



Research Article

Response of foliar application of humic acid and micronutrient mixture on growth and grain yield of maize crop

T. Pandiaraj, Prakash Yadav, D. K. Singh, Vinod Kumar

Abstract

The efficiency of humic acid (HA) and micronutrient (MN) mixtures as a source, either separately or in combination, was studied to increase the productivity and growth of maize (*Zea mays* L.). The research was carried out in the College of Agriculture, Azamgarh, Uttar Pradesh, India during the spring season of 2022. The treatments were replicated three times in a randomized complete block design. The HA and MN mixtures were sprayed separately at 0.2% and 0.4% each. Further, the combination of HA @ 0.2% + MN @ 0.2% and HA @ 0.4% + MN @ 0.4% was also applied. The application was done by foliar spray twice on 35 and 50 DAS, along with control using water. The result revealed that foliar spraying of HA at 0.4% + MN at 0.4% significantly ($P=0.05$) improved the height (cm), LAI, and dry matter accumulation (g m^{-2}) of the maize crop. In comparison to the MN combination, HA generally had more maize growth and yield. A foliar spray with a combination of HA and MN at 0.4% each could result in a higher grain yield of the maize crop, which recorded a 42.62% higher grain yield than the control. Hence, based on the study, foliar application of the HA+MN mixture at 0.4% could be advised to boost maize crop growth and grain yield during the spring season.

Keywords humic acid, maize, silking, tasselling, yield

Introduction

Maize (*Zea mays* L.) is a worldwide growing common cereal crop. It is a vital crop in India, especially during the Kharif and summer periods. In 2021–2022, India produced about 33.62 million metric tonnes from 9.70 million hectares [1]. Maize grains are chiefly used for human food, livestock, and poultry sectors, as well as other industries. The total maize production is inadequate to meet the demand of the region because of poor yields and a smaller growing area. As a result of the sharp rise in global food demand over the past few decades, vast agricultural lands have been converted to intensive agriculture, essentially putting heavy pressure on the environment's natural resources, including the land. Many types of soil are unable to provide high yields due to the need for micronutrients. Even the most fertile soils will eventually experience pressure if appropriate measures are not taken to replenish nutrients removed from the soil and maintain a balanced nutrient budget for optimal crop growth.

Soil productivity and crop yield depend on improving the condition of the soil as well as maintaining a balance of plant nutrients.

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Authors:

T. Pandiaraj ✉, P. Yadav, D. K. Singh,
V. Kumar
College of Agriculture, Kotwa, Azamgarh
Acharya Narendra Deva University of
Agriculture and Technology, Kumarganj,
Ayodhya, Uttar Pradesh, India

✉ pandianeagro@gmail.com

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Contrary to the general belief, the overuse of agrochemicals for farming has resulted in ecological problems including physical soil damage and imbalance of soil nutrients [2]. According to Majidian et al., [3], applying chemical fertilizers and organic manures together could result in boosting the quality of maize and production, as well as minimizing the usage of chemical fertilizers and improving soil conditions.

Numerous chemical molecules have been investigated to enhance effective plant nutrient absorption and minimize environmental pollution; these substances are classified as "biostimulants," like humic substances (HS). "Soil organic matter naturally contains humic acid, a water-soluble organic acid". Humic compounds make up 60-70 percent of total organic compounds [4]. Humic substances (HS) have been proven to have a number of positive impacts on soil structure and microbial diversity, as well as enhance and alter mechanisms that encourage the growth of plants, nutrient absorption, and permeability of cells, leading to increases in all of these [5-6].

The precise quantities and names of every derived compound of humic acids in the root zone that might affect the growth of plants, in general, have yet to be discovered [7]. Humic compounds appear to have the potential to affect both respiration and photosynthesis [8]. The growth of plant roots is significantly influenced by humic substances. The promotion of root initiation, as well as greater root growth, may be seen when HS is applied to the soil [9]. According to Chen et al., [10], the promoting effects of HS have a direct correlation with increased micronutrient uptake, including Zn, Fe, Mn, and Cu.

Micronutrients (MN) are essential for increasing productivity. They are needed in small quantities, but their proper application increases the availability of nutrients and has strong effects on physiological cell processes, which are apparent in yield too [11]. According to Khan et al., [12], the application of mineral fertilizers raised the Fe, Zn, Mn, and Cu levels of wheat leaf and grain, which is significant given the growing environmental and economic concerns [13]. The foliar application of zinc fertilizer in the first and second seasons of maize considerably increased the grain zinc content by 27 and 37 percent and by 28 and 89 percent in wheat crops, respectively. More study is needed, however, to evaluate the potential value of humic acid as an organic source of nutrients in combination with macro- or micronutrients in enhancing the yield of crops.

Methodology

A study was carried out in the College of Agriculture in Azamgarh, Uttar Pradesh, India, to investigate the humic acid compounds and micronutrient mixture's effect on maize growth and yield in the Kharif season in 2021. The study site was located at 26°1' N latitude and 83°8' E longitude, 84 m above MSL. The experimental field had sandy loam soil. The treatment consists of two different levels of each humic acid (HA) and micronutrient (MN) separately and in combination. These treatments comprise foliar sprays of HA at 0.2 and 0.4% and MN at 0.2 and 0.4%, as well as the combination of HA + MN at 0.2% and 0.4% each along with one control using water spray. The HA and MN were applied in liquid form to the standing crop on 35 and 50 DAS. The spray was done just before irrigation. This study was designed in a completely randomized block by replicating three. The plots were allocated treatments at random. The experimental plot is 3.3 m long and 5.0 m wide. The single maize seed per hole was dibbled with a spacing of 60 cm × 20 cm, 4-5 cm deep. The recommended dose of 120-60-40 kg NPK per hectare was applied. The total N was applied in three splits i.e., 50% N during the time of sowing, and the rest of 50% N was given equally during the stage knee-high and tasselling stages. The other agronomical practices for maize crop production were followed as recommendations. The height of the plant was evaluated from the ground to the apex bud of the five chosen plants. Similarly, the mean number of leaves per plant and leaf area from the chosen plants were measured to calculate the leaf area index (LAI) using an extinction coefficient of 0.75 [14]. Dry matter accumulation (DMA) of plant samples was estimated for each treatment by keeping the samples in a hot air oven at 70 °C. During the study, days taken to 75% tasselling, silking, and



maturity were also observed. Using the TNAU STAT application, all the data were evaluated using an analysis of variance (ANOVA). Duncan's multiple range tests (DMRT) were employed to compare treatments and controls statistically.

Results and Discussion

Growth characters

The experimental result revealed that the humic acid (HA) and micronutrient mixture (MN) foliar spray effect was significant on all growth parameters except days taken to 75% tasselling, silking, and maturity (Table 1). The results showed that foliar spraying with HA and MN to maize significantly improved the height of the plants compared to the control. The HA application showed a more prominent effect than the MN application. However, combined foliar application of HA + MN at 0.4% each showed a stimulatory and significant ($P=0.05$) effect on producing higher plant height (221.3 cm), but statistically, it was similar to combined foliar application of HA + MN at 0.2% (217.5 cm). The lowest plant height (188.4 cm) of the maize was recorded in the control treatment. The improved development and expansion of plant cells were likely the cause of the increased plant height in the HA treatments. According to Celik et al., [15], humus has positive impacts on the nutrient availability, uptake, and transport in maize, which improves the maize plant growth and boosts maize production. Numerous researchers have proved that humic acid promotes plant growth [16-17]. In addition, the results exhibited the harmonious effects of MNs on promoting crop growth and major physiological functions. These findings corroborated those of Potarzycki and Grzebisz [18].

Table 1. Growth characters of maize as affected by different humic acid and micronutrient mixture concentrations

Treatments	Plant height (cm)	DMA (g m^{-2})	LAI	Days taken to 75% Tasseling	Days taken to 75% Silking	Days taken to 75% Maturity
Control	188.4 ^e	2361 ^d	2.87 ^c	49.59 ^c	63.82 ^b	91.57 ^a
Spray HA@ 0.2%	199.1 ^{cde}	2447 ^{bc}	2.93 ^c	49.17 ^{bc}	63.27 ^{ab}	90.34 ^a
Spray HA@ 0.4%	207.8 ^{bc}	2498 ^{bc}	2.96 ^{bc}	48.86 ^{abc}	62.33 ^{ab}	88.62 ^a
Spray MN @ 0.2%	196.3 ^{de}	2421 ^{cd}	2.92 ^c	49.37 ^c	63.49 ^{ab}	90.81 ^a
Spray MN @ 0.4%	201.7 ^{cd}	2486 ^{bc}	2.94 ^c	49.01 ^{abc}	62.72 ^{ab}	89.17 ^a
Spray HA@ 0.2% + MN @ 0.2%	217.5 ^{ab}	2517 ^b	3.12 ^b	47.24 ^{ba}	61.47 ^{ab}	88.31 ^a
Spray HA@ 0.4% + MN @ 0.4%	221.3 ^a	2598 ^a	3.38 ^a	47.11 ^a	60.58 ^a	87.64 ^a

Note: Treatments means followed by a common letter (s) are not significantly different among each other according to LSD ($P=0.05$) test

The maize plant's response to micronutrients such as zinc, iron, and Manganese can be linked to these nutrients' significant functions in enzyme activation and hormone regulation, carbohydrate, protein, and auxin metabolism, and various processes such as development, division, and differentiation of cell [19]. Furthermore, Fe has the ability to become a component of chlorophyll and participate in oxidation-reduction processes. Additionally, Mn directly affects the balance of indole acetic acid in response to plant height, while Zn is crucial for the synthesis and metabolism of tryptophan [20]. The optimal balancing of the aforementioned elements may have contributed to the mixture treatment's improved results by encouraging the plants to grow efficiently and uptake more NPK.

Similarly, HA and MN spray strongly influenced the dry matter accumulation (DMA) of maize. The combined foliar spray of HA + MN at 0.4% each significantly produced a higher DMA (2598 g m^{-2}) followed by a combined foliar spray of HA + MN at 0.2% each (2517 g m^{-2}). However, later treatments did not statistically show a significant variation from the rest of the treatments. The lowest DMA of the maize crop (2361 g m^{-2}) was observed with the treatment of control. The treatments, such as spray HA at 0.2%, HA at 0.4%, and MN at 0.4%, resulted in statistically similar DMA in the study. The DMA in HA + MN at 0.4% each and HA + MN at 0.2% each produced 10.04% and 6.72%, respectively,



higher as compared to the control. The HA administration boosted the nitrogen and other nutritional content of the maize crop and improved the production of plant biomass. These results were consistent with Delfine et al., [21], the use of HA resulted in a greater production of crop dry matter compared to the unfertilized control. These findings were broadly corroborated with those made by Zandanadi et al., [22] and Rahmat et al., [6].

Regarding leaf area index (LAI), a significantly higher value of LAI (3.38) was recorded when the foliar spray of HA + MN at 0.4% each was applied to the maize crop. It was followed by a foliar spray of HA + MN at 0.2% each (3.12) and showed no significant differences in the rest of the other treatments, including the control treatment. The lowest LAI (2.87) was estimated for the treatment of the control in the experiment. These effects might be attributed to the action of HA and MN combinations, which are important in boosting vegetative development through enhancing leaf area and cell size, which increases the photosynthesis rate.

Days taken to 75% tasselling, silking, and maturity failed to vary significantly across treatments in this study. However, the HA application has enhanced the initiation of tasselling slightly earlier than the MN mixture spray. It was found that foliar spray of HA + MN at 0.4% each helped in the earlier initiation of 75% tasselling of the maize crop (47.11 days), followed by HA + MN at 0.2% each (47.24 days), and HA at 0.4% (48.86 days). A longer number of days to achieve 75% tasselling (49.59 days) was observed with the control treatment.

Akin to tasselling character, none of the treatments have significantly ($P=0.05$) influenced the days taken to achieve 75% silking character. The foliar application of HA + MN at 0.4% each had achieved earlier days taken from sowing to 75% silking (60.58 days), followed by HA + MN at 0.2% each (61.47 days), HA at 0.4% (62.33 days), and MN at 0.4% (62.72 days). The control treatment registered more days to achieve 75% silking (63.82 days).

The result revealed that HA followed by MN mixture application promoted considerably earlier maturity of the maize crop over the control treatment. However, no statistically significant difference was noticed among the treatments. This study revealed that foliar sprays of HA + MN at 0.4% each registered about four days earlier maturity than control treatments, i.e., 87.64 days taken to 75% maturity with foliar sprays of HA + MN at 0.4% each and 91.57 days with control treatments. The foliar spray of HA + MN at 0.2% each recorded 88.31 days to 75% maturity, followed by 90.34 days with spray HA at 0.4% and 89.17 days with spray MN at 0.4%. This may be related to the optimistic influences of HA and MN on plant physiology, which included improving biomass yields, triggering the development of fresh active roots, increasing cell respiration and uptake of nutrients through membranes, and exerting hormone-like activities that led to earlier completion of each phasic transition in the maize crop.

Grain yield

The foliar application of HA and MN mixtures had a significant effect on maize grain production. The results, as shown in Figure 1, showed that spraying HA and MN mixtures substantially enhanced maize grain yield when compared to the control. A significantly higher grain yield of maize (11897.9 kg ha⁻¹) was found from the foliar spray of HA + MN treatment at 0.4% each in comparison with the control (8342.1 kg ha⁻¹). This higher yield was found to be 42.62% higher than the control. The treatment foliar spray HA + MN @ 0.2% each was recorded as the next best treatment (11289.5 kg ha⁻¹) as showing a 35.33% higher yield over control in this study, followed by spray HA @ 0.4% (10682.4 kg ha⁻¹) with a 28.05% higher yield than control. The grain yield produced with spray MN mixture at 0.4% treatment (9861.7 kg ha⁻¹) was significantly similar to the yield produced under spray HA at 0.2% (9789.3 kg ha⁻¹).

The yield advantageous effect of maize and its constituent parts in this investigation reveals the synergistic consequence of HA and MN, which is supported by various investigations that show that HA increases mineral nutrient absorption [5]. The positive impacts of HA on physiological functions, including an impact on the metabolism of plant cells and a rise in leaf chlorophyll

concentration, increase crop production [8]. It is also confirmed by the line of Mohammadpourkhaneghah et al., [23]. A foliar spray of micronutrients such as Fe, Mn, and Zn may be necessary for achieving high yields because of their vital play in plant growth, respiration, involvement in photosynthesis, and other physiological as well as biochemical functions [24]. The results of Zeidan [25], Zeidan and Nofal [26], and Habib [27] supported the results of this study. Hegazi et al., [28] reported that foliar spraying of nutrients is mainly beneficial in nutrient-stress situations. This generally stands true for micronutrients including Zn, Fe, Cu, and Mn. In alkaline soils, soil particles commonly fix these nutrients, making them sparingly available to crop roots.

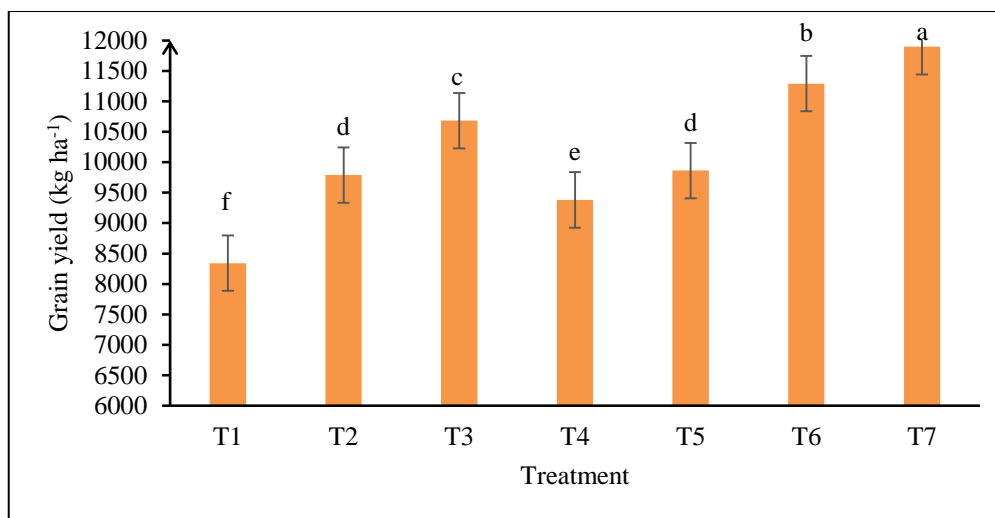


Figure 1. Grain yield of maize as influenced by different concentrations of humic acid and micronutrient mixture. Error bars indicate standard error. Treatments mean followed by a common letter (s) are not significantly different among each other according to LSD ($P=0.05$) test

Conclusion

From the results of the study, it was possible to conclude that the foliar spray of the HA and MN mixture had a significant effect on maize crop development and yield. Humic acid as a source of growth promoters had a significantly greater positive effect in most cases than micronutrient application. Finally, a combined foliar application of HA + MN at 0.4% each improved the maize crop growth and grain yield. However, more research for distinct plant habitats is required to validate the feasible applicability scale of this study in different locales.

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