JOURNAL OF THE
Selva Andina
Research Society
Official Journal of the Selva Andina Research Society

Research Note

ISSN 2072-9294 (print edition)
JSARS
ISSN 2072-9308 (online edition)

Cycocel and micronutrients on yield of (*Zea mays* L.)

Cycocel y micronutrientes sobre el rendimiento del (*Zea mays* L.)

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Keywords:

Approximate yield,
average yield,
biological yield,
biomass yield,
yield,
yield components.

***J. Selva Andina Res. Soc.* 2024; 15(1):14-28.**

Article ID: 173/JSARS/2023

Record from the article

Received September 2023.
Returned November 2023.
Accepted December 2023.
Available online, February 2024.

Edited by: Selva Andina Research Society

Palabras clave:

Rendimiento aproximado,
rendimiento medio,
rendimiento biológico,
rendimiento de biomasa,
rendimiento,
componentes del rendimiento.

Abstract

This investigation followed a split-plot factorial design involved three phases of water deficit stress (silking stage, blister stage and a control). Sub-treatments included micronutrients (0, 1000, and 1500 g ha^{-1}) and Cycocel (0, 442.5 and 885 mg L^{-1}). This study aimed to water deficit stress negatively impacted the yield and yield components of maize. Moreover, applying micronutrients and Cycocel (CCC) through foliar application at concentrations of 1500 g ha^{-1} and 885 mg L-^{1} also led to a notable enhancement in these characteristics. In the absence of stress and for untreated plants (control), the average seed yield was 8375.55 kg ha^{-1} during the mentioned two years, as a result of simultaneous foliar spraying with a concentration of 1500 g ha^{-1} of micronutrients and 885 mg L^{-1} of CCC, the two-year average grain yield had increased by 32 %. In the conditions of water limitation in the stage of silking, the two-year average yield of seeds had decreased by 82.5 % compared to the conditions without stress. The highest average seed yield (5340 kg ha^{-1}) was obtained during the mentioned two years under the conditions of foliar spraying of 1500 g ha^{-1} of micronutrients and 885 mg L^{-1} of CCC, which was an increase of 3.8 times compared to the two-year average control. According to the results of this study: the highest yield in stress conditions was obtained from micronutrient (1500 g ha^{-1}) foliar application and CCC (885mg L^{-1}).

Resumen

Esta investigación siguió un diseño factorial de parcelas divididas que involucra tres fases de riego deficitario (etapa de sedación, etapa de ampolla y un control). Los sub-tratamientos contienen micronutrientes (0, 1000 y 1500 g ha^{-1}) y Cycocel (0, 442.5 y 885 mg L^{-1}). Este estudio tuvo como objetivo que los riegos deficitarios impactaran negativamente el rendimiento y los componentes del rendimiento del maíz. Además, la aplicación de micronutrientes y Cycocel (CCC) mediante aplicación foliar en concentraciones de 1500 g ha^{-1} y 885 mg L^{-1} también condujo a una mejora notable en estas características. En ausencia de estrés y para plantas no tratadas (testigo), el rendimiento promedio de semilla fue de 8375.55 kg ha^{-1} durante los dos años mencionados. Como resultado de la aspersión foliar simultánea con una concentración de 1500 g ha^{-1} de micronutrientes y 885 mg L^{-1} de CCC, el rendimiento promedio de grano en dos años había aumentado en un 32 %. En las condiciones de limitación de agua en la etapa de formación de estrías, el rendimiento promedio de semillas de dos años había disminuido en un 82.5 % en comparación con las condiciones sin estrés. El mayor rendimiento promedio de semilla (5340 kg ha^{-1}) se obtuvo durante los dos años mencionados bajo las condiciones de aspersión foliar de 1500 g ha^{-1} de micronutrientes y 885 mg L^{-1} de CCC, lo que supuso un aumento de 3.8 veces en comparación con el control promedio de dos años. Según los resultados de este estudio, el mayor rendimiento en condiciones de estrés se obtuvo con la aplicación foliar de micronutrientes (1500 g ha^{-1}) y CCC (885 mg L^{-1}).

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops worldwide, serving as a major source of food, feed, and biofuel, with a total production of 1.16 billion tons from 201.98 million hectares cultivated[1]. Maize production is predominantly influenced by climatic conditions during the growing season, with water deficit having a significant impact on grain yield, comparable to the cumulative effects of all other environmental factors. In past climate, maize plants have suffered from water deficit stress during the individual or multiple growth stages, grain yield losses are most pronounced when deficit irrigations stress occurs during early reproductive stage[2]. That can lead to several reproductive development failures irreversibly even though the parent remains alive, especially ovary abortion in maize[3]. Yield losses from water deficit stress at early reproductive stage are foreseen to be as much as 30% based on modelling studies[4]. Yield losses from water deficit stress at early reproductive stage are foreseen to be as much as 30 % based on modelling studies[4]. Consequently, securing reproductive success in maize under water deficit stress is essential for increasing stability of food system. During the early reproductive stage, deficit irrigations stress reduces grain numbers in maize are often ascribed to a lack of egg fertilization, resulting in undeveloped ovules[4]. Due to pollen water potential always remains lower than parent or silk, female florets show more sensitive to water deficit stress than male florets, suggesting that the abortion is controlled by female inflorescence under water deficit stress. A study on the water deficit tolerance of 18 maize hybrids released during the 1953-2001 period[5] showed that genetic yield gains are associated with increased kernels per ear and reduced anthesis-silking interval (ASI) under water deficit stress at flowering stage. Later in early filling stage, water deficit stress also reduces kernel number due to less available carbon supply. There is abundant evidence that water deficit stress inhibits photosynthesis[6], impairs carbon metabolism[7] and ultimately triggers ovary abortion due to sugar starvation[6].With climate change, water deficit stress is projected to become more frequent, longer, and more severe, posing a huge challenge to sustainable maize production[8]. Water deficit stress occurring during the rapid vegetative growth period causes a little loss of final grain yield by 9-17 %, while more significant losses during the filling stage by 22-39 % are mostly through reducing kernel size, and severe losses during early reproductive stage by 36-99 % result from reductions in kernel numbers. Large agricultural losses can occur during the whole reproductive stage, but the irreversibility of the early events is particularly damaging. When water deficit stress occurs during the early reproductive stage, losses in kernel number are attributed to long ASI[9]. Assimilate partitioning and transportation under water deficit stress contribute significantly to reproductive growth and development of maize, particularly when an inadequate assimilate supply to ear causes severe grain yield losses[3]. Plant growth regulators (PGR), also known as plant hormones are synthetic substances that are similar to natural plant hormones. They are used to regulate the growth of plants and are important measures to ensure agricultural production. One such group of chemical is PGR which may act as plant growth promoters or plant growth retardants. Plant growth retardants, which are synthetic compounds applied to control plant size without obvious phytotoxicity[10]. Chlormequat Chloride (CCC) is 2-Chloroethyltrimethyl ammonium chloride inhibits the cyclization of geranylgeranyl pyrophosphate to copallyl pyrophosphate in the gibberellin biosynthesis pathway[10]. It is commercially available under the trade name CCC. Application of CCC either on foliage or to fruit cluster from one to three weeks before bloom increases fruit set. In addition to higher berry set, spraying shoots with CCC often resulted in darker green leaves, shortened internodes, retarded tendrils and increased number of inflorescences differentiated on lateral shoots. It can be used as the additives in fertilizers such as water flush fertilizer, foliar fertilizer, root fertilizer and so on, to raise the absorption to the nutrition and the plant growth[10].

The role of mineral nutrients in improving drought tolerance has been studied by many researchers. However, this is still insufficient and somewhat intangible. Macronutrients form the structural components of plants, and their deficiency causes symptoms in plants that are readily observed[10]. Conversely, the micronutrients affect the susceptibility of plants to diverse stress conditions by regulating the enzymatic activities, and modulating signal transductions and accumulation of compatible solutes[10]. There are many reports indicating the noxious impacts of nutrient deficiency on photosynthesis under water deficit stress. However, the studies related to the effect of water deficit on mineral nutrient uptake and their effect on plant physiology still have many dark areas[11].This study was designed and implemented with the aim of investigating the effect of CCC and micronutrient consumption under water deficit stress conditions on the yield, physiological traits and antioxidant levels of corn in Safi Abad Dezful Research Center.

Materials and methods

This research was conducted in the two agricultural years of 2016-2017 and 2017-2018 at the Safiabad Dezful Research Center located in Khuzestan province with a latitude of 32° 38' 11" North and a longitude of 48° 40' 58" East and 82 m above sea level.

Physical and chemical properties of the soil of the experimental plot. To determine the physical and chemical properties of the soil before the implementation of the project, samples were taken from the depth of 0-30 and 30-60 cm from different parts of the field where the experiment was carried out, which were analyzed after being transferred to the Safiabad. The results are listed in (Table 1).

Experimental design and factors. The experiment was conducted as a factorial split plot based on a randomized complete block design with four replications. The main factor of the experiment included water deficit stress in three levels (S_0) as a control without water deficit stress, (S_1) water deficit stress in the silking stage and (S_2) water deficit stress in the Blister formation stage. The secondary factor of the experiment is also the interaction effect of CCC in three levels (C_0): controlled foliar spraying with distilled water, (C_1) foliar spraying with 442.5 mg L^{-1} of CCC and (C_2) foliar spraying with 885 mg L^{-1} of CCC and micronutrient fertilizer in three level (m0) control or distilled water, (mL) foliar spraying with 1000 g ha^{-1} and (m^2) foliar spraying with 1500 g ha^{-1}, which were factorially placed in sub-plots. Foliar spraying was done at the ten-leaf stage (V_{10}) and 35 days after planting, and a factor was considered as a witness of no foliar spraying.

Measurement of traits

Yield components. 10 cobs were randomly separated from the cobs of each plot. First, the number of rows of 10 ears were counted separately and averaged. Up to the number of rows in the ear was calculated. Then, the seeds were averaged separately from the cobs. The average number of seeds per ear was calculated[12].

Table 1 Physical and Chemical Properties of Soil in the Agricultural Years of 2017 and 2018

Agricultural year	Soil depth (cm)	Soil texture	pH	Electrical conductivity ds m^{-2}	Organic materials (%)	Total nitrogen (%)	P (mg kg^{-1})	K (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Fe (mg kg^{-1})
First year	0-30	Sandy-Loam	7.62	.95	.76	.05	10.1	169	5.28	1.81	6.42
	30-60	Sandy-Loam	6.68	.52	.77	.04	0	120	6.88	2.12	4.3
Second year	0-30	Sandy-Loam	7.65	1.60	.83	.06	10.19	151	1.48	1.67	9.58
	30-60	Sandy-Loam	7.54	.52	.77	.05	3	100	8.88	2.12	6.6

The average number of seeds per row was calculated by dividing the number of seeds in the cob by the number of rows in the cob. From the produced seeds, 500 seeds were separated and weighed. So, the second sample was counted and if the difference in the weight of the two samples was less than five percent, the total weight of the seeds was considered as one thousand seeds[12].

Biological yield. After removing one meter from the beginning and end of each plot as a border effect, sampling was done from a surface equal to two square meters from the second, third and fourth lines. A portion of about 500 g was separated and placed in a ventilated oven at a temperature of 75° C for 48 h and after drying, their weight was calculated[12].

The harvest index. The calculated by dividing the seed yield by the biological yield, as a percentage, through equation, HI (%) = GY/BY×100 (2) In this regard, HI: Harvest index, GY: Grain yield and BY: Biological yield. The dry weight of the samples was determined after drying in a ventilated oven at a constant temperature of 75° C until reaching a constant weight (72 h), using a digital scale (accuracy to the hundredth of a g)[12].

Statistical analysis. To ensure the consistency of experimental error variances, the results of the two-year experiment underwent Bartlett's test using SAS software version 9.4 before conducting the combined analysis. Consequently, a combined analysis of variance was carried out for the two-year experiment. Furthermore, the means were compared using the Least Significant Difference (LSD) test at a significance level of 5 %. For this research, the year, replication, and each factor involved in the two-way interaction were assigned randomly, and the significance of F was determined by calculating their respective means.

Results

Production rate. The results of the Bartlett's test for the number of seeds in the ear, weight of 1000 seeds, seed yield, biological yield and harvest index etc. were significant and the analysis of variance was done in composite form (Table 2).

Table 2 Corn yield and components analyzed under micronutrient foliar application and cycocel during water deficit stress

Source of variation (sov)	Degrees of freedom (df)	MS				
		Thousand seed weight	Number of seeds	Seed yield	Biological yield	Harvest index
Bartlett´s test	1	.37^{ns}	.029^{ns}	.075^{ns}	.420^{ns}	.26^{ns}
Year	1	205.51^{ns}	432.03^{ns}	6490.0^{ns}	38002841.0^{ns}	26.80^{ns}
Block (year)	6	1157.57	1361.23	165695.0	8759729.0	25.96
Water deficit stress	2	802900.12**	673387.55**	820869279.0**	3337929686.0**	5350.51**
Year x water deficit stress	2	748.56^{ns}	364.61^{ns}	136266.0^{ns}	20188754.0^{ns}	16.56^{ns}
Main terrace errors	12	619.42	462.38	247599.0	9287360.0	20.97
Micronutrient	2	76798.90^{ns}	24734.34**	56384615.0**	42938999.0*	958.13**
Year x micronutrient	2	5342.38*	102.23^{ns}	25682.0^{ns}	1973741.0^{ns}	8.77^{ns}
Water deficit stress x micronutrient	4	3464.41^{ns}	213.78*	823691.0*	840124.0^{ns}	71.18**
CCC	2	175481.81*	46877.55**	65721490.0**	53231990.0*	1500.50**
Year x CCC	2	2187.21^{ns}	33.25^{ns}	202018.0^{ns}	2621102.0^{ns}	1.11^{ns}
Water scarcity stress x CCC	4	1539.89^{ns}	158.59^{ns}	7016815.0**	2946480.0^{ns}	316.11**
Micronutrient x CCC	4	25841.78**	1001.04^{ns}	4444060.0**	3991927.0^{ns}	122.07**
Year x water deficit stress x micronutrient	4	1558.30^{ns}	27.41^{ns}	75956.0^{ns}	1062577.0^{ns}	.95^{ns}
Year x water deficit stress x CCC	4	1370.67^{ns}	138.73^{ns}	106100.0^{ns}	951095.0^{ns}	2.65^{ns}
Year x micronutrient x CCC	4	608.03^{ns}	199.26^{ns}	188289.0^{ns}	2170042.0^{ns}	3.12^{ns}
Water deficit stress x micronutrient x CCC	8	2089.51*	216.56^{ns}	760245.0^{ns}	624670.0^{ns}	39.15*
Year x water deficit stress x micronutrient x CCC	8	599.60^{ns}	244.52^{ns}	257910.0**	3245864.0*	8.69*
Secondary terrace errors	144	1418.89	196.81	72895.0	1315894.0	3.64
Rate of change (%)	-	13.6	2.2	5.1	5.6	7.7

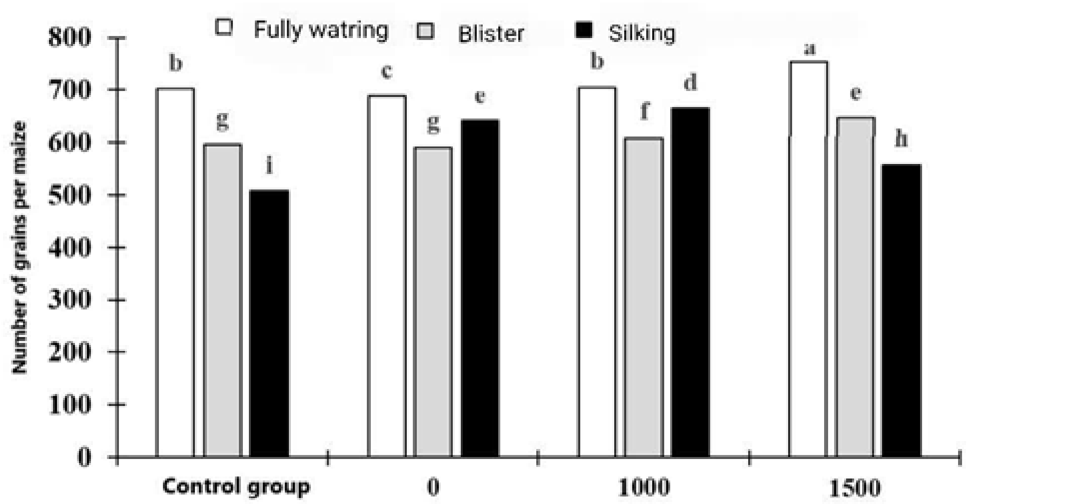
ns: not significant, *: Significant at the 5 % level, **: Significant at the 1 % level

Yield components. The results of composite analysis of grain yield components such as the number of seeds and the weight of 1000 seeds have also determined, the main effect of water deficit stress at the level of 1 % and CCC at the level of 1 and 5% was effective on both of these traits, but micronutrients only on the number seed had a significant effect at the level of 1 % (Table 2).

Table 3 Comparison of the average main effects of drought stress, micronutrient foliar application and cycocel on yield and yield components of corn

Factor	Level	Weight of 1000 seeds (g)	The number of seeds	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Water deficit stress (stop watering)	Silking	230.3	603.3	4298.5	17142.9	20.4
	Blister	274.4	651.9	4454.9	19832.3	25.3
	Full irrigation	327.1	697.3	7263.3	24437.7	28.9
$LSD_{0/05}$	-	38.3	33.12	779.6	4695.2	7.05
Micronutrient (g ha^{-1})	Control	-	601.9	3952.6	18560.8	19.0
	0	-	654.6	5489.6	19884.4	25.4
	1000	-	667.5	5605.4	20570.3	27.0
	1500	-	630.4	4921.7	20958.1	22.2
$LSD_{0/05}$	-		50.1	600.2	20187.4	5.8
Cycocel (mg L^{-1})	Control	220.6	601.9	3952.6	18560.8	19.0
	0	242.6	627.7	4331.7	19679.5	20.0
	442.5	255.3	648.9	5456.0	20383.4	25.8
	885	333.7	676.0	6229.0	21349.9	28.8
$LSD_{0/05}$	-	112.4	17.5	1367.4	2701.5	3.2

Figure 1 Examining the average impact of Water deficit on micronutrients in relation to the quantity of corn seeds per maize. Distinctive characters in each column signify a notable distinction based on the results of the LSD test, with a significance level of 5 %



The results also showed that the effect of the year in micronutrients alone on the weight of one thousand seeds, water deficit stress in micronutrients only on the number of seeds per plant and the mutual effect of micronutrients in CCC at the level of 1 % and the triple effect of water deficit stress in micronutrients in CCC at the level of 5 %, they were only effective on the weight of 1000 seeds (Table 2). Water deficit stress caused a decrease in the number of seeds and 1000 seed weight, and CCC improved the number and weight of seeds, but micronutrients only caused a significant increase in seed weight (Table 3).

The comparison of the average effect of water deficit stress on micronutrients regarding the number of seeds in the cob revealed that, under stress-free conditions, the application of 1500 g ha^{-1} of micronutrients caused a 7 % increase in the number of seeds in the cob, so that their number reached 753. In the irrigation stress during the blister stage, the effects of this level of micronutrient increased to 8 % compared to the control, and when the stress was applied during the silking stage, the effects increased by 10 % compared to the control. It was also observed that in the control plants (no foliar spraying), the effect of water deficit stress during the silking stage was about a 27 % decrease in the number of seeds, which reached 26 % in the foliar sprayed plants with 1500 g ha^{-1} of micronutrients (Figure1).

Table 4 A comparison of the mean combined impacts of water deficit on seed yield, biomass, and maize harvest index when foliar nutrient and CCC solution are applied

WSD	Foliar nutrient (g ha^{-1})	CCC (mg L^{-1})	Seed yield (kg ha^{-1})		Biomass yield (kg ha^{-1})		Harvest index (%)	
			2017	2018	2017	2018	2017	2018
	Control		1351.4	1438.0	12023.6	12315.2	8.9	7.2
		0	1365.0	1452.5	12145.1	12439.6	9.0	7.3
	0	442.5	2565.0	2545.0	13387.9	12745.3	14. 0	13.1
		885	3160.0	3190.0	14410.5	14130.6	16.1	15.3
Silking		0	1457.5	1575.0	13472.5	14172.6	8.2	8.1
	1000	442.5	3925.0	3915.0	13709.5	14765.2	20.4	19.9
		885	4065.0	4167.5	14564.5	14715.3	21.2	19.8
		0	2400.0	2475.0	13895.3	13808.7	13.2	12.7
	1500	442.5	4292.5	4335.0	15116.3	14492.3	22.1	20.8
		885	5300.0	5380.0	16371.4	16209.6	26.7	23.2
	Control		2069.1	2106.2	15159.8	19758.9	14.4	11.4
		0	2090.0	2127.5	15312.9	19568.2	17.3	17.1
	0	442.5	2630.0	2640.0	18375.4	19958.5	19.7	20.9
		885	2990.0	3285.0	19769.6	20936.7	20.7	23.3
		0	2947.5	2650.0	17758.3	19451.5	17.1	16.9
	1000	442.5	4100.0	4287.5	18675.4	19811.0	30.1	30.3
Blister		885	4602.5	4790.0	19955.2	21130.5	31.9	32.7
		0	3702.5	3605.0	18289.6	19721.6	19.6	18.9
	1500	442.5	5057.5	5077.5	19653.8	21132.5	33.6	35.0
		885	5915.0	6075.0	19889.4	23340.7	36.3	37.6
	Control		8393.0	8358.1	26111.6	25995.6	30.3	29.9
		0	8477.8	8442.5	26375.3	26258.2	31.9	30.8
	0	442.5	8934.0	8380.0	26471.9	27274.5	32.2	31.9
Full watering		885	8665.8	8528.8	27164.4	27352.2	33.9	32.2
		0	8524.8	8652.5	26304.5	27405.2	32.0	31.2
	1000	442.5	8581.5	8853.8	27704.3	28123.6	32.5	32.3
		885	9453.8	9215.0	28352.2	29465.5	34.2	32.8
		0	9903.0	9440.0	26983.3	27910.5	36.7	33.9
	1500	442.5	10303.5	9577.5	27486.4	28285.2	37.6	33.9
		885	10729.5	11500.0	28761.1	30469.5	37.4	37.8
LDS $_{0/05}$			377.3		1603.3		2.66	

Comparison of the average effect of water deficit stress on micronutrients in CCC also determined the weight of 1000 grains, in the condition without stress (full irrigation), the weight of 1000 corn grains was about 315 grams. Simultaneous foliar spraying of micronutrients and CCC has a double effect on this trait, so that as a result of foliar spraying of 1500 g ha^{-1} of micronutrients and 885 mg L^{-1} of CCC, the weight of one thousand seeds reached 531.7 grams with a growth of 68 % (Table 4). It was also found that the water deficit stress caused a decrease in the weight of a thousand grains in corn. For example, water deficit stress during the blister stage caused a 25 % decrease in the weight of 1000 seeds, which was estimated to be about 65 % due to water deficit stress during the silking stage. Foliar spraying with micronutrients and CCC at its highest level caused a 130 % and 64 % increase in the weight of 1000 seeds, respectively, when was water deficit stress during the blister stage and when was water deficit stress during the silking stage (Table 3).

Grain yield (kg ha^{-1}). The results of combined analysis of grain yield also determined that, this attribute in addition to the main effects, was affected by water deficit stress in micronutrients ($P \leq 0.05$), water deficit stress in CCC ($P \leq 0.01$), micronutrients in CCC ($P \leq 0.01$) and the triple effects of the year in micronutrients in CCC ($P \leq 0.05$) and the quadruple effect of the year in water deficit stress in micronutrients in the CCC ($P \leq 0.01$) were found (Table 2). Water deficit stress caused a decrease in grain yield, and micronutrient foliar application and CCC improved grain yield in corn (Table 4). The comparison of the average effect of year in water deficit stress in micronutrients in CCC regarding seed yield showed that in non-stress conditions and untreated plants (control) the seed yield was about 8393.0 and 8358.1 kg ha^{-1} in the first year and the second year, respectively. The second was that as a result of simultaneous foliar spraying with a concentration of 1500 g ha^{-1} of the micronutrient 885 mg L^{-1} of CCC, the grain yield increased by 27 and 37 % in 2016 and 2017 to 10729 and 11500 kg ha^{-1} (Table 4). Water deficit stress during the blister stage caused a 70 and 74 % decrease in grain yield in the first and second year, and also foliar spraying of 1500 g ha^{-1} of micronutrients and 885 mg L^{-1} of CCC increased the grain yield by 180 and 190 % compared to the control. Also, in the condition of water limitation in the silking stage of, the grain yield decreased by 83 and 82 %, respectively, and reached about 1351 and 1438 kg ha^{-1} in the first and second year. The highest grain yield (5300 and 5380 kg ha^{-1} in the first and second year respectively) was obtained from foliar spraying of 1500 g ha^{-1} of micronutrients and 885 mg L^{-1} of CCC, which is 3.9 and 3.7 times higher than the control (Table 4).

Biological yield (kg ha^{-1}). Water deficit stress at the level of 1 % and micronutrients and CCC at the level of 5 % had an effect on biological yield. Also, the quadruple effect of year on water deficit stress in micronutrients in CCC was also significant at the 5 % level on this trait (Table 2). The creation of stress caused a decrease in the biological yield and micronutrient foliar application and CCC improved the biological yield of corn (Table 3). The effect of the year in water deficit stress in micronutrients in CCC regarding biological yield was shown in Table 4, in non-stress conditions and untreated plants (control) the biological yield was about 26111 kg ha^{-1} in the first year and 25995 kg ha^{-1} in the year. The second was that as a result of simultaneous foliar spraying with a concentration of 1500 g ha^{-1} of micronutrient 885 mg L^{-1} of CCC, the biological yield reached 28761 and 30469 kg ha^{-1} with an increase of 10 and 17 % in the first year and the second year, respectively. Water deficit stress during the blister stage caused a 41 % and 24 % decrease in biological yield in the first and second year, and also foliar spraying of 1000 g ha^{-1} of micronutrients and 885 mg L^{-1} of CCC in the first year caused a 31 % increase in biological yield compared to the control. Meanwhile, in the second year, the highest biological yield was obtained from the concentration of 1500 g ha^{-1} of micronutrients and 885 mg L^{-1} of CCC, which resulted in an 18 % increase in biological yield compared to the control. Also, in the condition of water limitation in the stage of female flower formation, the biological yield decreased by 53 and 110 % compared to the non-stressed conditions and reached 12023 and 12315 kg ha^{-1} in the first and second year, respectively. The highest biological yield in these conditions was obtained in the first year (16371 kg ha^{-1}) from foliar application of 1500 g $ha^{-1}$of micronutrients and 885 mg L^{-1} of CCC and in the second year (16209 kg ha^{-1}), which shows an increase of 36 and 31 % compared to the control (Table 4).

The beginning of the appearance of the male inflorescence was the most sensitive stage of growth to the water deficit stress. Biological yield is the result of the yield of seeds and vegetative organs. At the beginning of the appearance of the male inflorescence, due to the severe decrease in seed yield due to water deficit stress, despite the relative stability of vegetative organs, the biological yield has decreased. Biological yield is affected by climate, soil and plant conditions, and water deficit stress has directly and indirectly reduced the production of dry matter through the reduction of leaf area, the reduction of amass and the closing of stomata.

Foliar spraying of micronutrients and CCC in concentrations of 1500 g ha^{-1} and 885 mg L^{-1}, respectively reduced the negative effects of deficit irrigations stress and improved biological yield (Table 4).

Harvest index (%). The harvest index is also affected by water deficit stress ($P \leq 0.01$), micronutrients ($P \leq 0.01$), water deficit stress in micronutrients ($P \leq 0.01$), CCC ($P \leq 0.01$), water deficit stress in CCC ($P \leq 0.01$), micronutrients in CCC ($P \leq 0.01$), water deficit stress in micronutrients in CCC ($P \leq 0.05$) and year in water deficit stress in micronutrients in CCC ($P \leq 0.05$) were placed (Table 2). According to the results of this study, by restricting irrigation, the harvest index decreased, and micronutrient foliar spraying and CCC improved it in corn (Table 3). Comparison of the average effect of the year in water deficit stress on micronutrients in CCC also determined about this trait, in the condition of no stress and untreated plants (control), the harvest index was around 30.3% in the first year and 29.9 % in the second year, as a result of simultaneous foliar spraying with a concentration of 1500 g ha^{-1} of micronutrient 885 mg L^{-1} of CCC, the harvest index increased by 23 and 26 % in the first year and the second year to 37.4 and 37.8 % , respectively (Table 4). Water deficit stress during the blister stage caused a 52 % and 61 % decrease in the harvest index in the first and second year, respectively, and also foliar spraying of 1500 g ha^{-1} of micronutrients and 885 mg L^{-1} of CCC increased the harvest index by 2.5 and 3.3 times, respectively became a control. Also specified that, in the conditions of water limitation in the silking stage, the harvest index decreased by 3.5 and 2.4 times compared to the conditions without stress and reached about 8.9 and 7.2 % in the first and second year, respectively. The highest harvest index under these conditions was obtained in the first year (26.7 %) and the second year (23.2 %) from foliar application of 1500 g ha^{-1} of micronutrients and 885 mg L^{-1} of CCC, which is an increase of 3 and 3.2 compared to the control, they showed equality (Table 4).

Discussion

Securing maize grain yield is crucial to meet food and energy needs for the future growing population, especially under frequent water deficit events and elevated CO_2 due to climate change. To maximize the kernel setting rate under drought stress is a key strategy in battling against the negative impacts. Firstly, the major limitations to leaf source and kernel sink in maize under water deficit stress, and identified that loss in grain yield is mainly attributed to reduced kernel set. Reproductive water deficit tolerance can be realized by collective contribution with a greater assimilate import into ear, more available sugars for ovary and silk use, and higher capacity to remobilize assimilate reserve. As such, utilization of micronutrients and CCC by improved photosynthesis and greater reserve remobilization is a key strategy for coping with water deficit stress under climate change condition. Consequently, stabilizing maize production under water deficit stress can be achieved by securing reproductive success by the research is ready. According to the report by Farooq et al.[13], the attributed effect of moisture stress on the reduction of seed number to the increase in the proportion of sterile organs before seed filling, the death of inflorescences, and disturbance in pollination and seed filling due to water deficit. Our study showed that, In the stress stage of female flower formation, the number of seeds in the cob using foliar spraying of 1000 g of micronutrients per hectare of 603.3 to 667.5, and also the yield in this stage of stress increases from 4298.5 to 5605.4. Using the foliar spraying of 885 mg L^{-1} CCC, the number of seeds per cob increases to 676 and the seed yield per hectare increases to 6229.0. Herero & Johnson[14], Other times pollination and emergence of cockles caused by the lack of moisture in the plant were considered as an effective problem in the number of seeds in the cob.

These differences in the number of seeds in the cob and the yield, the treatments of this study have a positive effect (Table 3). Ahmadi et al.[12], reported the spraying micronutrients and CCC by affecting the photosynthetic capacity of the plant due to the ability to produce carbon dioxide has caused the production of dry matter in the plant to improve, followed by yield components such as the weight of a thousand seeds. In this study, the weight of a thousand seeds during water deficit stress, at the stage of female flower formation, it reaches 230.3 grams, which reaches 333.7 grams by using 885 mg L^{-1} of CCC treatment. This difference shows exactly the effect of using CCC treatment (Table 3). Fisher et al.[15], reported the by in their experiments, they came to the conclusion that the most important reason for yield reduction under water deficit stress is the decrease in the weight of 1000 seeds. According to the report by Tomov et al.[16], They stated that the application of stress during the filling stage of the seeds significantly reduces the capacity of transferring photosynthetic materials to them and causes the seeds to shrink and the weight of one thousand seeds to decrease. NeSmith & Ritchie[17], in their research, they came to the conclusion that the water deficit stress reduces the intensive period of the seed and causes the production of smaller seeds. In this way, it can be seen that if the water deficit continues or its intensity increases, the weight of the seeds will also decrease. NeSmith & Ritchie[17], they stated that the lack of water in the early stage of flowering significantly reduces seed formation and fertility. It seems that water deficit stress, especially in the seed stage, causes the seeds to shrivel and thus lead to a decrease in the weight of a thousand seeds. Fisher et al.[15], they stated that in the conditions of water deficit stress, due to the reduction of water available to the plant, the duration of seed growth is reduced and the seeds cannot be filled completely. Our results showed, the two-year average grain yield was 8375.55 kg ha^{-1} in two years in the full irrigation stage. When the amount of 1000 g ha^{-1} of micronutrients and 442.5 mg L^{-1} is sprayed. The two-year average yield increases to

8717.65 kg ha^{-1}. Likewise, with 885 mg L^{-1}, the two-year average yield is 9334.4. These differences in yield increase the effect of micronutrients and CCC treatments in increasing yield from 8375.55 kg to 9334.42. Now, in the very important stage of the stress of female flower formation, the average the two-year yield reaches 1394.7 kg ha^{-1}. Using 1000 g of micronutrients and 442.5 mg L^{-1} of CCC, the average yield increases to 3920 kg and 885 mg L^{-1} to 4116.25 kg ha^{-1}. The average two-year yield reaches 2087.65 during the swelling phase. Using 1000 g ha^{-1} of 442.5 mg L^{-1} of CCC, the two-year average yield increases to 4193.75 and using 1500 g ha^{-1} and 885 mg of CCC 5995 kg ha^{-1} (Table 4). Szécsényi et al.[18], reported the Under the conditions of water deficit stress, the abscisic acid hormone derived from the root of flow increases transpiration and regulates the opening and closing of the stomata in the leaf, and then the production of active oxygen causes damage to the cell membrane, which ultimately causes a decrease ATP in production and performance. Schussler & Westgate[19], they have reported a decrease in grain yield due to increased soil moisture stress. Lazar e al.[20], Water deficit stress, while reducing the leaf area, also accelerates their aging, and by this means, it can reduce the amount of production much more than what is reduced due to the effects of reducing the intensity of net photosynthesis.

NeSmith & Ritchie[17], in their research, they observed that when photosynthesis decreases in each plant due to water deficit stress or other non-living stresses, the growth of the crown is delayed and increases the time interval between pollination and the appearance of the crown, which ultimately leads to seed abortion. According to the report by Nabavi Moghadam et al.[21], reported that the consumption of micronutrients had a significant effect on the dry biological yield of single cross 704 fodder corn. They stated that the reason for the increase in biological yield is due to the increase in photosynthesis, which, as a result, caused the amount of soluble carbohydrates to increase to a large extent, and the increase in soluble carbohydrates caused an increase in yield, considering that micronutrient element foliar spraying was done. It was able to improve the growth indices, including the leaf area index, the dry matter production per unit area and the growth rate of the product. Our results indicate that, the effect of water deficit stress in the stage of female flower formation on the biological yield is 17142.9. When the nutrient treatment is 1500 g ha^{-1}, the biological yield increases to 20958.1 and from 885 mg L^{-1} cycle cell to 21349.9 kg ha^{-1}. 9.21349 kg ha^{-1} increases (Table 4). Attributed the positive effects of CCC to the increase in the duration of greenness of leaves and cob pods, which results in the production of more dry matter. In this regard, Shekoofa & Emam[22], also reported that the use of CCC on wheat shoots caused a decrease in the rate of growth of treated plants. In the flowering stage, this trend was reversed, so that the dry weight of the plants at the time of final harvest was more than the control and the seed yield also increased. Other researchers have also attributed the positive effect of growth regulators on biological performance to the development of roots and the continuation of the photosynthesis process under water deficit stress conditions and the production of more dry matter[23]. Seyed Sharifi et al.[24], also attributed the increase in wheat biomass due to the effect of CCC due to the effect of this substance in delaying the aging of leaves and thus preserving the green pigments caused by the decomposition of chlorophyll. The use of CCC in cereals has led to an increase in the length and weight of the root or a greater ratio of root to stem and was considered as a strategy to prevent the destructive effect of environmental stresses such as drought and salinity[25]. According to the report by Setter et al.[26], reported that the harvest index of corn under the influence of yield stress is almost constant, because as yield stress reduces the grain yield, it also reduces the total dry weight, unless severe stress causes a large reduction in grain. And as a result, the harvesting index will decrease. Our study showed that, the effect of yield stress in the stage of female flower formation on the harvest index trait reaches 20.4 %, and using foliar spraying of 1000 g of micronutrients, the harvest index trait reaches 27 %. And using 885 mg L^{-1} CCC, the harvest index increases to 28.8 %. These differences The amount of corn harvest index shows the positive effect of micronutrient and CCC treatments, which shows the negative effects of water deficit stress in one of the most sensitive reproductive stages, namely the female flower formation stage, which can destroy up to 75 % of the crop (Table 3). That zinc foliar application at the time of tassel emergence and grain filling caused an increase in corn harvest index[27]. In another study, Yosefi et al.[28], reported the improvement of corn harvest index due to the application of micronutrients (iron, zinc, manganese and copper). Malakoti[29], stated that the micronutrient elements increased the rate of photosynthesis and improved the durability of the leaf surface, increasing the grain yield and biological yield, which also increases the harvest index. Also, by increasing the period of leaf greenness and the period of seed filling, CCC has been able to play an effective role in the process of seed filling through current photosynthesis and retransmission, and in this way, increase the share of cultured material in favor of the seed, which increases the index. It also brings the harvest[24]. Also, the positive effect of CCC on the development of roots and the continuation of the photosynthesis process in the conditions of[27] stress and the production of more dry matter has been reported, which has been able to increase the harvest index as well[23].

The results of the research showed that different levels of water deficit stress caused a decrease in all the measured traits. The results of this research show that the decrease in grain yield due to the effect of water deficit stress is due to the decrease in the weight of the biomass accumulation of the organs and the decrease in the allocated biomass. It was to the grain. Foliar spraying with micronutrients and CCC at its highest level caused 130 and 64 % increase in the weight of 1000 seeds, respectively, when was water deficit at the swelling stage and irrigation was stopped at the female flower formation stage. In the irrigation stress during the swelling stage, the effects of this level of micronutrients increased to 8 % compared to the control (stress without foliar spraying), and when stress was applied during the female flower formation stage, the effects increased by 10 % compared to the control (stress without foliar spraying). In the present study, it was observed that foliar spraying of micronutrients at a concentration of 1500 g ha^{-1} along with 885 mg L^{-1} of CCC reduced the negative effects of stress and improved grain yield. Foliar spraying of micronutrients and CCC in concentrations of 1500 g ha^{-1} and 885 mg L^{-1}, respectively, reduced the negative effects of water deficit stress and improved biological yield. The highest harvest index under these conditions in the first year (26.7 %) and the second year (23.2 %) was obtained from foliar spraying of 1500 g ha^{-1} of micronutrients and 885 mg L^{-1} of CCC, which is an increase of 3 and 2.3 compared to the control. The most effective foliar spray treatment for corn under water-limited conditions was achieved by applying 1500 g kg^{-1} of micronutrients and 885 mg L^{-1} of CCC. Finally, the successful compatibility of corn with vital role in ensuring global food security in the face of the weather is changing fast.

Source of funding

In the framework of supporting academic research in relation to corn production against climate change, this agricultural research center has given comprehensive support to this scientific research.

Conflicts of interest

The authors declare that they have no conflicts of interest with respect to the research, authorship and/or publication of this article.

Acknowledgments

Our group of officials of different departments of Safi Abad Agricultural Research Station; We thank the departments of seed research, soil science, botany, laboratory, meteorology, pest control, hydrology, plant physiology, and statistics who supported us in conducting this research.

Ethical considerations

The present work was carried out in field and laboratory conditions, again research does not involve living organisms (humans and animals), so it is not subject to an ethical analysis.

Research limitations

The time established for the completion of the project is a limitation that was presented, however the common work by the members helped a lot to meet the goals and objectives.

Authors' contributions

Conceptualization, *Ali Reza Shokofar* and *Nouredin Ghaffari*. Methodology, *Ali Reza Shokofar* and *Mani Mojadam*. Formalanalysis, *Ali Reza Shokofar*. Investigation, *Nouredin Ghaffari* and *Aziz Aferinesh*. Resources, *Ali Reza Shokofar* and *Mani Mojadam*. Shahram Lakm Data curation. *Ali Reza Shokofar* and *Nouredin Ghaffari*, writing-original draft preparation, *Ali Reza Shokofar* and *Nouredin Ghaffari*, *Shahram Lak*, writing-review and editing, *Ali Reza Shokofar* and *Nouredin Ghaffari*, *Shahram* Lak, supervision, *Ali Reza Shokofar*, *Shahram Lak*. The approval of the final version to be published was approved by all the authors, which is ratified with the letter of originality.

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