayed *et al*., 2020; Bawya *et al*., 2025). Humic acid works to promote root growth and increase the activity of absorption enzymes and humic substances have biological stimulation properties like hormones, according to Canellas *et al*. (2014). Humic acid was confirmed to work by activating the hydrogen pump Hz -ATPase, as reported by (Zandonadi *et al*., 2010; Ali, 2021).

Number of leaves

Fig 2 indicates that the number of leaves per plant was significantly affected by the treatment of humic acid and clay liquid. The number of leaves per plant without humic acid was 25 (leaves $plant^{-1}$) on average. This rose to 30.44 (leaves $plant^{-1}$) when treated with 5 mg L^{-1} humic acid and it continuously rose when treated with 10 mg L^{-1} humic acid. The number also rose when treated with clay liquid, from 26.56 (leaves $plant^{-1}$) when treated with 0 mL L^{-1} clay liquid to 33.00 leaves per plant when treated with 10 mL L^{-1} clay liquid, then decreased to 32.56 (leaves $plant^{-1}$) when treated with 30 mL L^{-1} clay liquid.The joint effect of humic

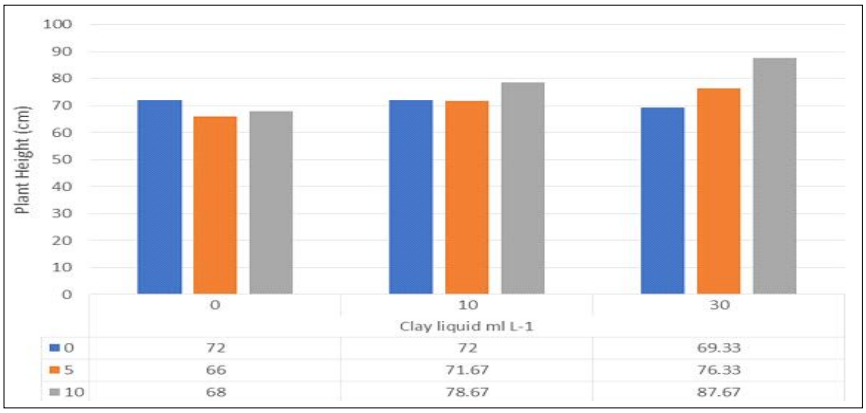


Fig 1: Effect of humic acid and clay liquid application and their interaction on plant height (cm) LSD (P≤0.05) for humic acid = 3.699; clay liquid = 3.699; interaction = 6.408.

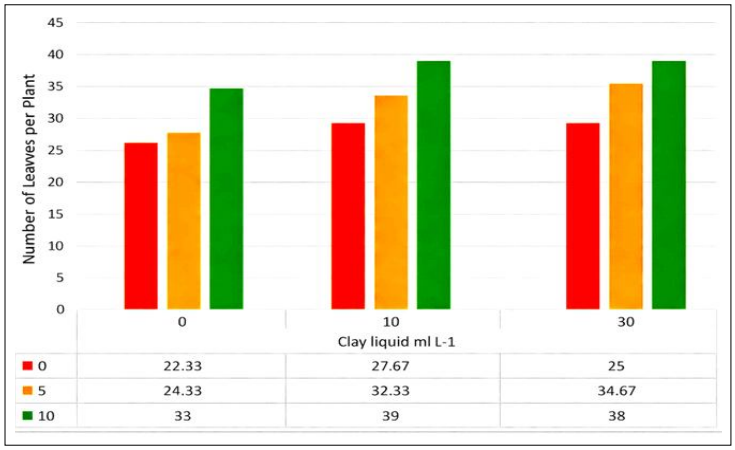


Fig 2: Effect of humic acid and clay liquid application and their interaction on number of leaves per plant LSD (P≤0.05) for humic acid = 2.079; clay liquid = 2.079; interaction = 3.601.

acid and clay liquid gave the highest number of leaves per plant when 10 mg L^{-1} of humic acid and 10 mL L^{-1} of clay liquid were used. By the LSD test at a significance level of 0.05, it reveals that both single and joint treatments significantly affected the number of leaves per plant.

Number of branches

From the data shown in Fig 3, it was determined that the number of branches per plant was greatly affected and promoted by the use of humic acid and clay liquid. In the control treatment, the average number of branches per plant was 5.00. The use of humic acid promoted the number of branches up to 7.33 for the 5 mg L^{-1} concentration, although this was slightly reduced to 7.11 branches for the 10 mg L^{-1} concentration. The use of clay liquid was shown to have a positive effect, increasing from 5.78 branches per plant under the untreated treatment to 7.56 and 7.89 branches per plant for the 10 and 30 mL L^{-1} clay liquids, respectively. The interaction of humic acid and clay liquid yielded the highest number of branches, totaling 8.67 branches per plant for the combination of humic acid and 30 mL L^{-1} of clay liquid. This was in agreement with El-Sayed *et al*. (2020), where clay liquids with higher contents of montmorillonite improved the condition of sandy soil, thereby decreasing water evaporation, enhancing the cation exchange capacity and promoting nutrient availability.

Leaf area

The results related to leaf area index are presented in Fig 4. The application of humic acid had a clear positive effect on increasing leaf area index, with the highest value (24.89 cm^2) recorded at 10 mg L^{-1} compared to 12.81 cm^2 in the control. With respect to clay liquid application, the leaf area index showed variations among treatments, with values of 19.68, 18.18 and 18.94 cm^2 at 0, 10 and 30 mL L^{-1}, respectively. Although the response was not linear, the differences between treatments were statistically significant. The combined application of

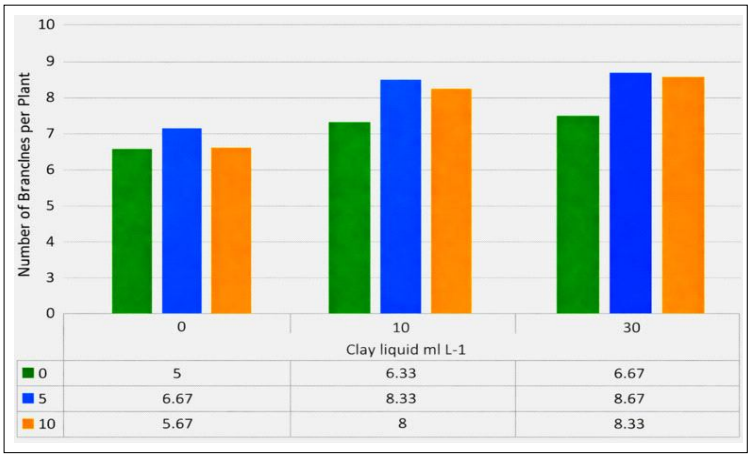


Fig 3: Effect of humic acid (mg L^{-1}) and clay liquid (mL L^{-1}) application on number of branches per plant LSD ($P \leq 0.05$) for humic acid = 0.805; clay liquid = 0.805; interaction = 1.394.

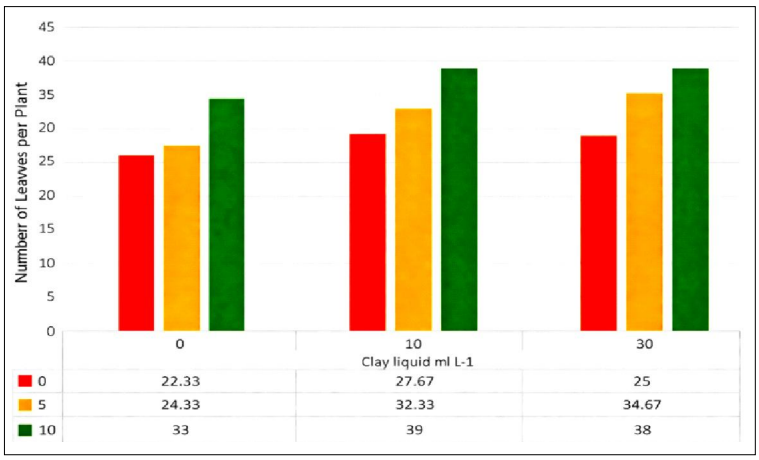


Fig 4: Effect of humic acid and clay liquid application and their interaction on leaf area (cm^2 $plant^{-1}$) LSD ($P \leq 0.05$) for humic acid = 0.725; clay liquid = 0.725; interaction = 1.256.

10 mg L^{-1} humic acid and 30 mL L^{-1} clay liquid produced the highest leaf area index (26.47 cm^2 $plant^{-1}$) and the difference between the highest and lowest values exceeded the LSD value for interaction, indicating a significant combined effect.

Root dry weight

Fig 5 clearly indicates the influence of humic acid and clay liquid on the root dry weight of *M. oleifera*. At the concentration of 10 mg L^{-1} humic acid, the root growth was increased from 3.43 g $plant^{-1}$ for the control group to 4.46 g $plant^{-1}$. The use of the clay liquid produced a positive effect, where the root dry weight was increased from 4.16 g $plant^{-1}$ to 4.30 g $plant^{-1}$. However, this was slightly reduced for the highest concentration of clay liquid, which was 30 mL L^{-1}. The mixture of humic acid and clay liquid contributed the most towards the root dry weight, reaching 5.08 g $plant^{-1}$ where humic acid and clay liquid reached the highest concentration of 10 mg L^{-1} and 30 mL L^{-1}, respectively. The difference was above the LSD value, meaning there was significance. Similar synergistic effects were reported by (Al-Jibouri, 2019, Al-Saady *et al*., 2022; Shahad *et al*., 2025).

Shoot dry weight

From the data presented in Fig 6, it was seen that there was a significant effect on the shoot dry weight of Moringa oleifera due to the treatment of humic acid and clay liquid. Among the individual treatments, the treatment where humic acid was applied at 5 mg L^{-1} yielded the greatest mean value of shoot dry weight (0.20 g $plant^{-1}$). When both humic acid and clay liquid were used, it was seen that a combination of 10 mg L^{-1} and 30 mL L^{-1} of clay liquid was most effective and yielded the greatest shoot dry weight (0.23 g $plant^{-1}$), clearly showing that there is a marked synergistic effect due to the combination of both treatments and their combination is a sustainable practice that can be used to reduce the dependency on chemical fertilizers. The results were consistent with the data provided by Miller and Horn (2021), who stated that a combination of humic

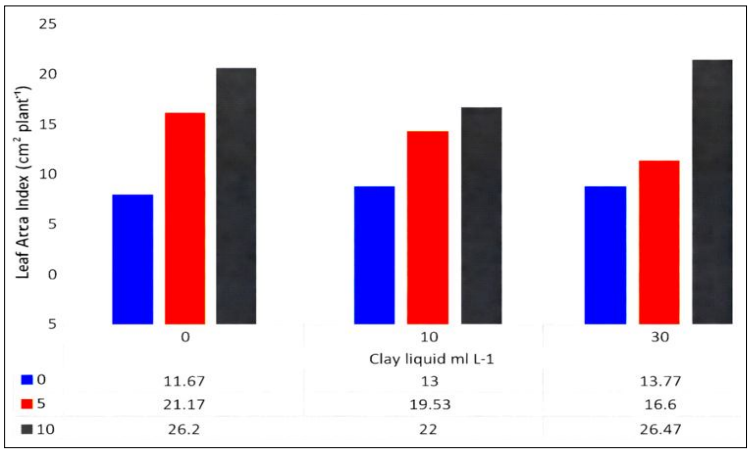


Fig 5: Effect of humic acid and clay liquid foliar application and their interaction on root dry weight (g $plant^{-1}$) LSD ($P \leq 0.05$) for humic acid = 0.415; clay liquid = 0.415; interaction = 0.720.

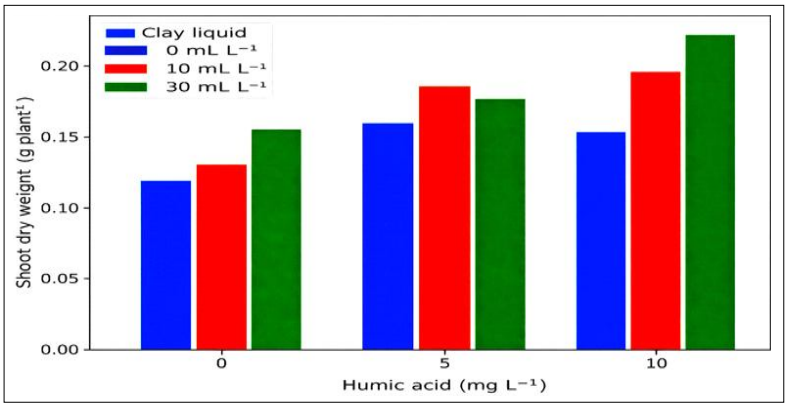


Fig 6: Effect of humic acid and clay liquid foliar application and their interaction on shoot dry weight (g $plant^{-1}$) LSD ($P \leq 0.05$) for humic acid = 0.024; clay liquid = 0.024; interaction = 0.041.

acid and natural, biostimulants improves soil properties and increases productivity.

CONCLUSION

From the results obtained, it can be seen that *Moringa oleifera* responded well to the treatment using humic acid and clay liquid on sandy soil. Humic acid helped to promote increased plant height, leaf area and root growth, while clay liquid helped to significantly promote shoot growth and increase the number of branches. The combination of 10 mg L^{-1} humic acid and 30 mL L^{-1} clay liquid helped to promote all parameters related to vegetative growth. Based on the results, it can be concluded that the combination of humic acid and clay liquid can be considered as one method that can be implemented to promote soil fertility and Moringa oleifera growth.

Conflict of interest

We confirm that there is no conflict of interest among the authors regarding the publication of this manuscript.

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