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Alleviation of Water Stress Effects on Wheat by Mepiquat Chloride

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ABSTRACT

Two field experiments were carried out to study the effect of water stress and possible ameliorative effect of mepiquate chloride (MC) on wheat. The experiments were carried out in newly cultivated sandy lands in New Salheyia Region, Sharkia Governorate. Water stress was imposed by skipping one irrigation at tillering, heading or milk-ripe stage. Mepiquate chloride was foliarly applied at 0, 600, 900, 1200 or 1500 ppm. Water stress decreased the growth, the content of chl. a, chl. b and carotenoids, endogenous growth promoters (IAA, GA_3, cytokinins), and yield components (number, weight and length of spikes, grain, straw and biological yield). However, specific leaf area (SLW), ABA content and grain proteins were increased by water stress imposition. The most sensitive growth stage of wheat to water stress was the tillering stage. Foliar application of MC alleviated the previous water stress adverse effects on wheat: increased growth, photosynthetic pigments, growth promoters and yield components. The effect of MC was more pronounced at 900 ppm. High concentrations of MC (1200 or 1500 ppm) were inhibitory. The data were discussed in terms of interaction of water stress and MC on wheat plants.

Key Words: Wheat; Mepiquat Chloride; Water stress

INTRODUCTION

Seif El-Yazal *et al.* (1984) found that with holding irrigation either at milky, heading, booting or tillering stage decreased grain yield in wheat. Abd El-Gawad *et al.* (1993) and Eid and Yousef (1994) reported that decreasing the number of irrigations also reduced the yield and its components in wheat. Grain yield was decreased when wheat plants were subjected to water stress at tillering, heading, milk-ripe and dough-stage (Abo-Shtaia & Abd El-Gawad, 1995; Sharaan *et al.*, 2000; Abo El-Kheir *et al.*, 2001). Extensive efforts are, therefore, continuously paid for increasing wheat productivity as well as other crops either by vertical or horizontal planting. In Egypt, wheat covers about 2.5 million fedan distributed mainly in the old land and partially in the new land. For saving irrigation water, wheat cultivars that produce high yield under suitable water regime should be developed. A possible approach to minimize drought-induced crop losses is the foliar application with plant growth regulators. Mepiquat Chloride (MC, 1, 1-dimethyl piperidinium chloride) is one of the most widely used plant growth retardants. MC has been used to overcome the water stress effects and increase yield in cotton (Xu & Taylor, 1992). Several useful effects have been reported with other crop plants (Ramdan, 1992; Morvan & Dupperay, 1996; Abo El-Kheir *et al.*, 1999; Jeyakumar & Thangaraj, 1998; Mekki & El-Kholy, 1999).

This investigation was, therefore, undertaken to examine the influence of foliar applied Mepiquat chloride in mitigating the effects of water stress in wheat. Wheat plants were grown under moisture stress imposed at certain developmental growth stages using wheat cv. Giza-164 cultivar. Determination of growth and yield was adopted to address this question.

MATERIALS AND METHODS

Caryopses of *Triticum aestivum* L., cv. Giza 164 were obtained from Ministry of Agriculture and used in this study. The present investigation was carried out during the two successive seasons of 2002/2003 and 2003/2004 in newly cultivated lands of sandy soil conditions at the New Salheyia Region, Sharkia Governorate. Soil characteristics are given in Table I. Each experiment was laid out in split-plot design with four replications. The main plots included the irrigation treatments while MC treatments were distributed in the sub-plots. The experimental unit consisted of 15 rows, each of 3.5 meter length and 20 cm apart, seeded at a rate of 60 kg/fed. Sowing took place on 25th and 29th November in 2002 and 2003 in the two seasons, respectively. The normal agronomic practices of wheat growth were followed until harvest as recommended by Wheat Research Dept., Agriculture Research Center.

Each experiment included 16 treatments: combination of four irrigation treatments to induce different water stress level and four MC treatments. The irrigation treatments were as follows: 1) Normal irrigation where wheat plants irrigated with seven days intervals up to ripe state (145 days from sowing), i.e., control treatments. 2) Missing one irrigation at tillering stage (50 days from sowing date). 3) Missing one irrigation at heading stage (85 days after sowing). 4) Missing one irrigation at milk-ripe stage (110 days after sowing). The mepiquat chloride treatments were as follows: 1) tap water (control treatment); 2) 600 ppm; 3) 900 ppm; 4) 1200 ppm; 4) 1500 ppm. Spraying with MC was twice at 40 and 50 days after sowing.

Growth measurements. Samples of five guarded plants were taken at random of each plot of the four replications to determine the growth parameters at 115 and 130 days: plant height, tiller number, dry weight of tillers, number of blades and spikes per plant. Flay leaf area (cm^2) and blade area (cm^2/plant) were determined according to Bremner and Taha (1966). Leaf are index (LAI) was measured according to Watson (1951), and specific leaf weight (SLW) was determined according to Pearce *et al.* (1969).

Photosynthetic pigments. The content of the photosynthetic pigments blades (mg/g dry wt.) were determined according to Van Wettestein (1957).

Phytohormones. Auxin (IAA), gibberellic acid (GA_3) cytokinins and abscissic acid (ABA) were determined in the shoots by the method of Wasfy and Smith (1975) using HPLC (Waters, USA).

Yield measurements. Ten plants were randomly taken of the middle rows of each plot at harvest time to determine the number of spikes/plant, spikes weight (g/plant), main spike length (cm), grain index (1000 grains, g), grain, straw and biological yield (g/plant). In addition, grain, straw and biological yields (ton/fed) were calculated for the plot area and then converted to yield per feddan. Crude protein in grains was determined according to A.O.A.C. (1994).

Statistical analysis. Data were analyzed by analysis of variance and differences among means were determined by least significant difference (LSD) at 5% level (Snedecor & Cochran, 1990).

RESULTS AND DISCUSSION

Effect of water stress and MC on growth. Water stress induced at different developmental stage significantly decreased the all growth parameters test (except SLW at heading and milk-ripe stages) (Table II). The negative effect of water stress on the growth might be attributed to the loss of turgor (Kramer & Boyer, 1995), inadequate uptake of essential elements and photosynthetic capacity reduction (Abo-Shetaia & Abd El-Gawad, 1995; Kramer & Boyer, 1995; Shangguan *et al*., 1999; Kandil *et al*., 2001) induced by water stress. The effect of water stress on the growth obtained in our study is confirmed by previous reports (Abd El-Gawad *et al.,* 1993; Eid & Yousef, 1994; Abo Shetaia & Abd El-Gawad, 1995; Gad El-Rab *et al.,* 1995; Yousef & Hanna, 1998; Sharaan *et al*., 2000; Abo El-Kheir *et al*., 2001; Kandil *et al*., 2001). Table II shows that the most sensitive stage to water stress was the tillering stage, which is consistent with the data of Seif el-Yazal *et al.* (1948), McMaster *et al.* (1994), Abo-Shetaia and El-Gawad (1995) and Kandil *et al.* (2001). It is, therefore, suggested that irrigation at late jointing is critical to tiller survival and can affect yield.

Foliar spraying of MC alone increased the all growth parameters examined in this study, the effect was more pronounced with 900 ppm (with few exeptions, Table II). However, MC at 1200 ppm and 1500 ppm had negative effect on the growth of wheat plants.

Interaction of water stress and foliar spraying of MC presented in Table III. Foliar application of MC at low conc. (600 & 900 ppm) counteracted the inhibitory effect of water stress on growth, more so at 900 ppm. High conc. of MC in presence of water stress had inhibitory effect on growth (Table III). Our data are in agreement with those reported by Orabi (1994), Abo El- Kheir *et al*. (2001), Jeyakumar and Thangaraj (1998), Mekki and El–Kholy (1999) and Shah and Prathopasenan (1993). MC enhanced influence on the growth might be explained by MC effects on photosynthetic surface area, photosynthetic pigments and endogenouns hormones (Wood-Word & Marshall, 1988). Shalaby and El-Ashry (2001) and El-Ashry and Shalaby (2001) worked on faba bean and chickpea indicated that growth retardants at low conc. induced endogenous growth promoters whereas at high conc. of growth retardants a remarkable decrease in endogenous hormones was observed. This may be the case in our study where growth stimulation and inhibition were obtained at low and high conc. of MC, respectively (Table II) in presence and absence of water stress.

Effect of water stress and MC on the photosynthetic pigments. Water stress induced by skipping an irrigation decreased the chl. a, chl. b and carotenoids (Table IV). The effect was more pronounced when water stress imposed at tillering stage. This reduction in the photosynthetic pigments under water stress observed here is in agreement with the results of Abo El-Kheir (1985) and Imam *et al.* (1995).

MC applied alone increased the photosynthetic pigment contents (Table IV), the greatest increase was obtained with 900 ppm. High conc. of MC (1200 and 1500 ppm) decreased chl. a, chl. b and carotenoid contents. Foliar application of MC (600 & 900 ppm) overcame the water stress-induced reduction in the photosynthetic pigment contents and increased their levels compared with the control plants (Table V), more so at 900 ppm. The influence of MC on alleviating the water stress effect on the photosynthetic pigments might be due to the fact that MC enhanced the endogenous level of cytokinins (Tables IV, V), which stimulates chlorophyll synthesis (Harvey *et al*., 1974).

Effect of water stress and MC on the endogenous hormones. Water stress decreased the contents of IAA, GA_3 and cytokinins, whereas it increased ABA content (Table IV). Water stress induced by skipping one irrigation at the tillering stage had the greatest effect on the endogenous hormone levels. Our results are supported by the findings of Davies *et al*. (1986), Oshio *et al.* (1990), Bekheta (1993) and Imam *et al*. (1995) who reported similar changes in the endogenous hormones under water stress.

MC applied in presence or absence of water stress increased the level of IAA, GA_3, cytokinins and decreased

Table I. Mechanical and chemical analysis of soil at experimental sites (Average of 2002/2003 and 2003/2004 seasons)

Sand	Silt	Clay	Texture	PH	Organic matter O.M	Available N p.p.m	Available N p.p.m	Available K p.p.m
73.25%	23.30%	3.44%	Sandy	8.00	0.50%	44.0	12.6	136.00

Table II. Effect of water stress at certain developmental stages and mepiquat chloride concentrations on different growth parameters of wheat plant (average of 2001/2002 and 202/2003 seasons)

Irrigation ragime	Mepiquat chloride conc. ppm	Plant height (cm)		No of tiller/plant		No. of leaves/plant		No. of spikes/plant		Tillers+sheats dry wt.(g/plant)		Blades dry wt. (g/plant)		Spikes dry wt. (g/plant)		Flag leaf area cm^2		Blades area cm^2/plant		Leaf area index (LAI		Specific leaf weigth (SLW) mg/cm^2	
		115	130	115	130	115	130	115	130	115	130	115	130	115	130	115	130	115	130	115	130	115	130
1		131.44	128.06	6.70	6.36	26.80	25.15	6.05	5.70	13.57	12.12	4.79	4.40	11.27	17.53	23.28	24.83	797.73	723.51	7.98	7.24	6.00	6.08
2		110.78	105.17	4.07	3.62	19.42	17.11	3.56	3.42	8.60	6.79	3.48	3.26	8.50	12.63	13.79	14.47	606.27	544.68	6.06	5.45	5.75	6.02
3		115.4	111.07	5.19	4.58	22.77	20.36	4.57	4.20	11.23	9.17	4.05	3.72	9.07	14.47	15.90	19.07	644.66	569.24	6.45	5.69	6.28	6.55
4		119.49	115.26	5.82	5.10	24.81	22.79	5.36	4.92	12.01	10.90	4.37	3.91	9.49	16.04	19.93	21.89	704.6	621.8	7.05	6.22	6.91	6.28
L.S.D at 5% level		4.13	3.12	0.68	0.75	0.57	0.38	0.42	0.12	0.39	0.09	0.18	0.11	0.34	0.56	1.29	0.48	19.36	16.42	0.50	0.28	0.04	0.03
	Control	118.45	113.83	5.60	4.95	23.16	21.03	4.80	4.59	10.93	9.57	4.13	3.81	9.20	14.84	18.22	19.62	676.6	587.65	6.77	5.88	7.09	6.48
	600	125.94	122.13	5.95	5.50	25.46	22.63	5.42	4.98	12.92	10.66	4.39	4.06	10.46	16.63	19.80	21.25	729.88	651.37	7.30	6.51	7.43	6.23
	900	130.42	124.43	6.53	5.88	26.85	24.45	5.87	5.43	13.73	11.96	4.78	4.28	11.90	17.87	21.91	23.61	778.95	707.4	7.79	7.07	7.54	6.05
	1200	114.92	110.06	4.83	4.42	21.54	19.65	4.34	4.09	9.89	8.55	3.85	3.61	8.46	13.76	16.71	18.60	651.4	576.54	6.51	5.77	5.91	6.26
	1500	106.83	103.99	4.33	3.84	20.28	19.00	4.01	3.71	9.29	7.99	3.70	3.37	7.90	12.74	15.93	17.25	604.75	551.0	6.05	5.51	6.12	6.12
L.S.D. 5% level		4.18	1.62	0.46	0.52	0.12	0.14	0.17	0.13	0.22	0.15	0.07	0.05	0.19	0.23	0.86	1.39	21.50	24.50	0.13	0.24	0.11	0.12

1= No skipping, 2= Skipping an irrigation at tillering stage, 3= Skipping an irrigation at heading stage, 4= Skipping an irrigation at milk-ripe stage

Table III. Effect of interaction between water stress and mepiquat chloride concentrations at certain developmental stages on growth attributes of wheat plants (Average of 2001/2002 and 2002/2003 seasons)

Irrigation regime	Mepiquat chloride (MC) conc. ppm	Plant height cm		No of tiller/plant		No. of leaves/plnat		No. of spikes/plant		Tillers+sheats dry wt. g/plnat		Blades dry wt. g/plant		Spikes dry wt. g/plant		Flag leaf area cm^2		Blades area cm^2/plant		Leaf area index (LAI)		Specific leaf weigth (SLW) mg/cm^2	
		115	130	115	130	115	130	115	130	115	130	115	130	115	130	115	130	115	130	115	130	115	130
	Control	109.5	103.1	4.00	3.7	18.54	16.50	3.6	3.57	8.31	6.59	3.42	3.21	8.05	12.66	13.70	14.4	590.0	503.7	5.90	5.04	5.80	6.37
Skipping	600	117.0	113.4	4.33	3.98	21.17	18.40	3.76	3.60	9.40	7.04	3.62	3.35	9.60	13.95	14.09	15.06	659.0	592.1	6.60	5.92	5.49	5.66
at tillering	900	121.6	115.6	5.00	4.1	22.70	19.0	4.00	3.77	10.50	8.6	4.04	3.60	10.0	14.04	16.52	17.82	701.75	637.6	7.02	6.38	5.76	5.65
stage	1200	107.4	100.33	3.60	3.33	17.67	16.00	3.33	3.17	7.59	6.04	3.18	3.09	7.53	11.48	12.85	13.08	580.0	400.0	5.80	5.00	5.48	6.18
	1500	98.4	93.40	3.40	3.00	17.00	15.67	3.10	3.00	7.18	5.66	3.42	3.05	7.31	11.03	11.80	12.00	500.0	490.0	5.00	4.90	6.24	6.22
Skipping	Control	115.68	109.4	5.40	4.6	21.78	19.8	4.28	4.0	10.46	8.31	4.01	3.76	8.70	14.0	16.93	18.32	631.0	540.94	6.31	5.41	6.35	6.95
at heading	600	120.53	118.43	5.67	5.17	24.90	21.0	5.00	4.7	12.57	10.2	4.24	3.97	10.12	15.48	17.76	20.08	683.9	596.8	6.84	5.97	6.20	6.65
stage	900	125.90	121.2	6.30	5.8	26.50	24.0	5.80	5.33	13.38	11.47	4.58	4.24	10.76	17.06	19.02	22.7	714.4	685.0	7.14	6.85	6.41	6.19
	1200	111.77	104.80	4.70	4.0	21.0	19.0	4.17	3.80	10.05	8.14	3.83	3.49	8.00	13.12	16.0	17.28	600.0	514.46	6.00	5.14	6.38	6.78
	1500	103.80	101.0	3.90	3.33	19.67	18.0	3.60	3.17	9.68	7.71	3.60	3.15	7.76	12.68	15.58	16.98	594.0	509.0	5.94	5.09	6.06	6.19
	Control	119.17	114.2	6.17	5.0	25.3	23.1	5.30	5.0	11.55	11.0	4.34	4.0	9.19	16.07	19.37	21.06	700.0	605.0	7.00	6.05	6.20	6.61
Skipping	600	125.74	121.5	6.30	5.5	26.73	23.8	6.0	5.3	14.03	12.11	4.60	4.15	10.03	17.28	22.14	23.51	752.0	646.0	7.52	6.46	6.12	6.42
at milk-	900	130.93	123.0	6.95	6.0	28.0	26.0	6.50	6.0	14.90	13.08	4.98	4.47	11.93	19.0	24.80	25.89	808.0	701.0	8.10	7.01	6.16	6.38
ripe stage	1200	114.20	111.72	5.00	4.67	23.0	20.7	4.67	4.30	10.16	9.31	4.00	3.68	8.32	14.60	17.0	21.0	655.0	612.0	6.55	6.12	6.11	6.01
	1500	107.40	105.9	4.70	4.33	21.10	20.33	4.33	4.0	9.43	9.00	3.92	3.27	8.00	13.25	16.33	18.0	608.0	545.0	6.08	5.45	6.45	6.00
L.S.D. at 5% level		8.36	3.24	0.92	1.04	0.24	0.28	0.34	0.26	0.44	0.30	0.14	0.10	0.38	0.46	1.72	2.78	43.00	49.00	0.26	0.48	0.22	n.s

that of IAA (Table V), 900 ppm showed the greatest effect. The high conc. of MC (1200 & 1500 ppm) had the opposite effect on the hormone levels. The hormonal changes observed in response to MC indicated that the tillering stage was the most sensitive to the MC application. The reduction in the content of the growth promoters induced by water stress imposition may disturb some physiological processes: e.g. photosynthesis, protein synthesis, enzyme activities (Simpson, 1981). Appliction of MC mitigated this reduction in the growth promoters as indicated in the current study.

Effect of water stress and MC on yield components. Water stress imposed by one irrigation skipping either at tillering, heading or milk– ripe stage decreased yield components tested in this study (no. of spikes, spike weight and length, grain yield, straw yield, biological yield, Table VI), the effect was more pronounced at tillering stage. On the other hand, water stress increased the grain proteins (Table VI). It is proposed that water stress might disturb protein synthesis which resulted in its accumulation. The results of Seif El-Yazal *et al.* (1984), McMaster *et al.* (1994), Karmer and Boyer (1995) Shangguan *et al.* (1999), Abo El-Kheir *et al.* (2001) and Kandil *et al.* (2001) support our data. Yield reduction induced by water stress might be explained to water stress effects on chlorophyll synthesis, hormonal decrease and turgor loss (Kramer & Boyer, 1995).

Table IV. Effect of water stress at certain developmental stages and Mepiquat chloride concentrations on photosynthetic pigments content and endogenous hormones content of wheat plants (average of 2001/2002 and 2002/2003 seasons)

Irrigation regime	Mepiquat chloride conc. (ppm)	Photosynthetic pigment content (mg/g dry wt. of leaves)			Endogenous hormone content (per 100 g fresh wt.)			
		Chl.a	Chl.b	Carotenoids	IAA (μg)	ABA (μg)	GA_3 (mg)	Cytokinins (μg)
1		2.99	1.30	1.81	301.63	53.83	400.53	66.40
2		2.18	0.89	1.20	196.43	108.59	252.38	45.45
3		2.37	1.06	1.30	231.44	86.55	294.76	49.90
4		2.61	1.22	1.54	268.35	67.94	344.44	56.79
L.S.D at 5% level		0.13	0.05	0.11	-	-	-	-
	Control	2.43	1.08	1.42	250.82	75.21	305.17	54.69
	600	2.86	1.19	1.57	278.66	63.97	355.36	60.83
	900	2.96	1.29	1.65	299.49	58.88	385.81	66.70
	1200	2.26	1.03	1.34	228.58	93.54	294.16	50.67
	1500	2.17	1.00	1.28	1.89.78	104.55	249.56	40.29
L.S.D. at 5% level		0.14	0.02	0.08	-	-	-	-

1= No skipping, 2= Skipping an irrigation at tillering stage, 3= Skipping an irrigation at heading stage, 4= Skipping one irrigation at milk-ripe stage

Table V. Effect of interaction between water stress and Mepiquat chloride at certain developmental stages on photosynthetic pigment content and endogenous hormone content of wheat plants (average of 2001/2002 and 2002/2003 seasons)

Irrigation regime	Mepiquat chloride (ppm)	Photosynthetic pigment content (mg/g dry wt. of leaves)			Endogenous hormone content (per 100 g fresh wt.)			
		Chl.a	Chl.b	Carotenoids	IAA(μg)	ABA (μg)	GA_3 (mg)	Cytokinins (μg)
Skipping one irrigation at tillering stage	Control (tap water)	1.94	0.82	1.15	192.73	103.61	250.97	43.27
	600	2.61	1.03	1.27	228.90	82.53	289.0	52.30
	900	2.74	1.10	1.36	255.88	71.38	325.07	60.20
	1200	1.83	0.75	1.12	173.20	136.85	225.0	40.49
	1500	1.78	0.74	1.10	131.46	148.60	171.85	31.00
Skipping one irrigation at heading stage	Control (tap water)	2.21	1.05	1.31	232.01	79.83	319.28	50.46
	600	2.77	1.09	1.36	266.50	64.92	342.6	54.18
	900	2.81	1.12	1.44	289.00	60.00	356.0	61.79
	1200	2.05	1.03	1.21	205.7	104.48	248.94	46.88
	1500	2.00	1.01	1.19	164.0	123.50	207.0	36.17
Skipping one irrigation at milk-ripe stage	Control (tap water)	2.53	1.19	1.45	276.44	64.96	350.3	58.79
	600	2.87	1.26	1.71	293.08	60.22	366.0	62.42
	900	3.01	1.41	1.92	302.43	58.90	404.0	66.641
	1200	2.36	1.13	1.36	248.51	73.44	328.5	52.90
	1500	2.27	1.11	1.24	221.30	82.17	273.4	43.25
L.S.D. at 5%		0.28	0.04	0.16	-	-	-	-

Regular irrigation after water stress imposition did not recover the water stress adverse effects on yield reduction. Abd El-Gawad *et al.* (1993) reported that retardation of photosynthetic enzymes under water stress might cause such effect. Since tillering stage was affected by water deficit, it is suggested that water deficit induced perturbation of physiological processes at late jointing critical to yield production and therefore water deficit should be avoided at this growth stage.

Low conc. of MC (600, 900 ppm) increased yield components, whereas 1200 or 1500 ppm had opposite effect (Table VI). Foliar application of MC at 600 or 900 mitigated the negative effect of water stress on the yield components (Table VII), 900 ppm was more effective. MC ameliorative effect observed in yield components might be due to its influence on increasing the photosynthetic surface area, chlorophyll synthesis, growth promoters reported in this study. Similar conclusion has been reached in different crop plants by Orabi (1994) and Abo El-Kheir *et al.* (2001), Jeyakumar and Thangaraj (1998) and Mekki and El-Kholy (1999).

In conclusion, foliar spraying of MC alleviated the water stress adverse effects on wheat. MC at 900 ppm was more effective in counteracting the water stress-induced harmfull effects. Wheat plants was more sensitive to water deficit at tillering stage compared with other growth stages.

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Table VI. Effect of water stress at certain developmental stages and mepiquat chloride on yield and its components of wheat plants (average of 2001/2002 and 2002/2003 seasons)

Irrigation regime	MC coc. (ppm)	No. of spikes/ plant	Spikes wight g/plant	Main spike length cm	Grain index g	Grain yield g/plant	Straw yield g/plant	Biological yield g/plant	Grain yield ton/fed	Straw yield ton/fed	Biolog-ical yield ton/ fed	Protein % per grains
1		5.51	25.04	14.96	37.28	19.99	22.94	42.93	2.67	3.81	6.48	10.00
2		3.38	20.62	11.53	29.52	14.33	18.48	32.81	2.19	3.34	5.53	11.00
3		4.08	21.50	12.58	33.13	16.65	20.68	37.33	2.32	3.68	6.00	10.33
4		4.73	22.56	13.18	35.89	18.18	22.26	40.44	2.43	3.68	6.11	10.13
L.S.D. at 5% level		0.14	1.08	1.24	0.49	0.92	0.17	1.16	0.23	0.13	0.35	0.02
	Control	4.47	22.28	13.02	33.41	16.95	19.83	36.78	2.27	3.55	5.82	10.06
	600	4.79	24.49	13.82	35.62	18.43	23.35	41.78	2.71	3.83	6.54	10.35
	900	5.26	25.80	15.04	37.21	20.22	25.31	45.53	2.82	4.11	6.93	10.60
	1200	3.99	20.71	12.05	32.11	15.71	18.90	34.61	2.18	3.39	5.57	10.65
	1500	3.67	18.89	11.39	31.30	15.10	18.10	33.20	2.05	3.25	5.30	10.17
L.S.D. at 5% level		0.15	0.94	0.27	0.24	0.95	0.32	1.54	0.19	0.06	0.16	0.03

1= No skipping, 2= Skipping one irrigation at heading stage, 3= Skipping one irrigation at milk-ripe stage, 4= Skipping and irrigation at milk-ripe stage

Table VII. Effect of interaction between water stress and Mepiquat chloride at certain developmental stages on yield component of wheat plants (average of 2001/2002 and 2002/2003 seasons)

Irrigation regime	MCconc (ppm)	No. of spikes/ plant	Spikes weight g/plant	Main spike length cm	Grain index g	Grain yield g/plant	Straw yield g/plant	Biological yield g/plant	Grain yield ton/fed	Straw yield ton/fed	Biolog-ical yield ton/ fed	Protein % per grains
Skipping	Control	3.50	20.80	11.09	29.14	13.62	17.59	31.21	2.04	3.23	5.27	10.96
one	600	3.60	22.92	12.28	30.52	15.38	20.65	36.03	2.57	3.55	6.02	11.04
irrigation at	900	3.70	23.25	13.11	32.70	17.45	21.38	38.83	2.64	3.90	6.54	11.38
tillering	1200	3.10	18.22	10.60	27.68	12.60	16.56	29.16	1.96	3.04	5.00	11.39
stage	1500	3.0	17.92	10.56	27.55	12.55	16.23	28.82	1.84	2.97	4.81	10.23
Skipping an	Control	3.80	21.40	12.75	32.40	16.52	19.46	35.98	2.17	3.60	5.77	10.02
irrigation at	600	4.67	23.26	13.55	34.63	17.85	22.09	39.94	2.66	3.76	6.42	10.27
heading	900	5.17	24.00	14.20	36.47	19.20	24.63	43.83	2.75	4.00	6.75	10.61
stage	1200	3.67	20.16	11.41	31.28	14.95	19.0	33.95	2.04	3.54	5.58	10.62
	1500	3.10	18.69	10.98	30.85	14.71	18.24	32.95	1.96	3.49	5.45	10.14
Skipping an	Control	4.90	22.17	13.40	35.90	18.00	20.8	38.80	2.31	3.70	6.01	9.65
irrigation at	600	5.00	24.46	14.28	37.58	19.10	25.31	44.41	2.70	3.94	6.64	10.12
milk-ripe	900	5.67	25.86	15.31	38.42	20.87	27.01	47.88	2.83	4.15	6.89	10.40
stage	1200	4.17	21.15	11.93	34.46	16.93	19.70	36.63	2.28	3.44	5.57	10.41
	1500	3.90	18.17	11.00	33.09	16.00	18.48	34.48	2.03	3.12	5.15	10.06
L.S.D. at 5% level		0.30	1.88	0.54	0.48	1.90	0.64	3.08	0.38	0.12	0.32	0.84

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