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Humic Acid Foliation and Nutrient Levels Concerning Yield and Quality of Sweet Corn (*Zea mays* L. Convar. Saccharata)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The increasing demand for sweet corn has driven the need for innovative agricultural practices to enhance yield and quality. One such promising approach is the foliar application of humic acid combined with varied nutrient levels. We aimed to conduct a field to study the effect of foliar application of humic acid on the growth and yield of Sweet corn (*Zea mays* convar. *saccharata* L.) at AHRS Kathalagere, University of Agricultural and Horticultural Sciences, Shivamogga the summer of 2021. The various treatments included a combination of RDF with different concentrations of humic acid to improve the yield and quality of sweet corn. The significant effect of

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the application of humic acid with varied nutrient levels at recommended dosages on plant height, number of leaves, Leaf area, leaf area index, yield, yield parameters, and quality parameters of sweet corn were studied. The highest cob yield of 198.18 q ha^{-1} was in the application of 125% RDF + humic acid at 2% foliar spray as compared to the recommended dose of fertilizers with an increase of 25.28% and green fodder yield of 263.80 q ha^{-1} was achieved with an increase of 17.88%. The accumulation of crude protein (5.25%), total sugars (23.21%), reducing sugars (3.14%) and non-reducing sugars (19.06%) were observed to be highest in the foliar spray of 2% humic acid combined with 125% RDF. With these additional effects of humic acid, farmers can achieve higher yield and good quality of sweet corn to fulfill the increasing demand.

Keywords: Foliar application; humic acid; nutrient levels; sweet corn; total sugars.

1. INTRODUCTION

Sweet corn (*Zea mays* L. convar*. saccharata*), originally from Peru, is a popular maize variety known for its high natural sugar content. Widely grown across America, it is often called sugar corn or pole corn due to its sweetness [1]. This higher sugar content and soft texture makes it ideal for fresh consumption. This hybrid maize has gained popularity in many developed countries, where it is commonly consumed as a frozen vegetable rather than as grain in the USA, Canada, Australia, and increasingly in India and other Asian countries. In India, sweet corn is grown by some farmers and private organizations to meet domestic demand. It provides a higher income than traditional maize because it is harvested earlier at the milky stage, with harvests possible in 65 to 90 days, depending on the variety, and offers good export opportunities for farmers. Sweet corn is favorable for fresh consumption because of its delicious taste, and soft and sugary texture compared to other corn varieties.

The increasing demand for sweet corn has driven the need for innovative agricultural practices to enhance yield and quality. One such promising approach is the foliar application of humic acid combined with varied nutrient levels. Humic acid, a major component of humic substances, is derived from the decomposition of organic matter. It has been widely recognized for its role in improving soil health, promoting nutrient uptake, and enhancing plant growth [2-4]. When applied as a foliar spray, humic acid can directly affect plant physiology by stimulating enzymatic activity, enhancing photosynthesis, and improving nutrient absorption [5]. This mode of application is particularly advantageous as it allows for the direct uptake of nutrients through the leaves, bypassing potential soil-related limitations.

The nutrient levels in sweet corn cultivation also play a crucial role in determining both yield and quality. Essential nutrients such as nitrogen, phosphorus, potassium, and trace elements are vital for the development of the plant and the accumulation of sugars in the kernels. Balancing these nutrients optimally can lead to improved growth rates, higher yields, and better-quality produce. The combined effect of humic acid and varied nutrient levels on sweet corn is a subject of significant interest. The foliar application of humic acid, in particular, may offer a more efficient and targeted method of nutrient delivery, thereby maximizing the plant's growth potential and improving the quality of the sweet corn produced.

We seek to investigate the effects of foliar humic acid in conjunction with different nutrient levels on the yield and quality of sweet corn. By understanding these interactions, farmers can adopt more effective cultivation practices, ultimately leading to better crop performance and increased profitability.

2. MATERIALS AND METHODS

A field experiment was conducted at AHRS Kathalagere, KSNUAHS, Shivamogga, during the summer of 2021, to study the impact of humic acid foliar spray and nutrient levels on yield and quality of sweet corn. The experiment was in a Randomized Complete Block Design with eight treatments replicated thrice. The treatments as follows: T_1; absolute control, T_2; 75% RDF, T_3; 100% RDF, T_4; 125% RDF, T_5; humic acid at 0.2% foliar spray, T_6; 75% RDF + humic acid at 0.2% foliar spray, T_7; 100% RDF + humic acid at 0.2% foliar spray and T_8; 125% RDF + humic acid at 0.2% foliar spray. The recommended dose of fertilizer for Sweet corn was 150:75:45 kg ha^{-1}. Foliar application of humic acid was applied at 15, 30, and 45 days after sowing. Before sowing, the soil was analyzed for soil pH using a potentiometer which was determined by digital pH meter having the glass electrode, organic carbon, and the availability of nitrogen, phosphorus, and potassium. The soil at the experimental site was slightly acidic, with a pH of 6.3 and a low salt load, indicated by an electrical conductivity (EC) of 0.18 dS m^{-1} (Labtronics, Model: Lt 23). The soil had a medium level of organic carbon at 0.63%, with nitrogen (Kel Plus Kjeldahl Distillation Assembly, Model: Supra lx va) and potassium (Digital flame photometer, Model: LJ-381) at medium levels (284.85 kg ha^{-1} and 281.65 kg ha^{-1}, respectively) but the phosphorus content was high, at 65.64 kg ha^{-1}. Data on growth parameters were recorded at 30 DAS, 60 DAS, and harvest. Both biological and economic yields were recorded from individual plots at harvest and converted to kg/ha.

Statistical analysis: Data obtained on growth, yield and quality parameters was subjected to statistical analysis adopting Fisher's method of analysis of variance as out lined by Gomez and Gomez [6]. In case of significant results, critical difference (CD) at a 5% level of probability was calculated for testing the difference between the two treatment means.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Plant height gradually increases with each stage of crop development. Data analysis revealed that plant height increased with crop age, but notable increases were only seen between 30 and 60 days after sowing (DAS) and peaked at harvest. The application of 125% RDF with foliar spray of 0.2% humic acid (T_8) significantly ($P<0.05$) influenced the plant height at 30, 60 DAS, and harvest as compared to the application T_3. Similarly, the number of leaves also significantly ($P<0.05$) increased with T_8 which is also on par with the T_3. (Table 1). The increase in plant height and number of leaves is attributed to overall improvements in plant growth, vigor, and photosynthesis. This enhancement is due to better nutrient availability from both soil and foliar applications. Foliar application of humic acid boosts cell division and elongation, resulting in taller plants. Specifically, treatments with 125% of the recommended dose of fertilizer (RDF) and 0.2% humic acid foliar spray demonstrated notable growth and increased plant height. Suruthi et al. [7] observed similar results in barnyard millet, where the application of additional inorganic nutrients and humic acid enhanced photosynthesis and activated various enzymes, facilitating the transport of assimilates to growing regions. The observed increase in plant height can be attributed to the roles of nitrogen, phosphorus, potassium, and humic acid in key physiological processes such as enzyme activation, stomatal regulation, and chlorophyll formation Jan et al., [8] Nardi et al., [9] and Vidhyashree, [10].

The growth and development of crops depend on the assimilatory surface, such as the number of leaves and leaf area. At all growth stages, T_8 led to a significant ($P<0.05$) higher number of leaves, leaf area and leaf area index compared to the same parameters using T_3 alone, which showed lower values in these parameters (Table 1). This improvement can be attributed to the enhanced nutrient availability from both inorganic and organic sources, which supports greater metabolic activity and photosynthesis. The increased number of nodes in taller plants leads to more leaves, and the higher leaf area and leaf area index result from improved leaf expansion, cell division, and cell enlargement. The effective photosynthetic structure, facilitated by the combined application of RDF and humic acid, supports greater synthesis, accumulation, partitioning, and translocation of photosynthates, contributing to the overall growth and development of the crop [11]. Additionally, humic acid appears to enhance respiration and photosynthesis by modifying mitochondrial and chloroplast functions, which helps alleviate the negative effects of abiotic stresses on plants, as supported by Shen et al. [12].

3.2 Yield Attributes

The yield attributes like number of cobs per plant, cob length, and cob girth were significantly ($P<0.05$) increased with the application of humic acid with RDF. Among the various treatments, applying T_8 resulted in significantly ($P<0.05$) more cobs per plant and longer cobs and thicker cobs. This was followed by T_4, and T_3. The improved NPK levels during the reproductive stage, due to increased nutrient availability, enhanced the source-sink relationship in sweet corn. This increase in NPK fertilization led to better growth, photosynthesis, and overall plant development and yield. These results are consistent with findings by Sulok Kevin et al. [13].

Table 1. Plant height, number of leaves, leaf area, and Leaf area index of sweet corn at different growth stages as influenced by foliar application of humic acid with varied nutrient levels

Treatment	Plant height (cm)			Number of leaves			Leaf area (cm^2 $plant^{-1}$)			Leaf area index		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T_1	34.12	151.37	165.28	6.15	11.09	9.00	562.83	5286.85	3418.43	0.42	3.92	2.53
T_2	43.93	164.54	187.37	7.23	13.36	11.61	706.92	7991.15	4293.90	0.52	5.92	3.18
T_3	47.40	178.30	202.40	7.70	15.87	11.87	828.96	8795.59	4809.72	0.61	6.52	3.56
T_4	49.17	189.93	213.58	8.21	18.78	14.35	1192.45	9443.63	5548.87	0.88	7.00	4.11
T_5	39.37	158.43	181.65	7.16	13.15	11.60	689.08	6167.39	3917.53	0.51	4.57	2.90
T_6	45.50	175.39	194.50	7.42	14.43	11.72	756.88	8536.89	4573.21	0.56	6.32	3.39
T_7	48.59	186.65	207.53	7.97	17.71	14.16	847.25	9054.91	5385.67	0.63	6.71	3.99
T_8	49.93	198.46	223.40	8.54	19.54	14.88	1262.41	9720.57	5986.54	0.94	7.20	4.43
SE.m ±	0.37	2.75	3.05	0.26	0.88	0.67	23.71	207.57	201.45	0.02	0.15	0.15
CD @ 5%	1.13	8.21	9.08	0.79	2.60	1.98	71.92	629.61	611.03	0.05	0.47	0.45

Note: RDF - 150: 75: 45 kg (N: P_2O_5: K_2O / ha), RDF- Recommended dose of fertilizer, DAS- Days after sowing. T_1: Absolute control, T_2: 75% RDF, T_3: 100% RDF, T_4: 125% RDF, T_5: Humic acid at 0.2 % foliar spray, T_6: 75% RDF + Humic acid at 0.2% foliar spray, T_7: 100% RDF + Humic acid at 0.2% foliar spray, and T_8: 125% RDF + Humic acid at 0.2% foliar spray

3.3 Cob and Green Fodder Yield

The combined application of both organic and inorganic sources facilitated greater availability of nutrients for the development of vegetative structures, cell division, number of grains, husk weight, more dry matter accumulation, nutrient uptake, improved translocation of photosynthates from source to sink and partitioning which resulted in higher fresh cob yield and green fodder yield as observed at T_8 which was on par with the application of T_4 (Table 2). The increase in growth and yield due to the application of fertilizers combined with humic acid can be attributed to the essential role of these nutrients in nucleotides, proteins, chlorophyll, and enzymes, which are involved in various metabolic processes affecting both the vegetative and reproductive phases of plants [14]. The combined application of organic and inorganic sources enhances nutrient availability, supporting vegetative structure development, increased photosynthetic activity, accelerated respiration, hormonal growth responses, and better nutrient uptake. This leads to improved cell division, grain number, husked weight, dry matter accumulation, and translocation of photosynthates from source to sink, resulting in higher fresh cob and green fodder yields. Similar observations have been reported by Reddy et al. [15] Shahzad et al. [16] and Sofyan et al. [17].

Table 2. Yield and yield attributes of sweet corn at harvest as influenced by foliar application of humic acid with varied nutrient levels

Treatment	No. of cobs plant^{-1}	Cob length (cm)	Cob girth (cm)	Fresh cob yield with husk (q ha^{-1})	Green fodder yield (q ha^{-1})
T_1	1.00	13.92	9.72	87.72	125.70
T_2	1.10	16.42	10.70	142.91	205.65
T_3	1.13	18.60	13.63	158.19	223.78
T_4	1.27	19.82	15.11	181.17	254.87
T_5	1.00	14.97	10.17	120.62	173.65
T_6	1.20	17.13	11.85	153.84	212.45
T_7	1.27	19.63	14.43	171.45	240.15
T_8	1.40	21.42	15.77	198.18	263.80
SE.m ±	0.09	0.34	0.32	7.21	11.78
CD @ 5%	NS	1.01	0.97	21.49	29.28

Note: RDF - 150: 75: 45 kg (N: P_2O_5: K_2O / ha), RDF- Recommended dose of fertilizer, DAS- Days after sowing, NS – Non-significant. T_1: Absolute control, T_2: 75% RDF, T_3: 100% RDF, T_4: 125% RDF, T_5: Humic acid at 0.2 % foliar spray, T_6: 75% RDF + Humic acid at 0.2% foliar spray, T_7: 100% RDF + Humic acid at 0.2% foliar spray, and T_8: 125% RDF + Humic acid at 0.2% foliar spray

Table 3. Quality parameters of sweet corn as influenced by foliar application of humic acid with varied nutrient levels

Treatment	Crude protein (%)	Total sugars (%)	Reducing sugars (%)	Non reducing sugars (%)
T_1	3.94	18.70	1.91	15.95
T_2	4.88	20.61	2.29	17.40
T_3	5.04	21.90	2.62	18.32
T_4	5.13	22.81	2.95	18.87
T_5	4.31	19.34	2.02	16.45
T_6	5.01	21.23	2.45	17.84
T_7	5.06	22.28	2.79	18.52
T_8	5.25	23.21	3.14	19.06
SE.m ±	0.29	1.06	0.21	1.01
CD @ 5%	NS	NS	NS	NS

Note: RDF - 150: 75: 45 kg (N: P_2O_5: K_2O / ha), RDF- Recommended dose of fertilizer, DAS- Days after sowing, NS – Non-significant. T_1: Absolute control, T_2: 75% RDF, T_3: 100% RDF, T_4: 125% RDF, T_5: Humic acid at 0.2 % foliar spray, T_6: 75% RDF + Humic acid at 0.2% foliar spray, T_7: 100% RDF + Humic acid at 0.2% foliar spray, and T_8: 125% RDF + Humic acid at 0.2% foliar spray

Table 4. Economics of sweet corn cultivation as influenced by foliar application of humic acid with varied nutrient levels

Treatment	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C
T_1	61,000	109,086	48086	1.79
T_2	81,563	206,344	124781	2.53
T_3	83,459	228,025	144566	2.73
T_4	84,881	261,008	176127	3.07
T_5	78,850	174,167	95317	2.21
T_6	83,363	221,237	137874	2.65
T_7	85,259	246,904	161645	2.90
T_8	86,681	284,009	197328	3.28
SE.m ±		12125	12125	0.14
CD @ 5%		36778	36778	0.44

Note: RDF - 150: 75: 45 kg (N: P_2O_5: K_2O / ha), RDF- Recommended dose of fertilizer, DAS- Days after sowing, T_1: Absolute control, T_2: 75% RDF, T_3: 100% RDF, T_4: 125% RDF, T_5: Humic acid at 0.2 % foliar spray, T_6: 75% RDF + Humic acid at 0.2% foliar spray, T_7: 100% RDF + Humic acid at 0.2% foliar spray, and T_8: 125% RDF + Humic acid at 0.2% foliar spray

3.4 Quality Parameters

Quality parameters like crude protein, total sugars, reducing and non-reducing sugars were analyzed and the results showed a non-significant improvement among the treatments. Quality aspects involve complex physiological processes that are challenging to control through management practices in just one season. However, data on quality parameters revealed that applying T_8 resulted in higher crude protein total sugar, reducing sugar, and non-reducing sugar as showed in the Table 3. This improvement is mainly due to the hormonal effects of humic acid, which enhance respiratory catalytic activity, cell permeability, and nutrient uptake [18]. Similar findings were reported by Bakry et al. [19].

3.5 Economics

Higher gross return, net return and B: C ratio was recorded in the treatment 125% RDF + Humic acid at 0.2% foliar spray which received 125% RDF + humic acid at 0.2% foliar spray. However, which was on par with the application of 125% RDF (Table 4). The higher gross return and net return were mainly attributed to higher fresh cob yield and green fodder yield of sweet corn. Similar findings were also observed by Patel [20-23] in wheat.

4. CONCLUSION

Results of the study concluded that the application of T_8 (125% RDF + humic acid at 0.2% foliar spray) was able to produce 25.27% higher fresh cob yield with husk and 17.88% higher green fodder yield compared to the application of T_3 (100% RDF). Humic acid in combination with RDF has an additional effect on the growth and yield parameters of sweet corn with a higher B:C ratio which might help farmers to produce good quality sweet corn with increased yield.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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