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EFFECT OF EXTENDED IRRIGATION INTERVALS AND FOLIAR APPLICATION OF POTASSIUM SULFATE AND PROLINE ON SOME YIELD COMPONENTS AND MINERAL CONTENT OF MAIZE (*ZEA MAYS* L.) GRAINS

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Abstract:
Background and Objectives: Water stress is a major challenge for maize cultivation, detrimentally affecting the development of yield components and the nutritional value of grains. This study aimed to evaluate the role of foliar-applied potassium sulfate and proline in improving specific ear characteristics (ear length, number of rows, and grains per row) and the mineral content (nitrogen and phosphorus) of grains under varying water-deficit conditions.
Materials and Methods: A field experiment was conducted using a split-plot arrangement within a Randomized Complete Block Design (RCBD). The main plots consisted of four irrigation intervals (4, 8, 12, and 16 days), while the sub-plots comprised factorial treatments of foliar-applied potassium sulfate (0, 2500, and 5000 mg·L^{-1}) and proline (0, 100, and 200 mg·L^{-1}). Ear morphological traits were measured, and the mineral content of the grains was analyzed at maturity.
Key Results: Extending the irrigation interval from 4 to 16 days led to a significant decrease in ear length (from 24.30 to 19.74 cm), number of rows (from 17.44 to 16.07), grains per row (from 47.27 to 39.48), grain nitrogen content (from 1.31% to 0.94%), and phosphorus content (from 0.65% to 0.53%). Foliar application of potassium (5000 mg·L^{-1}) and proline (200 mg·L^{-1}) significantly improved all studied traits. The highest ear length (25.67 cm) was recorded in the interaction treatment of a 4-day irrigation interval combined with 5000 mg·L^{-1} potassium and 100 mg·L^{-1} proline, while the highest nitrogen content (2.19%) was observed under the same irrigation interval with 5000 mg·L^{-1} potassium and 200 mg·L^{-1} proline.
Conclusions: Foliar application of potassium and proline is an effective tool for improving ear structure and its nutritional composition under water-stress conditions. Combining these treatments with proper irrigation management enhances both the yield potential and the nutritional quality of maize.

Keywords: Maize, yield components, water stress, potassium, proline, foliar application, mineral content.

1. INTRODUCTION

In light of escalating global issues such as climate change and population increase, improving the productivity of key crops like maize (*Zea mays* L.) is critically important. Maximizing the genetic potential of maize by comprehending genetic factors and heterosis is a pivotal study domain (Al-Jubouri *et al*., 2024). Nonetheless, environmental limitations sometimes restrict its potential. Water stress, caused by water shortage or inconsistent rainfall, is a significant limitation on agricultural yield in several regions globally (Ali & Abdelaal, 2022). Water stress not only diminishes total yield but also adversely influences its essential components and nutritional quality via intricate physiological and biochemical processes.

Water deficit is especially significant during the flowering and grain-filling stages, as it can extend the Anthesis-Silking Interval (ASI), resulting in inadequate pollination and a diminished kernel count per ear. Drought hinders photosynthesis, leading to reduced production and accumulation of assimilates essential for kernel development and filling. This results in shorter ears, fewer rows, and shriveled kernels (Huang et al., 2022). Additionally, diminished transpiration under water stress restricts the absorption of essential nutrients such as nitrogen and phosphorus from the soil, resulting in decreased concentrations in grains and a reduction in their nutritional value as feed or food (Abaza et al., 2023).

Agricultural strategies designed to improve plant stress tolerance have emerged to address these challenges. The foliar application of nutrients and osmoprotectants represents an effective and rapid method. Potassium (K) is essential for alleviating water stress effects through its contributions to osmotic adjustment, enhancement of water use efficiency, and facilitation of photosynthate translocation to grains (Al-Jobouri & Al-Jobouri, 2020; Al-Seidy et al., 2024). Proline, an amino acid, serves as an effective osmoprotectant, protecting cells from oxidative damage and preserving the integrity of membranes and proteins, thus facilitating metabolic processes during stress conditions (Ali et al., 2008).

Although numerous studies have investigated the individual effects of these factors, there is still a critical need to understand the complex interactions between water management and protective foliar nutrition, especially as recent research continues to explore these dynamics (Shaker, 2025). Therefore, this study aimed to evaluate the impact of extended irrigation intervals, foliar application of potassium and proline, and their interactions on some yield components and mineral content of maize, and to identify the optimal treatments that can enhance both crop productivity and its nutritional quality under water-scarce conditions.

2. MATERIALS AND METHODS

Experimental Site and Environmental Conditions: The field experiment was conducted during the 2023 autumn season in an agricultural field in Kirkuk Governorate, Iraq. The site's soil is characterized by a Silty Loam texture.

Plant Material: Commercially certified seeds of maize (*Zea mays* L.) cv. 'Sajunto' were used.

Experimental Design and Treatments: The experiment was designed as a split-plot arrangement in a Randomized Complete Block Design (RCBD) with three replications. The main plots were assigned to four irrigation intervals: 4, 8, 12, and 16 days. The sub-plots included factorial (3 × 3) foliar application treatments:

1. Potassium sulfate (K_2SO_4; 41.5% K^+) at three concentrations: 0 (control), 2500, and 5000 mg·L⁻¹.
2. Proline at three concentrations: 0 (control), 100, and 200 mg·L⁻¹.

Agronomic Practices and Treatment Application: Seeds were sown manually following recommended practices for plant and row spacing. Phosphate and nitrogen fertilizers were applied as a basal dose at planting. Foliar treatments were applied using a knapsack sprayer. The first spray was applied 30 days after emergence, and the second was applied 30 days after the first, ensuring full coverage of the foliage and avoiding spray drift to adjacent experimental units.

Data Collection and Measurements: At physiological maturity, ears were harvested from randomly selected plants from the central rows of each experimental unit to measure the following traits:

1. **Ear Length (cm):** Measured from the base to the tip of the ear using a graduated ruler.
2. **Number of Rows per Ear:** Counted manually for each ear.
3. **Number of Grains per Row:** Calculated as the average of three rows from each ear.
4. **Grain Analysis:** Grains were dried, ground, and then analyzed for:
   - **Nitrogen Content (%):** Determined using the micro-Kjeldahl method (A.O.A.C., 1980).
   - **Phosphorus Content (%):** Determined spectrophotometrically according to the method of Matt (1970).

Statistical Analysis: Data were subjected to Analysis of Variance (ANOVA) using SAS software (Version 9.4) according to the split-plot design model. Treatment means were compared using Duncan's Multiple Range Test (DMRT) at a 5% significance level ($P \leq 0.05$).

3. RESULTS

Ear Length (cm): Table (1) shows the significant effect of different treatments on ear length. Increasing the irrigation interval led to a gradual and significant decrease in this trait, with the 4-day interval recording the highest average (24.30 cm), while the 16-day interval yielded the lowest (19.74 cm). Conversely, foliar application of both potassium sulfate and proline caused a significant increase in ear length, with concentrations of 5000 mg·L⁻¹ potassium and 100 mg·L⁻¹ proline being superior. The two-way interaction between irrigation intervals and potassium was significant, with the best results achieved at the 4-day interval combined with 5000 mg·L⁻¹ potassium (25.07 cm). Similarly, the interaction between irrigation and proline was significant, where the 4-day interval with 100 mg·L⁻¹ proline excelled (24.89 cm). The interaction between potassium and proline was also significant, with the combination of 5000 mg·L⁻¹ potassium and 100 mg·L⁻¹ proline yielding the highest average (23.56 cm). Regarding the three-way interaction, the treatment combining a 4-day irrigation interval with 5000 mg·L⁻¹ potassium and 100 mg·L⁻¹ proline recorded the longest ear (25.67 cm), whereas the shortest ear (16.89 cm) resulted from the 16-day interval without any foliar spray.

Table 1: Effect of irrigation intervals, foliar sprays of potassium sulfate and proline, and their interaction on ear length (cm).

Irrigation Intervals (days)	Potassium Sulfate mg.L^{-1}			Average Irrigation Intervals
	0	2500	5000	
4	23.59 c	24.22 bac	25.07 a	24.30 a
8	21.18 ed	23.96 bc	24.59 ba	23.25 b
12	19.89 gf	20.59 ef	22.00 d	20.83 c

16	17.89 h	19.48 g	21.85 e	19.74 d
Potassium sulfate ml.L^{-1}	Proline mg.L^{-1}			Average Potassium Sulfate
	0	100	200	
0	20.36 c	20.75 c	20.81 c	20.63 c
2500	21.61 b	22.33 b	22.25 b	22.06 b
5000	23.19 a	23.56 a	23.39 a	23.38 a

Proline mg.L^{-1}	Irrigation Intervals (days)				Average Proline
	4	8	12	16	
0	23.70 b	23.55 bc	20.59 ed	19.04 f	21.72 b
100	24.89 a	23.48 bc	20.78 d	19.70 ef	22.21 a
200	24.30 ba	22.70 c	21.11 d	20.48 ed	22.15 ba

Effect of Interaction Between Irrigation Intervals, Potassium Sulfate and Proline				
Irrigation Intervals (days)	Potassium Sulfate mg.L^{-1}	Proline mg.L^{-1}		
		0	100	200
4	0	22.67 d-i	23.78 c-f	24.34 a-d
	2500	23.00 c-i	25.22 ab	24.44 a-d
	5000	25.44 ab	25.67 a	24.11 a-e
8	0	22.00 g-j	21.44 g-l	20.11 k-n
	2500	23.22 c-g	24.78 abc	23.89 a-f
	5000	25.44 ab	24.22 a-e	24.11 a-e
12	0	19.89 lmn	19.67 l-o	20.11 k-n
	2500	20.56 j-m	20.22 k-n	21.00 i-l
	5000	21.33 h-l	22.45 e-i	22.22 f-j
16	0	16.89 b	18.11 op	18.66 no
	2500	19.66 l-o	19.11 mno	19.67 l-o
	5000	20.56 j-m	21.89 g-k	23.11 c-g

Means within the table followed by the same letter(s) are not significantly different at $P \leq 0.05$ according to Duncan's Multiple Range Test (DMRT).

Number of Rows per Ear: As shown in Table (2) the number of rows per ear decreased significantly as the irrigation interval was extended, from 17.44 rows (at 4 days) to 16.07 rows (at 16 days). Potassium application significantly increased this trait, while different proline concentrations had no significant effect. The two-way interaction between irrigation and potassium was significant, where the 8-day interval with 5000 mg·L^{-1} potassium produced the highest number of rows (17.70). The interaction between irrigation and proline was also significant, with the 4-day interval and 100 mg·L^{-1} proline treatment being superior (17.67 rows). A significant interaction was also observed between potassium and proline, where 5000 mg·L^{-1} potassium with 100 mg·L^{-1} proline recorded the highest average (17.70 rows). In the three-way interaction, the highest value (18.56 rows) was achieved with an 8-day irrigation interval combined with 5000 mg·L^{-1} potassium and 100 mg·L^{-1} proline.

Table (2) : Effect of irrigation intervals, foliar sprays of potassium sulfate and proline, and their interaction on Number of Rows per Ear.

Irrigation Intervals (days)	Potassium Sulfate mg.L^{-1}			Average Irrigation Intervals
	0	2500	5000	
4	17.18 ab	49.53 a	17.18 ab	17.44 a
8	15.67 cd	40.05 cd	15.67 cd	16.60 b
12	15.44 d	43.52 bc	15.44 d	16.22 cb
16	15.93 cd	32.97 e	15.93 cd	16.07 c
Potassium sulfate ml.L^{-1}	Proline mg.L^{-1}			Average Potassium Sulfate
	0	100	200	
0	16.03 de	15.70 e	16.45 bcd	16.06 b
2500	16.33 cde	16.92 bc	17.14 ab	16.80 a
5000	16.78 bc	17.70 a	16.25 cde	16.91 a

Proline mg.L^{-1}	Irrigation Intervals (days)				Average Proline
	4	8	12	16	
0	17.04 ab	16.70 bc	15.18 e	16.59 bc	16.38 a
100	17.67 a	16.70 bc	16.67 bc	16.04 dc	16.77 a
200	17.63 a	16.41 bc	16.81 bc	15.59 de	16.61 a
Effect of Interaction Between Irrigation Intervals, Potassium Sulfate and Proline					
Irrigation Intervals (days)	Potassium Sulfate mg.L^{-1}	Proline mg.L^{-1}			
		0	100	200	
4	0	17.22 a-g	17.00 a-g	17.33 a-g	
	2500	16.56 d-i	17.78 a-d	18.33 ab	
	5000	17.33 a-g	18.22 bac	17.22 a-g	
8	0	15.33 h-k	15.33h-k	16.34 d-j	
	2500	17.33 a-g	16.22 d-k	15.78 g-k	
	5000	17.45 a-f	18.56 a	17.11 a-g	
12	0	14,89 jk	15.22 ijk	16.22 d-h	
	2500	15.33 h-k	17.67 a-e	18.22 abc	
	5000	15.33 h-k	17.11 a-g	16.00 f-k	
16	0	16.67 c-i	15.22 ijk	15.89 f-i	
	2500	16.11 e-k	16.00 f-k	16.22 d-k	
	5000	17.00 a-g	16.89 b-h	14.67 k	

Means within the table followed by the same letter(s) are not significantly different at P ≤ 0.05 according to Duncan's Multiple Range Test (DMRT).

Number of Grains per Row: As indicated in Table (3), extended irrigation intervals had the most pronounced effect on the number of grains per row, which decreased from 47.27 grains (at a 4-day interval) to 39.48 grains (at a 16-day interval). Potassium application led to a significant increase, with the 2500 mg·L^{-1} concentration being optimal. Proline showed no significant individual effect. All two-way interactions were significant; the combination of a 4-day interval and 2500 mg·L^{-1} potassium (49.62 grains), a 4-day interval and 100 mg·L^{-1} proline (49.78 grains), and 2500 mg·L^{-1} potassium and 100 mg·L^{-1} proline (46.36 grains) were superior. The three-way interaction demonstrated a clear superiority for the treatment of a 4-day interval with 2500 mg·L^{-1} potassium and 100 mg·L^{-1} proline, which recorded the highest number of 56.89 grains per row.

Table (3) : Effect of irrigation intervals, foliar sprays of potassium sulfate and proline, and their interaction on Number of Grains per Row .

Irrigation Intervals (days)	Potassium Sulfate mg.L^{-1}				Average Irrigation Intervals
	0	2500	5000		
4	45.07 cd	49.62 a	47.11 b		47.27 a
8	44.70 d	46.45 cb	42.45 ef		44.53 b
12	41.00 f	41.15 f	40.92 f		41.02 c
16	39.07 g	36.41 h	42.96 e		39.48 d
Potassium sulfate ml.L^{-1}	Proline mg.L^{-1}				Average Potassium Sulfate
	0	100	200		
0	44.44 b	42.06 de	40.89 e		42.46 b
2500	42.97 cd	46.36 a	40.89 e		43.41 a
5000	44.06 cb	43.03 cd	43.00 cd		43.36 a
Proline mg.L^{-1}	Irrigation Intervals (days)				Average Proline
	4	8	12	16	
0	47.70 b	47.56 b	40.52 ef	39.52 fg	43.82 a
100	49.78 a	43.22 dc	41.74 be	40.52 ef	43.82 a
200	44.43 c	42.82 dc	40.82 ef	38.41 g	41.59 b
Effect of Interaction Between Irrigation Intervals, Potassium Sulfate and Proline					
Irrigation Intervals (days)	Potassium Sulfate mg.L^{-1}	Proline mg.L^{-1}			
		0	100	200	

4	0	50.89 b	43.33 f-j	41.00 j-p
	2500	45.11 d-j	56.89 a	46.89 cde
	5000	47.11 cde	49.11 cb	45.11 d-g
8	0	48.33 cb	45.00 d-j	40.78 i-p
	2500	48.00 bcd	48.22 cb	43.11 g-k
	5000	46.33 c-f	36,45 sr	44.56 e-h
12	0	40.22 j-p	39.78 m-p	43.00 g-l
	2500	42.11 g-n	41.78 h-o	39.56 m-q
	5000	39.22 n-r	43.67 f-j	39.89 l-p
16	0	38.33 pqr	40.11 k-o	38,87 o-r
	2500	36.67 qrs	38.56 pqr	34.00 s
	5000	43.56 f-j	42.89 g-l	42.44 g-m

Means within the table followed by the same letter(s) are not significantly different at P ≤ 0.05 according to Duncan's Multiple Range Test (DMRT).

Nitrogen Content in Grains (%): The results in Tables (4) indicated that the nitrogen percentage in grains decreased significantly with longer irrigation intervals. Foliar application of potassium and proline significantly increased this percentage, with the 5000 mg·L⁻¹ potassium and 200 mg·L⁻¹ proline concentrations being superior. The two-way interaction between irrigation and potassium was significant, with the 4-day interval and 5000 mg·L⁻¹ potassium treatment yielding the highest nitrogen percentage (1.67%). Similarly, the interactions between irrigation and proline, and between potassium and proline, were significant. The three-way interaction was highly significant; the treatment combining a 4-day interval with 5000 mg·L⁻¹ potassium and 200 mg·L⁻¹ proline recorded the highest nitrogen percentage of 2.19%, while the 16-day interval with no spray recorded the lowest.

Table (4) : Effect of irrigation intervals, foliar sprays of potassium sulfate and proline, and their interaction on Nitrogen Content in Grains (%).

Irrigation Intervals (days)	Potassium Sulfate mg.L^{-1}			Average Irrigation Intervals
	0	2500	5000	
4	1.06 j	1.19 d	1.67 a	1.31 a
8	0.95 i	1.09 f	1.51 b	1.19 b
12	0.85 j	1.03 h	1.36 c	1.08 c
16	0.75 k	0.94 i	1.16 e	0.94 d
Potassium sulfate ml.L^{-1}	Proline mg.L^{-1}			Average Potassium Sulfate
	0	100	200	
0	0.82 h	0.92 g	0.97 f	0.90 c
2500	1.00 e	1.10 d	1.09 d	1.06 b
5000	1.15 c	1.33 b	1.79 a	1.43 a

Proline mg.L^{-1}	Irrigation Intervals (days)				Average Proline
	4	8	12	16	
0	1.14 e	1.04 g	0.94 i	0.84 j	0.99 c
100	1.26 s	1.15 e	1.08 f	0.98 h	1.12 b
200	1.51 a	1.37 b	1.23 d	1.03 g	1.29 a

Effect of Interaction Between Irrigation Intervals, Potassium Sulfate and Proline

Irrigation Intervals (days)	Potassium Sulfate mg.L^{-1}	Proline mg.L^{-1}		
		0	100	200
4	0	0.97 pq	1.08 kl	1.12 ij
	2500	1.15 hi	1.18 h	1.22 g
	5000	1.29 f	1.52 d	2.19 a
8	0	0.87 s	0.95 qr	1.03 mn
	2500	1.04 lm	1.12 ijk	1.11 jk

	5000	1.19 gh	1.38 e	1.79 b
12	0	0.76 u	0.87 s	0.92 r
	2500	0.95 qr	1.08 jk	1.04 m
	5000	1.10 jk	1.27 f	1.71 c
16	0	0.65 v	0.77 u	0.18 t
	2500	0.85 st	1.00 nop	0.98 opq
	5000	1.01 mno	1.15 hi	1.29 f

Means within the table followed by the same letter(s) are not significantly different at P ≤ 0.05 according to Duncan's Multiple Range Test (DMRT).

Phosphorus Content in Grains (%): The results in Tables (5) showed a similar pattern to that observed for nitrogen content. The phosphorus percentage in grains decreased significantly with longer irrigation intervals. Application of 5000 mg·L^{-1} potassium and 200 mg·L^{-1} proline achieved the highest phosphorus percentages. All two-way interactions were significant, with superiority for the combination of a 4-day interval and 5000 mg·L^{-1} potassium (0.92%), a 4-day interval and 200 mg·L^{-1} proline (0.73%), and 5000 mg·L^{-1} potassium and 200 mg·L^{-1} proline (0.92%). The three-way interaction showed that combining frequent irrigation (every 4 days) with the highest concentrations of potassium and proline resulted in the highest phosphorus content in grains, reaching 0.98%.

Table (5): Effect of irrigation intervals, foliar sprays of potassium sulfate and proline, and their interaction on Phosphorus Content in Grains (%).

Irrigation Intervals (days)	Potassium Sulfate mg.L^{-1}			Average Irrigation Intervals
	0	2500	5000	
4	0.39 h	0.63 e	0.92 a	0.65 a
8	0.38 h	0.61 e	0.88 b	0.62 b
12	0.35 i	0.57 f	0.82 c	0.58 c
16	0.28 j	0.51.j	0.79 d	0.53 d
Potassium sulfate ml.L^{-1}	Proline mg.L^{-1}			Average Potassium Sulfate
	0	100	200	
0	0.21 h	0.39 g	0.45 f	0.35 c
2500	0.48 f	0.58 e	0.68 d	0.58 b
5000	0.77 c	0.86 b	0.92 a	0.85 a

Proline mg.L^{-1}	Irrigation Intervals (days)				Average Proline
	4	8	12	16	
0	0.54 e	0.52 e	0.48 f	0.40 g	0.49 c
100	0.67 b	0.64 cb	0.60 d	0.55 e	0.61 b
200	0.73 a	0.71 a	0.66 b	0.62 cd	0.68 a

Effect of Interaction Between Irrigation Intervals, Potassium Sulfate and Proline

Irrigation Intervals (days)	Potassium Sulfate mg.L^{-1}	Proline mg.L^{-1}		
		0	100	200
4	0	0.25 q	0.44 lmn	0.48 kl
	2500	0.53 jk	0.62 hi	0.73 ef
	5000	0.84 cd	0.93 ab	0.98 a
8	0	0.25 q	0.42 mno	0.47 klm
	2500	0.52 jk	0.61 hi	0.69 fg
	5000	0.79 de	0.88 bc	0.96 a
12	0	0.22 q	0.37 op	0.44 lmn
	2500	0.47 klm	0.57 ij	0.65 hi
	5000	0.74 ef	0.84 cd	0.88 bc
16	0	0.10 r	0.33 p	0.40 no
	2500	0.37 op	0.52 jk	0.62 hi

	5000	0.71 f	0.80 d	0.84 cd

Means within the table followed by the same letter(s) are not significantly different at P ≤ 0.05 according to Duncan's Multiple Range Test (DMRT).

4. DISCUSSION

The results of the current study confirm that water stress, induced by extended irrigation intervals, imposes severe limitations on the development of yield components in maize. This aligns with findings from other studies demonstrating that reduced irrigation frequency negatively impacts maize growth and productivity (Ali & Abdelaal, 2022). The significant reduction in ear length, number of rows, and grains per row reflects the adverse impact of water deficit during the critical periods of pollination, fertilization, and early kernel development. Drought impairs physiological processes, particularly photosynthesis, which reduces the flow of assimilates to the developing ear, leading to an increased rate of kernel abortion and a smaller final ear size (Ibrahim & Kandil, 2007; Huang et al., 2022).

The positive role of foliar-applied potassium in mitigating these effects was prominent, a finding supported by research showing that potassium application enhances maize growth and yield traits (Al-Jobouri & Al-Jobouri, 2020). The notable increase in all studied yield components underscores potassium's role in improving the plant's water status through stomatal regulation and facilitating the translocation of sugars from the leaves (source) to the grains (sink) (Al-Seidy et al., 2024). The significant interaction between irrigation and potassium suggests that potassium is most effective when the plant has sufficient moisture to utilize this element efficiently.

The significant reduction in nitrogen and phosphorus levels in grains subjected to water stress indicates a diminished capacity of the roots to uptake these nutrients from arid soil (Abaza et al., 2023). The foliar application of potassium markedly enhanced the mineral content of the grains. This effect can be elucidated through two complementary mechanisms: firstly, enhanced overall plant health attributed to potassium positively influences root efficiency; secondly, potassium may serve a synergistic function in promoting nutrient transport. Research indicates that balanced fertilization, incorporating NPK, enhances maize characteristics (Hussien & Ahmed, 2023).

Proline application enhanced the studied traits, primarily owing to its role as an osmoprotectant (Dar et al., 2016). The interaction between proline and potassium indicates an integrative mechanism, wherein proline offers physiological protection and potassium contributes nutritional and metabolic support (Ashraf & Foolad, 2007). The significant three-way interaction, corroborated by analogous multi-factor studies (Shaker, 2025), represents the primary finding. The findings indicate that optimal productivity is contingent upon a cohesive agronomic management system that concurrently addresses the plant's requirements for water, nutrients, and protection.

5. CONCLUSION

This study concludes that extending irrigation intervals negatively affects the yield components and the nitrogen and phosphorus content of maize. Foliar application of potassium sulfate and proline can effectively mitigate these adverse effects, especially when applied together. The interaction between optimal irrigation management (4-day intervals) and foliar application of high concentrations of potassium and proline demonstrates a promising strategy for maximizing both the ear size and the nutritional quality of maize in regions facing water challenges.

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