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Effects of Sowing Dates and CCC Application on Yield and Yield Components of Barley (*Hordeum vulgar* L.) Cultivars in the North of Iran

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Abstract: In order to evaluate effect application of CCC on growth, yield and yield components at sowing dates on barely cultivars. The experiment was conducted as split factorial arrangement was based on a randomized complete block design with three replications on 2009-2010 in Iran. The treatments comprised three sowing dates including; 7 Nov., 26 Nov. and 11 Dec. as main plots, thee cultivars including; Sahra, Productive and Line M_{12} and two CCC application; 0 and 2.8 Kg/ha, as subplots. Results indicated that there was significant difference in fertile tiller numbers per plant, grain numbers per plant, spikelet numbers and fertile spikelet per spike ($P \leq 0.01$). In cultivars, there was significant difference on unfertile and fertile tiller numbers per plant, grain numbers per plant, spikelet numbers and fertile spikelet per spike. ($P \leq 0.01$). In all traits of upper, Sahar and Line M_{12} cultivars had the highest and the lowest with 1.23, 0.99 numbers, 4.39, 4.11 numbers, 89.91, 56.62 grain, 115.90, 86.06 numbers and 75.72, 63.04%, respectively. There was significant difference ingrain and straw yields and spike numbers per plant in sowing dates, cultivars ($P \leq 0.01$). In sowing dates, the highest and lowest of grain yield and spike number per plant were obtained by 26 Nov. and 11 Dec. with 293.10 g m^{-2}, 4.03 spike/plant and 259.40 g m^{-2}, 2.92 spike/plant, respectively. In cultivars, the highest and lowest of grain yield and spike numbers per plant were obtained by Sahar and Line M_{12} with 316.90 g m^{-2}, 3.81 spike/plant and 244.40 g m^{-2}, 3.17 spike/plant, respectively. In grain numbers per plant, sowing dates × CCC interaction and cultivars × CCC interactions were significant ($P \leq 0.05$).

Key words: Barley · CCC · Cultivars · Lodging · Grain yield

INTRODUCTION

Lodging was the most critical problem in the wheat and especially barely crops, but application chlormequat chloride (2-chloroethyl-trimelhyl ammonium chloride, CCC) in reducing cereal crops height was successes, thereby reducing or preventing lodging ensured in the late 1960s, i.e. in a period when lodging was perhaps the most critical problem in the wheat crop, [1, 2]. Barley, (*Hordeum vulgare* L.) has shown good potential for dry matter yield of good quality during the winter in the Gezira Research Farm [3]. For grain production, Lazim (1973) [4] showed that sowing of barley at mid Nov. had resulted in the highest yield in Sudan.

Application of CCC increased yield of both wheat and barley, independently of any control on lodging [5]. In barley, a timely application of CCC at a prescribed stage of apical development has been shown to increase the grain yield by 10-20% through increasing grain number without any compensatory decrease in grain size [6, 7].

Growth retardants such as CCC have the reverse action i.e. they decrease the elongation growth [8], slow the rate of apical development [7, 9] and are expected to act by reducing the amount of active gibberellin available [10]. Furthermore, Stapper and Fischer (1990) [11] showed that higher density was associated with a significant reduction in number of tillers per plant. The same conclusion has been made by Darwinkel, 1978 [12].

Not only do PGRs reduce straw length and lodging sensitivity, but they may also directly enhance grain yield production through improved yield components built up from excess photosynthate not used for stem

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elongation. For example, in several studies with barley and wheat, PGR treatments resulted in more grains per ear [1, 2, 13-15]. The effect of PGRs on yield formation may range from yield enhancement to yield reduction depending on growing conditions [1, 2]. Genotypic differences in response to PGRs have also been reported by Peltonen-Sainio and Rajala, 2001 [16]. These are principally due to differences in straw length, but also due to genotypic differences in yield components and source to sink interaction. For this reason different barely types were used in this research. The landrace is a long-strawed, lodging sensitive cultivar with a relatively low grain to straw ratio (i.e., harvest index), compared with other husked cultivars [17]. Application of CCC on wheat grown under arid conditions increased root growth, resulting in more efficient water extraction from the deeper layers of soil, thereby highergrain yield [18]. The CCC treated plants had greater leaf area and more dry matter accumulation at anthesis than the untreated plants [19]. By applying CCC at the beginning of stem elongation and the other PGRs at later stages, prior to heading, cereal straw could be shortened [20]. Although the introduction of semi-dwarf wheat cultivars had largely solved the problem of lodging, evidence was already accumulating that a timely application of a growth retardant such as chlormequat (CCC) or ethephon could increase the grain yield of both wheat and barley, independently of any control of lodging [21]. The effect of PGRs on yield formation may range from yield enhancement to yield reduction depending on growing conditions [22].

The objective of the present study was (i) to evaluate effect application of CCC on barley yield and yield components at sowing dates and cultivars were studied (ii) to determine the optimum cultivars of barley.

MATERIALS AND METHODS

The investigation was carried out to evaluate the responses of sowing dates to CCC application in three cultivars of barley. The study was carried out for season 2009-2010 in the Baikolah Research Farm of the Agricultural Research Center of Mazandaran (ARCM) at Neka, Iran (Latitude 36°46 N, Longitude 53°13 E and altitude 4 m above sea level) (Table 1). The soil is Oxisol with clay, silt and loam content 25, 32 and 58%, respectively (Table 2).

The study involved barley which is characterized by vigorous growth, high grain yield, moderate height, no lodging and short gestation period for grain yield. The experiment was in a split factorial arrangement was based on a randomized complete block design with three replications. The treatments comprised three sowing dates including; 7 Nov., 26 Nov. and 11 Dec. as main plots, three cultivars including; Sahra, Productive and Line M_{12} and two CCC application; 0 and 2.8 Kg/ha, as subplots. Each replicate consisted of 18 plots of 8 m^2 (2×4). The six treatments of the experiment were composed of 3 sowing dates, 2 plant growth regulator levels (treated and untreated) and 3 cultivars of barely. The CCC treatment was applied with a precision sprayer at constant pressure of 3 bars at the "lemma primordium stage" of apical development (developmental score DS 3.0 according to the Waddington scale (Waddington *et al.*, 1983) [23] which occurred 100 days after sowing. To all the miniplots, nitrogen, potassium and phosphorus were added uniformly (46, 50 and 50 Kg ha^{-1}, respectively) at planting time. During the season all the plots were top-dressed with nitrogen at mid-tillering and stem elongation, each at the rate of 46 kg N ha^{-1}. Nitrogen was added simultaneously with the seeds at the rate of 300 Kg urea/ha.

Seed of cultivars " Sahra, Productive and Line M_{12} " with 99% germination were hand sown with square spacing giving 400 plants m^2 in 48 miniplots of 4x2 m in sowing dates of treatments in 2009. Planting was by drilling the seeds to about 3 cm depth, on the top of the ridges. Regulation of spacing and uniformity of sowing depth was achieved. Plant establishment and survival were excellent in all treatments. No herbicide was applied since crop plots were regularly hand weeded twice.

Table 1: Weather condition in experiment site in corn growth stages at Neka in 2009-2010

Variable	Oct.	No.	Dec.	Jan.	Feb.	March	April	May	June
Minimum tem.	17.2	9.8	6.3	1.8	4.6	6.6	7.8	13.8	18.5
Maximum tem.	23.2	17.8	14.6	10.3	12.7	15.4	16.3	22.3	27.7
Precipitation	94	65	230	42	112	23	108	26	10

Table 2: Selected soil properties for composite samples at experimental site in 2009-2010

Soil texture	K (ppm)	P (ppm)	N (%)	OM (%)	pH	EC (μmohs/cm)	Depth (cm)
Loam clay	216	12.6	0.22	1.8	7.4	0.74	0-30

Irrigation water was not applied throughout the growing season because rain was adequate. For the final yield, the crop was cut from ground level in an area of 1 × 2 m at the harvest stage. Plant height of the final yield was taken as the mean of 5 readings of the main shoot. True stem length, fertile and total tiller number per plant, ear length and spikelet number per ear were recorded throughout the growing season. Within each plot an area of 1 m^2 was marked and left for harvesting at crop maturity (ripe grain) which was used for yield component analysis. Dry weights were recorded after the plant material had been oven-dried at 80°C for 72 hours. The samples were oven dried at 80°C for 48 hours and then weighed for the determination of dry matter yield. Prior to the drying, a subsample was taken and separated into grains and stem, leaves and sheath to obtain the harvest index ratio. The data were analyzed by analysis of variance and the means compared by Duncan's new multiple range test (DNMRT).

RESULTS AND DISCUSSION

Yield Components: There was significant difference in fertile tiller numbers per plant, grain numbers per plant, spikelet numbers per plant and fertile spikelets per spike ($P \leq 0.01$) (Table 3). Fertile tiller numbers and grain numbers per plant of A_2 and A_3 had the highest and lowest with 4.60, 102.90 and 3.79, 44.61 numbers, respectively. Thus, the fertile tiller numbers and grain numbers per plant were decreased with early or late sowing dates. Spikelet numbers per plant and fertile spikelets per spike of A_2 and A_3 had the highest and lowest with 126.60 numbers, 80.65% and 76.61 numbers, 56.73%, respectively. Also, spikelet numbers per plant and fertile spikelets per spike were decreased with early or late sowing dates and there was similar to fertile tiller numbers and grain numbers per plant (Table 4). There was positive correlation between grain numbers with spike numbers and spikelet numbers (0.91** and 0.96**, respectively). So, early sowing date was increased unfertile tillers per plant and result in decrease fertile tiller numbers per plant, while late sowing date was produced low total tillers per plant that reason short duration of tillering (Table 4).

In cultivars, there was significant difference on unfertile tiller numbers per plant and fertile tiller numbers per plant, grain numbers per plant, spikelet numbers per plant and fertile spikelets per spike ($P \leq 0.01$). In all traits of upper, Sahar and Line M_{12} cultivars had the highest and lowest with 1.23, 0.99 numbers, 4.39, 4.11 numbers, 89.91,

Table 3: Mean squares of sowing dates and CCC application on yield components of barley cultivars

S.O.V.	DF	Unfertile tiller numbers per plant	Fertile tiller numbers per plant	Grain numbers per plant	Spikelet numbers per plant	Fertile spikelets per spike
Replication	2	3.77^{*}	8.26^{**}	1717.33^{*}	2256.07^{*}	310.55^{*}
Sowing dates (A)	2	1.04^{ns}	3.97^{**}	15413.93^{**}	11294.46^{**}	2257.23^{**}
E (a)	4	0.51	0.15	168.52	128.13	25.33
Cultivars (B)	2	0.34^{**}	0.46^{**}	5038.70^{**}	4024.80^{**}	737.19^{**}
A×B	4	0.14^{*}	0.08^{ns}	124.20^{*}	246.27^{**}	118.14^{**}
CCC (C)	1	0.48^{**}	4.05^{**}	5947.20^{**}	3986.96^{**}	1128.97^{**}
A×C	2	0.01^{ns}	0.4^{ns}	140.91^{*}	115.24^{*}	22.10^{ns}
B×C	2	0.01^{ns}	0.09^{ns}	107.13^{*}	15.80^{ns}	49.19^{ns}
A×B×C	4	0.08^{ns}	0.91^{ns}	13.08^{ns}	14.32^{ns}	1.07^{ns}
E	30	0.06	0.12	42.07	26.29	38.68
C.V. (%)	-	21.48	8.35	8.97	5.09	9.03

*Significant at $P \leq 0.05$, ** Significant at $P \leq 0.01$, ns, non significant

Table 4: Mean comparison of sowing dates and CCC application on yield components of barley cultivars.

Treatments	Levels	Unfertile tiller numbers per plant	Fertile tiller numbers per plant	Grain numbers per plant	Spikelet numbers per plant	Fertile spikelets per spike
	7 Nov. (A1)	1.40^{a}	4.13^{b}	69.37^{b}	98.89^{b}	69.25^{b}
Sowing dates	26 Nov. (A2)	1.12^{a}	4.60^{a}	102.90^{a}	126.60^{a}	80.65^{a}
	11 Dec. (A3)	0.92^{a}	3.79^{b}	44.61^{c}	76.61^{c}	56.73^{c}
	Sahra (B1)	1.23^{a}	4.39^{a}	89.91^{a}	115.90^{a}	75.72^{a}
Cultivars	Productive(B2)	1.22^{a}	4.13^{b}	70.37^{b}	100.10^{b}	67.86^{b}
	Line M12 (B3)	0.99^{b}	4.11^{b}	56.62^{c}	86.06^{c}	63.04^{c}
CCC (Li./ha)	0	1.05^{b}	3.94^{b}	61.08^{b}	92.11^{b}	64.30^{b}
	2.8	1.24^{a}	4.41^{a}	82.79^{a}	109.30^{a}	73.44^{a}

Values within a column followed by same letter are not significantly different at $P \leq 0.05$.

Table 5: Mean squares of sowing dates and CCC application on yield and yield components of barley cultivars

S.O.V.	DF	Biological yield	Straw yield	Grain yield	Spike numbers per plant
Replication	2	750601.85^{ns}	384212.96^{ns}	69490.74^{ns}	1.10^{ns}
Sowing dates (A)	2	179074.07^{ns}	535046.30**	510324.07**	5.62**
E (a)	4	178935.19	97615.74	25046.30	0.23
Cultivars (B)	2	5493101.85**	599212.96**	2502824.07**	1.84**
A×B	4	145185.19*	37407.41^{ns}	65046.30**	0.04^{ns}
CCC (C)	1	350416.67*	2962.96^{ns}	288935.19**	1.60**
A×C	2	6666.67^{ns}	3657.41^{ns}	879.63^{ns}	0.06*
B×C	2	2638.89^{ns}	1712.96^{ns}	601.85^{ns}	0.03^{ns}
A×B×C	4	24305.56^{ns}	12407.41^{ns}	2546.30^{ns}	0.01^{ns}
E	30	63990.74	27425.93	9083.33	0.02
C.V. (%)	-	3.85	4.34	3.46	4.16

* Significant at P ≤ 0.05, ** Significant at P ≤ 0.01, ns, non significant

56.62 grain, 115.90, 86.06 numbers and 75.72, 63.04%, respectively (Table 4). Therefore, increase spikelet numbers per plant result in high grain numbers per plant although fertile spikelets per spike also increased. Sowing dates × cultivars interaction was significant in unfertile tiller numbers per plant and grain number per plant(P≤0.05) and spikelet number per plant and fertile spikelet per spike (P≤0.01) (Table 3). Therefore, interaction of $A_2 \times B_1$ and $A_3 \times B_3$ had the highest and lowest fertile spikelets per spike, spikelet numbers per plant and grain numbers per plant with 85.27, 46.98%, 146.30, 68.67 spikelet and 125.40, 33.28 grain, respectively (Table 7).

There was significant difference on unfertile tiller numbers per plant and fertile tiller numbers per plant, grain numbers per plant, spikelet numbers per plant and fertile spikelets per spike in CCC application (P≤0.01). Application CCC increased all traits, but increase unfertile tiller numbers per plant with 1.05 to 1.24 tillers relation to control was exception that there was negative effect and may be increase total tiller duo to producing high unfertile tiller numbers per plant (Table 4). Ma and Smith, (1991) [9] showed that increases in spikes m^{-2} were accompanied by decreases in 1000-grain weight and/or grains per spike, which offset or more than offset potential benefits from increased spikes m^{-2}.

In grain numbers per plant, sowing dates × CCC interaction and cultivars × CCC interaction were significant (P≤0.05) and sowing dates × CCC interaction on spikelet numbers per plant was significant (P≤0.05) (Table 3). Therefore, reaction of CCC application with sowing dates and cultivars had relationship and at time of CCC application will establish spikelet numbers as a factor affects grain numbers per plant in grain filling period.

Yield: There was significant difference in grain and straw yields and spike numbers per plant in sowing dates, cultivars (P≤0.01) (Table 5). In sowing dates, the highest and lowest of grain yield and spike numbers per plant were obtained by A_2 and A_3 with 293.10 g m^{-2}, 4.03 spike/plant and 259.40 g m^{-2}, 2.92 spike/plant, respectively (Table 6). Also in Sudan, Lazim (1973) showed that sowing of barley at mid Nov. had resulted in the highest yield. In cultivars, the highest and lowest grain yield and spike numbers per plant were obtained by Sahar and Line M_{12} with 316.90 g m^{-2}, 3.81 spike/plant and 244.40 g m^{-2}, 3.17 spike/plant, respectively (Table 6). Ma and Smith, (1991) [4] found the results varied between among cultivars. The mixtures of CCC + ethephon or ethephon alone, produced significant increases in 88. Ethephon and ethephon containing mixtures reduced the yields of *Joly* and *Leger* in 1988. But, Ma and Smith, (1991) [4] showed that, in both years, CCC had no effect on spikes m^{-2} for all cultivars. In sowing dates, the highest of straw yields was A_3 with 401.40 g m^{-2} and lowest A_1 and A_1 with 371.40 and 371.70 g m^{-2}, respectively. In cultivars, the highest and loweststraw yield was obtained by Sahar and Line M_{12} with 402.50 g m^{-2} and 369.70 g m^{-2}, respectively (Table 6). There was significant difference in grain and spike numbers per plant by application of CCC (P≤0.01) (Table 5). Application of CCC had the greatest grain yield and spike numbers per plant with 283.00 g m^{-2} and 3.66 spike/plant, respectively (Table 6). In grain yield sowing dates × cultivars interaction (P≤0.01) and in spike numbers per plant sowing dates × CCC interaction were significant (P≤0.05) (Table 5). There was positive correlation between grain yield with fertile tiller numbers and spike numbers (0.43** and 0.66**). There was significant difference in biological yield on cultivars (P≤0.01), CCC application and interaction sowing dates × cultivars (P≤0.05) (Table 5). So, the highest of biological yield was Sahar with 719.40 g m^{-2} and the lowest was Line M_{12} with 614.20 g m^{-2}. Therefore, results varied among cultivars. Biological yield of application of CCC had the higher than control with 649.10

Table 6: Mean comparison of sowing dates and CCC application on yield and yield components of barley cultivars

Treatments	Levels	Biological yield g m^{-2}	Straw yield g m^{-2}	Grain yield g m^{-2}	Spike numbers per plant
	7 Nov. (A1)	645.80^{a}	371.40^{b}	274.40^{b}	3.50^{b}
Sowing dates	26 Nov. (A2)	664.70^{a}	371.70^{b}	293.10^{a}	4.03^{a}
	11 Dec. (A3)	660.80^{a}	401.40^{a}	259.40^{c}	2.92^{c}
	Sahra (B1)	719.40^{a}	402.50^{a}	316.90^{a}	3.81^{a}
Cultivars	Productive(B2)	637.80^{b}	372.20^{b}	265.60^{b}	3.47^{b}
	Line M12 (B3)	614.20^{c}	369.70^{b}	244.40^{c}	3.17^{c}
CCC (Li ha^{-1})	0	649.10^{b}	380.74^{a}	268.30^{b}	3.31^{b}
	2.8	665.20^{a}	382.22^{a}	283.00^{a}	3.66^{a}

Values within a column followed by same letter are not significantly different at $P \leq 0.05$

Table 7: Interaction yield and yield components of barley cultivars in sowing dates and CCC application

Interaction	Fertile spikelets per spike %	Spikelet numbers per plant	Grain numbers per plant	Biological yield g m^{-2}	Grain yield g m^{-2}
A_1B_1	74.33^{bcd}	116.30^{c}	86.98^{c}	715.00^{ab}	315.00^{b}
A_1B_2	70.99^{cd}	96.33^{e}	68.77^{d}	623.30^{cde}	261.70^{d}
A_1B_3	62.43^{ef}	84.00^{f}	52.35^{e}	599.20^{e}	246.70^{e}
A_2B_1	85.27^{a}	146.30^{a}	125.40^{a}	740.00^{a}	345.80^{a}
A_2B_2	76.97^{bc}	128.00^{b}	99.13^{b}	642.50^{cd}	281.70^{c}
A_2B_3	79.70^{ab}	105.50^{d}	84.22^{c}	611.70^{de}	251.70^{de}
A_3B_1	67.56^{de}	85.17^{f}	57.35^{e}	703.30^{b}	290.00^{c}
A_3B_2	55.64^{f}	76.00^{g}	43.20^{f}	647.50^{c}	253.30^{de}
A_3B_3	46.98^{g}	68.67^{h}	33.28^{g}	631.70^{cd}	235.00^{f}

Values within a column followed by same letter are not significantly different at $P \leq 0.05$.

Table 8: Correlation between yield and yield components of barley cultivars in sowing dates and CCC application

Correlation	1	2	3	4	5	6	7	8	9
1. Fertile tiller numbers	1								
2. Unfertile tiller numbers	0.21^{*}	1							
3. Spike numbers	0.75^{**}	0.13	1						
4. Spikelet numbers	0.72^{**}	0.20	0.95^{**}	1					
5. Fertile spikelets percentage	0.47^{**}	0.08	0.75^{**}	0.71^{**}	1				
6. Grain numbers	0.63^{**}	0.25	0.91^{**}	0.96^{**}	0.74^{**}	1			
7. Grain yield	0.43^{**}	0.05	0.66^{**}	0.69^{**}	0.60^{**}	0.69^{**}	1		
8. Straw yield	-0.20	-0.23^{*}	-0.17	-0.18	-0.09	-0.17	0.44^{**}	1	
9. Biological yield	0.17	-0.04	0.33^{*}	0.35^{**}	0.32^{*}	0.38^{**}	0.81^{**}	0.71^{**}	1

and 665.20 g m^{-2}, respectively (Table 6). Sowing dates × cultivars interaction of biological yield was significant ($P \leq 0.05$) (Table 5). There was high positive correlation between biological yield and straw yield with grain yield (0.81**, 0.71**, respectively.

CONCLUSION

According to these results with changes in planting date grain yield and yield components of the barely was different. Reactions cultivars to change planting date was the same. Sahra cultivar in all three planting date was the best. CCC consumption leads to increased biological yield, fertile tiller and number of spikelet and grain in the barely as a cumulative factor in increasing grain yield emerged. General, CCC consumption product plant biomass and yield increase. Late planting date due to high vegetative growth and low reproductive growth period the production of straw yield was high. While the early planting date due to high biological yield and thus inter competition such a low harvest index and grain yield were produced little. Due to the high positive correlation grain yield with panicle number, number spikelet in plants and grain per plant, an important component in the grain yield of barley were on the planting date and CCC consumption of these components increase will lead to improved yield.

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