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Effects of Uniconazole and Cycocel on Growth, Yield and Nutrients Uptake of Pearl Millet under Drought Stress Condition

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Abstract: A field experiment was carried out to investigate the effects of uniconazole and cycocle on growth, yield and concentration of macronutrients in forage of pearl millet under drought stress condition in 2007-2008 growing season in Experimental Farm of University of Zabol. The experiment was conducted in split plot base on randomized completely block design with three replications. Main plots included of: S_1 (full irrigation), S_2 (withholding irrigation during stem elongation stage) and S_3 (withholding irrigation during ear emergence stage). Sub plots comprised of four levels of plant growth regulators foliar application: R_1 (Control), R_2 (foliar application of 300 mg L^{-1} uniconazole), R_3 (foliar application of 100 mg L^{-1} cycocle) and R_4 (foliar application of 300 mg L^{-1} uniconazole + 100 mg L^{-1} cycocle). The Results indicated that the highest value of plant height, forage dry matter, grain yield, 1000-seeds weight and harvest index were obtained from S_1 treatment. Furthermore, the highest nitrogen and phosphorus content in forage was achieved from S_1 treatment. But irrigation treatment hadn't significant effect on potassium content. Among PGR treatments the highest plant height obtained from control and the lowest value achieved from uniconazole + cycocle foliar Application. 1000-seeds weight was highest in barley plants that sprayed with cycocle. In addition the highest values in the forage dry matter, grain yield and macronutrients content recorded from foliar application of uniconazole + cycocle. However, PGR foliar treatments hadn't significant influence on harvest index of pearl millet plants.

Key words: Drought stress · Uniconazole · Cycocle · Macronutrients · Pearl millet · Yield

INTRODUCTION

The limited available water resources represent the major limiting factor confronting agricultural production in arid and semi-arid regions. Furthermore, the climatic change models predict that in many regions, crop losses due to increasing aridity will further increase in future [1]. Drought stress is one of the most important environmental factors limiting the growth and productivity of crops [2].

Millet can be successfully grown in a wide range of environmental conditions, being better adopted than most crops to dry regions. Millet plants have a potential value particularly in semi-arid regions because of their short growing season. They can tolerate drought stress or avoid this condition by growing to maturity very quickly [3].

Yadav *et al.* [4] reported that drought stress after flowering of pear millet decreased number of ear per m^2, grain per ear and grain weight and thus reduced grain yield. Bidinger *et al.* [5] examined midseason (panicle initiating to flowering) and terminal (flowering to maturity) drought stresses on pearl millet and found that yield and its components more reduced by the terminal stress than midseason stress.

Several researches have shown the stimulatory effects of plant growth regulators on the vegetative growth and yield of crops. Plant growth regulators are known to influence growth and development at very low concentrations but inhibit plant growth and development at high concentrations [6]. Uniconazole, as a potent and active member of the triazole family, inhibits gibberellin biosynthesis within the plant [7] and developed for use as plant growth retardant and is increasingly used to manipulate plant growth and yield [8]. Wang-Xi *et al.* [9] found that uniconazole increased grain yield, yield components and rate of photosynthesis of rice plants.

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Cycocel (CCC) is gibberellin biosynthesis inhibitor involved in the inhibition of cyclization of geranyl-geranyl pyrophosphate to copyallyl pyrophosphate. Growth regulators which inhibit the biosynthesis of gibberellins have been shown to enable the plants to tolerate against water stress [10]. Al-Tabbal *et al.* [11] found that grain yield of durum wheat cultivars grown under optimum moisture and drought stress conditions increased due to mepiquat chloride application. Fuller and Zajicek [12] noted that water use of plants, treated with uniconazole, was 35% reduced due to reduction in the leaf area and lower stomatal conductance. Li *et al.* [13] reported that corn seeds treated with uniconazole had increased antioxidant system responses in a drought tolerant cultivar and this did not affect the drought sensitive cultivar. Imam *et al.* [14] reported that number of tillers, leaves and yield of wheat plants increased as affected by uniconazole under water stress conditions. Lone (2001) found that exogenous foliar application of 400 ppm cycocel enhanced the uptake of nitrogen, phosphorus and potassium in mustard cultivars under drought stress. Turk and Tawaha [15] found that cycocel could increase the grain yield of both wheat and barley. Foliar application of CCC at the rate of 300 ppm at the flower initiation stage improved the number of pods per plant in soybean plants [16]. Cia *et al.* [17] showed an increase in seed weight of both cotton and sunflower due to CCC application.

The aim of this study was to investigate the effect of foliar application of uniconazole and cycocel and its cobination on growth, yield and nutrient uptake of pearl millet grown under drought conditions.

MATERIALS AND METHODS

This experiment was conducted out at the Experimental Farm, College of Agriculture, Zabol University,, Iran (61° 29× N, 31° 2× E; 483 m above sea level) in 2007-2008 growing season. Mean annual precipitation and temperature value are 85 mm and 16.5° C, respectively. Soil characteristics and chemical analysis of irrigation water are presented in Tables 1 and 2, respectively.

The experiment performed as split plot randomized complete block design with three replications. Main plots comprised of different levels of drought stress (S_1: full irrigation, S_2: withholding irrigation during stem elongation stage and S_3: withholding irrigation during ear emergence stage. Sub plots comprised of four levels of Plant Growth Regulators (PGR) (R_1: none foliar application, R_2: foliar application of uniconazole, R_3: foliar application of cycocle and R_4: foliar application of uniconazole + cycocel).

The experimental plots consisted of 10 rows, each of 4 meter length and 20 cm apart and 10 cm between plants. Sowing took place on 15th May, 2007. Millet plants were foliar sprayed with cycocel (100 mg L^{-1}) and uniconazole (3000 mg L^{-1}) during two stages (beginning of stem elongation and 3 weeks after ear emergence). Combination of the concentrations of two PGRs was also applied. Millet plants irrigated every 10 days in control treatment (full irrigation).

In order to measurement the dry forage yield, the plants in an area of 1 m^2 at each experimental plot were harvested at soft-dough stage on 22th July, 2007. Then, plant samples were dried in an electric oven with drift fan at 70°C for 48 hr. Potassium content of the forage was estimated photometrically using a flame photometer according to Brown and Lilliand [18]. Total nitrogen was determined using the Kjeldahl method [19]. Phosphorus was measured in the dry ash digestion by atomic absorption spectrophotometer [20].

At harvest time on 6th August, 2007, the mean values of yield, plant height, 1000-seeds weight and harvest index (HI) were measured.

Data collected were subjected to analysis of variance using MSTATC software. The least significant difference (LSD) test was used for the mean comparisons.

RESULTS AND DISCUSSION

Plant Height: Data in Table 3 show that drought stress significantly decreased the plant height, compared with the control. The highest plant height (134.9 cm) was obtained from control and the lowest value (96.1 cm)

Table 1: Soil chemical properties of experimental area.

Mn (mg.L^{-1})	Zn (mg.L^{-1})	P (mg.L^{-1})	K (mg.L^{-1})	N (mg.L^{-1})	EC (dS m^{-1})	pH
0.32	1.615	1.56	317	0.027	1.8	7.2

Table 2: Chemical characteristics of irrigation water.

Mn (mg.L^{-1})	Zn (mg.L^{-1})	P (mg.L^{-1})	K (mg.L^{-1})	N (mg.L^{-1})	EC (ds m^{-1})	pH -
0.03	0.015	-	6.17	-	2.2	7.8

Table 3: Effects of drought stress and PGR application on quantitative traits of pearl millet.

Treatment	Plant height (cm)	Forage dry matter (kg ha^{-1})	Grain yield (kg ha^{-1})	1000-seeds weight (g)	Harvest index (%)
Drought stress					
Control (Full irrigation)	134.9a	9189.7a	1009.7a	1.59a	11.27a
Drought stress in					
stem elongation stage	96.1c	8126.2b	799.4b	1.41b	10.12c
Drought stress in					
ear emergence stage	112.5b	6732.4c	700.6c	1.34c	10.52b
Foliar spraying					
Control (None)	127.4a	6974.3c	712.2c	1.39c	10.32a
CCC (100 mg L^{-1})	93.7b	7731.6b	877.1b	1.50b	10.27a
Uniconazole (300 mg L^{-1})	99.9b	7922.9b	927.4ab	1.63a	10.28a
Uniconazole+cycocle	90.1b	8869.5a	971.1a	1.61a	10.30a

Means within each column with the same letters are not significantly different using LSD (0.05).

was obtained from drought stress during stem elongation stage. Gonda [21] compared response of twenty-four pearl millet genotypes to water stress and concluded that plant height reduced by 25.5% due to water stress. Maqsood and Ali [22] also reported a decrease in plant height of finger millet under drought stress than control. Plant growth regulators applied during growth stages significantly affected plant height. Among all treatments, control treatment had the highest (127.4 cm) and foliar spraying with 300 mg L^{-1} uniconazole + 100 mg L^{-1} cycocel had the lowest (90.1 cm) value (Table 3). Bora and Sarma [23] noted that the reduction in plant height caused by plant growth retardants might be due to shortening of internodes by decreasing cell division and cell numbers. Rajala and Peltonen-Sainio [24] also noted that due to applying cycocel during the beginning of stem elongation cereal straw could be shortened.

Forage Dry Matter: Forage dry matter was affected by drought stress, PGR application and interaction effect of these two factors. As shown in Table 3, the highest value (9189.7 kg ha^{-1}) was obtained from full irrigation and the lowest value (6732.4 kg ha^{-1}) was obtained from drought stress during ear emergence stage. Drought stress during this stage induced 36.5% decrease in dry forage yield than control. Winkel *et al.* [22] stated that total above-ground biomass of pearl millet reduced by 48% in drought stress in flowering stage than control. Also, Maqsood and Ali [22] noted that drought stress induced a decrease in dry matter production of finger millet. The reduction in forage dry matter due to drought stress apart from reducing cell division and enlargement [25] is consistent with closure of stomata for water saving and thus, low CO_2 fixation [22]. Our results indicated that application of PGRs induced an increase in forage dry matter. The highest value recorded from plants which sprayed with mixture of uniconazole and cycocel and the lowest means recorded from control treatment (Table 3). Lone [26] reported that exogenous application of CCC significantly increased dry matter of *Brassica juncea* cultivars. The interaction effect between drought stress and PGR application had a significant influence on forage dry matter. Data presented in Table 5 show that among all treatments, the highest level recorded from full irrigation and uniconazole + cycocel application (S_1R_4) and the lowest value obtained from drought stress in ear emergence stage and none PGR application (S_3R_1).

Grain Yield: From the results presented in Table 3, it could be concluded that grain yield of pearl millet plants decreased as influenced by drought stress. Drought stress in stem elongation and ear emergence stages decreased grain yield of pearl millet as compared with control treatment by 26.3% and 44.1%, respectively. This result confirms the findings of Seghatoleslami *et al.* [27]. Seetharama *et al.* [28] stated that flowering and early grain filling are very sensitive to water stress in pearl millet.

Our results also showed that millet plants which treated by plant growth regulators showed an increase in grain yield than control. Data in Table 3 reveal that application of mixture of uniconazole and cycocle increased grain yield of pearl millet higher than those obtained under uniconazole or cycocle singly. Regarding the interaction effect between drought treatment and foliar spraying with PGR on grain yield the data presented in Table 5 indicate that the interaction effect between full irrigation and cycocel application (S_1R_3) increased grain yield more than other treatments, although, the difference between it and full irrigation and uniconazole + cycocle application (S_1R_4) was not statically significant. Also, the lowest value recorded from drought stress in ear emergence stage and none foliar spraying treatment

Table 4: Mean comparisons of the main effects of drought stress and PGR application on macronutrients content in forage of pearl millet.

Treatment	Nitrogen (%)	Phosphorus (%)	Potassium (%)
Drought stress			
Control (Full irrigation)	2.93a	0.38a	2.48a
Drought stress in stem elongation stage	2.22c	0.22	2.44a
Drought stress in ear emergence stage	2.36b	0.32b	2.45a
Foliar spraying			
Control (None)	2.41c	0.21c	2.71c
CCC	2.80b	0.29b	2.94b
uniconazole	2.94ab	0.30b	3.01ab
uniconazole + cycocle	3.07a	0.33a	3.08a

Means within each column with the same letters are not significantly different using LSD (0.05).

Table 5: Mean comparisons of interaction effects on dry forage yield, grain yield and macronutrients content in forage of pearl millet.

Treatment	Dry forage yield (kg ha^{-1})	Grain yield (kg ha^{-1})	N (%)	P (%)
S_1R_1	8024.7c	891.3bc	2.67cd	0.27b
S_1R_2	8607.6b	966.1b	2.88b	0.35a
S_1R_3	8741.1b	1099.8a	2.95ab	0.36a
S_1R_4	9212.3a	1177.2a	3.04a	0.37
S_2R_1	7431.3e	767.1cd	2.32f	0.19c
S_2R_2	8026.8c	854.1c	2.49e	0.26bc
S_2R_3	8176.1c	896.2bc	2.67cd	0.28b
S_2R_4	8539.9b	943.9b	2.71c	0.31ab
S_3R_1	6891.7f	703.5d	2.36f	0.25bc
S_3R_2	7546.0e	771.6cd	2.61d	0.28b
S_3R_3	7695.1d	845.4c	2.68cd	0.28b
S_3R_4	7990.7c	873.2bc	2.73c	0.35a

(S_3R_1). Imam *et al.* [14] indicated that application of cycocel improved the drought tolerance of wheat plants. Also, Leul and Zhou [29] reported that foliar spraying of uniconazole increased tolerance to stress of rape seed plants than control treatment.

1000-Seeds Weight: Drought stress significantly decreased 1000-seeds weight compared with the control treatment. The most significant decrease in this parameter achieved in drought stress in ear emergence stage (Table 3). Kumari [30], Bidinger *et al.* [5] and Seghatoleslami *et al.* [27] also reported similar results. Bradford [31] demonstrated that reduction of seed weight under drought stress might be due to cytokinin reduction and, therefore, less endosperm cells is produced in seeds. The highest value of 1000-seeds weight was observed with full irrigation treatment. The data shown in Table 3 indicate that PGR application induced an increase in the 1000-seeds weight significantly over control. In the plots which cycocel spraying was applied, the1000-seeds weight was higher. However, the difference between cycocel and uniconazole + cycocel treatments was not statistically significant, while the lowest value was recorded with control treatment. Gurmani *et al.* [32] reported that rice plants that treated by cycocel showed an increase in 1000-seeds weight compared with control.

Harvest index: Among drought stress, PGR application and interaction effects treatments, only drought stress affected the harvest index of pearl millet. Control treatment had the highest while, drought stress during ear emergence stage treatment had the lowest value of harvest index (Table 3). Seghatoleslami *et al.* [27] reported similar findings and noted that at ear emergence stage, the drought stress increased the floret death and loss of weight of seeds which resulted in the reduction in the harvest index.

N, P and K Concentration in Forage: Data presented in Table 4 show a decrease in N and P percentage in forage of pearl millet as a result of drought stress in stem elongation stage as compared with full irrigation treatment. Baligar *et al.* [33] noted that drought stress generally results in reduced total nutrient uptake and frequently reduces the levels of mineral nutrients in crops. Ali *et al.* [34] reported that water stress decreased uptake of N, P and K in corn plants.

Results indicated that foliar spraying with PGRs increased N and P percentages of forage as compared with the control. Among all treatments, foliar spraying with mixture of uniconazole and cycocle induced the most influence in nitrogen and phosphorus percentage and increased them 27.4% and 57.1% than control, respectively (Table 4). Singh [35] stated that exogenous application of CCC increased nitrogen content of wheat. Furthermore, Han and yang [36] found that N content of in different organs of wheat plants was increased with uniconazole application.

Regarding the interaction effect of drought stress and PGR foliar spraying (Table 5), it is obviously clear that foliar spraying with mixture of uniconazole and cycocle under full irrigation (S_1R_4) had the highest values of N (3.04%) and P (0.37%). The lowest value of nitrogen (2.32%) and phosphorus (0.19%) recorded from drought stress in stem elongation stage and without foliar spraying (S_2R_1).

Data in Table 4 show that drought stress treatments had not significant effect on K content of millet forage. Eck and Musick [37] found that drought stress did not affect the K concentration of sorghum plants. Our results indicated that PGR foliar application significantly induced an increase of macronutrients percentage of forage. Plants that treated with uniconazole+cycocle or cycocel had the highest value whereas untreated plants with PGR showed the lowest value (Table 4).

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