DOI: 10.34101/ACTAAGRAR/1/16502

Maize stem diameter variation under precision drip irrigation and foliar micronutrient treatments

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SUMMARY

Foliar application of micronutrients has gained research interest due to the growing need to efficiently and precisely deliver plant nutrients at the most critical growth stages. Stem diameter has proved to have a positive significant correlation with yield across many crop species such as maize, due to its vigorous and robust ability to transport water and micronutrients. Therefore, this study examined the effects of precision drip irrigation and foliar application of micronutrients on stem diameter of FAO490 maize hybrid. A field experiment laid as a split–split-plot design with treatments consisting of foliar treatment and control under irrigation and non-irrigation was conducted. Stem diameter data were collected at the 12-leaf stage (V12), tasseling stage, R1, and R6. ANOVA results showed that precision drip irrigation significantly influenced stem diameter ($P<0.001$), while foliar fertilisation and its interaction with precision drip irrigation showed meaningful effects. The mean stem diameter under precision drip irrigation was 26.96 mm compared to non-irrigated conditions (24.24 mm). Foliar fertilisation treatment had a higher mean stem diameter (26.63 mm) compared to control (24.57 mm), representing an 8.4% growth difference. Foliar fertilisation was more effective under precision drip irrigation with the mean stem diameter significantly high (28.83 mm) for treatment over the control (25.08 mm) thus a 14.9% stem diameter enhancement. Foliar fertilisation under non-irrigated conditions recorded a 1.6% stem diameter increase between treatment (24.43 mm) and control (24.05 mm). This study indicates that precision drip irrigation primarily influenced stem diameter growth and development, however foliar fertilisation further enhanced stem growth under adequate water supplementation, suggesting a positive significant synergistic effect under precision drip irrigated conditions.

Keywords: *maize; foliar fertilisation; precision drip irrigation; stem diameter*

INTRODUCTION

Cereals have been documented as major source of food and animal feed globally (Shiferaw et al., 2011; Grote et al., 2021), addressing food security, livelihood concerns, global biofuel production and rural economic development (Horváth et al., 2021; Erenstein et al., 2022). The three major cereals, namely maize, wheat and rice, dominate the human and nutritional diet by 60% (FAO, 2024). The global production of cereals has recently increased by 8.3 million tons (0.3%), representing maize (1,151.36), wheat (783.8), rice (502.98) and barley (150.48) according to (FAO, 2024). Therefore, sustainable cereal production enhances nutritional needs for the exponential world population. Maize as one of the major cereals faces production constraints related to severe climate changes such as drought, water scarcity, and soil infertility inhibiting food production thus the need to promote sustainable maize farming strategies to ensure global food security and economic resilience (Bojtor et al., 2021). Therefore, enhancing physiological growth and average yield of maize should be a priority for every breeding and research program.

The effects of climate change have led to scarcity of water for both domestic and agricultural purposes (Li et al., 2021; Ukwu et al., 2025), the significant over utilisation of available water resources by the growing population growth (Yang et al., 2023) have greatly affected cereal production (Li et al., 2022; Cao et al., 2023), since water is a major production requirement. Water scarcity and its impacts can be significantly alleviated by precision water distribution through irrigation (Li et al., 2021). Irrigation commonly applicable in crop production delivers water to plants to alleviate drought stress (Horváth et al., 2021; Mohammed et al., 2022; Ma et al., 2024). Precision irrigation systems offer efficient and sustainable means of water supplementation to cereals and other plants (Pool et al., 2021), enhances soil aeration and moisture content (Illés et al., 2021). The principal drivers of water use efficiency include selection of proper irrigation system, available technologies, and critical crop growth stages according to Qu et al. (2024).

Foliar fertilisation has proved a significant precision tool towards proper management of crops through timely delivering of plant nutrients at critical growth stages (Froese et al., 2020). Foliar fertilisation refers to direct fertiliser application to plant leaves (Patil & Chetah, 2018), mitigating severe impacts of plant stresses on crop growth such as chlorophyll content, photosynthetic rate and yield of crops (Elmer & White, 2016; Ssemugenze et al., 2025) thus promoting optimal plant growth. This fertiliser application method minimises the time between application and absorption (Pinciroli et al., 2019; Tóth et al., 2022), lessens nutrient supply challenges encountered during soil fertiliser application like delayed fixation (Ocwa et al., 2024b) and inadequate topsoil moisture required for nutrient absorption by

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roots from the soil (Amanullah et al., 2013). It also offers higher efficacy than soil fertiliser applications (Brankov et al., 2020), although limited by its scorching effect due to high fertiliser concentration (Szeles & Nagy, 2012), the prohibitive cost of multiple applications (Brankov et al., 2020), and effects of weather changes (Patil & Chetah, 2018).

The size of plant stem offers several advantages to different crops including maize ranging direct plant support, water, minerals and nutrient transportation, to withstand several environmental stresses. Plants with larger stem diameters grow have been observed to be stable, flexible and strong enough to grow upright since plant weight is evenly distributed, larger surface area for production of leaves and pods, the branches are fully supported as well as proper connection to the root system. Such plants easily withstand drastic weather challenges such as strong winds, heavy rain, and drought. Plants with thicker stems have huge reservoirs for water and nutrients to save plants during drought spells. Big stem diameter implies more well-developed vascular tissue system that efficiently transports water, minerals, and vital plant nutrients from the roots to the leaves, enhancing the rate of photosynthesis and overall plant growth. Larger plant stems act as stores for energy thus helping the plants recover easily from stress. Therefore, stem size acts as a critical factor towards plant growth, health and productivity especially maize. Based on the above background, this study objectively investigated the impact of precision drip irrigation and foliar nutrient application on stem size of maize.

MATERIALS AND METHODS

This experiment was done at Látókép Crop Production Experimental Station of the University of Debrecen, Debrecen, Hungary during the year 2025. The temperature and precipitation during the season were as follows; The highest temperature was recorded during the month of June (22.193 °C) and lowest temperature during the month of October (10.2 °C) respectively. The overall annual precipitation was 241.7 mm; highest precipitation occurred during the month of July (86 mm) and the lowest at 3 mm during October (*Figure 1*). The experimental design was a randomized split-plot with three replications, with control and a foliar fertilizer treatment, split into irrigated and non-irrigated part. The size of each plot was 30 m^2. The total area of the experiment was 0.5 ha, containing a total of 26 different maize hybrids. The hybrid studied for this research was FAO490 characterized by outstanding yield potential, long growing season, excellent drought tolerance to drought and shows a stay-green phenotype of physiological maturity. Precision drip irrigation system was laid on 6th June 2025 along the rows supplying water at 3 liters per hour to maize plants and removed from the field on 26th September 2025 respectively. The total amount of irrigation water supplied monthly was June (132 mm), July (220 mm) and August (66 mm). The precision drip irrigation system was controlled by Hydrawise app, managed by the meteorological station of the Experimental Site. Foliar fertilizer treatment was a mixture, composed of four different products consisting of different nutrients (*Table 1*) which were applied on 4th June 2025 at vegetative stage when leaves of plants had fully developed. Basal fertilizer was applied at autumn 2nd of October 2024 with 300 kg ha^{-1} NPK 4-24-24, and at spring before sowing on 16th of April 2025, with 500 kg ha^{-1} CAN 27-7-5. Then fertigation through the precision drip irrigation system was applied for the irrigated part of the experiment with 50 kg Megasol, meaning 10 kg ha^{-1} N, 16.7 kg ha^{-1} P_2O_5, and 133 kg ha^{-1} K_2O. Stem diameter was measured using vernier calipers at different physiological growth stages namely 12 leaf stage (V12), tasseling stage (VT) and kernel blister stage (R1, and R6). A random selection of ten (10) plants was done from each treatment. Data was analyzed using ANOVA method in GenStat software (18th edition). OriginPro Graphing and Analysis Software (version 2024) was used for drawing different figures.

Figure 1. **Average monthly temperature and total monthly precipitation during the 2025 growing season**

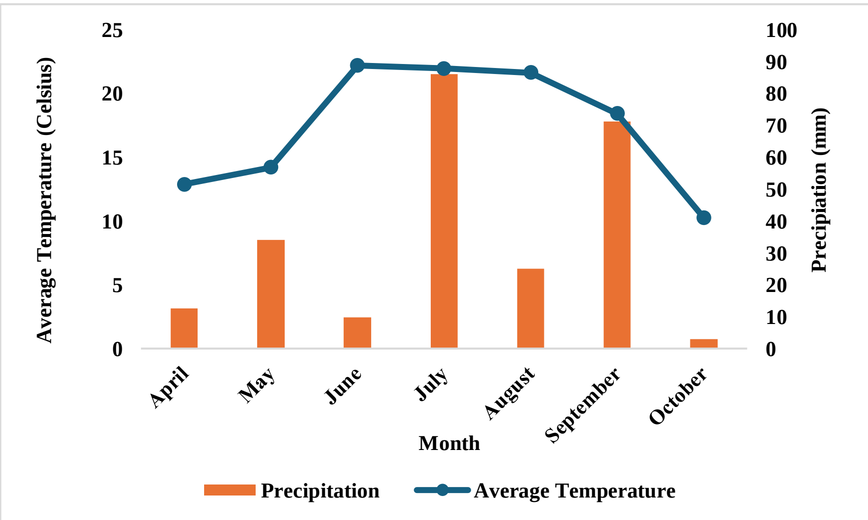

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Table 1. **Composition of the mixture of foliar fertilisers used for treatment**

Product 1: 3 l ha^{-1}	Composition	g l^{-1}
	Nitrogen	132
	(P_2O_5)	1.2
	(K_2O)	36
	(Ca)	0.96
	(Co)	0.0324
	(Cu)	1.56
	(Mg)	4.8
	(Zn)	1.8
	(Fe)	3.6
	(Mn)	2.4
	(Mo)	0.12
	(B)	2.4
	(S)	4.8
Product 2: 1 l ha^{-1}	**Composition**	**g l^{-1}**
	(Zn^{2+})	120
	(SO_4^{2-})	59.4
Product 3: 1 l ha^{-1}	**Composition**	**g l^{-1}**
	($S_2O_3^{2-}$)	330
	(SO_3)	825
	(NH_4^+)	165
Product 4: 1 l ha^{-1}	**Composition**	**g l^{-1}**
	(Mg^{2+})	64.9
	(MgO)	106.4
	(NH_4^+)	73.8

RESULTS AND DISCUSSION

Precision drip irrigation significantly influenced ($p = 0.034$) stem diameter of maize plants (*Figure 2*). The mean stem diameter under precision drip irrigation was 26.96 mm compared to non-irrigated conditions (24.24 mm). This represented a mean stem diameter difference of 11.2%. The results correlate with Ocwa et al. (2025) whose findings indicated the significant effect ($p<0.05$) of water management on stem diameter during the 2022–2023 growth seasons at the vegetative and reproductive growth stages. Stem diameter increased by 9.4% during reproductive (R2) growth stage during the 2022 growing season due to application of precision drip irrigation compared to non-irrigated conditions. While during the 2023 growing season, stem diameter increased by 6.6%, 7.4% and 8.2% at the VT, R2, and V12 growth stages due to application of precision drip irrigation compared to non-irrigated conditions (Ocwa et al., 2024a). Similarly, Nawaz et al. (2024) also noted that stem diameter of maize improved due to irrigation. Water supplementation at high quantity through irrigation improved stem diameter by 8.5% compared to low water supplementation (Guo & Li, 2024). Foliar fertilisation had a significant weak marginal effect ($p = 0.066$) on stem diameter of maize plants. Though the significance was marginal, foliar fertilisation treatment had a higher mean stem diameter increased stem diameter (26.63 mm) compared to control (24.57 mm), representing an 8.4% growth difference (*Figure 3*). Irrigation × foliar fertilisation interaction had no significant effect on stem diameter. However, notable differences were recorded between treatment and control under irrigated and non-irrigated conditions. Foliar fertilisation was more effective under precision drip irrigated conditions with the mean stem diameter significantly high (28.83 mm) for treatment over the control (25.08 mm) thus a 14.9% stem diameter enhancement. Foliar fertilisation under non-irrigated conditions recorded a 1.6% stem diameter increase between treatment (24.43 mm) and control (24.05 mm) (*Figure 4*). This study indicates that precision drip irrigation primarily influenced stem diameter growth and development, however foliar fertilisation further enhanced stem growth under adequate water supplementation, suggesting a positive significant synergistic effect under precision drip irrigated conditions. Joy et al. (2023) justified the impact of stem diameter trait towards maize production since it correlates with other parameters such as stem weight and plant height. It has been recently noted by different studies that the larger the stem diameter, the higher the height of plants (Joy et al., 2023; Yerli et al., 2023). Recent findings by Ocwa et al. (2024a) concur with our findings that foliar application of biostimulant had no significant effect on stem diameter. However, a progressive positive effect of foliar treatments on stem diameter was observed during both seasons under irrigated conditions compared to non-irrigated conditions (Ocwa et al., 2025). Notably, Tariq et al. (2014) noted that foliar zinc fertilisation significantly influenced several plant physiological characteristics. Relatedly, stem diameter was higher due to the interactive effect of different foliar fertilizers and 30% deficit irrigation according to Chinasho et al. (2023). Zou et al. (2024) noted a stem diameter decline because of low levels of fertilizer application. Ocwa et al. (2024a) further evidenced conspicuous effects of precision drip irrigation on stem diameter compared to biostimulant and micronutrients. Contrary, Al-Ghazal et al. (2023) noted that biofertiliser foliar application positively influenced growth parameters except the number of cobs, stem diameter and plant height. Also, treatment of experimental variants had better stem diameter (8.8%–17.0%) over the control variant (Kudaibergenova et al., 2023).

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Figure 2. **Response of stem diameter to precision drip irrigation during the 2025 growing season**

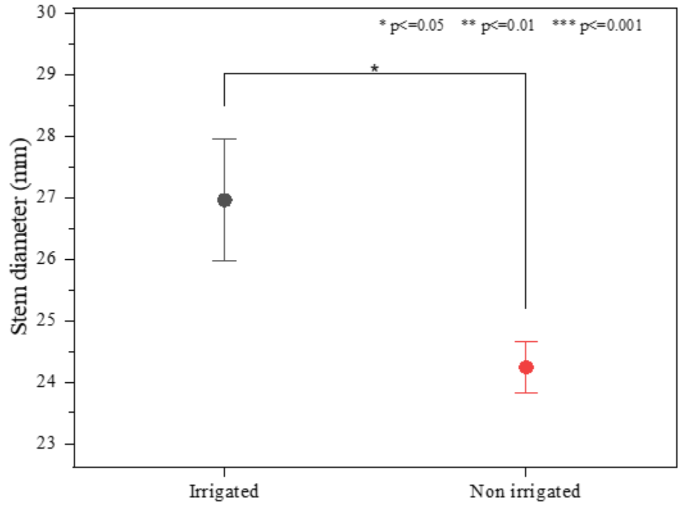


Figure 3. **Response of stem diameter to foliar nutrient application during the 2025 growing season**

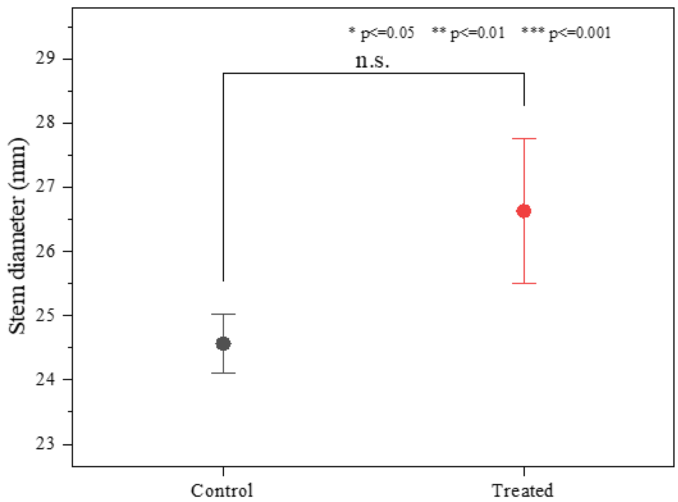
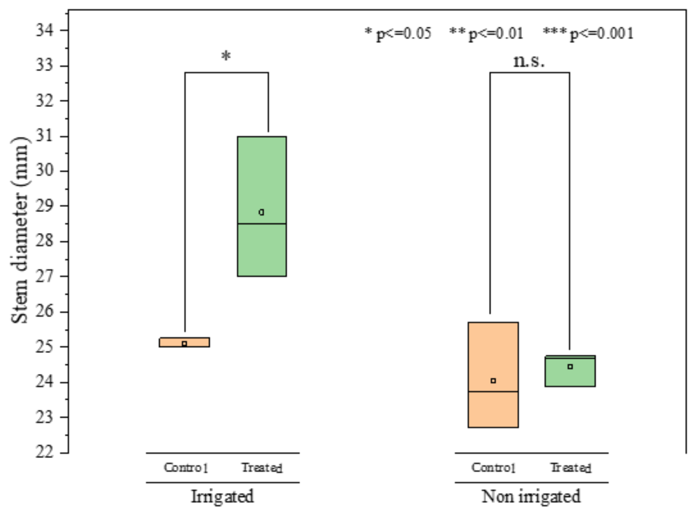


Figure 4. **The interaction effect of precision drip irrigation x foliar fertilisation on stem diameter during the 2025 growing season**



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CONCLUSIONS

Stem diameter is an important physiological growth parameter as it plays a critical role in transportation of water and micronutrients. This study examined the effects of precision drip irrigation and foliar application of micronutrients on stem diameter of FAO490 maize hybrid. Results showed that precision drip irrigation significantly influenced stem diameter ($P<0.001$), while foliar fertilisation and its interaction with precision drip irrigation showed meaningful effects. The mean stem diameter under precision drip irrigation was 26.96 mm compared to non-irrigated conditions (24.24 mm). Foliar fertilisation treatment had a higher mean stem diameter (26.63 mm) compared to control (24.57 mm), representing an 8.4% growth difference. Foliar fertilisation was more effective under precision drip irrigation with the mean stem diameter significantly high (28.83 mm) for treatment over the control (25.08 mm) thus a 14.9% stem diameter enhancement. This study indicates that precision drip irrigation primarily influenced stem diameter growth and development, however foliar fertilisation further enhanced stem growth under adequate water supplementation, suggesting a positive significant synergistic effect under precision drip irrigated conditions.

ACKNOWLEDGEMENTS

This paper has been supported by the János Bolyai Research Scholarship of the Hungarian Academy of Sciences (BO/00068/23/4).

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