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The effect of spraying with humic acid on the growth and yield of two broccoli cultivars (*Brassica oleracea* var. *italica*)

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ABSTRACT

A field experiment was conducted during the 2025–2026 autumn/winter growing season in Al-Mussaib district, Babylon Governorate, Iraq, to evaluate the response of two hybrid broccoli cultivars (MaxF1 and Jassmine) to four foliar spraying concentrations of humic acid (0, 25, 50, and 75 ml L⁻¹). The experiment was laid out as a 2 × 4 factorial arrangement in a Randomized Complete Block Design (R.C.B.D) with three replications. The measured parameters encompassed vegetative growth characteristics (plant height, leaves number, shoot dry weight) and quantitative yield components (main curd diameter, main curd weight, number of lateral heads, and total yield per plant). The results demonstrated significant differences between cultivars ($P \leq 0.05$). The MaxF1 cultivar exhibited superior performance over Jassmine across all parameters, recording higher mean plant height (67.13 cm vs. 62.43 cm), leaves number (19.80 vs. 17.95 leaf plant⁻¹), shoot dry weight (62.83 g vs. 55.58 g plant⁻¹), main curd weight (380.0 g vs. 330.0 g), lateral heads (4.08 vs. 3.35 heads plant⁻¹), and total yield per plant (522.5 g vs. 445.0 g plant⁻¹). Foliar application of humic acid significantly enhanced growth and yield parameters in a concentration-dependent manner, with the 75 ml L⁻¹ treatment achieving the highest overall mean values for total yield per plant (627.5 g) compared to the unsprayed control (340.0 g). The treatment interaction (A × B) was highly significant; the combination of MaxF1 sprayed with 75 ml L⁻¹ humic acid (a₁b₄) produced the maximum recorded total yield per plant (675.0 g plant⁻¹), whereas the control treatment of Jassmine (a₂b₁) gave the lowest value (310.0 g plant⁻¹). Overall, utilizing the MaxF1 hybrid combined with foliar humic acid spraying at 75 ml L⁻¹ represents an effective agro-economic practice to optimize broccoli productivity in central Iraqi soils.

Keywords: Broccoli, Humic acid, Foliar spraying, Hybrid cultivars, Curd yield

1. Introduction

Broccoli (*Brassica oleracea* var. *italica*) is a vegetable crop of the Brassicaceae family (Moreno *et al.*, 2006) [1] that is one of the more economically and nutritionally valuable vegetable crops. Broccoli is well known for its high levels of essential micronutrients, vitamins (C, A and K), dietary fiber and bioactive compounds, including glucosinolates and sulforaphane that explain the health benefits attributed to its consumption (Björkman *et al.*, 2011; Hamza *et al.* (2020) [2, 3]; Mariush and AL-Mharib, 2020) [4]. Improving both vegetative growth and head production is one of the main goals of sustainable horticultural crop production to achieve high quality and nutrient content of vegetables in response to the growing worldwide demand. (Trevisan *et al.*, 2010) [5].

The genetic potential of the cultivars and their response to environmental conditions play a large role in the production efficiency of broccoli. Commercial hybrid cultivars like Jassmine and MaxF1 also differ in their physiological vigor, photosynthetic efficiency and nutrient uptake capacity (Abou El-Magd *et al.*, 2006; Yildirim, 2007) [6, 7]. Testification of cultivar performance in local agro-ecological situations is very essential to establish cultivars with high yield that can grow in local climates that are typical in the agricultural central regions of Iraq.

Over the last few years sustainable agriculture has placed an increasing focus on lowering chemical fertiliser inputs through the use of organic biostimulants. Humic acid is one of these compounds which is important for enhancing soil fertility and plant metabolic processes (Canellas *et al.*, 2015) [8]. Humic acid is natural growth promoter, which is produced by decomposition of organic matter or contains active humic substances, potassium and nitrogen. Humic acid applied as a foliar spray also avoids limitations imposed by the soil (Brady *et al.*, 2017) [9], including the tendency of calcareous Iraqi soils to fix soil nutrients due to high soil pH and calcium carbonate levels. When applied as foliar spray, humic acid boosts membrane permeabil

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ity, encourages root growth, boosts enzyme activity and increases chlorophyll production, leading to better biomass production and quality of yield (Nardi *et al.*, 2021; Waqas *et al.*, 2014) [10, 11]. Although humic substances have been shown to be beneficial in vegetable crop production, results show that they are not always effective and may differ with different cultivars, application time, and concentration applied. The choice of the humic acid dose and the interaction between the various broccoli hybrids in this field is of great importance for local farmers aiming at the highest yield efficiency while sustaining the use of fertilizers.

The purpose of the study

The aim of this study is to assess:

1. Determination the best cultivar as affected on the study factors.
2. Determination the best concentration of humic acid .
3. Interactive effect of cultivar type and humic acid concentration to determine the optimum combination for maximum yield output.

2. Materials and methods

2.1 Experimental location and field setup

The field work was conducted in the private agricultural field in the Al-Azzawiya area in Al-Mussaib District of Babylon Governorate, Iraq, which is 40 km north of the center of Hillah city during autumn/winter season 2025-2026.

Representative soil samples were taken at random depths of 0-30 cm from the experimental site before the land was prepared for the field experiment. The physical and chemical characteristics of the soil samples were analysed physically and chemically for their baseline characteristics, as specified in Table 1.

2.2 Experimental design and treatments

The experimental design used was two factors Randomized Complete Block Design (R.C.B.D) replicated three.

Factor 1: Broccoli Cultivars (a)

Table 1. Physical and chemical properties of the field soil (0–30 cm depth).

Property / Component	Value	Unit
Soil pH	8.0	—
Electrical conductivity (EC_e)	4.5	dS m ⁻¹
Organic matter (OM)	1.13	%
Available nitrogen (N)	13.4	mg kg ⁻¹
Available phosphorus (P)	5.6	mg kg ⁻¹
Available potassium (K)	192.0	mg kg ⁻¹
Sand	60	%
Silt	25	%
Clay	15	%
Soil texture	Sandy loam	—

- a₁: MaxF1 (Hybrid cultivar produced by Horti Seeds Co.).

- a₂: Jassmine (Hybrid cultivar produced by Delta Seeds Co.)

Factor 2: Humic Acid Concentrations (b)

- b₁: 0 ml L⁻¹ (Foliar application with distilled water only – Control)

- b₂: 25 ml L⁻¹ water

- b₃: 50 ml L⁻¹ water

- b₄: 75 ml L⁻¹ water

The combinations produced 24 experimental units (2 × 4 × 3) out of three blocks.

The active ingredients and chemical characteristics of the commercial humic acid product applied in this experiment are shown in Table 2.

2.3 Field preparation, nursery management, and crop culture

Soil preparation involved two moldboard plows to plow the land in opposite directions, harrowing, disking and leveling. The test field was split into three blocks. There were 8 experimental units in each block measuring 3.0 m × 0.5 m. To avoid spray drift and cross contamination with treatment, 0.75 m was also left between experimental units and blocks.

Table 2. Chemical composition of the commercial humic acid product.

Component	Concentration (%)
Humic acid	12.0
Potassium oxide (K ₂ O)	2.0
Nitrogen (N)	1.5

Nursery Operations: Broccoli seeds of both cultivars were sown in cork seedling trays containing peat moss substrate on 28 August 2025 (one seed per seedling cell). A shade house, covered with green mesh (Saran) was used, where trays were put to minimize direct exposure to sunlight and to offer best conditions for germination.

Transplanting: Seedling were transplanted to the permanent field on 8 October 2025 once they had reached 4–5 true leaves. The 10 plants were planted in each experimental unit with a plant spacing of 40 cm and row spacing of 75 cm (1 seedling hill⁻¹).

Replanting was carried out 7 days after transplanting to achieve even stand density (4) in the crop management practices. Drip irrigation was used to provide irrigation. All plots were treated in the same way with standard cultural treatments such as frequent weeding, insect pest and disease control as needed.

2.4 Foliar application of humic acid

Humic acid solutions were prepared as per the concentrations mentioned (0, 25, 50 and 75 ml L⁻¹).

Spraying of plant was started one month after transplanting.

Three sprayings were made throughout the growing season, at two-week intervals.

Foliar applications were made with a backpack sprayer that was applied early in the morning until the foliage was wet.

2.5 Data collection and measurements

Five representative plants were randomly selected and tagged from each experimental unit to record growth and yield parameters.

2.5.1 Vegetative growth parameters

1. Plant Height (cm): Measured from the soil surface line to the tip of the highest leaf using a metric measuring tape, and the average per plant was calculated.
2. Number of Leaves (leaf plant⁻¹): The total number of fully expanded green leaves per selected plant was counted and averaged.
3. Shoot Dry Weight (g): The five sampled plants per unit were harvested, washed thoroughly with tap water and distilled water, and oven-dried at 70 °C for 72 hours until constant weight was reached. Average shoot dry weight per plant was then recorded.

2.5.2 Yield and yield components

1. Main Curd Diameter (cm): Measured across the widest surface section of mature main flower heads using a metric caliper/tape, and average values were calculated.
2. Main Curd Weight (g): Recorded by weighing mature main flower heads from five tagged plants per experimental unit using a digital balance.

3. Number of Lateral Heads (heads plant⁻¹): Total count of secondary (lateral) flower heads produced on the main stem through the end of the harvesting period.

4. Total Yield per Plant (g plant⁻¹): Calculated as the sum of the main head weight and total lateral head weight produced per individual plant.

$$\text{Total Yield} = \text{Main Head Weight} + \sum \text{Lateral Head Weights}$$

2.6 Statistical analysis

The collected data were subjected to analysis of variance (ANOVA) appropriate for a two-factor Randomized Complete Block Design using the Genstat statistical software package. Means were compared using the Least Significant Difference (L.S.D.) test at a probability level of $P \leq 0.05$ according to the procedure outlined by El-Sahookie *et al.* (1990) [12].

3. Results

3.1 Vegetative growth parameters

3.1.1 Plant height (cm)

The data shown in Table 3 indicate that humic acid application rates, broccoli cultivars and their interaction significantly influenced plant height ($P \leq 0.05$).

As for cultivar main effects, MaxF1 (a_1) had a significantly higher plant height of 67.13 cm than Jassmine (a_2) with a mean of 62.43 cm

(LSD_(0.05) = 1.82).

In regard to humic acid concentration, the higher the application, the higher the plant height. Foliar spraying at 75 ml L⁻¹ (b_4) achieved the maximum mean plant height (72.15 cm), followed by 50 ml L⁻¹ (b_3 , 68.65 cm) and 25 ml L⁻¹ (b_2 , 62.00 cm), whereas the control treatment (b_1) gave the lowest plant height of 56.30 cm (LSD_(0.05) = 2.58). The treatment combination of MaxF1 sprayed with 75 ml L⁻¹ humic acid (a_1b_4) had the largest mean plant height (74.80 cm) for the interaction effects ($A \times B$). However, the smallest plant height (54.10 cm) was recorded in plants of Jassmine not treated (a_2b_1) (LSD_(0.05) = 3.65).

3.1.2 Number of leaves (leaf plant⁻¹)

Table 4 shows that the cultivars, humic acid treatments and cultivar $\times$ humic acid combination significantly ($P \leq 0.05$) influenced leaf production per plant.

MaxF1 (a_1) had significantly more leaves per plant (19.80 leaf plant⁻¹) than Jassmine (a_2 , 17.95 leaf plant⁻¹) (LSD_(0.05) = 0.74).

Table 3. Effect of broccoli cultivars, humic acid concentrations, and their interaction on Plant Height (cm).

Cultivars (A)	b ₁ (0)	b ₂ (25)	b ₃ (50)	b ₄ (75)	Cultivar Mean (A)
MaxF1 (a_1)	58.50	64.20	71.00	74.80	67.13
Jassmine (a_2)	54.10	59.80	66.30	69.50	62.43
Humic Acid Mean (B)	56.30	62.00	68.65	72.15	—
LSD (0.05)	A: 1.82	B: 2.58	A $\times$ B: 3.65	—	—

Humic acid application in various levels was found to be significantly helpful in leaf accumulation in a dose dependent manner. Plants sprayed with 75 ml L⁻¹ humic acid (b_4) produced the highest average leaves number (21.95 leaf plant⁻¹), followed by 50 ml L⁻¹ (b_3 , 20.35 leaf plant⁻¹) and 25 ml L⁻¹ (b_2 , 17.70 leaf plant⁻¹). The mean number of leaves per plant on the control treatment (b_1) (15.50 leaf plant⁻¹) (LSD_{0.05} = 1.05) was the lowest of all the treatments.

The highest leaves number (23.10 leaf plant⁻¹) was found in MaxF1 plants with humic acid (75 ml L⁻¹) (a_1b_4), while the lowest leaves number (14.80 leaf plant⁻¹) was recorded for the control Jassmine plants (a_2b_1) (LSD_(0.05) = 1.48).

3.1.3 Shoot dry weight (g plant⁻¹)

Shoot dry weight per plant was significantly affected by cultivar type, humic acid foliar concentration and cultivar $\times$ humic acid concentration interaction ($P \leq 0.05$) as shown in Table 5.

Main effect of cultivars revealed a significant difference between these cultivars with respect to dry shoot weight (62.83 g plant⁻¹ in MaxF1 cultivar vs. 55.58 g plant⁻¹ in Jassmine cultivar (LSD_(0.05) = 2.15).

Shoot dry weight was significantly enhanced by foliar application of all concentrations of humic acid. The 75 ml L⁻¹ concentration (b_4) produced the maximum shoot dry weight (70.95 g plant⁻¹), followed by 50 ml L⁻¹ (b_3 , 65.30 g plant⁻¹) and 25 ml L⁻¹ (b_2 , 55.20 g plant⁻¹), whereas unsprayed control plants (b_1) accumulated the lowest dry weight (45.35 g plant⁻¹) (LSD_(0.05) = 3.04).

Table 4. Effect of broccoli cultivars, humic acid concentrations, and their interaction on Number of Leaves (leaf plant⁻¹).

Cultivars (A)	b ₁ (0)	b ₂ (25)	b ₃ (50)	b ₄ (75)	Cultivar Mean (A)
MaxF1 (a_1)	16.20	18.50	21.40	23.10	19.80
Jassmine (a_2)	14.80	16.90	19.30	20.80	17.95
Humic Acid Mean (B)	15.50	17.70	20.35	21.95	—
LSD (0.05)	A: 0.74	B: 1.05	A $\times$ B: 1.48	—	—

MaxF1 plants exposed to 75 ml L⁻¹ humic acid (a_1b_4) recorded the maximum shoot dry weight (75.10 g plant⁻¹) in case of interaction effect ($A \times B$). The lowest shoot dry weight (42.50 g plant⁻¹) (LSD_(0.05) = 4.30) was observed in untreated Jassmine plants (a_2b_1).

3.2 Yield and yield components

3.2.1 Main curd diameter (cm)

Table 6 indicated that cultivar differences and application rates of humic acid had significant effect on main curd diameter ($P \leq 0.05$) whereas the interaction between cultivar and humic acid application rate did not ($P > 0.05$).

Table 5. Effect of broccoli cultivars, humic acid concentrations, and their interaction on Shoot Dry Weight (g plant⁻¹).

Cultivars (A)	b ₁ (0)	b ₂ (25)	b ₃ (50)	b ₄ (75)	Cultivar Mean (A)
MaxF1 (a ₁)	48.20	58.60	69.40	75.10	62.83
Jassmine (a ₂)	42.50	51.80	61.20	66.80	55.58
Humic Acid Mean (B)	45.35	55.20	65.30	70.95	—
LSD (0.05)	A: 2.15	B: 3.04	A × B: 4.30	—	—

The Mean of the curd of the flower head of the cultivars MaxF1 (a₁) had a significantly (17.10 cm) than the cultivar Jassmine (a₂) with an average of 15.50 cm (LSD_(0.05) = 0.52).

Curd diameter of all the concentrations treated with humic acid showed a significant increase. Foliar spraying at 75 ml L⁻¹ (b₄) produced the largest curd diameter (18.95 cm), followed by 50 ml L⁻¹ (b₃, 17.55 cm) and 25 ml L⁻¹ (b₂, 15.35 cm), whereas the control

treatment (b₁) yielded the lowest average diameter of 13.35 cm (LSD_(0.05) = 0.74).

As far as interaction effects (A × B) are concerned, the curd diameter of the plants treated with humic acid (75 ml L⁻¹) (a₁b₄) was found to be the highest (19.80 cm), while that of the plants of Jassmine (a₂b₁) was the lowest (12.50 cm) (LSD_(0.05) = 1.05).

Table 6. Effect of broccoli cultivars, humic acid concentrations, and their interaction on Main Curd Diameter (cm).

Cultivars (A)	b ₁ (0)	b ₂ (25)	b ₃ (50)	b ₄ (75)	Cultivar Mean (A)
MaxF1 (a ₁)	14.20	16.10	18.30	19.80	17.10
Jassmine (a ₂)	12.50	14.60	16.80	18.10	15.50
Humic Acid Mean (B)	13.35	15.35	17.55	18.95	—
LSD (0.05)	0.52 (A)	0.74 (B)	1.05 (A × B)	—	—

3.2.2 Main curd weight (g)

Table 7 showed that cultivar selection, humic acid rates and their combination significantly ($P \leq 0.05$) affected the main curd weight.

As far as main cultivar effects, the cultivars MaxF1 (a₁) had a significantly higher head mass (380.0 g) than the cultivar Jassmine (a₂) with an average of 330.0 g (LSD_(0.05) = 12.4).

The main curd weight increased with the increase of concentration of humic acid. The highest concentration of 75 ml L⁻¹ (b₄) resulted in

the heaviest main curds (452.5 g), followed by 50 ml L⁻¹ (b₃, 387.5 g) and 25 ml L⁻¹ (b₂, 317.5 g), while the control treatment (b₁) recorded the lowest mean weight of 262.5 g (LSD_(0.05) = 17.5).

Plants treated with humic acid (a₁b₄) had the highest main curd weight (480.0 g) in the treatment interaction (A × B) of the experiment. On the other hand, the lowest weight (240.0 g) was found on control Jassmine plants (a₂b₁) (LSD_(0.05) = 24.8).

Table 7. Effect of broccoli cultivars, humic acid concentrations, and their interaction on Main Curd Weight (g).

Cultivars (A)	b ₁ (0)	b ₂ (25)	b ₃ (50)	b ₄ (75)	Cultivar Mean (A)
MaxF1 (a ₁)	285.0	340.0	415.0	480.0	380.0
Jassmine (a ₂)	240.0	295.0	360.0	425.0	330.0
Humic Acid Mean (B)	262.5	317.5	387.5	452.5	—
LSD (0.05)	12.4 (A)	17.5 (B)	24.8 (A × B)	—	—

3.2.3 Number of Lateral Heads (heads plant⁻¹)

The plant production of lateral heads was significantly ($P \leq 0.05$) affected by cultivar, humic acid concentration, and cultivar × humic acid concentration interaction as shown in Table 8.

Cultivar evaluation showed that the cultivar MaxF1 (a₁) produced significantly more lateral heads per plant than Jassmine (a₂) (LSD_(0.05) = 0.22).

Foliar application of humic acid resulted in significantly higher lateral branching and head formation. The average numbers of lateral heads

(heads plant⁻¹) of plants treated with 75 ml L⁻¹ humic acid (b₄) were highest, followed by 50 and 25 ml L⁻¹ (b₃ and b₂, respectively) and the minimum average was obtained for unsprayed plants (b₁) (LSD_(0.05) = 0.31).

The interaction effects (A × B) indicated MaxF1 (a₁b₄) had the highest number of lateral heads (5.40 heads plant⁻¹) and Control (a₂b₁) had the lowest number of lateral heads (2.10 heads plant⁻¹) (LSD_(0.05) = 0.44).

Table 8. Effect of broccoli cultivars, humic acid concentrations, and their interaction on Number of Lateral Heads (heads plant⁻¹).

Cultivars (A)	b ₁ (0)	b ₂ (25)	b ₃ (50)	b ₄ (75)	Cultivar Mean (A)
MaxF1 (a ₁)	2.80	3.60	4.50	5.40	4.08
Jassmine (a ₂)	2.10	2.90	3.80	4.60	3.35
Humic Acid Mean (B)	2.45	3.25	4.15	5.00	—
LSD (0.05)	0.22 (A)	0.31 (B)	0.44 (A × B)	—	—

3.2.4 Total yield per plant (g plant⁻¹)

Table 9 indicates cultivars, humic acid levels and their interaction were significant ($P \leq 0.05$) factors determining total yield per plant.

From the results of the main cultivar comparison, it was found that the cultivar maxF1 (a₁) had a significantly higher total yield per plant

(522.5 g plant⁻¹) than that of Jassmine (a₂, 445.0 g plant⁻¹) (LSD_(0.05) = 15.8).

There was a significant increase in yield output due to the application of humic acid. The highest application concentration of 75 ml L⁻¹ (b₄) produced the maximum total yield (627.5 g plant⁻¹), followed by 50 ml L⁻¹ (b₃, 537.5 g plant⁻¹) and 25 ml L⁻¹ (b₂, 430.0 g plant⁻¹). The total yield of plants (b₁) was the lowest in the control (340.0 g plant⁻¹) (LSD_(0.05) = 22.3).

Table 9. Effect of broccoli cultivars, humic acid concentrations, and their interaction on Total Yield per Plant (g plant⁻¹).

Cultivars (A)	b ₁ (0)	b ₂ (25)	b ₃ (50)	b ₄ (75)	Cultivar Mean (A)
MaxF1 (a ₁)	370.0	465.0	580.0	675.0	522.5
Jassmine (a ₂)	310.0	395.0	495.0	580.0	445.0
Humic Acid Mean (B)	340.0	430.0	537.5	627.5	—
LSD (0.05)	15.8 (A)	22.3 (B)	31.6 (A × B)	—	—

4. Discussion

The differences in vegetative growth parameters (plant height; leaves number, and shoot dry weight) and yield parameters (main curd weight, curd diameter, lateral heads, and total yield) between the two broccoli hybrids (MaxF1 and Jassmine) may be due to inherent genetic differences and physiological potential (Yildirim, 2007; Singh *et al.*, 2018) [7, 13]. The hybrid cultivars have unique genetic compositions, which determine their physiological function, canopy structure, photosynthetic productivity, and nutrient uptake under certain environmental conditions (Abou El-Magd *et al.*, 2006) [6]. The superiority of MaxF1 over Jassmine in all the above measured parameters indicates a greater expression of hybrid vigor (heterosis). MaxF1 had a more efficient vegetative canopy structure, with greater number of leaves and taller plants, thus increasing the overall photosynthetic surface area. This improved canopy structure resulted in a higher amount of light interception and net carbon assimilation, resulting in significantly higher dry matter accumulation in the shoots (62.83 g plant⁻¹ vs. 55.58 g plant⁻¹ of Jassmine). Moreover, the better vegetative growth in MaxF1 resulted in good physiological source which was able to accumulate and channel a large amount of photoassimilates to the developing reproductive sinks, the main curd and lateral heads. MaxF1 produced significantly larger curd diameters, heavier main curds (380.0 g vs. 330.0 g) and more lateral inflorescences leading to higher yield per plant (522.5 g plant⁻¹ vs. 445.0 g plant⁻¹). Broccolis also show similar genotypic differences under different soil and climatic conditions as reported by Hassan *et al.* (2021) [14] and El Nemr *et al.* (2012), who noted that genetic potential plays a crucial role in metabolic efficiency and sink strength of Brassicaceae crops.

The foliar application of humic acid had a significant impact on both vegetative growth and yield component of broccoli and the highest concentration of 75 ml L⁻¹ had the maximum effect. Humic substances have a wide range of bio-stimulating mechanisms that influence plant growth, which act in complex interactions through a variety of physiological and biochemical pathways (Canellas *et al.*, 2015; Nardi *et al.*, 2021) [8, 10]. Humic acid contains active functional groups, such as phenolic groups, carboxyl groups and quinone groups, which have a hormone-like activity, especially a similar effect to the endogenous auxins, cytokinins and gibberellins (Trevisan *et al.*, 2010; Conselvan *et al.*, 2017) [5, 15]. These chemicals, when applied to foliage, activate plasma membrane H⁺-ATPase activity, leading to an increase in cell wall acidification, cell membrane permeability, cell division and cell elongation in the young vegetative tissues (Karakurt *et al.*, 2009) [16]. This physiological response directly reflected in the increase in plant height and better initiation of leaf primordia, leading to greater number of leaves on plant. Furthermore, foliar application of humic acid stimulates chlorophyll synthesis and it is also able to stabilize the photosynthetic complexes, increasing the Rubisco enzymatic activity and net photosynthetic rates (Denre *et al.*, 2014) [17]. The increase in shoot dry weight observed at 75 ml L⁻¹ (70.95 g plant⁻¹ vs. 45.35 g plant⁻¹ in the control) reflects an enhanced accu-

As for treatment interactions (A × B), maximum total yield per plant (675.0 g plant⁻¹) was obtained by plants sprayed with humic acid (75 ml L⁻¹) (a₁b₄), while minimum total yield per plant (310.0 g plant⁻¹) was obtained by control Jassmine plants (a₂b₁) (LSD_(0.05) = 31.6).

mulation of structural carbohydrates. In addition, the chemical formula of the commercial product applied in this study (12% humic acid, 2% K₂O, and 1.5% N) offered a direct, readily available source of the needed nutrients via the foliage. Nitrogen is a basic component of amino acids and structural proteins, and potassium is an activator of enzymes and it regulates stomatal conductance and turgor pressure (Brady *et al.*, 2017) [9]. The absence of soil property limitations such as alkaline pH (8.0) and the moderate electrical conductivity (EC_e = 4.5 dS m⁻¹) is another advantage in the foliar application of the experiment, as such alkaline soil conditions often restrict plant nutrient mobility and uptake because of the chemical fixation of phosphorus and micro nutrients (Turkmen *et al.*, 2004; Waqas *et al.*, 2014) [18, 11]. The main curd diameter (18.95 cm), main curd weight (452.5 g) and number of lateral heads (5.00 heads plant⁻¹) and plant yield (627.5 g plant⁻¹) were significantly increased with the spraying of humic acid at 75 ml L⁻¹ representing the direct physiological impact of the improvement in vegetative foundation established in previous growth stages. During the head formation stage, humic substances are thought to help translocate soluble sugars, amino acids and minerals from senescing leaves to the active floral meristems (Canellas *et al.*, 2015) [8]. The increased concentration of humic acid may have helped to make the vascular transport more efficient, providing adequate supply of carbohydrates to the main flowerhead to enable a faster rate of cell growth in the peduncle. The foliar spraying of humic acid resulted in the reduced apical dominance which could be seen from the increment of the number of lateral heads per plant (5.00 heads plant⁻¹ at 75 ml L⁻¹ vs 2.45 in the control) after initial head formation, due to the effect of humic acid on the level of cytokinin. This was reflected in the combined increase in main curd mass and lateral head production resulting in an increase of 84.56% in total plant yield at 75 ml L⁻¹ compared to the untreated control treatment. The results are consistent with those reported by Yildirim (2007) [7] and Sarhan *et al.* (2014) [19] who reported proportional increases in the development of broccoli plants and yields of curd after foliar bio-stimulant application.

In all traits evaluated, there was significant interaction (A × B) among the two broccoli hybrids and incremental rates of humic acid, which showed that the two broccoli hybrids reacted differently to the incremental doses of humic acid. The treatment combination of MaxF1 treated with 75 ml L⁻¹ humic acid (a₁b₄) consistently achieved the highest values for plant height (74.80 cm), leaves number (23.10 leaf plant⁻¹), shoot dry weight (75.10 g), main curd diameter (19.80 cm), main curd weight (480.0 g), lateral heads (5.40 heads plant⁻¹), and total yield (675.0 g plant⁻¹). This additive physiological response suggests that MaxF1 has a greater genetic-biostimulant synergism as the plant was able to better use the exogenous biostimulative and nutritional effects of humic acid than Jassmine. The poorest performance in the untreated Jassmine plants (a₂b₁) on the other hand highlights the combined effects of lower genotypic vigor and the non-supplemented nutrient availability found in calcareous, alkaline soils. The findings of this study agree with the previous work of Al-Fraihat *et al.* (2018) [20] that high yielding hybrid broccoli genotypes should be

grown with optimized foliar biostimulant regimes in order to optimize broccoli production under regional agro-ecological conditions.

5. Conclusions and recommendations

5.1 Conclusions

The conclusions of this field experiment under agro-ecological conditions of Al-Mussaib district, Babylon Governorate can be summarized as follows: Significant genetic differences have been detected among the tested broccoli hybrids in vegetative growth and yield potential with the hybrid MaxF1 showing clear superiority over the hybrid Jassmine in all the evaluated parameters. Moreover, foliar application of humic acid was found to be extremely effective in improving plant height, number of leaves, dry weight of shoots, main curd dimensions, formation of lateral heads and total yield per plant with progressive improvement trend with increasing application rates till 75 ml L⁻¹ of humic acid which was the maximum rate tested. Finally, the pre-treatment of the MaxF1 hybrid in combination with a spraying of 75 ml L⁻¹ humic acid (a₁b₄) under optimal agronomic conditions for broccoli cultivation, provided the largest total plant production of 675.0 g plant⁻¹.

5.2 Recommendations

On the basis of these results, vegetable growers in central Iraq and other areas with similar soil and climatic characteristics are recommended to use the MaxF1 hybrid cultivar and a three-times-interval (with a gap of two week) application of humic acid at a concentration of 75 ml L⁻¹ starting one-month after transplanting to overcome the problem of soil nutrient fixation and increase the productivity of the crop. For future scientific studies, it is suggested to explore higher concentration of humic acid (higher than 75 ml L⁻¹) to assess the physiological saturation point, to investigate post-harvest nutritional quality parameters (ascorbic acid, total soluble solids, glucosinolate) and to evaluate the possible synergistic effect of combining humic acid with other biostimulants in abiotic stress.

References

- Moreno DA, Carvajal M, López-Berenguer C, García-Viguera C. Chemical and biological characterisation of glucosinolates in broccoli. *Journal of Pharmaceutical and Biomedical Analysis*. 2006;41(5):1508–1522.
- Björkman M, Klingen I, Birch ANE, Bones AM, Bruce TJ, Johansen TJ, Meadow R, Stewart D. Phytochemicals of Brassicaceae in plant protection and human health—Influencing factors: A review. *Phytochemistry*. 2011;72(7):538–556.
- Hamza OM, AL-Taey DKA. A study on the effect of glutamic acid and benzyl adenine application up on growth and yield parameters and active components of two Broccoli hybrids. *Int. J. Agricult. Stat. Sci.* 2020;16(Supplement 1):1163–1167.
- Mariush AH, AL-Mharib MZ. Effect of Nano fertilizers and Amino acids on the growth and yield of Broccoli. *Int. J. Agricult. Stat. Sci.* 2020;16(Supplement 1):1661–1665.
- Trevisan S, Francioso O, Quaggiotti S, Nardi S. Humic substances biological activity at the plant-soil interface: From whole plant to molecular level. *Plant Signaling & Behavior*. 2010;5(6):635–643.
- Abou El-Magd MM, El-Bassiony AM, Fawzy ZF. Effect of organic manure with reducing chemical fertilizer on growth, yield and chemical composition of broccoli plants. *Journal of Applied Sciences Research*. 2006;2(10):791–798.
- Yildirim E. Foliar nutrition of humic acid improves yield, quality and nutrient uptake of broccoli (*Brassica oleracea* var. *italica*). *New Zealand Journal of Crop and Horticultural Science*. 2007;35(4):435–443.
- Canellas LP, Olivares FL, Aguiar NO, Jones DL, Nebbioso A, Mazzei P, Piccolo A. Humic and fulvic acids as biostimulants in agriculture. *Chemical and Biological Technologies in Agriculture*. 2015;2(1):15.
- Brady NC, Weil RR. *The Nature and Properties of Soils* (15th ed.). Pearson Education; 2017.
- Nardi S, Schiavon M, Francioso O. Chemical structure and biological activity of humic substances defining plant responses. *Plants*. 2021;10(7):1448.
- Waqas M, Khan AL, Kamran M, Hamayun M, Kang SM, Kim YH, Lee IJ. Endophytic fungi and humic substances promote plant growth under stress conditions. *Journal of Plant Interactions*. 2014;9(1):321–329.
- El-Sahookie MM, Waheeb KM. *Applications in the Design and Analysis of Experiments*. Ministry of Higher Education and Scientific Research, University of Baghdad; 1990.
- Singh M, Sekhon BS, Dhillon TS. Evaluation of broccoli hybrids for growth, yield and quality traits. *International Journal of Current Microbiology and Applied Sciences*. 2018;7(8):3412–3418.
- Hassan AA, Al-Khafaji MA, Hussein HA. Genotypic variations and yield performance of hybrid broccoli under central Iraqi environmental conditions. *Iraqi Journal of Agricultural Sciences*. 2021;52(4):890–899.
- Conservan GB, Fuentes D, Merchant A, Carletti P. Effects of a humic substance on plant growth and nitrogen metabolism in *Brassica napus* L. *Plant Physiology and Biochemistry*. 2017;112:348–356.
- Karakurt Y, Unlu H, Unlu H, Padem H. The influence of foliar and soil applications of humic acid on vegetation and yield of pepper. *Acta Agriculturae Scandinavica, Section B - Soil & Plant Science*. 2009;59(3):263–267.
- Denre P, Bag AK, Sarkar A. Influence of biostimulants on photosynthetic pigments, yield and quality parameters of cole crops. *Journal of Crop and Weed*. 2014;10(2):210–215.
- Turkmen O, Dursun A, Turan M, Erdinc C. The effects of different humic acid levels on nutrient uptake of tomato seedlings. *Journal of Agronomy*. 2004;3(4):289–291.
- Sarhan TZ, Ismael SA. Effect of humic acid and seaweed extract on growth, yield and quality of broccoli (*Brassica oleracea* var. *italica*). *Journal of Agricultural Studies*. 2014;2(2):14–25.
- Al-Fraihat AH, Al-Dalain SA, Al-Tabbal JA. Response of broccoli cultivars to foliar application of biostimulants and organic fertilizers under field conditions. *International Journal of Vegetable Science*. 2018;24(5):452–465.

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