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EFFECT OF EXTRA POTASSIUM SUPPLY ON CORN YIELD AND SEED QUALITY UNDER DEFICIT IRRIGATION CONDITIONS

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Abstract

Deficit water treatment studies and some practices to reduce the effects of drought on plant can be made in Mediterranean region. Therefore the study was carried out at three different supplies as non-fertilization, standard fertilization [210 kg.ha^{-1} pure N, 60 kg.ha^{-1} pure P, 60 kg.ha^{-1} pure K (NH_4NO_3, P_2O_5 and K_2O – 60 kg.ha^{-1} with 15-15-15 composite before planting and H_2NCONH_2 – 150 kg.ha^{-1} with urea before first water)] and extra potassium (standard fertilization +60 kg.ha^{-1} K_2SO_4) and three irrigation doses (500 mm, 400 mm and 300 mm) during development stages [(8 leaf stage (V8), before Tasselling (VT), after blister, milk stage and dough stage)] in the Aegean region of Turkey during 2013 summer growth periods. The experiment was a randomized block design with three replications. 31G98, 31D24 and NK-Arma corn cultivars were used to material of the experiment. Seed yield and some yield components such as cob length, the number of seed per cob and 1000 seed weight were measured. Additionally some seed quality traits such as oil content, protein content, starch content, ASH and cellulose contents of corn seed were also measured in the study. The results of this study showed that extra potassium supply was effected on seed yield, the seed number in corncob and ash and cellulose contents of corn seed positively. However 1000 seed weight, corncob length, oil, protein, starch contents of corn seed didn't effect or negatively affect with extra potassium supply. It was revealed that seed yield, 1000 seed weight, oil and starch contents of corn seed were decreased with deficit water treatments (300 mm and 400 mm) according to standard water treatment (500 mm). In contrary that cob length, the number of seed per cob, protein, ASH and cellulose contents of corn seed values does not give similar responses (increasing or decreasing) with deficit water treatments. The highest seed yield was obtained from 31G98 corn cultivar in standard irrigation dose (500 mm) and extra potassium treatment because of having high thousand seed weight. As a result of the experiment, it was suggested that extra potassium treatment should increase yield and some properties of corn but only extra potassium isn't exactly effective against negative effects of drought.

Key words: *corn, seed yield, 1000 seed weight, protein rate, ASH rate, oil rate.*

INTRODUCTION

Human population is increasing by 1.65 percent every year. Thus food production must be increased with agricultural products (Rafat et al., 2012). Drought is one of the important stress factors for plant growth. Especially limited water sources are a prohibitive factor for improving crop production (Zhang, 2004).
Annual corn production is highly dependent on irrigation supplies on the world (Ebrahimi et al., 2011). Similarly irrigation water is becoming an increasingly limited resource in many areas of Mediterranean region (Edmeads et al., 1994). Corn is affected by water deficits especially during the seed filling period. Magnitude of the effect from water stress depends on occurrence time, intensity of the stress, growing phase and genotype (Nejad et al., 2010).
Various experiments carried out for water efficiency under deficit irrigation condition during crop growing cycle (Li et al., 1999; Deng et al., 2002; Zhang et al., 2004). Additionally all of them were shown that deficit irrigation during the seed filling period negatively affected quantity and quality of corn seed (Fabeiro et al., 2001; Kang et al., 2002; Zhang et al., 2006).
Water stress was effected at the pollination stage (pre-flowering stage) will induce embryo abortion, and thus a lower yield (Kramer and

Boyer, 1995). Water deficit pre and post flowering stage caused seed abortion and ultimately reduces the number of seed (Bänziger et al., 1999). The most effective of drought stress on seed weight was during seed filling because of causing small seed sizes (Wardlaw and Willenbrink, 2000; Mut and Akay, 2010).

There are some studies about different practices such as planting date, genotype selection, reduced tillage, and diversification of crop, organic matter and mineral application to reduce drought vulnerability (Carr, 2010; Knutson et al., 2011; Allen, 2012). Potassium application is the one of treatments for maximum yield against the effects of drought on plant. Because potassium plays a vital role in control of ionic balance and regulation of stomas for water use (Reddya et al., 2004; Rafat et al., 2012). Besides potassium is a primary regulator for osmotic potential while maintaining low water potential of crop. Therefore, accumulating K+ in their tissues may play an important role for crops under drought condition (Zare et al., 2014). The study were investigated to influence of standard and extra potassium fertilizer (60 $kg.ha^{-1}$ K_2SO_4) on seed yield and its components and seed quality parameters under deficit irrigation conditions.

MATERIALS AND METHODS

The research was carried out in Aydin with typical Mediterranean climate (hot summer and mild winter), located in west Turkey at 37º44 N 27º44 E at 65 m above sea level; and was conducted during 2013. Initial result of soil analysis is shown in Table1.

Table 1. Soil texture and chemical analysis

Soil texture[1] (%)			pH^2	Organic mater[3]
Sand	Silt	Clay		(%)
72.0	16.7	11.3	8.4	1.2

Method of; [1]Bouyoucos; [2]1:2.5 Saturasyon; [3]Walkley-Black

(Bouyoucos G.J. 1962; Ayers and Westcot 1989; Walkley and Black 1934)

The experimental soil in studied field contains with sandy loamy structure with alkaline characteristic and it mixed with quite low organic matters.

Monthly temperature, total rainfall and long-term (1975–2013) values in Aydin shown in Table 2. The temperature of 2013 was higher than long term means expect for June and July. Rainfall data analysed that May, July and August were showed lower value than long term means.

Table 2. Monthly temperature and total rainfall during corn growth period and long-term mean (1975-2013) in Aydin

Months	Temperature (°C)		Precipitation (mm)	
	2013	Long term	2013	Long term
April	16.1	15.7	42.6	45.5
May	23.2	20.9	1.0	33.5
June	25.3	25.9	18.4	14.0
July	27.9	28.4	2.4	3.5
August	27.8	27.2	0.0	2.2
September	22.6	23.2	22.8	14.4

Experimental design

The experiment was set up as split block experimental design with 3 replications. All parcels were sowed April 26, 2013 and the first seed emergence observation was conducted on May 13, 2013. Each plot area was 28 m^2 (5 m x 5.6 m) and consisted of 8 rows. Distance between rows was 70 cm and intra row spaces were 18 cm. NK-Arma, P31G98 and 31D24 cultivars were used as the crop material. All cultivars are hybrid (F1) and have single cross corn (*Zea mays* L.) cultivar. NK-Arma is produced by Syngenta Turkey Co. Ltd., and the others are produced by Pioneer Turkey Seed Distribution and Marketing Co. Ltd.

Treatment factors were created out with non-fertilizer, standard fertilizer and extra potassium application. There was not been any applications fertilizers form to non-fertilizer parcels. Standard fertilizer application from soil was applied as 210 $kg.ha^{-1}$ pure nitrogen (NH_4NO_3) (60 $kg.ha^{-1}$ with 15-15-15 composite was applied immediately at the beginning of cultivation – 150 $kg.ha^{-1}$ with urea (H_2NCONH_2) before first water), 60 $kg.ha^{-1}$ phosphor (P_2O_5) and 60 $kg.ha^{-1}$ potassium (K_2O). Extra potassium application was formed to by being added to 60 $kg.ha^{-1}$ K_2SO_4 onto the standard fertilizer application.

Soil from the field experiment [(0-30 cm, 30-60 cm and 60-90 cm depth (Rd)] was put into pots. The water content of the soil after being saturated by irrigation and allowed to drain is called field capacity (FC). Crop can no longer take up water from the soil is referred wilting point (WP). The water held by the soil between field capacity and the permanent wilting point is considered available water. Corn is capable of using 50% of the available water (AW). Irrigation water requirement (100 mm) was calculated with the following formulas (Martin and Gilley, 1993; Lamm et al., 1994).

$$AW = Rd\,(FC-WP)/100$$

Irrigation doses was formed as standard (5X100 mm) during 5 times (V8, before VT, after blister, milk stage and dough stage), as deficit irrigation (4X100 mm) during 4 times (V8, before VT, after blister and milk stage) and as more deficit irrigation (3X100) during 3 times V8, before VT and after blister) at corn growth period. All irrigation applied and time were given in Table 3.

Table 3. Irrigation times in corn growing season

Irrigation time	Irrigation rate per plot		
	300 mm	400 mm	500 mm
20th June 2013	X	X	X
04th July 2013	X	X	X
12th July 2013	X	X	X
25th July 2013	-	X	X
06th August 2013	-	-	X
10th September 2013	Harvest time		
X: Applied 100 mm water			

The traits studied in this research were determined in the following ways:

Seed number per ear: The number of seeds in 10 ears was counted after they had been shelled, and was divided by the number of ears.

1000 seed weight: Thousand seed weights was calculated by taking four different samples of 100 seeds from the seed yield per plot and by weighing and averaging these samples.

Seed yield: Ears from each plot were dried for about three months at room temperature, and then the seed was shelled and weighed. Consequently, the seed yield.ha^{-1} was calculated by multiplying the computed seed weight for each plot.

Protein, starch, oil, ASH and cellulose content: Corn seed was analyzed using NIRS-FT (Bruker MPA) (Gislum et al., 2004). The samples were first packed (90 g) as uniformly as possible in mini sample cups with a depth of approximately 2.8 cm and a diameter of 9 cm.

Statistical analysis

All the plant data collected from all treatments were statistically analysed using the TARIST package software (Açıkgöz et al., 1994) as a split plot design with three replications using analysis of variance to evaluate the effect of different fertilization doses (non-fertilization, standard fertilization and extra potassium) and deficit irrigation levels (500 mm, 400 mm, 300 mm) on the corn. Means among treatments were compared using Least Significant Difference (LSD) at $P \leq 0.05$ probability.

RESULTS AND DISCUSSIONS

The calculated mean squares with variance analyses for treatment factors (different fertilization) and water doses (deficit doses) and cultivar and their interactions are presented in terms of seed yield, yield component and seed quality parameters in Table 3.

Table 4. The calculated mean squares with variance analyses for all components measured of corn

Variance Source	SY	NSC	TSW	PRO	STA	OIL	ASH	CEL
Irrigation doses (A)	397963.7**	23985.1ns	20594.1*	5.7**	3.1ns	0.2ns	0.0ns	0.0ns
Fertilizer doses (B)	1418856.3**	134239.6**	2386.3ns	17.8**	20.5**	0.1ns	0.0*	0.0ns
Cultivar (C)	8457.3ns	47041.4**	4120.0*	4.4**	8.0*	0.1ns	0.0**	0.2*
A x B	21546.5*	17533.4**	6300.1**	2.6**	9.3**	0.1ns	0.0ns	0.0ns
A x C	123418.3**	14743.1*	1832.0ns	1.6**	1.8ns	0.2**	0.0ns	0.1ns
B x C	114583.0**	1769.4ns	3324.0*	0.1ns	1.6ns	0.1ns	0.0ns	0.1ns
A x B x C	28522.7**	15037.1**	3285.0*	0.3ns	3.0ns	0.0ns	0.0*	0.1ns
Error 1	6247.7	13994.9	2910.7	0.1	2.0	0.1	0.0	0.1
Error	7959.4	4429.5	1229.4	0.1	1.6	0.0	0.0	0.0

** P<0.01; * P<0.05, ns: non-significant

SY: seed yield, NSC: number of seed per cob, TSW: 1000 seed weight, PRO.: protein, STA.: Starch, CEL.: cellulose

Table 5. Effect of extra potassium on seed yield and components of corn under deficit irrigation conditions

Treatment	İrrigation Dose	Cultivar	Seed yield ($kg.ha^{-1}$)	Number of seed per cob	1000 seed weight (g)
Non -fertilization	300 mm	31G98	4703.0	420.0	207.6
		31D24	4642.0	353.3	265.6
		NK-Arma	9961.0	595.7	249.5
	Average		6435.0	456.3	240.9
	400 mm	31G98	9038.0	405.0	264.2
		31D24	9508.0	622.3	324.3
		NK-Arma	7857.0	573.3	320.0
	Average		8801.0	533.6	302.8
	500 mm	31G98	7820.0	623.3	285.9
		31D24	7608.0	570.3	358.1
		NK-Arma	9147.0	581.0	341.0
	Average		8192.0	591.6	328.3
Average of non-fertilization			**7809.0**	**527,1**	**290.7**
Standard fertilization	300 mm	31G98	10094.0	545.3	310,7
		31D24	8727.0	529.0	339,1
		NK-Arma	9671.0	700.3	258.5
	Average		9497.0	591.6	302.8
	400 mm	31G98	12408.0	660.0	353.4
		31D24	13087.0	657.3	284.1
		NK-Arma	8670.0	695.3	352.6
	Average		11388,0	670.9	330.1
	500 mm	31G98	13390.0	594.3	272.3
		31D24	13311.0	625.7	317.3
		NK-Arma	10890.0	625.0	292.4
	Average		12530.0	615.0	294.0
Average of standard fertilization			**11139.0**	**625.8**	**308.9**
Extra Potassium supply	300 mm	31G98	10736.0	668.0	222.4
		31D24	11316.0	676.3	284.9
		NK-Arma	11103.0	657.3	285.6
	Average		11052.0	667.2	264.3
	400 mm	31G98	12426.0	622.3	320.5
		31D24	12990.0	656.0	321.0
		NK-Arma	12249.0	758.7	292.0
	Average		12555,0	679.0	311.2
	500 mm	31G98	13864.0	588.0	352.4
		31D24	13078.0	671.7	314.0
		NK-Arma	12072.0	675.3	340.6
	Average		13005.0	645.0	335.7
Average of Extra potassium supply			**12204.0**	**663.7**	**303.7**
Average of irrigation doses					
300 mm			8995.0	571.7	269.3
400 mm			10915.0	627.8	314.7
500 mm			11242.0	617.2	319.3
LSD irrigation*potassium*cultivar (0,05)			1466.0	109.4	57.6

Table 6. Effect of extra potassium on seed quality parameters on corn seed under deficit irrigation conditions

Treatment	İrrigation Dose	Cultivar	PRO (%)	STA (%)	ASH (%)	OIL (%)	CEL (%)
Non -fertilization	300 mm	31G98	7.4	73.2	1.3	3.5	2.2
		31D24	7.5	71.1	1.3	3.2	2.1
		NK-Arma	7.8	72.4	1.3	3.7	2.5
		Average	7.5	72.3	1.3	3.5	2.3
	400 mm	31G98	7.2	71.0	1.4	3.4	2.1
		31D24	7.5	73.2	1.3	3.5	2.1
		NK-Arma	6.7	72.5	1.3	3.5	2.4
		Average	7,1	72.2	1.3	3.5	2.2
	500 mm	31G98	8.1	72.2	1.4	3.9	2.4
		31D24	7.4	72.7	1.3	3.4	2.2
		NK-Arma	6.3	73.6	1.3	3.3	2.4
		Average	7.2	72.8	1.3	3.5	2.3
Average of non-fertilization			**7.3**	**72.4**	**1.3**	**3.5**	**2.3**
Standard fertilization	300 mm	31G98	9.2	69.7	1.4	3.4	2.1
		31D24	9.4	71.6	1.3	3.6	2.3
		NK-Arma	9.3	72.2	1.3	3.8	2.7
		Average	9.3	71.2	1.3	3.6	2.3
	400 mm	31G98	9.0	70.1	1.3	3.7	2.3
		31D24	9.2	72.2	1.4	3.7	2.4
		NK-Arma	7.8	71.3	1.3	3.6	2.3
		Average	8,6	71.2	1.3	3.7	2.3
	500 mm	31G98	8.9	69.4	1.3	3.5	2.3
		31D24	9.5	69.0	1.3	3.4	2.4
		NK-Arma	8.2	71.3	1.3	3.5	2.1
		Average	8.9	69.9	1.3	3.4	2.3
Average of standard fertilization			**8.9**	**70.8**	**1.3**	**3.6**	**2.3**
Extra Potassium supply	300 mm	31G98	8.8	68.7	1.4	3.6	2.6
		31D24	9.2	70.2	1.4	3.3	2.1
		NK-Arma	9.0	70.3	1.3	3.6	2.4
		Average	9,0	69.7	1.4	3.5	2.4
	400 mm	31G98	9.0	71.5	1.3	3.7	2.3
		31D24	8.7	70.7	1.3	3.8	2.4
		NK-Arma	7.4	72.0	1.3	3.7	2.4
		Average	8.4	71.4	1.3	3.7	2.4
	500 mm	31G98	7.4	72.8	1.3	3.6	2.3
		31D24	7.2	71.5	1.4	3.3	2.3
		NK-Arma	6.5	72.7	1.3	3.3	2.4
		Average	7.0	72.3	1.3	3.4	2.3
Extra potassium supply			**8.1**	**71.2**	**1.3**	**3.5**	**2.3**
Average of irrigation doses							
300 mm			8.6	71.1	1.3	3.5	2.3
400 mm			8.0	71.6	1.3	3.6	2.3
500 mm			7.7	71.7	1.3	3.5	2.3
LSD irrigation*potassium*cultivar (0,05)			-	-	0.1	-	-
LSD irrigation*cultivar (0,05)			0.4	-	-	0.2	-
LSD irrigation*treatment (0,05)			0.4	1.2	-	-	
LSD cultivar (0.05)			-	0.7	-	-	0.1

PRO.: protein, STA.: Starch, CEL.: cellulose

Irrigation dose x treatment factor x cultivar interaction was found to be significant seed yield, number of seed per cob, 1000 seed weight and ASH rate parameters. Furthermore, irrigation dose x treatment factor interaction was significant for protein and starch rate. Irrigation dose x cultivar interaction was significant for protein and oil rate.

Table 5 and Table 6 were edited as seed yield, yield component and seed quality parameters under deficit irrigation conditions.

Seed yield, number of seed per cob and 1000 seed weight were shown in Table 5. Treatment average of seed yield and number of seed per cob were increased with standard fertilization and extra potassium application according to non-fertilization. 1000 seed weight didn't give similar responses (sometime increasing and sometimes decreasing) with all the treatments. Otherwise it is shown that increasing water doses was increased seed yield and 1000 seed weight. Number of seed per cob and 1000 seed weight are mainly component for seed yield (Geetha and Jayaraman, 2000; Mohammadi et al., 2003). These components increased regularly in some treatments (standard fertilization and 400 mm water), whereas moved irregularly in the others (extra potassium and 500 mm water). We obtained that yield components (number of seed per cob and 1000 seed weight) should be moved regularly for maximum seed yield under deficit irrigation condition.

Protein rate, starch rate, oil rate, ASH and cellulose rate of corn seed provided in Table 6. Protein rate was increased with standard fertilization and extra potassium supply compared to control. Similarly increased water dose was increased protein rate of corn seed. But treatments (standard fertilization and extra potassium supply) were seen decreasing protein rate under deficit conditions owing to increasing seed yield. Therefore when protein rate was increasing, starch rate was decreasing with changing irrigation doses in extra potassium supply. The result parallel with the study result which density of starch in seed will increase consequently amount of protein will decrease (Nematı et al., 2009). Otherwise protein and starch rate moved irregularly in the other treatments (standard fertilizer and non-fertilizer). Average of ASH concentration of corn seed was stabile with all treatments and irrigation doses. The same as the average of oil rate was also little movements with all treatments and irrigation doses. The major factor for oil rate chancing was genotypes. The highest oil rate in the experiment was measured 31G98 cultivar under 500 mm irrigation and non-fertilization condition. The content of oil was also enhanced when seed development occurred under severe water stress (Roche et al., 2006).

Cultivar was significant for changing cellulose rate. 31G98 and NK-Arma cultivars were given higher cellulose rate than 31D24 with all treatments. Additionally these cultivars take higher cellulose rate score under 300 mm irrigation dose than 400 mm and 500 mm. So we said that deficit irrigation condition in all treatment may cause increasing cellulose rate of corn seed. Increasing cellulose rate was decreased animal feed quality. Therefore the result has showed that animal feed quality was decreased under deficit irrigation condition.

CONCLUSIONS

Based on the results of our study, we can be clearly seen that water shortage during milk stage and dough stage had a negative effect on seed yield and yield components. This results were shown that supplemental irrigation in seed feeling stages of corn is need to ensure maximum seed yield. Otherwise standard fertilization and extra potassium supply also reduced the negative effect of deficit irrigation condition and slightly positive effect for adequate yield.

Quality parameters of corn seed didn't move similarly seed yield and components. Seed quality parameters moved variably as increase or decrease unregularly under changing irrigation doses and chancing treatments (standard fertilizer and extra potassium).

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