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Effect of Potassium Nano Chelate and Water Deficit Stress on Quantitative and Qualitative Traits of Maize in Southwest of Iran (Ahvaz Region)

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RESEARCH ARTICLE

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ABSTRACT

BACKGROUND: Innovations for saving water in irrigated agriculture and thereby improving water use efficiency are of paramount importance in water-scarce regions. Conventional deficit irrigation is one approach that can reduce water use without causing significant yield reduction.

OBJECTIVES: The purpose of this study was to evaluate the effects of different irrigation regimes and Potassium nano chelate on effective traits on Corn crop production under the Mediterranean climatic conditions in Southwest of Iran.

METHODS: Current research was done according split plot experiment based on completely randomized block design at 2022. So the water deficit at three level [60 (control), 90 and 120 mm evaporation from class A evaporation pan] in main plots, and potassium nano chelate at three levels [0 (control), 2 and 4 $kg.ha^{-1}$) in sub plots.

RESULT: Significant difference in growth parameters was observed between water deficit and commercial fertilizer (potassium) treatments. Potassium chelate recorded higher yields relative to water deficit with similar 2 and 4 $kg.ha^{-1}$ rates, though statistically significant. Yield deficiency was observed in maize at controlled potassium application. Yield components, showed both K and water deficiencies in 7^{th} week, while control treatments showed K deficiency in 14^{th} week by potassium chelate at low application rates.

CONCLUSION: The agronomic optimal rate of potassium Chelate determined by evaporation pan function were found to be higher than that of 90 mm evaporation that was found to enhance growth and yields of crops potentially have greater benefits such as improving soil health and plant resilience.

KEYWORDS: *Chlorophyll, Corn, Irrigation, Nutrition, Yield*.

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1. BACKGROUND

Agriculture is the key driver to economic growth and the main source of livelihood in rural areas, approximately 80% of Kenyan population (Shoals, 2012). Maize is among important crops growth in Iran by smallholder farmers due to its strong impact on food security and farm income. Maize accounts for 55% of cultivated area and > 60% of staple food produced (Edgar *et al*., 2017). Soil fertility decline however, has contributed limiting nutrients are; nitrogen (N), phosphorus (P) and potassium (K) and also the most sought after to boost yields (Karuku *et al*., 2017). Sustainable agriculture implies maximizing the net benefits a farmer receives from agricultural production. This can be achieved by increasing crop yields, through increased nutrient and water use efficiency, improved soil health/quality among others. Maize, a globally significant crop celebrated for its robust water deficit tolerance, rapid growth, and substantial biomass production, stands out as a good candidate for chelate phytoremediation and revenue generation from marginally contaminated soil (An *et al*., 2023). Recent research has explored diverse approaches such as water deficit-tolerant genotypes (An *et al*., 2023), and potassium (Qiu *et al*., 2022), nano chelates supplementation and utilization (Cheng *et al*., 2023). The excessive accumulation of potassium chelate in plant triggers the production of reactive oxygen species (ROS), inducing changes in various physiological and biochemical processes, including photosynthesis, enzymatic, non-enzymatic reactions, plant hormone regulation, and related gene expression (Qiu *et al*., 2022). Si, the second most abundant element in the Earth's crust, has gained recognition for its capacity to mitigate Cd effects (Liu *et al*., 2023). Potassium accumulates around plant cell walls, obstructing the apoplastic route that transports minerals through to the xylem, preventing water deficit effects in leaf cell walls and vacuoles, and averting toxicity (Coskun *et al*., 2019). Potassium nano chelate application has been demonstrated to elevate plant oxidative stress (Vaculík *et al*., 2020).

2. OBJECTIVES

This study integrates physiological and transcriptomic approaches to unravel the mechanisms underlying potassium nano chelate application in maize responses to water deficit stress. The research aims to: (1) characterize the physiological changes induced by potassium under water deficit stress; (2) analyze qualitative and quantitative traits by which potassium nano chelate application alleviates water deficit stress in maize leaves. The findings will provide valuable insights into the molecular basis of potassium capacity to mitigate water deficit stress in maize leaves and identify potential yield production that efforts in maize.

3. MATERIALS AND METHODS

3.1. *Field and Treatments Information*

The experiment was conducted via split plot based on randomized block design, so water deficit in main plots [60 (control), 90 and 120 mm evaporation from class A evaporation pan], and potassium nano chelate at three levels [0 (control), 2 and 4 $kgha^{-1}$) belonged to sub plots.

3.2. *Farm Management*

In many areas, especially in developing nations, the necessary meteorological data are lacking, therefore limiting the application of FAO-PM Equation, even other estimation methods. In this context, simpler techniques are required and have been in use. One of the most common and reliable simple techniques for estimating evaporation has been from evaporimeters such as the Class A and B (Mauel *et al*., 2009). Pan evaporimeter holds water and the quantity of water loss during observation is determined as the evaporation, and are adjusted to obtain 60, 90 and 120 mm using a conversion factor called the pan coefficient (Smajstrla *et al*., 2000).

3.3. *Measured Traits*

The chlorophyll index at 28-day harvest, chlorophyll extraction was performed using acetone at 4 ℃ for 24 h, and its concentration was measured using a spectrophotometer (UV-3802). At 113 DAP, 25 random maize plants per replicate were harvested to determine number of grain yield per m^2, number of rows per corn, number of grains per row and individual grain weight using a precision scale. Grains were husked with the aid of a mechanical maize kernel remover. Three subsamples of fresh grains per treatment were milled at 2 mm, weighed for fresh weight, and oven-dried for 48 h at 70 ℃. Grain humidity was 15.5% and was calculated as the difference in weight between fresh and dry samples. At the same moment, 5 m2 from each replicate in the field were randomly selected using a 1 m to 1 m wooden frame, repeating the process 5 times per replicate. All the weeds' shoot within the selected area was collected, dried in an oven at 70 ℃ for 48 h and weighed to determine mean dry shoot biomass production per m^2.

3.4. *Statistical Analysis*

Statistical Analysis Data were analyzed by one-way Minitab (V.14.1) according to a randomized block design with three replicates. The mean values of the determinations in triplicate ± standard errors are shown. Means were compared through the confidence intervals at 95% confidence level, represented by the error bars in the charts. If there is an intersection between two intervals (error bars), we conclude that the means are not significantly different. Otherwise, there is evidence of a significant difference between means. In addition, the means were compared with least significant difference (Duncan test) at $p < 0.05$ (Lenth, 2016) was used to perform the analysis.

4. RESULT AND DISCUSSION

After 30 days of chelate treatment, plant growth was noticeably inhibited by water deficit stress, an effect mitigated through potassium application (Table 1). The application of potassium nano chelates significantly alleviated water deficit-induced toxicity in the leaves, leading to a reduction grain yield and grain weight (Table 2). Potassium exerted a significant stimulation effect on yield component enhances of

16.61 of grain yield in 4 kgha^{-1} of potassium, compared with evaporation content. Conversely, potassium application at 4 kgha^{-1} significantly increased number of grains in corn (15.09), Chl. index (20.23%) seed weight (11.49%) and number of grains in raw (35.15%) (Table 2). The impact of potassium was particularly pronounced on the concentration and content of evaporation in 28 days ($P \leq 0.01$). Furthermore, potassium and water deficit exhibited significant effects on yield components ($P \leq 0.01$) (Table 1). Notably, potassium application led to a significant reduction evaporation content after 28 days (Table 1).

Table 1. Result analysis of variance of measured traits

S.O.V	df	Grain yield	Chlorophyll index	Number of grain in corn	1000 grain weight	Number of grain in row
Replication (R)	2	2405^{ns}	69.5^{ns}	181.07^{ns}	36.1^{ns}	1.33^{ns}
Water deficit (A)	2	739101**	614.8**	52093.2**	4956.3**	181.04**
Error I	4	2126.4	51.03	1046.1	390.5	10.23
Fertilizer (B)	2	320981**	534.16**	62375.3**	5180.2**	137.5**
A×B	4	89324**	11.72**	29748.4**	3622.5**	200.06**
Error II	12	1744.5	37.03	889.3	245.12	7.91
CV (%)		8.71	14.12	7.53	10.01	9.41

ns, * and **: no significant, significant at 5% and 1% of probability level, respectively.

Significant effects of potassium (B), water deficit (A), and A × B interactions were observed on traits and chlorophyll content ($P \leq 0.05$) at the 28-day harvest (Table 2). Potassium treatment led to a significant increase in chlorophyll index. On the other hand, potassium treatment resulted in significant enhance in the chlorophyll content index rates, compared to the evaporation treatments. Potassium treatment also notably increased efficiency of yield production coefficient, respectively. Nano chelates exhibit severely plant growth and manifesting symptoms such as yield production, seed weight and reduced water deficit effects (Table 1). Potassium has demonstrated its efficacy in alleviating these water deficit-induced symptoms in maize leaves (Table 2). Evaporation content and content in shoots were increased with time from day 1 to day 28 after treatments (Table 1). Potassium tends to accumulate extensively within organelles, inhibit damage to chloroplasts and mitochondria. This disruption to the photosynthetic system leads to the formation of yellow spots on leaves, chlorosis, and eventual leaf senescence (An *et al.*, 2023), ultimately resulting in growth stimulation, seed weight, grain and raw number (Table 1). Potassium, on one hand, mitigates water deficit toxicity by binding to the cell wall, segregating within vacuoles, and with chelating (Vaculík *et al.*, 2020; Xiao *et al.*, 2022). On the other hand, nano chelate enhances the uptake and accumulation of other elements in maize (An *et al.*, 2023; Farooq *et al.*, 2016).

Table 2. Mean comparison effect of different level of irrigation intervals and humic acid on studied traits

Treatment	Grain yield ($kg.ha^{-1}$)	Chlorophyll index (Spad)	Number of grain in Corn	1000 grain weight (gr)	Number of grain in row
Evaporation Pan (mm)					
60	5758.18 [a]	47.01 [a]	471.81[a]	176.24[a]	34.61[a]
90	4672.65 [b]	42.73[b]	400.43[b]	151.61[b]	30.27[b]
120	3950.31 [c]	39.51[c]	335.75[c]	145.19[c]	24.73[c]
Potassium Nano Chelate ($Kg.ha^{-1}$)					
0	4048.27 [c]	38.49 [c]	341.68[c]	150.11[b]	23.01[c]
2	4802.15 [b]	42.51[b]	410.22[b]	155.25[ab]	31.14[b]
4	5530.72 [a]	48.25[a]	456.1[a]	167.7[a]	35.48[a]

*Means with similar letters in each column are not significantly different by Duncan's test at 5% probability level.

This detoxification mechanism could be attributed to the sequestration of oxygen radicals within vacuoles of leaf cells or deactivation through the formation of stable potassium complexes, simultaneously enhancing nutrient uptake and improving leaf photosynthetic efficiency (Bitarishvili *et al*., 2023; Vaculík *et al*., 2020). Studies have revealed that nano chelate treatment in oxygen exposed upregulates essential nutrient transporters (N, P, K, S) and (ATP) transporters (Sun *et al*., 2022). The related obtained from the water deficit vs potassium comparisons were subjected to further nano chelates enrichment analysis for common yield (Table. 2). Nano chelates exhibited significant enrichment in terms related to evaporation activity, response to biosynthetic process and metabolic process. For the evaporation content, the potassium displayed significant enrichment in terms related to cellular response to oxygen levels (Table. 2). These results were also associated with responses to oxygen levels. Moreover, enrichment was found in cellular and metabolic process. Nano chelates also influences the regulation of water deficit transporter genes as well as Si transporter genes, thus impacting elements such as potassium uptake and accumulation (Vaculík *et al*., 2020; Zhang *et al*., 2023). Tissues analysis has further demonstrated that K significantly regulates stomata related to plant transporter (Ca, B, Cu, Si, Na, P, Fe, Zn) and led to be growth at high abiotic stresses (Liu *et al*., 2023). Co-expression network analysis has highlighted the significant role of nano chelates in the regulation of water uptake and accumulation within dry lands (Table 2). These factors are not only involved in K uptake and accumulation but also play a role in enhancing water deficit tolerance. Importantly, these components facilitate the transport of various substrates, including hormones (Auxin), lipids protein phosphatases, and metal element (Fu *et al*., 2019). An increase in potassium levels can regulate the accumulation of osmolytes like proline, soluble sugars, and amines, influence mineral nutrition uptake, enhance ROS scavenging activity, and stimulate the production of secondary metabolites (Dutta *et al*., 2018). Nano chelates are closely intertwined with enzyme systems and water transport genes (Bucker-Neto *et al*., 2017). This suggests that plant nano chelates are intricately involved in various aspects of K-mediated defense against water deficit stress (Table 2).

5. CONCLUSION

The agronomic optimal rate of potassium Chelate determined by evaporation pan function were found to be higher than that of 90 mm evaporation that was found to enhance growth and yields of crops potentially have greater benefits such as improving soil health and plant resilience.

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FOOTNOTES

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