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The effect of application time of cycocel hormone and plant density on yield and yield components of wheat (Chamran cultivar) in Ahvaz weather conditions

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Abstract

In order to study the effect of plant density and cycocel (CCC) on yield and yield components of wheat (Chamran cultivar), a split plot experiment in randomized complete block design with four replications was carried out in Shahid Salemi field in Ahvaz during 2011-2012 croping season. The treatments included three levels of plant density (400, 600, 800 plants/m^2) and application time of cycocel hormone including lack of cycocel foliar spray (C0), cycocel foliar spray at 4-leaf stage (C1), and cycocel foliar spray at the beginning of stem elongation (C3). The results showed that during the application of chlormequat chloride, number of spikes per square meter, 1000-grain weight and grain yield significantly increased as compared to control treatment, while the number of grains per spike decreased. With increasing density from 400 to 800 plants/m^2, the grain yield, number of spikes per square meter, number of grains per spike and 1000-grain weight decreased, While there was no significant difference between 400 and 600 plants/m^2. The highest grain yield was recorded at 400 plants/m^{2}and application of chlormequat chloride at 4-leaf stage and the lowest grain yield was obtained at 800 plants without application of chlormequat chloride.

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Introduction

Even though rice, among grains, makes the main food of the majority of people around the world particularly in Asia, wheat in terms of importance with regard to cultivation area and its annual production on global scale is of primary importance. Therefore grain production is highly important throughout the world and among grains wheat is the most valuable one in terms of nutrition and economy all around the world and is ranked higher than other grains (Khoda Bandeh, 2010).

Wheat is one of the most strategic and essential products of the country and according to economists the increase of wheat production can lead to independency and elimination of dependency on other countries because it has a principal role in supplying food for people. In order to increase crop production per area unit optimal breeding and farming operations are necessary and when these two methods are used together, they will be profitable. Among the most important factors of optimal crop farming is the application of proper density, so that if all conditions such as good cultivar, fertilizer, etc. are provided but the density is not appropriate the maximum product per area unit won't be achieved. Optimal spacing or planting pattern and density is one of the most important factors in achieving maximum yield and highest quality which is mandatory to be observed for all agricultural products and consequently, one the most principal issues in relation to planting crops is selecting the most appropriate plant density per area unit (Sarmadnia and Kouchaki, 2005).

Hackle and Baker (1989) stated that if grain yield is considered, there is an optimal plant density in which the maximum grain yield is achieved. If the plant density is low, the production potential has not been used appropriately and beyond the optimal density assimilates will be used for vegetative growth or respiration of plants instead of being used for grain production. Moreover, planting seeds in high density leads to lodging which results in the decrease of light penetration to lower part of the canopy and causes stem growth in the dark and its thinning (Imam and Nik Nejad, 2004; McGregor, 1981).

Different measures are taken to prevent or reduce stalk lodging in planting wheat such as delayed sowing, planting fewer seeds per hectare and utilizing appropriate amounts of nitrogen fertilizer. Great steps have been taken recently to solve lodging problem such as application of plant hormones like chlormequat chloride which is usually known as ccc and reforming dwarf and moderate wheat which is resistant to lodging (Noor Mohamadi *et al*, 2005).

Cycocel with chemical name of chlormequat chloride is a derivative of Choline which is produced through the reaction of Tri Methyl Amine and an aliphatic halide named 1, 2- Chloroethane. The produced material is in crystalline form and is soluble in water. Cycocel is used as a plant growth regulator. Chlormequat chloride or cycocel belongs to the group of Ammonium compounds and is one of the most frequently used plant growth moderators particularly in Europe and nowadays it is highly used to reduce lodging and to control vegetative growth of crops (especially grain cereals) (Imam and Moayed,2000; Imam and Karimi; 1996). Growth regulating effect of chlormequat chloride was first proved by Tolbert (1960) in a wide range of plants and the primary purpose of chlormequat chloride application in crops production was to prevent lodging. The results of subsequent researches showed that application of chlormequat chloride even in the absence of lodging phenomenon would lead to the increase of grain yield (Ma & Smith, 1992).

This hormone also has a positive effect on all yield components and will lead to the increase of fertile tillers in area unit and production of more grains in each spike. According to the conducted researches, chlormequat chloride can increase the wheat yield up to 40% (Rafiei and Shoaei, 2010).

Since the increase of density results in the increase of plant height and loading phenomenon which is one of the most important factors that restrict the wheat yield, chlormequat chloride was used in a wide area of wheat farms particularly in Europe in the late 1960s. Therefore, this research aims to investigate the reaction of wheat (Chamran cultivar) to three plant densities and cycocel hormone application in different periods of growth under farming conditions in Ahvaz.

Materials and methods

Field experiment

This experiment was carried out in research field of Shahid Salemi in Ahvaz at altitude 31°20´ north, longitude 48°40´ east and 22.5 m above the sea level in 2011-2012. The experiment site had clay loam soil with a pH of 7.8 and EC = 5 and nitrogen rate of 5.7 ppm. The experiment was carried out as split plot in the form of randomized complete block design with four replications. In this experiment cycocel hormone was used as the main factor consisting of three levels of C0, C1, C2 including lack of cycocel foliar spray, hormone foliar spray at 4-leaf stage and hormone foliar spray at the beginning of stem elongation respectively and plant density as the sub factor in three levels of D1, D2, D3 including 400, 600, 800 plants per square meter respectively. To carry out the experiment the land preparation operation was done including irrigation before plowing, plowing to a depth of 20 cm, disc operation to a depth of 15 cm and leveling. Half of nitrogen fertilizer based on 50 kg/ha from the urea source (46% of nitrogen) was calculated and was distributed in land as the base fertilizer before planting and along with the disc, and the second half of nitrogen was added as the beginning of stem elongation. Phosphorous from the source of phosphate di-ammonium (18% of nitrogen and 46% of P_2O_5) based on 80 kg/ha was calculated and was distributed in land before planting together with disc. After preparation the land was plotted based on the plan. Each plot size was 4.5 x 1.5 m2 and each plot contained 7 planting line as long as 4.5 m and each two lines were spaced as 20 cm. planting was done manually based on densities of 400, 600, and 800 plants/m2 on Nov, 28, 2011. Irrigation was done immediately after planting. The weeds were cut manually after the seeds germination and stalks' strengthening. The amount of applied cycocel was measured to be 1500 ppm and was sprayed to the crops at two stages (4-leaf stage and beginning of stem elongation). Final harvest was done when the grains were quite mature on May 4, 2012. For the final harvesting, three lines of each plot (lines 3, 4, 5) were used after eliminating the margins and the final harvest area for each plot was 1.5 m2. Then, grain yield and yield components (1000-grain weight, number of spikes/m2, and number of grains per spike) were measured.

Data analysis

The analysis of variance of data was done by means of SAS software and the means were compared via Duncan's multiple tests at 5% and 1% levels. In order to draw diagrams and curves, EXCEL software was used.

Results and discussion

Grain Yield

The ANOVA results showed that the effect of application time of cycocel hormone and plant density on grain yield was significant at 5% and 1% levels respectively and the interactive effect of cycocel hormone and plant density on grain yield was not significant (Table 1). The mean comparison results indicated that the highest rate of grain yield belonged to the treatment with hormone foliar spray at 4-leaf stage by 531.90 g/m2 and the lowest rate belonged to the treatment without hormone foliar spray by 463.05 g/m2 (Table 2). In this research, the use of chlormequat chloride increased the grain yield compared to the control treatment. By affecting the yield components and also decreasing the plant height, chlormequat chloride led to the increase of grain yield compared to the control.

By increasing the number and survival of tillers and leaf area, cycocel causes more photosynthesis and more assimilates are mobilized towards grains and lead to the increase of grain yield (Sharif *et al*, 2007). Moreover, the results of cycocel application by Sing *et al* (1972) have shown that the treatment with application of growth moderator, i.e. chlormequat chloride decreased the plants height 23% which resulted in a significant increase of grain yield. In addition, Imam *et al* (1996) reported that the grain yield of Ghods wheat increased 12% due to the consumption of cycocel.

Other researchers also stated that the increase of grain yield resulting from foliar spray of rapeseed plant with growth moderators was associated with the increase of the number of pods and the number of grains in pods and 1000-grain weight, based on the cultivar (Zhou, 1999).

Among different densities, the highest grain yield by the average of 650.73 belonged to density of 400 plants and the lowest grain yield by 435.30 belonged to the density of 800 plants per square meter; however, densities of 400 and 600 were not significantly different from each other (Table 2). As many researchers believe, by increasing density in wheat the yield increases to a certain degree and then it is stable and in higher densities it will decrease (Stougard and Xue, 2004; Gracia *et al*, 2003). Hackle and Baker (1989) stated that if grain yield is considered, there is an optimal plant density in which the maximum grain yield is achieved. If the plant density is low, the production potential has not been used appropriately and beyond the optimal density assimilates will be used for vegetative growth or respiration of plants rather than for grain production. According to the research conducted by Govil and Pandy (1995) as the plant density increased, the wheat grain yield increased to some extent and then decreased. That is, the grain yield reached its maximum in a point and then decreased due to different reasons such as competition or limitation of resources.

Table 1. The ANOVA results of the effects of different levels of cycocel application time and planting density on traits of grain yield, number of spikes/m2, number of grains per spike and the weight of 1000-grain in wheat (Chamran Cultivar).

Mean squares					
1000-grain weight	Number of grains/spike	Number of spikes/m2	Grain yield	df	S.O.V
4.30	5.53	14910.79	78.79.73	3	Block
21.92 **	34.44 *	17691.31 **	18154.48 *	2	Application time of cycocel hormone
1.36	6.48	846.87	3492.49	6	Error (a)
13.92 **	42.64 *	16912.81 **	48125.21 **	2	Density
1.48 ns	1.41 ns	1548.09 ns	2403.54 ns	4	Hormone application time x density
1.52	7.19	2985.18	5696.61	18	Error (b)
3.53	9.58	10.59	15.00		Coefficient of variations (CV %)
34.84	27.99	515.96	503.07		Traits mean

Ns, *, ** respectively indicate non-significant difference, and significant difference at 5% and 1% levels.

1000-grain Weight

The ANOVA results showed that the effect of application time of cycocel and plant density on weight of 1000-grain was significant at 1%level, but the interactive effect of cycocel and plant density on 1000-grain weight was not significant (Table 1). The highest rate of 1000-grain weight by 35.64 and 35.60 g respectively belonged to hormone foliar spray at the beginning of stem elongation and at 4-leaf stage and the lowest rate by 32.28 g belonged to the control treatment without hormone foliar spray (Table 2). In this research through the foliar spray of cycocel treatment, the number of grains per spike was fewer than the control treatment which itself could be a cause of the increase of 1000-grain weight via cycocel solution. Moreover, by reducing the vegetative growth, cycocel allocates more assimilates to grain filling and increase of 1000-grain weight.

Researchers stated that the weight of grain would increase due to the treatment with cycocel application and explained that it would be caused by the increase of target power before flowering stage (Waddington and Cartwright, 1988).

Table 2. The mean comparison of the separate effects of different levels of application time cycocel hormone and planting density on grain yield, number of spikes per square meter, number of grains per spike, and 1000-grain weight in wheat (Chamran cultivar).

Traits mean				
1000-grain weight (g)	Number of grains per spike	Number of spikes/m2	Grain yield (g/m2)	treatments
				Application time of cycocel hormone
33.28 b	29.50 a	471.67 b	463.05 b	C0
35.60 a	27.72 ab	539.85 a	531.90 a	C1
35.64 a	26.75 b	536.36 a	514.31 ab	C2
				density
35.09 a	29.03 a	554.62 a	560.73 a	D1
35.77 a	28.04 a	513.60 ab	513.23 a	D2
33.66 b	26.90 b	479.65 b	435.30 b	D3

The mean of treatments with similar letters are not significantly different from each other based on Duncan's multiple range tests at 5%.

Some other reporters have reported that the increase of 1000-grain weight is resulted from the increase of photosynthesis (Akinirinde, 2006; Alam *et al*, 2007). In measuring the mean comparison of plant density the highest rate of 1000-grain weight by 35.09 and 35.77 g respectively belonged to the densities of 400 and 600 plants/m2 and the lowest rate of 1000-grain weight by 33.66 g belonged to the density of 800 plants/m2 (Table 2). The results were consistent with the findings of Varga *et al* (2001).

Even though the weight of 1000-grain is a traits which is basically less affected by environmental conditions compared with other yield components, the increase of planting density has made less assimilated be allocated to grain filling due to the increase of inter and intra plants competitions and eventually the weight of 1000-grain will decrease (Joseph *et al*, 1985; Lafond, 1994).

The decrease of 1000-grain weight in high densities could result from the superiority of vegetative organs to reproductive organs in their completion (Gardner *et al*, 2007).

Number of Spikes per Square Meter

The ANOVA results showed that the effect of application time of cycocel hormone and plant density on the number of spikes/m2 was significant at 1% level, but the interactive effect of cycocel and plant density on the number of spikes/m2 was not significant (Table 1).

Among different times of cycocel foliar spray the highest number of spikes /m2 by 539.85 and 536.36 respectively belonged to hormone foliar spray at 4-leaf stage and the beginning of stem elongation and the lowest number of spikes/m2 by 471.67 belonged to the control treatment without hormone foliar spray

(Table 3). In this research the use of cycocel hormone increased the number of spikes /m2 compared with the control which is consistent with the findings of Sainio and Rajala(2001), Soleiman *et al.* (1994), Cox and Otis (1989). It has been reported by De *et al* (1982) and Ma and Smith (1992) that in wheat and barley cycocel has led to the increase of the number of spikes and eventually the increase of yield throgh the increase of fertile branches. Among different levels of density, the highest number of spikes/m2 by 554.62 belonged to the density of 400 plants/m2 and the lowest number of spikes/m2 by 479.65 belonged to the density of 800 plants/m2 (Table 2). In bread with, through the increase of plant density a larger percentage of tillers wont be able to produce spike (Vali and Holliday, 1971). Fuki *et al* (1990) and Dufin and Knight (1992) reported that reported that the increase of density led to the decrease of plant spikes and sub stems.

Number of Grains Per Spike

The ANOVA results showed that showed that the effect of different application times of cycocel hormone and plant density on the number of grains per spike was significant at 5% level, but the interactive effect of cycocel and plant density on the number of grains per spike was not significant (Table 1).

The mean comparison results showed that among different times of cycocel foliar spray, the highest number of grains per spike by 29.50 belonged to the treatment without hormone foliar spray (control) and the lowest number by 26.75 belonged to hormone foliar spray at the beginning of stem elongation (Table 3) which were consistent with the findings of Marshal and Ohm (1987). The reason of significant decrease of the number of grains per spike in cycocel treatment might be the increase of spikes in each plant. Plants with fewer numbers of spikes have more potential to keep grains. Armstrong and Nicole (1991) have reported reverse changes among yield components particularly the number of pods and the number of grains per pod in rapeseed due to cycocel treatment. Other researchers found that the increase of pods in rapeseed plant would lead to less distribution of carbohydrates to pods and thus the number of grains in each pod would decrease (Imam and Ilkaei, 2002; Mendham *et al*, 1981).

The mean comparison results of sowing density showed that the highest number of grains per spike by 29.03 belonged to the density of 400 plants/m2 and the lowest by 26.90 belonged to the density of 800 plants/m2, but there was not a significant difference between densities of 400 and 600 plants/m2 and both of them were placed in the same group (Table 2). Through the increase of plant density, the amount of light absorbed by each plant is relatively low while in fewer densities each plant receives more light. Moreover, in high densities, there is more serious competition between plants and each plant has access to less nutrition and moisture. These factors can lead to the decrease of the number of grains per spike in high densities which are consistent with the findings of Joseph (1985), Donaldson *et al.* (2001), Imam and Nik Nejad (2004).

Conclusion

The results of the research showed that the increase of density up to 800 plants caused the decrease of yield and yield components and the highest yield belonged to the density of 400 plants per square meter.

Application of cycocel hormone (ccc) led to the increase of yield components except the number of grains per spike.

In general, the highest rate of grain yield belonged to cycocel foliar spray at 4-leaf stage and density of 400 plants per square meter.

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