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EVALUATION OF THE EFFECTIVENESS FOLIAR APPLICATION OF HUMIC ACID IN ENHANCING GROWTH AND YIELD OF SUGARCANE (*Saccharum officinarum* L.) VARIETIE

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ABSTRACT:

Sugarcane (*Saccharum officinarum* L.) is a crop of significant agro-industrial value. This study aimed to evaluate the effects of foliar application of humic acid at different concentrations (0, 10, and 15 g per 4 L water) on the growth and yield performances of three sugarcane varieties (CP72-2086, CP89-2143, and CP81-325), additionally it was to ensure of growing sugarcane because for the first time it has been tested in the Erbil environment. The experiment was done in 15 April 2024, at Grdarasha Field, College of Agricultural Engineering Sciences. The results indicated that CP81-325 *var.* superior to other varieties for all parameters. Also, growth and yield were significantly improved in the interaction treatment (S3H1), so the maximum values of plant height, internode length and total fresh yield were (3.79m, 35.00cm and 0.88 kg cane^{-1}), respectively. Similar result of total fresh yield (0.88 kg cane^{-1}), was recorded by the CP89-2143 *var.* when humic acid at the concentration of (15 g 4L^{-1} water) added to the plants, while in the control treatment (S2H0) just about (0.69 kg cane^{-1}). Mostly, humic acid 10 g 4L^{-1} water showed the significant role in response for all varieties. Applying humic acid is necessary, it is not only for enhancing productivity but also for soil improvement and environment protection.

KEYWORDS: Sugarcane, Humic Acid Foliar Application, Improve Productivity

1. INTRODUCTION

Saccharum officinarum L., commonly known as sugarcane, is one of the most widely cultivated crops worldwide. Its global value as the main source of sucrose and also it well known for its economic value that produce 70% of the world's sugar (Ali *et al.,* 2021). Sugarcane is a tall perennial grass in the genus *Saccharum*, used for sugar production. The plants are usually 2–6 m tall with stout, jointed, fibrous stalks that are rich in sucrose, which accumulates in the stalk internodes. India has been known as the original home of sugarcane and sugar. India is the second largest producer of sugar in the world after Brazil and produces more of cane sugar and not beet sugar. Sugarcane is the important commercial crop of the country (Nandhini & Padmavathy, 2017). Improving growth, yield and also quality of this kind of crop globally required especially in the developing countries and regions like Kurdistan Region, during this present study focused on using humic acid, which was to improve sugarcane productivity, additionally to further protect soil from pollution. Overuse of artificial fertilizers are contaminating the soil, water, and air, and also it is the major contributor to raise greenhouse gas (GHG) emissions and lastly, harming the earth, so applying of organic and bio-fertilizers is an alternative way, which is to agricultural sustainability (Salih, 2025). Sugar recovery is dependent on the juice quality and influenced by factors, viz. moisture stress, light, temperature and nutrient availability (Vasantha *et al.,* 2021). Humic substances (HS) are dominant components of soil organic matter and are recognized as natural, effective growth promoters to be used in sustainable agriculture. In recent years, many efforts have been made to get insights on the relationship between HS chemical structure and their biological activity in plants using combinatory approaches. Relevant results highlight the existence of key functional groups in HS that might trigger positive local and systemic physiological responses via a complex network of hormone-like signaling pathways. The biological activity of HS finely relies on their dosage, origin, molecular size, degree of hydrophobicity and aromaticity, and spatial distribution of hydrophilic and hydrophobic domains (Nardi *et al.,* 2021). Humic acid (HA) is a principal component of humic substances, which is present in various sources, such as soil, humus, peat, oxidized lignite, and coal. HA can have various biochemical effects on plants, such as increasing cell membrane permeability, increasing photosynthesis and respiration rates, enhancing mineral uptake and enhancing protein synthesis and hormone-like activity as a plant growth regulator (Shen *et al.,* 2020) .

On the other hand, continuous sugarcane planting for 30 years resulted in soil acidification, as well as C/N, alkali hydrolyzable nitrogen, organic matter, and total sulfur content significantly lower than in newly planted fields. Continuous

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sugarcane planting affected soil bacterial, fungal, and AM fungal communities (Pang *et al.,* 2021).

The aims of this present study were to investigate the effect of foliar application of different concentrations of humic acid on growth and yield of sugarcane plant. Additionally, which was to ensure growing of sugarcane plant in Erbil environmental condition.

2. MATERIALS AND METHODS

Study Site:

The experiment was conducted at Grdarasha Field, College of Agricultural Engineering Sciences, Salahaddin University-Erbil. The study site was located at latitude 36.10116°N and longitude 44.00925°E, with an elevation of 415 meters above sea level. The geographical location of the experimental site is shown in (Figure 1), (Salih *et al.,* 2022).

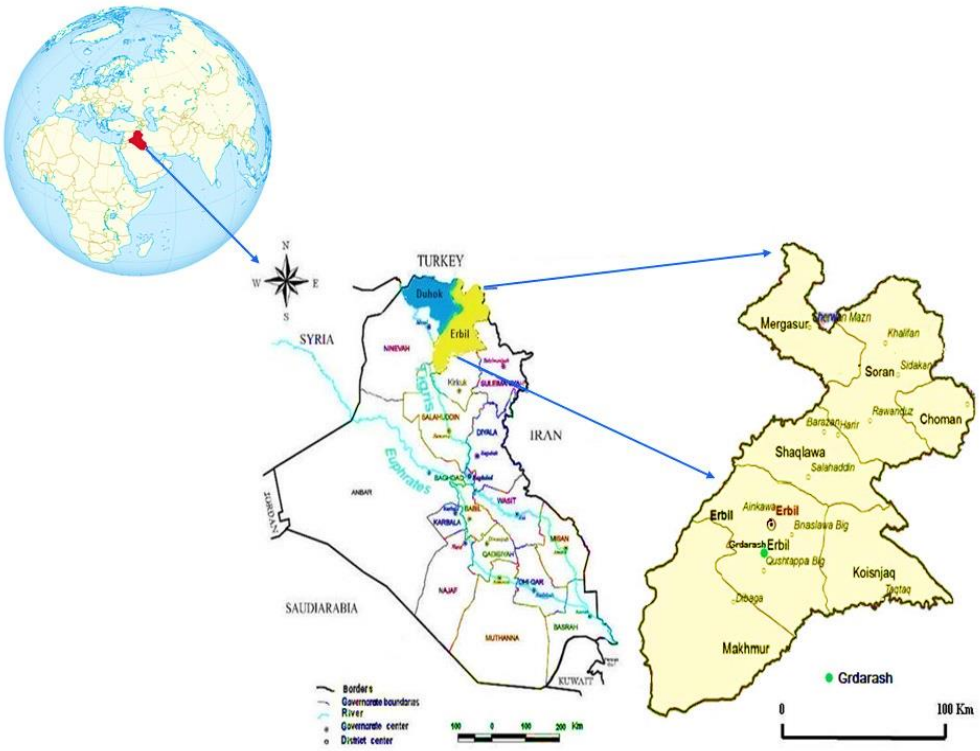

Figure 1: Geographical location of the study site. *Source:* (Salih *et al.,* 2022).

Experimental Design:

The experiment was carried out on 15 April 2024, which was an organized based on two factors with three replications in Factorial Randomized Complete Block Design (RCBD). The first factor was selected three sugarcane varieties (S1= CP72-2086, S2= CP89-2143, and S3= CP81-325), while the second factor was foliar applied of three different concentrations of humic acid (H0, H1 and H2); (0, 10 and 15g $4L^{-1}$ water). The humic acid used (BioHumic, 95% purity, 100% soluble, USA; Batch No. 201211) was applied at appropriate growth stages. Each experimental plot measured 6 m² (2 × 3 m) and included four rows, each 2 m long. Rows were spaced 0.75 m apart, with 2 m between replications and 1.5 m between plots. Planting was done at a depth of 10 cm, with a total of 27 plots occupying approximately 400 m² (13 × 30 m).

After eight months of growth, five plants were randomly selected from each plot to assess growth and yield characteristics.

Soil Sampling:

Before establishing the experiment, soil samples were collected from a 30 cm depth at multiple locations within the field. The composite samples were analyzed in the laboratory to determine physical and chemical properties (Table 1).

Table 1: Physical and chemical properties of the soil from the study site (Grdarasha Field).

	Soil Properties	
Chemical Properties	Nitrogen (mg Kg^{-1})	72.0
	Phosphorous (mg Kg^{-1})	5.12
	Potassium (mg Kg^{-1})	15.2
	$CaCo_3$ (%)	15.7
	Organic Matter (%)	1.73

Physical Properties	Bulk Density (g cm^3)	1.03
	CEC (meq 100 g $soil^{-1}$)	22.39
	EC (dS m^{-1})	0.19
	pH	8.04
	Soil Texture	Silty clay loam
	Sand (%)	16.28
	Silt (%)	49.24
	Clay (%)	34.47

Data Analysis:

From each treatment plots, five randomly selected plants were measured for various growth and yield parameters, including plant height, internode length, cane diameter, leaf number, and fresh biomass. The collected data were subjected to analysis of variance (ANOVA) using IBM SPSS Statistics 21. Treatment means were compared using Duncan's Multiple Range Test at a significance level of $P \leq 0.05$.

3. RESULTS AND DISCUSSIONS

Effect of Variety and Humic Acid on Growth and Yield Traits :

Table 2 shows the results of growth and yield traits, which were affected by each of variety and humic acid concentrations. Generally, significant differences were indicated between varieties for all growth and yield parameters except leaf number. The highest plant high, internode length and the biggest cane diameter were noted from the S3 variety (3.61m, 32.33cm and 25.67mm), respectively. While, S2 variety was recorded the smallest values of plant high and cane diameter (3.31m and 22.89mm), respectively. Moreover, each of these characteristics may cause to increase total fresh yield, fresh cane yield and also fresh leaf yield (0.81, 0.57 and 0.24) kg $cane^{-1}$, respectively which was again recorded by CP81-325 (S3) variety (Table 3). These present results were supported by Almubarak *et al.* (2024), who stated that sugarcane varieties were significantly affected stem high, the variety CP81-325 gave the highest stem height (3.8m), while CP89-2143 variety gave the lowest value (3.0m). Medeiros *et al.* (2013) was also reported that genotypes were significantly affected plant height. Stem yield of sugarcane was significantly differences between varieties (Abd El-Lattief, 2016 and Almubarak *et al.*, 2024). On the other hand, any significant was not found when humic acid was added to the plants except to internode length, so the longest value was recorded when humic acid (10 g $4L^{-1}$ water) was added, which was by (29.47cm).

Table 2: Single effects of variety and humic acid on growth characteristics of sugarcane.

Treatments	PH (m)	INL (cm)	CD (mm)	LN ($cane^{-1}$)
(S1)	3.34^{ab}	23.91^{b}	23.58^{b}	9.02^{a}
(S2)	3.31^{b}	25.20^{b}	22.89^{b}	8.89^{a}
(S3)	3.61^{a}	32.33^{a}	25.67^{a}	8.36^{a}
Humic acid				
H0	3.31^{a}	26.64^{b}	23.71^{a}	8.73^{a}
H1	3.55^{a}	29.47^{a}	24.49^{a}	8.53^{a}
H2	3.40^{a}	25.33^{b}	23.93^{a}	9.00^{a}

S1= CP72-2086, S2= CP89-2143, S3= CP81-325, H = Humic acid; H0= Control, H1= 10 g $4L^{-1}$ water, H2= 15 g $4L^{-1}$ water, TFY= Total fresh yield, FCY = Fresh cane yield, and FLY = Fresh leaf yield.

Table 3: Single effects of variety and humic acid on yield characteristics of sugarcane.

Treatments	TFY (Kg $cane^{-1}$)	FCY (Kg $cane^{-1}$)	FLY (Kg $cane^{-1}$)
(S1)	0.76^{b}	0.52^{a}	0.24^{a}
(S2)	0.75^{b}	0.54^{ab}	0.21^{b}
(S3)	0.81^{a}	0.57^{a}	0.24^{a}
Humic acid			
H0	0.76^{a}	0.53^{a}	0.23^{a}
H1	0.78^{a}	0.56^{a}	0.22^{a}
H2	0.78^{a}	0.55^{a}	0.23^{a}

S1= CP72-2086, S2= CP89-2143, S3= CP81-325, H = Humic acid; H0= Control, H1= 10 g $4L^{-1}$ water, H2= 15 g $4L^{-1}$ water, TFY= Total fresh yield, FCY = Fresh cane yield, and FLY = Fresh leaf yield.

Interaction Effects of Varieties and Humic Acid on Growth and Yield of Sugarcane:

The interaction between sugarcane varieties and humic acid concentrations significantly influenced plant height (Figure 2). The highest value (3.79 m) was observed in treatment S3H1 (CP81-325 with 10 g $4L^{-1}$ HA), followed by the treatments S2H2 and S1H1 (3.68 and 3.62 m), respectively. Plant height improved with humic acid, likely due to enhanced nutrient uptake, root activity, and stimulation of plant hormones (Ghareeb *et al.,* 2024; Mollah *et al.,* 2020; de Oliveira *et al.,* 2018a). Additionally, humic acid with nitrogen affected plant height significantly, likewise alone application of humic acid was also had significant affected (Khan *et al.,* 2019). Mekdad *et al.* (2021) indicated that the plant height was significantly increased by adding humic acid. Wahyuni *et al.* (2024) reported that biostimulant (Sucrosin, humic acid, and AM fungal) had significant affected plant height of sugarcan (Cenning *var.*).

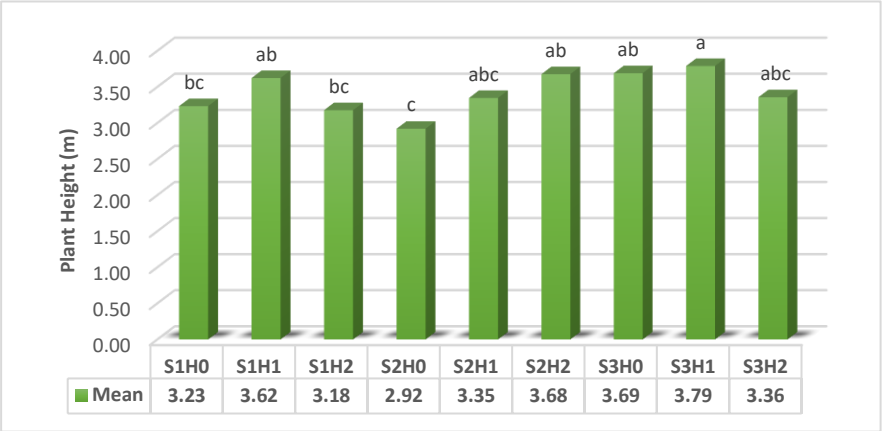

Figure 2: Interaction effects of varieties and humic acid on plant height (m).

Internode length was another growth parameter, which was significantly improved via adding humic acid especially at the conceneration of (10 g $4L^{-1}$ water). The best values were noted in the interaction treatments (SIH1, S2H1 and S3H1), were by (24.53, 28.87 and 35.00) cm, respectively (Figure 3). Having the suitable amount of nitrogen, phosphorus and potassium in the studied area with the optimal soil pH and also added humic acid may be one of the main factor, which was caused to improve this growth parameter in sugarcane (Table 1). From the statistical analysis of data presented that internode length was significantly affected by different levels of humic acid, the highest internode length was found when humic acid was applied to the sugarcane plant (Saeed & Sadiq, 2023).

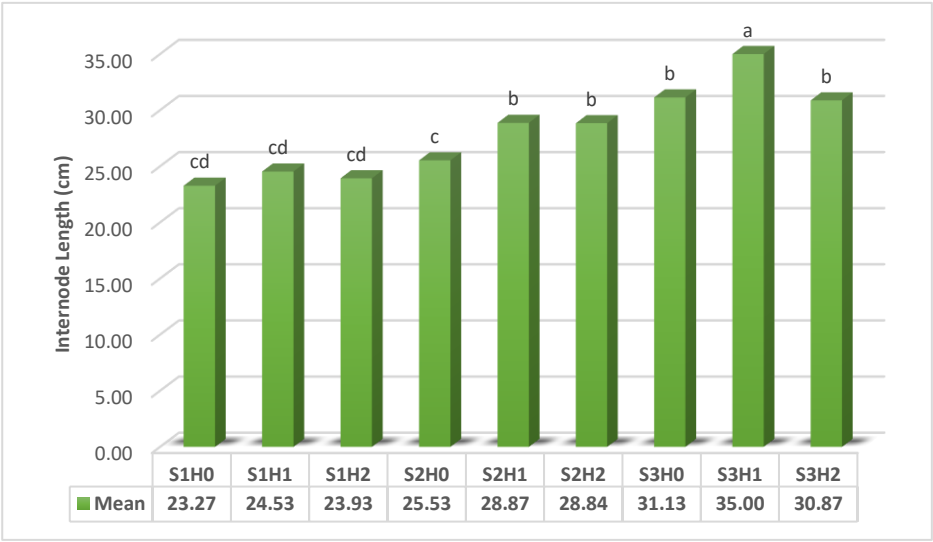

Figure 3: Interaction effects of varieties and humic acid on internode length (cm).

Statistical analysis of the data indicated that cane diameter in sugarcane varieties was significantly affected by the application of different humic acid concentrations (Figure 4). From the previous studies was confirmed that case. Teileb & Mourad (2019) stated that the high significance was noted in the interaction treatment on stem diameter of sunflower genotypes with humic acid and mineral fertilizers. Saeed & Sadiq (2023) reported that sugarcane stem diameter was increased with application of humic acid. Additionally, Ghareeb *et al.* (2024) whose indicated that interaction between humic acid levels and sunflower genotypes caused to record the biggest stem diameter.

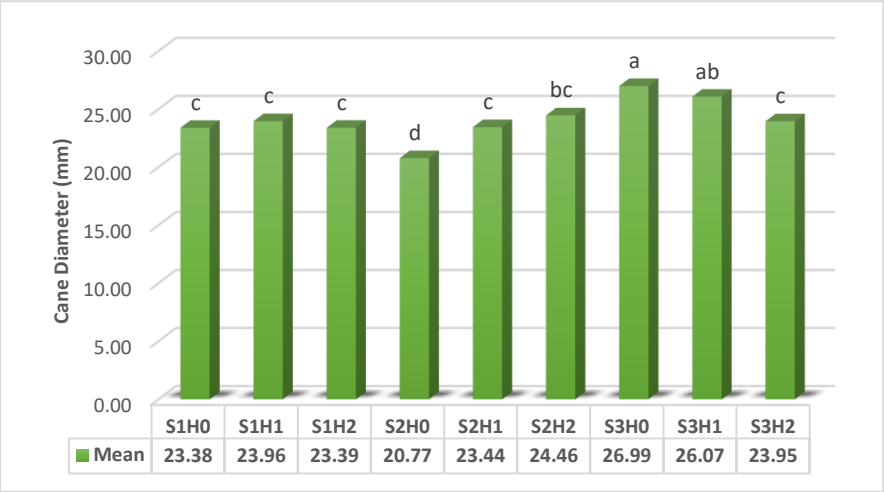

Figure 4: Interaction effects of varieties and humic acid on cane diameter (mm).

Any significant was not found between interaction treatments of leaf number, while in some cases noted to have slightly differnces with adding humic acid at the concenteration of (15 g $4L^{-1}$ water). The greatest leaf number was recorded in the treatments of (SIH2, S2H2 and S3H2), (9.33, 9.07 and 8.60), respectively (Figure 5). Leaf is the important organ of the plant which is the main source of food for the plant as the photosynthesis occurred in it. Humic acid concentration maximum number of leaves $plant^{-1}$, while minimum number of leaves $plant^{-1}$ was found in control treatment (Jan *et al.,* 2020). Number of leaves was incresed due to add humic substances for sugarcane (de Oliveira *et al.,* 2018b).

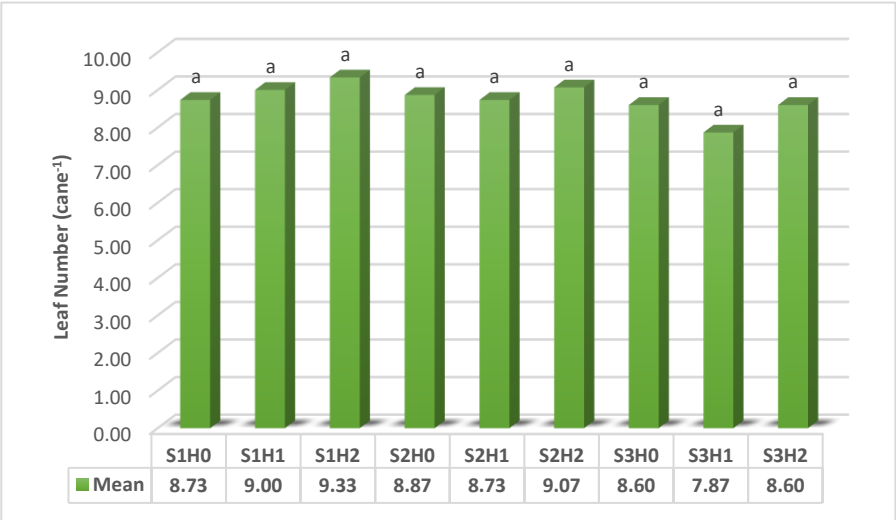

Figure 5: Interaction effects of varieties and humic acid on leaf number $cane^{-1}$.

Figure 6 displays total fresh yield (stem and leaf), of sugarcane, which was significantly improved when humic acid was added to the plants. Both humic acid concentrations had impact affected according to the varieties. The biggest values of total fresh yield were noticeable in the interaction treatments (SIH1, S2H2 and S3H1), were by (0.80, 0.88 and 0.88) kg $cane^{-1}$, respectively. On the other hand, humic acid not just effected on growth and productivity but also it might be improved soil physical and chemical properts, and then causes to improve growth and yield characteristics of sugarecane plants. However, may another reason refers to the ability of varieties to uptake nutrients as can be seen between varieties. These results in same line with the results were reported by (Ghareeb *et al.,* 2024). Sultan & Salih (2022) reperted that humic acid has numerous benefits for example; improved uptake of nutrients, decreasing of toxin, increased both water retention and microbial growth, which also enhanced the structure of soil. Besides, in some cases in this present study too much humic acid concentration (H2), was negatively affected total fresh yield as compared to (H1 and H0), these results were showed a great value economically and ecologically.

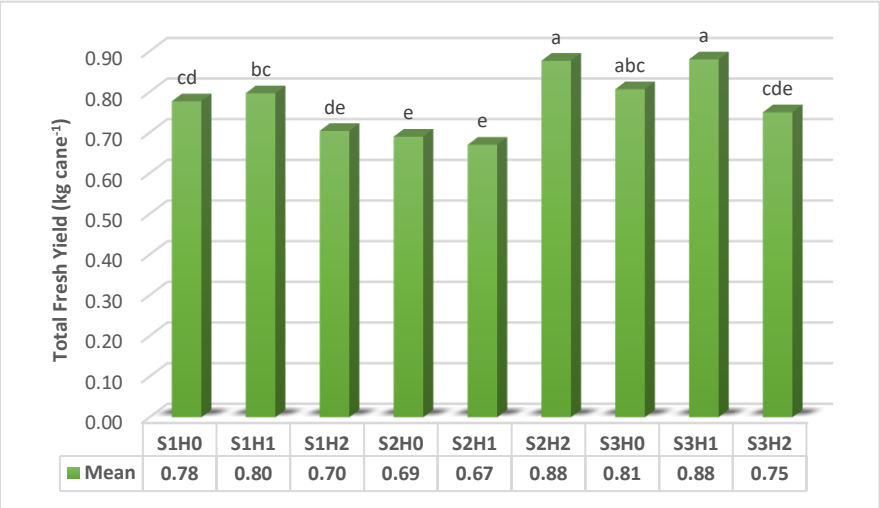

Figure 6: Interaction effects of varieties and humic acid on total fresh yield (kg cane^{-1}).

Fresh cane and leaf yields were significantly improved via adding humic acid concentrations to the sugarcane varieties (Figures 7 and 8). Maximum values of fresh cane yield were (0.56, 0.66 and 0.64) kg cane^{-1}, which were in the interaction treatments (SIH1, S2H2 and S3H1), respectively, while minimum amounts were found in the treatments (S1H2, S2H0 and S3H2), respectively. Humic acid with the chemical fertilizers were significantly increased cane yield of sugarecane (AL-Zubaidi *et al.,* 2020). Deshmukh *et al.* (2024) stated that cane yield was increased with adding humic acid at the rate of 10 kg ha^{-1}. Despite that, during this present study the second level of humic acid concentration (15 g 4L^{-1} water) was negatively affected fresh cane yield (Figure 7).

Figure 7: Interaction effects of varieties and humic acid on fresh cane yield (kg cane^{-1}).

The maximum fresh leaf yield of sugarcane was recorded by CP81-325 *var.* (S3), which was (0.25 kg cane^{-1}), in the both treatments (S3H1 and S3H2) as can be seen in the (Figure 8). While, the minimum amount of the same yield parameter was recorded by the CP89-2143 *var.* (S2), which was just about (0.19 kg cane^{-1}), followed by (0.22 kg cane^{-1}) in the interaction treatments of (S2H0 and S2H2), respectively.

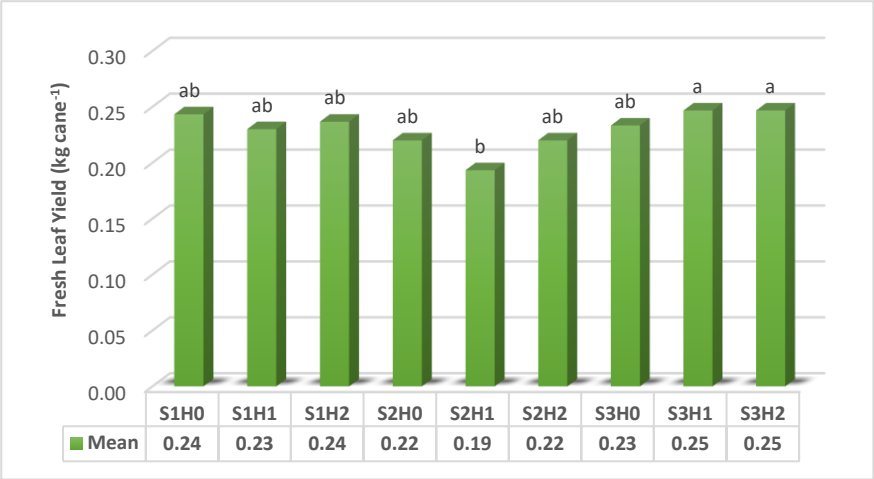

Figure 8: Interaction effects of varieties and humic acid on fresh leaf yield (kg cane^{-1}).

CONCLUSION

In this present study humic acid concentrations were applied to the sugarcane varieties, which was to improve growth and yield traits. Usually, humic acid has great role in improving soil physical and chemical properts, and also it improves soil microbiology. Results showed that, all varieties (CP72-2086, CP89-2143 and CP81-325), response to humic acid. Despite that, the maximum values of plant height, internode length and total fresh yield (stem and leaf) were recorded in the interaction treatment S3H1, (CP81-325 with 10 g 4L^{-1} HA). Generally, 10 g 4L^{-1} water of humic acid application in most cases superior to control and 15 g 4L^{-1} water. However, further research is needed to investigate the impact of the application of humic acid to the soil, which may be improve soil physio-chemical properts, and then enhance growth and yield of sugarcane.

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Author Contributions:

R. F. S. carried out the conception and design of the study, while S. D. A. collected and analysed the data and drafted the manuscript.

Declaration:

Authors confirms that have no conflict of interest to declare.

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