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Growth and yield response of maize (*Zea mays* L.) to foliar spray of NPK (19:19:19), PPFM, micronutrient mixture under deficit and excess water conditions

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Abstract

Maize (*Zea mays* L.) has high yield potential. Its productivity depends mainly upon nutrient management. Appropriate timing with effective fertilizer application methods and improper water and nutrient management are the two main factors that adversely affect the growth and crop productivity under deficit and excess water conditions in maize response to fertilizer through nutrient supplements and reduction of nutrient loss. The field experiment was conducted at Research Farm, Agricultural College, and Research Institute, Madurai district, Tamil Nadu, during the *summer* season of 2022 to study various sources and fertilizers' levels to influence under deficit and excess water conditions on the growth and yield of maize (*Zea mays*). The study revealed that excess water condition in moisture regime irrigations at Irrigation water / Cumulative Pan Evaporation (IW/CPE) ratio of 1.0 along with nutrient management practices (N_8) 125% Soil Test Crop Response (STCR) - NPK soil application by 1% foliar spray of micronutrient mixture. Significantly higher of mean values dry matter production (DMP) (16,401 kg ha^{-1}), plant height (249 cm) and yield (8,521 kg ha^{-1}) was comparable with IW/CPE ratio of 0.8, 0.6 along with other nutrient management practices at 100% and 75% STCR - NPK followed by foliar sprays 2% NPK (19:19:19) and Pink-pigmented facultative methylotrophs (PPFM) 1%. Hence, under a normal water availability situation, irrigation at an IW/CPE ratio of 0.8 was good enough to produce a higher yield, while under deficit and excess water conditions IW/CPE ratio of 1.0 along with 125% STCR-NPK by foliar spray of micronutrient mixture of 1% was suitable for obtaining optimum nutrient management for enhancing growth and yield of maize.

Keywords: Maize, growth, yield, foliar application, NPK, deficit and excess water conditions

Introduction

Maize (*Zea mays* L.) growth and yield are most sensitive to nutrient applications under deficit and excess water conditions. Improper fertilizer and water management are the two major factors adversely affecting maize growth and productivity. This research work aimed to find out suitable Irrigation and nutrient management combinations and their time of application for improving maize growth and maximizing yield under deficit and excess water conditions. Judicious use of proper fertilizer combination, to replenish the nutrient supply systems, is a key factor in the system aiming at the intensification of crop production for sustainable agriculture (Amanullah *et al*., 2019) [4]. Maize is the second most important crop after wheat in India but its yield in $unit^{-1}$ area is very low (Amanullah *et al*., 2021). The causes of the yield gap include the injudicious use of fertilizer by the farmers. To bridge this gap in maize productivity, the package of the latest production technology involving the use of foliar applications under deficit and excess water conditions at an appropriate time needs to be used to increase maize production as well as the net profit of the farmers under field conditions.

Efficient water management under deficit and excess water conditions could enhance crop productivity in the coming decades. The use of modern technology, particularly irrigation water management and nutrient application is essential to maximize crop production and returns for the farmers (Pandey *et al*., 2020) [13]. Water shortage during the vegetative stages of development limits the grain yield in many maize production areas. In northern China, maize is the second-most (following wheat) important cereal crop, which is frequently subjected to delay in irrigation or water stress (WS) causing a significant yield reduction (Li, 2017) [12]. Grain yield was reduced by 22.6-26.4% due to a decrease in kernel number and weight (Pandey *et al*., 2020) [13], and decreased by 37% due to a decline of 18% in kernel weight and 10% in kernel number under water stress conditions (Karam *et al*., 2013) [10].

Poor water availability and high temperatures result in significant stress during critical phases of maize (*Zea mays* L.) development (Al-Kaisi *et al.*, 2013) [13]. These stress factors lead to management challenges with insects, diseases, and reduced nutrient availability and uptake by plants.

Balanced use of nitrogen (N), phosphorus (P) and potassium (K) fertilizers could play a pivotal role in increasing the yields of cereals under deficit and excess water conditions. Among the limiting factors; the proper level and ratio of NPK are of prime importance (Asghar *et al*., 2020) [8]. Foliar applications of NPK (19:19:19), Pink-Pigmented Facultative Methylotrophs (PPFM) and Micronutrient mixture could increase crop productivity manyfold under deficit and excess water conditions. A foliar spray not only provides nutrients but can also provide a significant amount of water during the time of water stress. In addition to supplying a nutrient for plant growth, N application could enhance the drought tolerance of a plant to increase yield under water deficit and excess water conditions (Li, 2017: Chipman *et al*., 2021) [12, 9]. Research shows that, three levels (75%, 100% and 125%) of N: P_2O_5:K_2O STCR-NPK application during grain filling could enhance the remobilization from stored carbohydrates in vegetative organs to grain under moderate water stress (WS), which might benefit starch synthesis and grain yield formation under post-anthesis drought (Yang *et al*., 2020).

The primary objective of foliar applications is to allow fertilizer enhancing absorption of nutrients by the plant and therefore maximize their utilization. STCR-NPK fertilizers that are NPK (19:19:19), Pink-Pigmented Facultative Methylotrophs (PPFM) and Micronutrient mixture are most suitable for this purpose. Applying a balanced fertilizer in critical stages of growth will give greater benefit levels and quality of agricultural production. Foliar feeding is an effective method for correcting nutrient deficiencies and overcoming the soil's inability to transfer nutrients to the maize plant under low moisture conditions (Stigler *et al*., 2020). Foliar application is usually preferred because very small amounts of fertilizers are applied per unit area and decrease groundwater pollution. Application of NPK(19:19:19) at 2 percent concentration twice at 30 and 60 days after sowing (DAS) produced the highest single leaf area (415.0 cm 2) when compared with other application timings (Amanullah *et al*., 2020). Many investigators concluded that foliar application of nutrient sources during the growth stage increased grain and straw yields (Ahmed, *et al*., 2021). According to Abd El-Fattah *et al*., 2021, research revealed that foliar application of NPK fertilizers has a positive impact on maize yield parameters over soil application.

The present study was therefore designed to investigate best the fertilizers (75%, 100% and 125%) of N: P_2O_5:K_2O STCR-NPK by foliar applications of NPK (19:19:19), Pink-Pigmented Facultative Methylotrophs (PPFM) and Micronutrient mixture combination and its application time for improving maize productivity under deficit and excess water conditions.

Materials and Methods

A field experiment was conducted under deficit and excess water conditions to investigate the effects of Irrigation at IW/CPE ratios of 0.6, 0.8, 1.0 and three levels (75%, 100% and 125%) of N: P_2O_5:K_2O STCR-NPK by foliar applications of NPK (19:19:19), Pink-Pigmented Facultative Methylotrophs (PPFM) and Micronutrient mixture and their application time on the growth and yield of maize (*Zea mays* L., cv COH(M) 6) at the Research Farm of the Agricultural College and Research Institute, Madurai district, Tamil Nadu in *summer* 2022. The soil was red sandy clay loam with neutral in reaction (pH 6.9) and the electrical conductivity was normal (0.32 dSm-1 at 25 °C), medium organic carbon (0.65%), available nitrogen was medium (386.4 kg ha-1), available phosphorus was high (69.3 kg ha-1) and medium available potassium (291.53 kg ha-1). The experiment was laid out in a split-plot design using three replications. Each replication consisted of 30 treatments. The details of factors and their levels used were given below:

Control: One (N_1) in each replication (no foliar application)

Main plot: Moisture Regimes

I_1 - Irrigation at IW/CPE ratio of 0.6

I_2 - Irrigation at IW/CPE ratio of 0.8

I_3 - Irrigation at IW/CPE ratio of 1.0

Table 1: Subplot: Nutrient management practices

N_2	125% N:P_2O_5:K_2O STCR NPK + Foliar spray of 2% 19:19:19 (N:P:K)
N_3	100% N:P_2O_5:K_2O STCR NPK + Foliar spray of 2% 19:19:19 (N:P:K)
N_4	75% N:P_2O_5:K_2O STCR NPK + Foliar spray of 2% 19:19:19 (N:P:K)
N_5	125% N:P_2O_5:K_2O STCR NPK + Foliar spray of 1% PPFM
N_6	100% N:P_2O_5:K_2O STCR NPK + Foliar spray of 1% PPFM
N_7	75% N:P_2O_5:K_2O STCR NPK + Foliar spray of 1% PPFM
N_8	125% N: P_2O_5:K_2O STCR NPK + Foliar spray of 1% Micronutrient mixture
N_9	100% N: P_2O_5:K_2O STCR NPK + Foliar spray of 1% Micronutrient mixture
N_{10}	75% N: P_2O_5:K_2O STCR NPK + Foliar spray of 1% Micronutrient mixture

Soil Test Crop Response (STCR) approach was applied in each plot to treatments wise in the form of urea, diammonium phosphate, and muriate of potash, respectively. Sowing was done on 17 February 2022. The maize - COH (M) 6 seeds, the hybrid matures in 110 days. It is resistant to turcicum leaf blight and downy mildew. Individual plot size: 20 m^2, spacing was 60cm x 30cm; irrigation was given at the time of sowing, followed by life irrigation on the fifth to the seventh day. The subsequent irrigations were scheduled based on the moisture regimes of the main plot as per the IW/CPE. All the plots were irrigated at a depth of 50 mm and were measured using the Parshall flume. The other practices of growing maize were adequately taken for the management of experimental plots throughout the cropping season. The plant height was measured on dry matter production (DMP), and yield was computed at the harvest stage. The statistical analysis was carried out by AGRES software at a 5% level of significance.

Result and Discussion

Influence of deficit and excess water conditions on maize

Moisture regimes and nutrient management practices significantly influenced the crop DMP and plant height of maize (Table 2). IW/CPE ratio of 1.0 along with 125% STCR - NPK by foliar spray of 1% micronutrient mixture recorded significantly higher DMP (16,401 kg ha^{-1}) was on par with IW/CPE ratio of 0.8 over 0.6. Lower DMP (15,097 kg ha^{-1}) and IW/CPE ratio of 1.0 along with 125% STCR - NPK by foliar spray of 2% NPK (19:19:19) recorded significantly higher plant height (249 cm) in IW/CPE ratio of 0.8 and 0.6 along with 100% and 75% STCR - NPK. The reduction in dry matter accumulation under a lower moisture regime because of reduced water availability leads to water deficit conditions for most of the crop growing period. Biomass accumulation is sensitive to water stress and the degree of reduction of biomass accumulation depended on the severity of water stress. Similar results are in line with Chipman *et al*., (2021) [9] for allocation of nitrogen and dry matter for two soybean genotypes in response to water stress during reproductive growth. Another report that Arif, *et al*., (2016) [7] on the response of wheat to foliar application of nutrients depending on the intensity and duration of the stress.

Table 2: Influence of deficit and excess water conditions on dry matter production (kg ha^{-1}) and plant height (cm) at harvest stages of maize

Moisture Regimes	Nutrient management practices (kg ha^{-1})										
	N_1	N_2	N_3	N_4	N_5	N_6	N_7	N_8	N_9	N_{10}	Mean
	Dry Matter Production (kg ha^{-1})										
$I_{1.0}$	16,485	16,488	16,176	16,170	16,480	16,190	16,165	16,488	16,197	16,172	16,301
$I_{0.8}$	15,499	16,360	15,709	15,667	16,349	15,722	15,655	16,367	15,730	15,700	15,875
$I_{0.6}$	13,308	16,353	14,234	14,165	15,790	14,266	13,500	16,358	14,268	14,200	14,644
Mean	15,097	16,400	15,373	15,334	16,206	15,392	15,106	16,401	15,398	15,357	
	Plant Height (cm)										
$I_{1.0}$	251.70	259.50	254.30	245.80	257.20	256.60	250.00	258.70	251.80	248.20	253.38
$I_{0.8}$	243.10	254.80	248.70	245.20	251.49	252.19	245.50	252.50	247.49	252.49	249.34
$I_{0.6}$	219.60	235.20	229.50	224.60	230.59	232.50	225.20	233.90	227.79	218.30	227.72
Mean	238.13	249.83	244.16	238.53	246.43	247.10	240.23	248.36	242.36	239.66	

	Dry Matter Production (kg ha^{-1})				Plant Height (cm)			
	I	N	I at N	N at I	I	N	I at N	N at I
S.Ed	206.90	95.86	358.36	353.23	2.67	1.89	4.64	4.79
LSD (0.05)	415.96	273.30	742.65	732.01	5.38	5.40	NS	NS

$I_{1.0}$; $I_{0.8}$; $I_{0.6}$ - Irrigation at IW/CPE ratio. and N_1 - RDF, N_2 - 125%; N_3 -100% and N_4 - 75% STCR - NPK along with foliar spray of 2% N:P:K (19:19:19); N_5 -125%; N_6 -100%; N_7 - 75% STCR - NPK along with foliar spray of 1% PPFM, N_8 - 125%; N_9 -100% N_{10} -75% STCR - NPK along with foliar spray of 1% micronutrient mixture (N_2-N_{10} based on STCR - NPK). Means followed by different letters within a category of treatments are statistically different from each other using the least significant difference (LSD) test (p<0.5)

Yield

Moisture regimes and nutrient management practices significantly influenced the yield of the crop (Fig. 1). IW/CPE ratio of 1.0 and 0.8 along with 125% STCR - NPK by foliar spray of 1% micronutrient mixture recorded significantly higher yield (8588 and 7142 kg ha^{-1}) and significantly lower yield was recorded in IW/CPE ratio of 0.6. The increase in yield could be attributed to greater and more consistent available soil moisture due to an increased level of irrigation that resulted in better crop growth and yield components. The lower yield in irrigation at IW/CPE of 0.6 along with 100% and 75% STCR - NPK at 2% NPK (19:19:19) and 1% Pink-pigmented facultative methylotrophs was significantly higher than the control (N_1) might be attributed to the decrease in the synthesis of metabolites and reduction in absorption and translocation of nutrients from soil to plant under deficit and excess water conditions supply. According to Amanullah *et al.* (2013) [3], increasing the foliar application of nitrogen at different growth stages influences maize's phenology, growth, and yield. Furher, Amanullah *et al.*, (2019) [5] reported the effects of plant density and N on phenology and yield (7102 kg ha^{-1}) of maize. Similar findings were reported by Sanjeev *et al.*, (2017) [14] to improve the yield and yield components of winter maize as influenced by plant density and N levels.

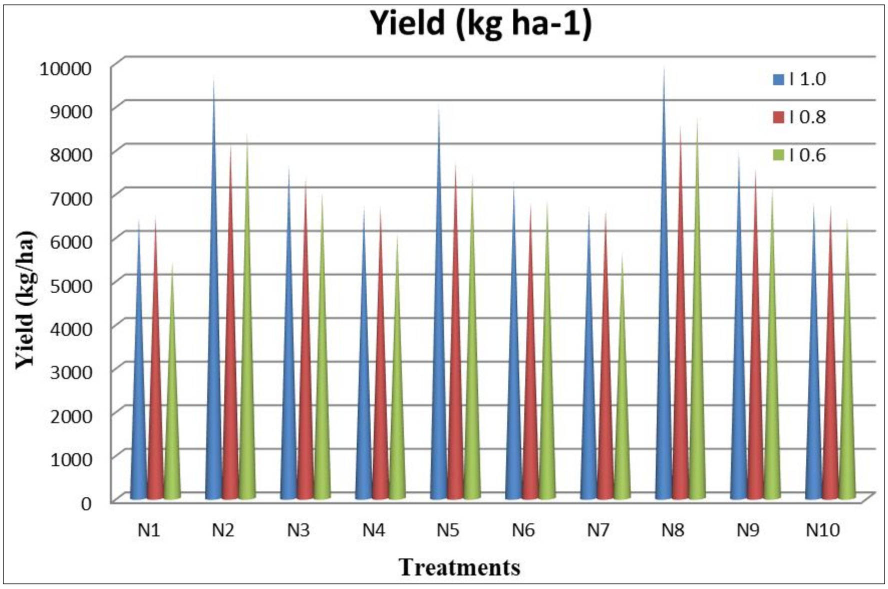

Fig 1: Influence of deficit and excess water on yield (kg ha^{-1}) of maize

$I_{1.0}$; $I_{0.8}$; $I_{0.6}$ - Irrigation at IW/CPE ratio. and N_1 - RDF, N_2 - 125%; N_3 -100% and N_4 - 75% STCR - NPK along with foliar spray of 2% N:P:K (19:19:19); N_5 -125%; N_6 -100%; N_7 - 75% STCR - NPK along with foliar spray of 1% PPFM, N_8 - 125%; N_9 -100% N_{10} -75% STCR - NPK along with foliar spray of 1% micronutrient mixture (N_2-N_{10} based on STCR - NPK).

Conclusion

Maize growth and yield are adversely affected under nutrient and moisture stress conductions. Foliar application of major nutrients (STCR-NPK) as sole or in combination improves growth and yield components of maize under moisture-stress conditions. Because foliar nutrients application not only provides the nutrients to the hungry plants under dryland conditions but it could also provide water to the thirsty maize plants under drought conditions. The benefits of foliar nutrition should be therefore demonstrated to the growers under dryland condition

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Conflicts of Interest

The authors declare no conflict of interest.

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