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Effects of NPK and Humic Acid on Growth and Yield of Melon under Semi-Arid Conditions of Kandahar

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ABSTRACT

Nitrogen-doped activated carbon (N-doped AC) from agricultural waste offers a low-cost route to solid sorbents for post-combustion CO_2 capture. However, there are limited straightforward and scale-up methods available to produce N-doped AC with large surface area, high nitrogen content, and strong CO_2 adsorption. Thus, this study aims to synthesize rice husk derived N-doped AC, by optimizing the surface morphology and nitrogen functionality to enhance CO_2 Capture efficiency and to quantifies adsorption, correlating the gains with BET surface area and microporosity. Rice husk was carbonized via pyrrole-assisted pyrolysis at 450 °C for 45 min with a 90 min dwell, the carbonized rice husk was then activated chemically using a 4:1 ratio of KOH to carbonized rice husk, heated to 800°C at a ramp rate of 15 °C per min under a flow of N_2 gas at 150 ml/min for 60 min, Subsequently, N-doping was performed by immersing the activated carbon in a urea solution with a mass ratio of 4:1 (urea solution to AC) at 600°C for 60 min. The obtained N-doped AC exhibits a remarkable surface area of 2986.6 m^2/g and a significantly enhanced CO_2 adsorption capacity of 6.5 mmol/g under ambient conditions. Incorporating approximately 6% nitrogen into the carbon structure optimizes its porosity and structural properties. The integrated carbonization, activation, urea post-doping sequence provides a reproducible pathway to high performance, waste derived CO_2 sorbents, highlighting rice husk as a viable feedstock and underscoring the synergistic roles of micro/mesoporosity and nitrogen functionalities in boosting physisorption dominated CO_2 capture.

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INTRODUCTION

Melon (*Cucumis melo* L.) is a widely consumed fruit worldwide and belongs to the Cucurbitaceae family (Lija & Beevy, 2021). Melon fruits exhibit substantial variability in form, shape, rind characteristics, flesh color, flesh thickness, sweetness, seed cavity size, and seed size (Lija & Beevy, 2021). It is cultivated in numerous countries and holds significant economic value globally, largely due to its adaptability to diverse climatic conditions and soil types (Khalid et al., 2021). Melon is an excellent source of bioactive compounds, owing to its appealing flavor and rich nutritional profile (Khalid et al., 2021). The fruit contains glucose, fructose, vitamins A, C, E, and K, as well as several B-complex vitamins (Khalid et al., 2021).

Application of 200 kg NPK ha^{-1} significantly increased the stem diameter of pepino melon by 14.01 mm (Mutua et al., 2021). Furthermore, the application of 70 g per plant of NPK Mutiara fertilizer produced the most significant improvements in the number of leaves, plant length, fruit circumference, fruit volume, and fruit weight (Ilmi et al., 2025). Moreover, the application of NPK (15:15:15) fertilizer significantly increased the number of fruits, fruit weight, and total fruit yield of muskmelon (Aluko, 2020). Similarly, applying 5 g per plant of NPK Mutiara fertilizer increased flowering time, harvesting time, stem diameter, maximum leaf area, and fruit weight (Muhamad, 2023).

In addition, the application of 300 kg NPK ha^{-1} in field-grown pepino melon resulted in the highest yield of 1102.48 kg ha^{-1} (Mutua et al., 2021). The application of NPK compound fertilizer also significantly affected fruit weight, fruit sweetness, fresh weight, and dry plant weight (Riesky et al., 2022). The combined application of straw mulch and NPK fertilizer at 125 g $plant^{-1}$ significantly increased melon yield (Neno & Raga, 2025).

Currently, humic acid has become an important approach for enhancing crop growth, yield, and soil fertility (Salihi et al., 2024). Humic acids (HA) are organic compounds that substantially improve soil properties, plant growth, productivity, and overall crop quality (Himatkhwah et al., 2025). The application of organic amendments such as humic acid and fulvic acid has been reported to increase the growth and productivity of cucurbit crops (Mohammed, 2024). Treatment with humic acid has been shown to influence melon vegetative growth positively (Samran et al., 2023). In addition to its effects during the vegetative stage, humic acid application has also improved the growth and yield performance of bitter melon (Widari, 2024). Moreover, the use of humic acid significantly increased plant height, stem diameter, fresh weight, dry weight, and chlorophyll content, with improvements reaching up to 33.17% (Zhu et al., 2025).

Additionally, the application of humic acid at a rate of 7 kg ha^{-1} resulted in the highest average plant height (175.6 cm) and number of leaves (37.2) (Widari, 2024). The maximum plant height recorded was 59.33 cm, achieved with the application of 1000 mg L^{-1} humic acid combined with 0.6 mL L^{-1} potassium (Al-Zubaidy & Al-Anbagi, 2019). Furthermore, foliar application of humic acid at 50 mg L^{-1} significantly increased plant height, leaf width, and leaf length (Samran et al., 2023). The application of 25 and 50 mg L^{-1} humic acid also improved the leaf greenness index (SPAD values) (Samran et al., 2023). Similarly, the application of 7 kg ha^{-1} humic acid produced the highest mean values for number of fruits (11.8), fruit length (26.97 cm), fruit diameter (5.71 cm), single fruit weight (320.17 g), fruit weight per plant (1145.55 g), and total fruit yield per harvest (10.31 kg) (Widari, 2024).

Application of organic fertilizer increased vegetative growth of melon (Raksun et al., 2019). The split application of 333 kg ha^{-1} NPK fertilizer significantly increased the number of leaves, leaf area, and plant length of muskmelon at 10 weeks after sowing (Aluko et al., 2021). In addition to the split application of NPK (15-15-15), 500 kg ha-1 increased muskmelon fruit yield significantly compared to a single application (Aluko et al., 2021). Application of NPK (15-15-15) fertilizer significantly increased Egusi melon yield in 2007 and 2008 (Ogbonna, 2009). Chemical fertilizers, especially macronutrients, are essential for melon growth and production. Since humic acid is a bio-stimulant, its role in improving crop growth and yield has been reported and confirmed. The application of humic acid along with NPK fertilizer may not only increase melon growth and yield but also reduce the need for chemical fertilizers. The effects of NPK fertilizers and humic acid on the growth and yield of melon have been studied previously. However, there is limited information on the combined effects of NPK and humic acid on melon growth and yield. Specifically, there is very limited information regarding the combined effects of chemical and organic fertilizers, including NPK and humic acid, in the study area. Thus, the study was conducted to investigate the issue in greater depth.

The objective of the study is:

- To analyze the effects of NPK and humic acid on the growth and yield of melon under semi-aired conditions of Kandahar, Afghanistan.

MATERIALS AND METHODS

This study evaluated the effects of NPK fertilizer and humic acid on melon growth and yield through a field experiment conducted during the 2025 growing season at ANASTU, Kandahar, following standard agronomic practices and data collection procedures.

Study Design

A field experiment was conducted during the 2025 growing season (21 March-06 July). The experiment was laid out in a Randomized Complete Block Design (RCBD) with seven treatments consisting of different levels of NPK fertilizer and humic acid: T1 (control, no NPK and no humic acid), T2 (50:60:50 NPK + 7 kg ha^{-1} humic acid), T3 (45:50:45 NPK + 7 kg ha^{-1} humic acid), T4 (40:45:40 NPK + 7 kg ha^{-1} humic acid), T5 (50:60:50 NPK + 10 kg ha^{-1} humic acid), T6 (45:50:45 NPK + 10 kg ha^{-1} humic acid), and T7 (40:45:40 NPK + 10 kg ha^{-1} humic acid). Each treatment was replicated three times.

Study Site

The experiment was conducted at the research farm of the Afghanistan National Agricultural Sciences and Technology University (ANASTU), Dand District, Kandahar, Afghanistan (31°30′ N, 65°50′ E, 1010 m above sea level). Soil physico-chemical properties of the experimental site were analyzed before the initiation of the study at the ANASTU University laboratory, and the results are presented in Table 1. These analyses were conducted to understand the baseline soil conditions that might influence melon growth and yield. The soil at the experimental site was sandy loam in texture, slightly alkaline in pH, and contained moderate organic matter and available nutrients, which are suitable for melon cultivation.

Table 1. *Physical and chemical properties of the experimental site soil*

pH	Electric Conductivity (EC)	Organic Carbon	Organic matter	Texture	Available N	Available P	Available K	Structure	Water Holding Capacity (WHC)

8.3	0.168 mS/cm	0.57%	0.97%	Sandy loam	0.02%	5ppm	120ppm	Single grained	33.66%

Meteorological data during the experimental period were recorded to provide context for the growing conditions, as temperature, rainfall, and humidity can affect plant growth and yield. The monthly data are summarized in Table 2. The recorded meteorological data indicate a typical semi-arid condition during the experimental period, with high temperatures, low rainfall, and low relative humidity, which are important factors influencing melon growth and yield.

Table 2. *Monthly meteorological data during the experimental period (21 Mar-6 Jul, 2025)*

Month	Max Temp (°C)	Min Temp (°C)	Rainfall (mm)	Relative Humidity (%)
March	27.00	15.00	2.00	28.00
April	35.00	22.00	0.00	21.00
May	37.00	26.00	0.00	16.00
June	39.00	27.00	3.00	17.00

Sample

The locally selected melon variety "Gulalai" was cultivated in 4 m² plots. Seeds were sown in rows with 70 × 70 cm spacing between plants and rows. The experimental unit consisted of one plot per treatment in each replication. Each treatment was replicated three times, resulting in a total of 21 experimental plots. Six plants per treatment and per replication were randomly selected for data collection using standard methods. Thus, a total of 126 plants (6 plants × 7 treatments × 3 replications) were included as sample plants for measurement and analysis.

Instrumentation

A measuring tape was used to measure plant length, fruit diameter, and fruit length. An electric balance was used to measure fruit yield. The number of branches and leaves per plant was manually counted.

Humic acid was applied in the form of potassium humate (commercial name: INDO APACHE Humic Potas Fulvic-Indogulf Cropsciences Ltd., India). The product was a water-soluble granule containing 60–70% activated potassium humate, 13–15% fulvic acid, 10–12% potassium (as K_2O), and 2.5% Fe-EDTA, with additional micronutrients in trace amounts (contents expressed on a dried basis). The product was 100% water-soluble and applied according to the experimental treatment design, while NPK fertilizers were supplied as urea, diammonium phosphate (DAP), and potassium sulfate obtained from the local market. The calculated amounts of fertilizers and humic acid were dissolved in 2 L of water and applied uniformly to the designated plots. Irrigation was applied uniformly to all treatments through the furrow method at four-day intervals according to crop requirements.

Data Collection Tools

The physicochemical properties of the experimental site soil were analyzed before the study began at the ANASTU University laboratory. Humic acid and NPK fertilizers were purchased from the local market and applied according to the experimental treatment design. All the data were recorded in the relevant datasheet.

Data Collection Procedure

Humic acid and NPK fertilizers were applied as a single dose 30 days after germination according to the experimental treatment design. NPK was applied at the base of the root zone and lightly incorporated into the soil to ensure proper nutrient availability. Six plants per treatment and per replication were randomly selected for data collection using standard methods. Plant length was measured from the soil surface to the plant tip using a measuring tape. The number of leaves and branches per plant was manually counted. Fruit diameter and fruit length were measured using a measuring tape in centimeters. The yield of melon was measured using an electric balance, and the calculation was conducted accordingly and recorded in tons per hectare. All the data were recorded in the relevant datasheet, and their averages were calculated.

Data Analysis

All data were subjected to analysis of variance (ANOVA) in SPSS (Statistical Package for the Social Sciences, 26), and Duncan's test was used to compare means at the $p<0.05$ significance level.

Validity and Reliability

The study's validity was ensured by using standard methods for measuring plant growth and yield parameters. Plant length, fruit diameter, and fruit length were measured using a measuring tape, while yield was measured using an electric balance. The number of leaves and branches per plant was manually counted using consistent procedures. Reliability was ensured by replicating each treatment three times and applying NPK fertilizers and humic acid uniformly, as specified in the treatment design. Irrigation and all other agronomic practices were kept uniform across all plots. All data were recorded systematically in the relevant datasheets to ensure consistency and minimize errors.

FINDINGS

The application of NPK and humic acid significantly affected melon growth and yield. Overall, treatments receiving combined NPK and humic acid performed better than the control, with improvements in plant height, number of leaves and branches, fruit size, and total yield. The effects varied with the levels of NPK and humic acid applied, indicating that both nutrients enhanced melon growth and productivity.

Vegetative Growth of Melon (Plant length, No. of Leaves and Branches/plant)

Vegetative development of melon plants was clearly influenced by the combination of NPK fertilizer and humic acid (Table 3). Plants in the control group, which did not receive either NPK or HA, showed the least growth in terms of height, leaf number, and branch formation. In contrast, the application of higher NPK levels along with 10 kg ha^{-1} HA significantly enhanced all vegetative parameters, with the T5 treatment (NPK 50:60:50 + HA 10 kg ha^{-1}) producing the tallest plants, most leaves, and the highest number of branches. Treatments with moderate nutrient levels or lower HA rates (T2, T6, T7) performed similarly and were noticeably better than treatments receiving lower nutrient combinations (T3, T4). These results suggest that integrating high NPK doses with adequate humic acid substantially promotes vegetative growth in melon.

***Table 3**. Effect of NPK fertilizer and humic acid on vegetative growth of melon*

Treatment	Plant Length (cm)	No. of Leaves/plant	No. of Branches/plant
T1 (Control - no NPK and no humic acid)	$160.84^{d} \pm 1.15$	$69.75^{e} \pm 0.59$	$8.47^{e} \pm 0.23$
T2 (NPK 50:60:50 + HA 7 kg ha^{-1})	$193.93^{b} \pm 3.18$	$102.84^{b} \pm 2.31$	$11.30^{d} \pm 0.75$
T3 (NPK 45:50:45 + HA 7 kg ha^{-1})	$182.95^{c} \pm 1.15$	$91.86^{d} \pm 0.87$	$11.99^{c} \pm 0.23$
T4 (NPK 40:45:40 + HA 7 kg ha^{-1})	$182.46^{c} \pm 2.60$	$91.37^{d} \pm 1.44$	$11.18^{d} \pm 0.4$
T5 (NPK 50:60:50 + HA 10 kg ha^{-1})	$209.98^{a} \pm 1.15$	$114.23^{a} \pm 1.15$	$14.11^{a} \pm 0.23$
T6 (NPK 45:50:45 + HA 10 kg ha^{-1})	$193.14^{b} \pm 2.89$	$102.05^{b} \pm 1.73$	$13.03^{b} \pm 0.58$
T7 (NPK 40:45:40 + HA 10 kg ha^{-1})	$190.26^{b} \pm 1.73$	$99.17^{c} \pm 1.15$	$12.11^{c} \pm 0.46$
F value	51.7	50	39.58

***HA = Humic Acid**

Fruit Development and Yield (Fruit Diameter, Length, and Yield)

Fruit size and yield were also positively affected by the nutrient treatments (Table 4). Plants without NPK or HA produced the smallest fruits and lowest yield, highlighting the impact of nutrient deficiency. Maximum fruit diameter, length, and total yield were recorded under T5 (NPK 50:60:50 + HA 10 kg ha^{-1}). Treatments with moderate nutrient levels and/or HA (T6, T7) achieved intermediate improvements, while lower nutrient combinations (T2–T4) resulted in smaller fruits and reduced yield, though still better than the control. Overall, these findings indicate that combining higher NPK levels with 10 kg ha^{-1} HA supports both vegetative vigor and fruit productivity, demonstrating the effectiveness of integrated nutrient management in melon cultivation.

***Table 4**. Effect of NPK fertilizer and humic acid on fruit characteristics and yield of melon*

Treatment	Fruit Diameter (cm)	Fruit Length (cm)	Yield (ton/ha)
T1 (Control - no NPK and no humic acid)	$29.15^{f} \pm 0.29$	$35.32^{f} \pm 0.20$	$36.56^{f} \pm 0.35$
T2 (NPK 50:60:50 + HA 7 kg ha^{-1})	$35.97^{cd} \pm 1.00$	$46.20^{b} \pm 2.00$	$43.74^{cd} \pm 1.23$
T3 (NPK 45:50:45 + HA 7 kg ha^{-1})	$35.34^{ed} \pm 0.65$	$41.57^{de} \pm 1.25$	$42.97^{d} \pm 1.25$
T4 (NPK 40:45:40 + HA 7 kg ha^{-1})	$33.98^{e} \pm 0.58$	$39.95^{e} \pm 1.25$	$41.19^{e} \pm 1.20$
T5 (NPK 50:60:50 + HA 10 kg ha^{-1})	$41.99^{a} \pm 1.00$	$53.84^{a} \pm 1.53$	$50.06^{a} \pm 1.20$
T6 (NPK 45:50:45 + HA 10 kg ha^{-1})	$39.14^{b} \pm 0.65$	$45.31^{bc} \pm 2.26$	$46.55^{b} \pm 1.50$
T7 (NPK 40:45:40 + HA 10 kg ha^{-1})	$37.20^{c} \pm 0.85$	$43.39^{cd} \pm 2.40$	$44.98^{c} \pm 0.74$
F value	45.80	45.00	45.00

*HA = Humic Acid

DISCUSSION

The application of NPK and humic acid together affected both growth and yield parameters of melon. Growth parameters such as plant length, number of leaves per plant, and number of branches per plant increased significantly. Application of NPK fertilizer at the proper growth stages of melon increases growth parameters. At the same time, the application of humic acid, which supports fertilization, improves nutrient availability in the soil, and stimulates melon growth, also improves growth parameters. Similarly, NPK and humic acid treatments significantly increased yield parameters of melon, including fruit diameter, fruit length, and yield. Macronutrients, especially NPK fertilizers, are essential for crop growth and yield. Humic acid application also stimulates crop growth and yield. Thus, the application of NPK fertilizer and humic acid improved melon growth and yield by providing nutrients at critical stages of melon development.

The greater plant length recorded under the combined application of NPK and humic acid reflects an enhanced vegetative response of melon to improved nutrient management. Adequate NPK supply during critical growth stages is fundamental for promoting cell division and elongation, thereby supporting vigorous plant development. In addition, humic acid has been widely reported to enhance nutrient availability and uptake efficiency by improving root growth, increasing soil cation exchange capacity, and facilitating the chelation of micronutrients. These improvements may stimulate physiological processes associated with vegetative growth, including enhanced carbohydrate synthesis, ultimately contributing to faster plant elongation and greater biomass accumulation. The findings were consistent with those of Zhu et al. (2025), who reported that applying humic acid significantly increased plant height. Similarly, the increase in the number of leaves under NPK and HA treatments may also be due to increased soil nutrient availability, which is effectively taken up by melon roots, stimulating plants to produce more leaves and grow faster. Widari (2024) also reported that the application of 7 kg ha^{-1} of humic acid increased the number of leaves in bitter melon. Furthermore, the improvement in the number of branches in the melon may also be due to the availability of nutrients in the soil as well as increased uptake of nutrients by melon roots, which was provided by NPK fertilizer at early growth stages, as well as the application of a high amount of humic acid, which may have also increased the availability of nutrient uptake and facilitated the absorption of nutrients by melon plant roots. Humic acid may also have stimulated growth hormone production in plants, leading to rapid growth and more branches.

Moreover, the increases in the fruit and yield attributes of melon with NPK and humic acid may be due to the increased carbohydrate provided during growth stages and stored in the source of melon plants, supporting sink fruits in reproductive stages. Similar findings were reported by Ilme et al. (2025): the combination of Hioto Grow Gold fertilizer and NPK significantly increased the melon source content. The improvement of fruit diameter and fruit length of melon may be due to the availability and increased amount of carbohydrates and their assimilation and translocation from sources to the sink in fruits. That produced during photosynthesis during growth stages stimulated by the application of NPK and humic acid increased cell division and elongation in fruits. Widari (2024) also reported that application of 7 kg humic acid ha^{-1} improved fruit length and diameter in bitter melon.

Finally, the increase in melon yield may also be due to favorable uptake and availability of macro- and micronutrients, facilitated by the combined application of NPK and humic acid. This increased carbohydrate production during photosynthesis, resulting in faster growth and improved source content; thus, the sink, fruit parameters, and yield increased. Similar findings were also reported by Ilmi et al. (2025): the application of Bioto Grow Gold (BGG) biological fertilizer at 3 ml $plant^{-1}$ and 70 g $plant^{-1}$ NPK Mutiara fertilizer increased melon yield.

Thus, the application of NPK and humic acid positively affected both melon growth and yield. Growth parameters, such as plant length, leaf number, and branch number, increased. As well as yield parameters such as fruit diameter and fruit length, yield increased significantly under the semi-arid conditions of Kandahar. Even though the study was limited to the local semi-arid conditions of Kandahar, due to limited resources, the experiment was not repeated, and we were unable to measure photosynthesis, chlorophyll, and fruit quality parameters.

CONCLUSION

The results revealed that the combination of NPK and humic acid not only affected melon growth but also positively affected yield in the study area. For instance, among the treatments, the T5 (NPK 50:60:50 + HA 10 kg ha^{-1}) resulted in an increase in plant length, number of leaves, and number of branches per plant by 30.55%, 63.77%, and 66.58%, respectively as well as the yield parameters, such as fruit diameter, fruit length, and yield, which were increased significantly by 44.04%, 28.28%, and 27.32%, respectively. It is recommended that applying NPK fertilizer (50:60:50) and 10 kg ha^{-1} of humic acid increase melon growth and yield in the climate and soil of the study area. Further studies are recommended to investigate the effect of humic acid on relative chlorophyll content and fruit quality attributes of melon in local areas.

AUTHORS CONTRIBUTION

Rahimullah Himatkhwah and Mirwais Khan Afghan conceptualized, outlined, and conducted the investigation. Rahimullah Himatkhwah composed the commentary, and Mohammad Sadiq Salihi conducted the writing review and was able to write and revise the initial manuscript. All authors reviewed and approved the final adaptation of the original copy.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest regarding the publication of this study. All the research, data collection, analysis, and interpretation were conducted independently, and no financial, personal, or professional relationships influenced the results or conclusions presented in this paper.

DATA AVAILABILITY STATEMENT

The data is accessible from the corresponding author upon reasonable request. All relevant data were generated and analyzed during the current considerations and have not been kept in an open repository due to organizational or regional limitations.

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