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Research Article

THE EFFECT OF APPLICATION TIME OF CYCOCEL HORMONE AND PLANT DENSITY ON GROWTH INDICES AND GRAIN YIELD OF WHEAT (CHAMRAAN CULTIVAR) IN AHVAZ WEATHER CONDITIONS

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ABSTRACT
In order to study the effect of planting density and cycocel hormone (CCC) on growth indices and grain yield of wheat (Chamran cultivar), a split plot experiment as randomized complete block design with four replications was carried out in Shahid Salemi field in Ahvaz in 2011-2012. The treatments included three levels of plant density (400, 600, 800 plants per square meter) and application time of cycocel hormone including lack of cycocel foliar spray (C_0), cycocel foliar spray at 4-leaf stage (C_1), and cycocel foliar spray at the beginning of stem elongation (C_3). The results showed that during the application of cycocel hormone physiological traits (dry matter accumulation, leaf area index, crop growth rate, and net assimilation rate) and also the grain yield increased significantly compared to the control treatment and the increase was maximized during the hormone foliar spray at 4-leaf stage. Moreover, due to the increase of density from 400 to 800 plants/m^2 growth indices and the grain yield decreased and the lowest rate of reduction belonged to the density of 400 plants/m^2.

Keywords**:** *Cycocel, Plant Density, Growth Indices, Grain Yield*

INTRODUCTION
Grain includes a group of crops (wheat, rice, corn, etc.) that the cultivated area of some of them is more than other crops in the world and the seeds of these crops which are their main product are used for making bread and feeding most people around the world. Moreover, grains are used for feeding animals and birds and their secondary products including the stalk and straw have a variety of uses. 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 (Sarmadnia and Kouchaki, 2005). 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 of the most principal issues in relation to planting crops is selecting the most appropriate plant density per area unit (Sarmadnia and Kouchaki, 2005). Most of the research on the effect of density on the crop yield shows that the yield increases within the range of medium densities and then it remains constant and only at very high densities it will decrease significantly (Gracias *et al.,* 2003; Stougard and Xue, 2004, Gubrak *et al.,* 2000). Very high density of plants causes the increase of shading within the vegetation and affects the grain yield and yield components through limiting the rate of light that the plants will receive (Shummay and cottern, 1989). Moreover, lack of adequate access of plant to the resources such as light, water, nutrients and right temperature might have a decreasing effect on growth indices of plant (Hunt, 1982). On the contrary, access to adequate nutrients enhances such indices (Khalifa, 1973). Increasing the plant density to improve the grain yield sometimes causes plant lodging and reduces photosynthesis efficiency and finally decreases the grain yield. If lodging occurs when the plant is active metabolically it will be followed by the direct reduction of grain yield (FAO, 1999). Improving the race in order to produce short foot cultivars, applying proper management methods to maximize light absorption and to reduce damage by pests and diseases, and using substances which slow down the growth are some important strategies that

have been suggested to reduce lodging (Hey and Walker, 1994; Kimber and McGregor, 1999, Child *et al*., 1989).

The most common and best-known group of plant growth retardants is substances that prevent gibberellins biosynthesis quoted from (Mohaghegh and Emam, 2007). In this regard, cycocel hormone nowadays has many applications in business. The effect of cycocel on different plants and various cultivars of one species are different and plant species show different reactions in response to the mentioned substance (Harper *et al.*, 1975). Chlormequat chloride (CCC) is a derivative of Chlorine which is produced through the reaction of Tri Methyl Amine and an aliphatic halide named 1, 2- Di-Chloromethane. 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 Oniome compounds and is one of the most frequently used plant growth moderators (Emam and Moaied, 2000). 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). Therefore, this research aims to investigate the effect of three plant densities and cycocel hormone application in different periods of growth on the physiological traits and grain yield of wheat (Chamran cultivar) under farming conditions in Ahvaz.

MATERIALS AND METHODS

Experimental Location

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 m^2 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/m^2 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 m^2. The grain yield and physiological traits (dry matter accumulation, leaf area index, crop growth rate, and net assimilation rate) were measured.

RESULTS AND DISCUSSION

Total Dry Matter Weight

Diagram (1) shows the changes trend of total dry matter at different levels of cycocel application time. The results showed that the rate of dry matter since 45 days after planting increased with a relatively mild steep and after reaching the maximum rate (120 days after planting) it remained constant. In this period, total dry matter didn't change significantly during the hormone foliar spray at 4-leaf stage and stem elongation stage. Dry matter production increased since the early days in the treatment with cycocel compared to the control treatment and this trend continued to the end of growth season, so that the highest rate of dry matter belonged to the treatment with hormone foliar spray at 4-leaf stage and the beginning of stem elongation and the lowest rate belonged to the treatment without cycocel foliar spray. At the beginning of growth period, dry matter increases a little and total dry matter was only made up of the lead dry matter, so that the total dry weight of plant in this stage included a low percentage of total dry matter at maturity stage. According to the authors' observations, the use of chlormequat chloride since the early days during the growth period improved the light penetration into the plant community by changing the leaves angle and thus increased the photosynthesis rate and more dry matter was produced. Leaves angle changes and plant shading structure along with the consumption of growth regulators in wheat and barley farms have been reported by other researchers (Humphries, 1968; Naylor *et al.*, 1987).

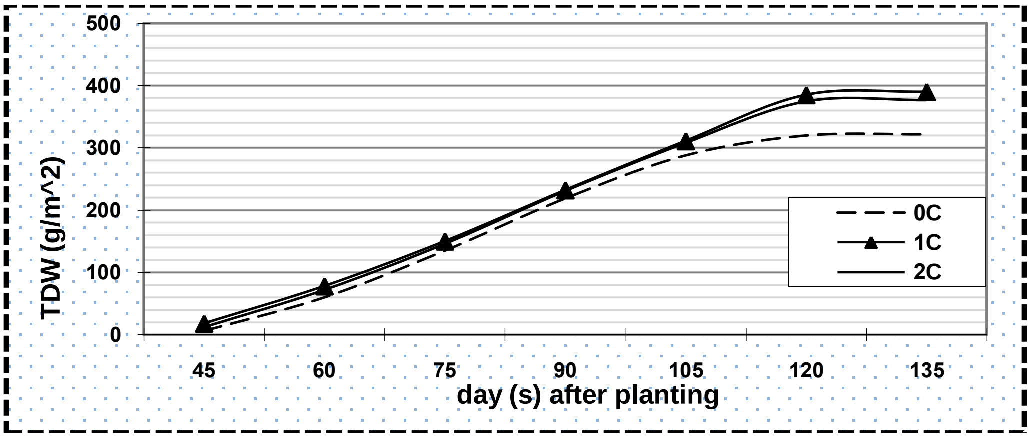

Diagram 1: Changes trend of total dry matter at different levels of cycocel application time

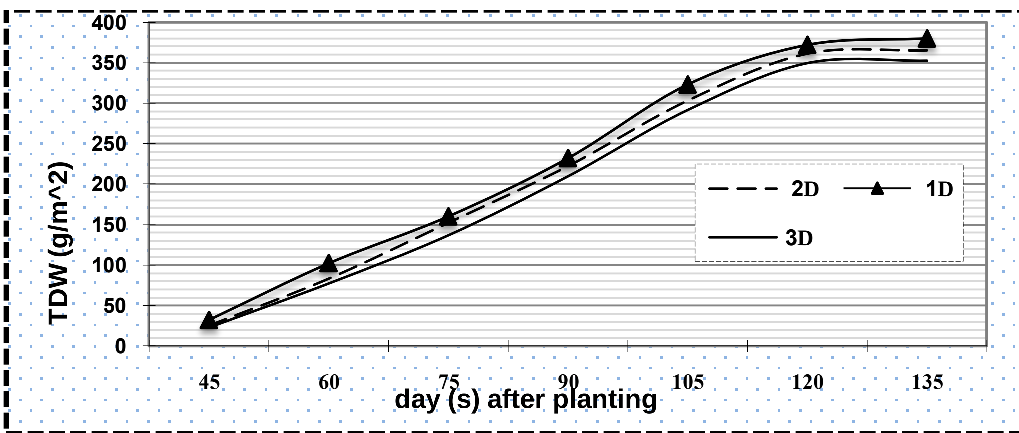

Diagram 2: Changes trend of total dry matter at different levels of planting density

Investigating the effect of different levels of density on the changes trend of total dry matter in diagram (2) showed that since 45 days after planting the dry weight had an increasing trend and after reaching the maximum amount (120 days after planting) had a constant trend. The highest rate of dry matter accumulation belonged to the density of 400 plants/m^2 and the lowest rate belonged to the density of 800 plants/m^2. This could be due to low competition between species, sufficient space for further growth of plant and production of further leaves in low densities. The results are consistent with the findings of stone *et al.*, (1998) and Major *et al.*, (1978).

Shirani Rad *et al.*, (1996) did a research on canola in three densities (40, 80, 120 plants/m^2) and reported that the highest and the lowest rate of total dry weight belonged to the densities of 40 and 80 plants/m^2, respectively.The conducted studies on the effect of density on dry matter yield showed that dry matter yield increased as the density increased up to a stable constant level and only in very high densities a significant decrease of dry matter production was observed (Hey and Robert, 1989; Donald, 1963).

Leaf Area Index (LAI)

Changes trend of leaf area index at different levels of cycocel application time in Diagram (3) showed that since 45 to 60 days after planting no difference was observed in leaf area index at different levels of cycocel application time. At this stage, the leaf area index had an increasing trend until about 90 days after planting and after reaching a maximum amount (90 days after planting) it decreased with a relatively sharp steep and then approached zero 135 days after planting. The highest leaf area index belonged to the treatment with hormone foliar spray at 4-leaf stage and the lowest leaf area index belonged to the treatment without hormone foliar spray. During cycocel foliar spraying, the leaf area index increased which could be due to the increase of number of tillers and leaves. Growth retardants cause the increase of leaf area index through decreasing the growth speed and delaying the maturity (Sliman and Mostafa, 1994).

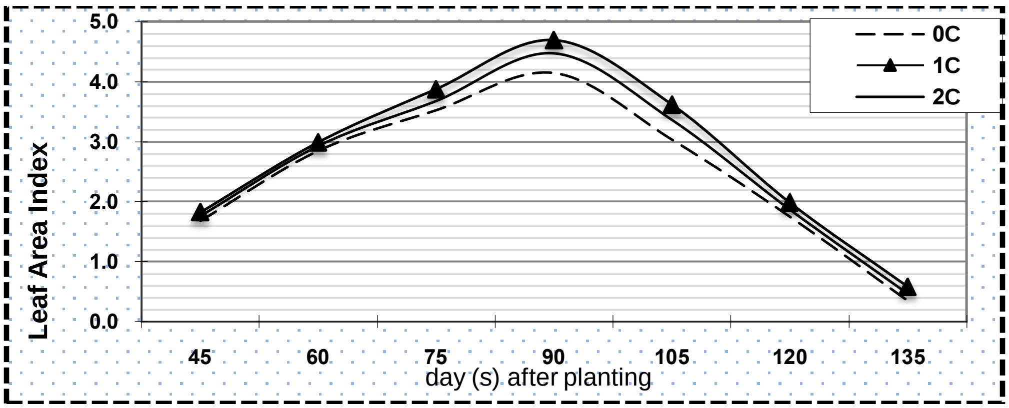

Diagram 3: Changes trend of leaf area index at different levels of cycocel application time

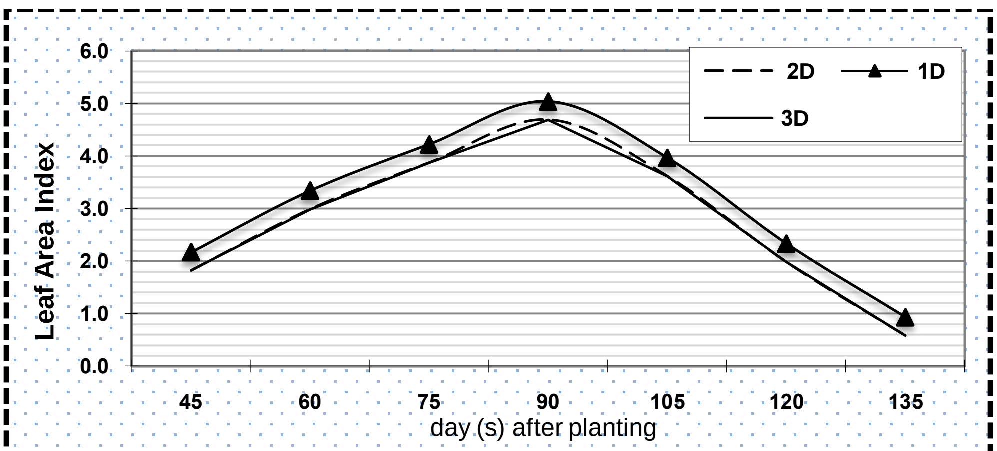

Diagram 4: Changes trend of leaf area index at different levels of planting density

Investigating the effect of different levels of density on leaf area index (Diagram 4) showed that at the beginning of growth stage the highest leaf area index belonged to the density of 400 plants and the densities of 600 and 800 plants/m^2 were not significantly different in terms of leaf area index since 45 to 75 days after planting. Leaf area index at different levels of density was maximized 90 days after planting and then it had a decreasing trend and even then the densities of 600 and 800 plants were not significantly different and the reduction was minimized at the end of growth period. The decrease of leaf area index at the end of growth period could be due to the aging and loss of the leaves and consequently the decrease of nutrients and low penetration of light into the canopy (Javadi *et al.*, 2006). The highest rate of leaf area index belonged to the density of400 plants/m^2 and the lowest rate belonged to the density of 800 plants/m^2. Higher leaf area index in 400-plant density is due to the proper vegetation that is created by the plants that have made better use of environmental factors and have produced more sub branches and leaves. The maximum rate of leaf area index is more at low density even though it reaches the peak later (Austin *et al.*, 1997).

Crop Growth Rate (CGR)

Diagram (5) shows the crop growth rate since 45 to 135 days after planting. According to the table, the crop growth rate had an increasing trend with a mild steep since 45 to about 90 days after planting and then it was maximized at different levels of cycocel application time 90 days after planting. Afterwards, as the plant age increased the crop growth rate had a decreasing trend and 135 days after planting it was about 2 g/m^2 per day. In this diagram, the highest crop growth rate belonged to the treatment with hormone foliar spray at 4-leaf stage and the lowest crop growth rate belonged to the treatment without hormone foliar spray. The increase of crop growth rate during the hormone foliar spraying at 4-leaf stage could be due to the gradual increase of light absorption concurrent with the increase of leaf area index and consequently the increasing rate of dry matter accumulation. The results were consistent with the findings of Traore *et al.*, (2003). Child *et al.*, (1988), did an experiment and reported that the crop growth rate in cycocel treatment was more than the control treatment. Investigating the effect of different levels of density on crop growth rate (Diagram 6) showed that since 45 to 90 days after planting, the crop growth rate had an increasing trend with a mild steep and 90 days after planting the crop growth rate at different levels of density was maximized and then it had a decreasing trend and 135 days after planting it was minimized (as the time passed and the leaf area increased and the leaves began to shade the crop growth rate began to decrease). At different levels of density, the highest crop growth rate belonged to the density of 400 plants/m^2 and the lowest crop growth rate belonged to the density of 800 plants/m^2. The results were consistent with the findings of Farhangi (1996). Some researchers believe that there is a direct relationship between CGR and the photosynthetic surface, so that in desired densities the distribution of plants and leaf area per area unit is more uniform and the leaves find better opportunity for the light absorption and photosynthesis and thus CGR will increase (Sildlauskas and Bernotas, 2003). Pandi *et al.*, (2000) reported that planting density is an important environmental factor affecting CGR. The increase of planting density leads to the increase of plants competition to absorb nutrients and ultimately the lack of nutrients leads to the decrease of CGR.

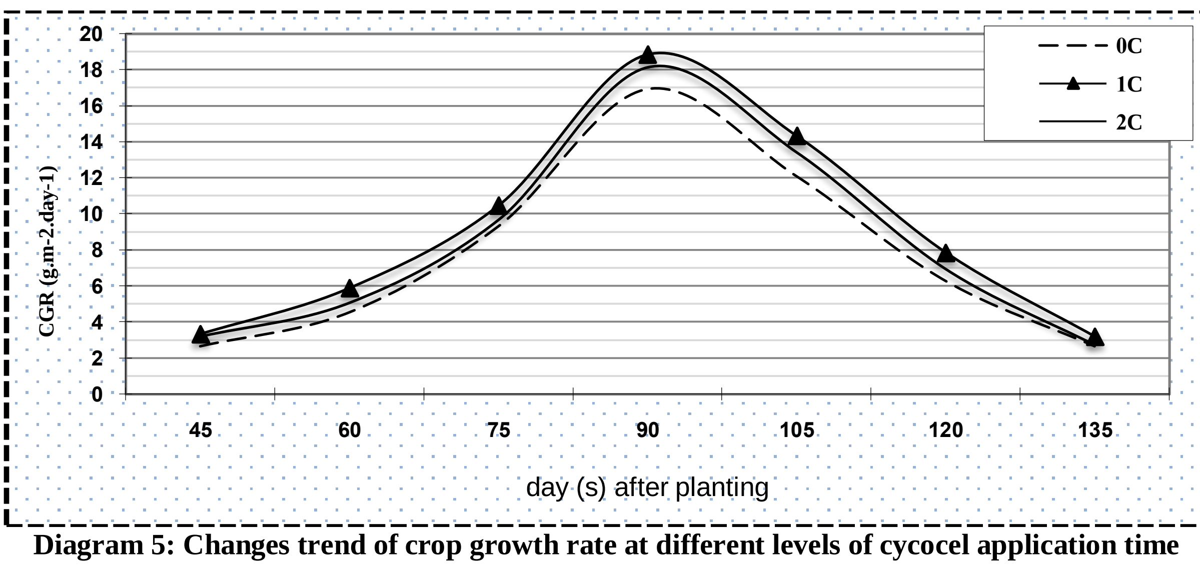

Diagram 5: Changes trend of crop growth rate at different levels of cycocel application time

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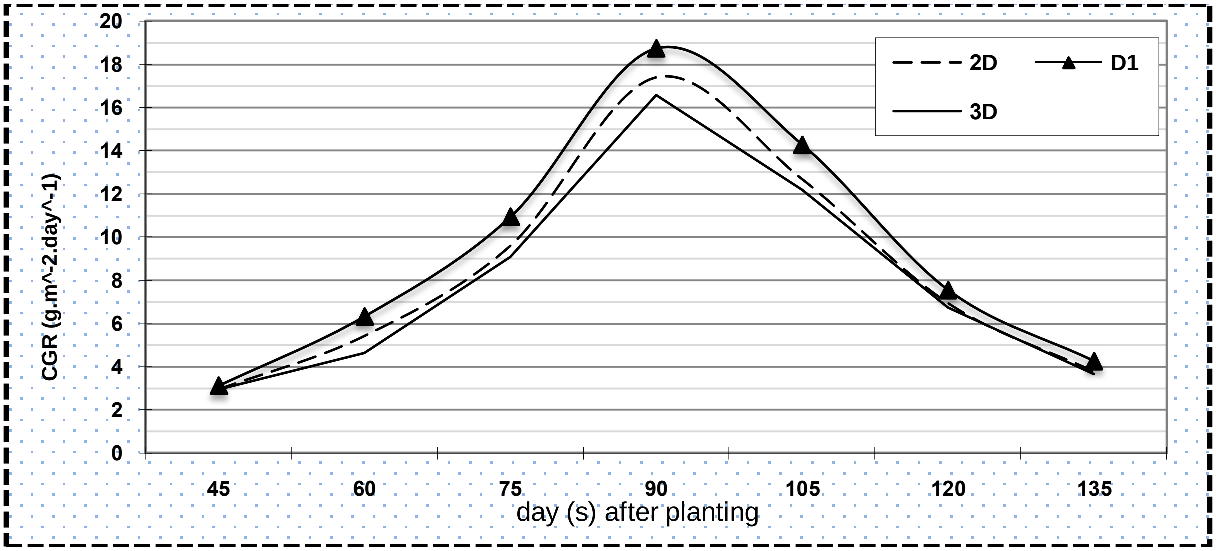

Diagram 6: Changes trend of crop growth rate at different levels of planting density

Net Assimilation Rate (NAR)

The results of Diagram (7) showed that at different levels of cycocel application time, the net assimilation rate was maximized 45 days after planting due to lack of shading and decrease of leaves respiration and then due to more shading by plants and more respiration per plant the NAR reduced and began its decreasing trend and at the end of growth season and with the loss of leaves and the decrease of leaf area it approached zero. The highest net assimilation rate belonged to the treatment with hormone foliar spray at 4-leaf stage and the lowest rate belonged to the treatment without hormone foliar spray. The increase of NAR at 4-leaf stage could be due to the increase of leaf area index and absorption of more light and production of more assimilates. The results were consistent with the findings of Javadi *et al.*, (2006). Changes trend of net assimilation rate at different levels of density in Diagram (8) showed that at different density levels the NAR increased at the beginning of growth season and then it had a linear decreasing trend and reached about zero 135 days after planting. Moreover, the highest net assimilation rate belonged to the treatment with 400 plants and the lowest rate belonged to the treatment with 800 plants /m^2. In general, the net assimilation rate is affected by the amount of photosynthetic radiation, uniform distribution of light within the leaves surfaces, and the plant respiration (Gardner *et al.*, 1993).

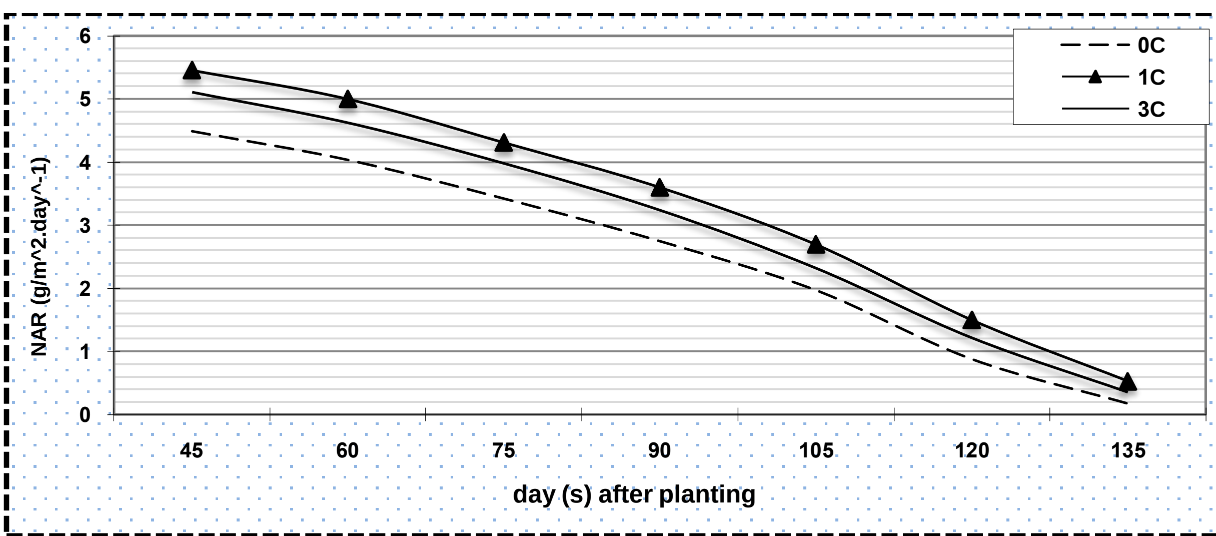

Diagram 7: Changes trend of net assimilation rate at different levels of cycocel application time

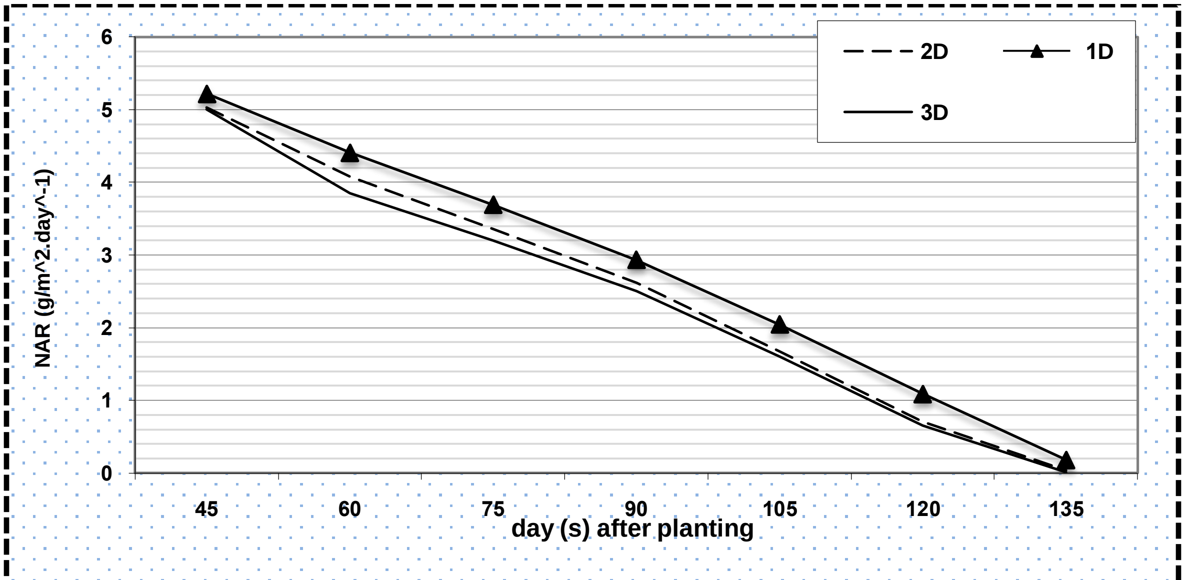

Diagram 8: Changes trend of net assimilation rate at different levels of planting density

The results of the research conducted by different researchers such as Cox (1997) and Suieska (1990) indicate that as the density increases the net assimilation rate decreases due to the increase of leaf area index and leaves' shading on each other.

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/m^2 and the lowest rate belonged to the treatment without hormone foliar spray by 463.05 g/m^2 (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, Emam *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 grain yield of wheat (Chamran cultivar) at different levels of cycocel hormone application time and planting density

Grain yield	df	S.O.V
78.79.73	3	R
18154.48 *	2	C
3492.49	6	Ea
48125.21 **	2	D
2403.54 ns	4	C×D
5696.61	18	Eb
15.00	(CV %)	
503.07	Traits mean	

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

Table 2: Mean comparison of the simple effect of different levels of cycocel application time and planting date on the grain yield of wheat (Chamran cultivar)

Grain yield (g/m^2)	Cycocel application time
463.05 b	C0
531.90 a	C1
514.31 ab	C2
	Density
560.73 a	D1
513.23 a	D2
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%

Conclusion

The results of the research showed that cycocel hormone foliar spray increased the growth indices compared to the control treatment. Moreover, the highest rate of growth indices belonged to the treatment with density of 400 plants /m^2. 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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