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Effects of Nitrogen Fertilization and Plant Growth Regulators (PGRs) on Yield of Wheat (*Triticum aestivum* L.) cv. Shiraz

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ABSTRACT

Plant growth regulators (PGRs) are widely used for lodging control in winter wheat (*Triticum aestivum* L.) grown at high N rates. Although the introduction of semi-dwarf wheat cultivars had largely solved the problem of lodging, evidence was already accumulating that the timely application of a growth retardant such as chlormequat (CCC) or ethephon could increase the grain yield of wheat, by the alteration of dry matter partitioning independently of any control of lodging. A field experiment was conducted the during 2004-5 growing season at the experimental farm of the College of Agriculture, Shiraz University (Shiraz, Iran,) located at Badjgah. The design of the experiment was a randomized complete block with treatments arranged as split plot with four replicates. Nitrogen levels (0, 100 and 200 kg ha^{-1}) were the main plots. The N was applied as Urea (46% N), half at the time of stem elongation and the other half at onset of flowering. The PGR treatments included CCC at 2.20 kg ha^{-1} applied at Zadoks growth stage (ZGS) 25, ethephon at 0.28 kg ha^{-1} at Zadoks growth stage (ZGS) 39, and controls (without any PGR) were assigned to sub-plots. The results showed that both PGR treatments reduced the plant height and this reduction played an important role in the increase of the grain yield in wheat, via the alteration of dry matter partitioning into the spikes. However, CCC at 2.20 kg ha^{-1} applied at ZGS 25 increased the grain yield (8.9 t/ha) significantly, compared to the ethephon (8.2 t ha^{-1}) and control (7.2 t ha^{-1}) treatments; the highest grain (8.9 t ha^{-1}) yield was obtained at 200 kg ha^{-1} N and 2.20 kg ha^{-1} CCC application. The beneficial interactive effects of PGRs and nitrogen rates on winter wheat yield are worthy of further exploration.

Keywords: CCC, Ethephon, Nitrogen, Wheat, Yield , Yield components.

INTRODUCTION

Wheat is the leading cereal grain produced, consumed and traded in the world today (Oleson, 1994). Hence, interest in maximizing winter wheat (*Triticum aestivum* L.) yields has led to the development of intensive cereal management practices.

These practices integrate the management of seeding dates and rates, row spacing, soil fertility, diseases, insects, and lodging to maximize the grain yield (Wiersma *et al.*, 1986). Efficient nitrogen (N) fertilization is crucial for economic wheat production and the protection of ground and surface waters (Alley *et al.*, 1999). Nitrogen fertilizer rate and timing are the major tools available after planting for manipulating wheat growth and development to produce a greater grain yield per unit area (Simons, 1982; Alley *et al.*, 1999).

Part of such intensive management systems is to increase N fertilizer rates and control lodging with PGRs ultimately to increase grain yields (Knapp and Harms, 1988; Van Sanford *et al.*, 1989; Tripathi, *et al.*, 2003). Plant growth regulators (PGRs) are widely used in winter wheat (*Triticum aestivum* L.) grown at high N rates (Van Sanford *et al.*, 1989). According to the lit-

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erature, there are several phases during the growth cycle where PGRs could be applied to modify plant growth and development. For example, by applying CCC at the beginning of stem elongation and the other PGRs at later stages, prior to heading, cereal straw could be shortened (Rajala and Peltonen-Sainio, 2001). 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 (Pinthus and Rudich, 1967; Kust, 1986; Wiersma *et al.*, 1986; Turk and Tawaha, 2002). Results of several field experiments showed that in winter wheat the number of spikes per unit area generally increases as the N rate increases, while mean kernel weight usually declines (Batey and Reynish, 1976; Knapp and Harms, 1988; Alley *et al.*, 1999). The grain yield increases from CCC treatment have been attributed to an increase in number of spikes/m^2 (Karchi, 1969; Knapp and Harms, 1988), whereas the ethephon effects on number of spikes per unit area has been reported to be variable (de Wilde, 1971; Brown and Earley, 1973).

The objectives of this research were to investigate the effects of N fertilization and PGR effects on yield and the yield components of wheat cv. Shiraz under the agro-climatic conditions of southern Iran.

MATERIALS AND METHODS

The field experiment was conducted during the 2004-5 growing season at the experimental farm of the College of Agriculture, Shiraz University (Shiraz, Iran,) located at Badjgah (29° 50´ N and 52° 46´ E; elevation 1,810 m above mean sea level) on a clay soil. Precipitation was 243 mm during the growing season. Some physico-chemical properties of the soil (fine, mixed, mesic, calcixerollic and xerochrepts) were as follows: pH= 7.6, total organic carbon (%) = 1.17, total nitrogen (%)= 0.114, EC (dS m^{-1}) = 0.402, potassium (mg kg^{-1})= 590, phosphorus (mg kg^{-1})= 26. The cultivar Shiraz with a 75-80 cm stem height was chosen as a common winter wheat in Shiraz area. The seeds were hand-sown in plots 3 m wide and 4 m long that were seeded at the rate of 250 plants/m^2 in mid-November. Uniformity of sowing depth was achieved by using a hand dibbler to make holes of 3-5 cm deep and the spaces between the two rows were 20 cm in all plots.

The design of the experiment was a randomized complete block with treatments arranged as split plot with four replicates. Nitrogen levels (0, 100 and 200 kg ha^{-1}) were the main plots. The N was applied as Urea (46% N), half at the time of stem elongation and the other half at onset of flowering. The PGR foliar treatments included CCC at 2.20 kg ha^{-1} sprayed over the foliage at growth stage (ZGS) 25, (Zadoks *et al.*, 1974) ethephon at 0.28 kg ha^{-1} sprayed over the foliage at growth stage (ZGS) 39, and the controls (without any PGR) were assigned to sub-plots. The measured variables included grain yield (t ha^{-1}), spike m^{-2}, grains plant^{-1}, plant height (cm), spike length (the main shoot spike, cm), LAI (the leaf area was determined with a Leaf Area meter delta T Device model) and dry matter produced (g plant^{-1}). Within each plot, an area 1m×1m (with guard rows) was marked and left undisturbed for harvesting at crop maturity. Dry weights were recorded after the plant material had been oven-dried at 70ºC for 48 hours.

The data collected were subjected to analysis of variance using MSTATC software and using the SAS statistical technique. The least significant difference (LSD) test was used for the mean comparisons.

RESULTS AND DISCUSSION

Effects of PGRs and Nitrogen on Vegetative Growth

Both PGRs (CCC and ethephon) applied at growth stages (ZGS) 25 and 39 significantly decreased the plant height, compared with

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the control (Table 1). Similar results have been observed by Dahnous *et al.* (1982) and Humphries (1968). Our results also showed that CCC and ethephon produced the same plant height reduction, without significant differences. This finding was in agreement with the results of Nafziger *et al.* (1986) and Knapp and Harms (1988). Reductions in plant height as a consequence of both growth regulators were associated with reduced elongation of the internodes. The uppermost internodes and peduncle, in particular, were shortened (Data not shown). Rajala and Peltonen-Sainio (2001) also reported similar findings.

The PGR treated (CCC and ethephon) plants had higher leaf area index and greater dry matter accumulation during anthesis (Table 1). Increased dry matter accumulation and leaf area indices at anthesis have been correlated with increased grain yield. In fact the increase in source size (i.e. leaf area of the treated plants) or photosynthesis rate with the CCC and ethephon treatments might be an alternative explanation for the yield enhancement from both PGR applications. Similar attributions have been made by others such as Van Sanford *et al.* (1989), Ma and Smith (1991 and 1992) and Emam *et al.* (1997). Researchers have also demonstrated that the application of growth regulators (e.g. CCC at growth stage (ZGS) 32 and ethephon at growth stage (ZGS) 39) on small grain cereals could increase leaf area indices and dry matter accumulation compared with the control (Ma and Smith, 1992; Emam and Moaied, 2000).

Our data also suggested that both plant growth regulator treatments significantly increased the spike length (Table 1). This finding was in agreement with the results of Karchi (1969) and Turk and Tawaha (2002) who evaluated the effects of varying N rates and ethephon application on yield, yield components and phenological traits of irrigated winter wheat. Indeed, they applied ethephon after stem elongation and their results showed that ethephon could increase the spike length markedly.

On the other hand, the dry matter accumulation, leaf area index and spike length were not significantly affected by N rates; however, N application significantly affected the plant height (Table 1). Tripathi *et al.* (2004) in an investigation with spring wheat reported similar results. Indeed, the N applied at the beginning of stem elongation promoted the survival of tillers which, as has been previously shown by Gallagher *et al.* (1976), would otherwise die at this stage. The results of the present study also indicated that sink size could be manipulated during the early reproductive phase, i.e., when a small reduction in the rate of spike development, and therefore stem elongation, in the leading shoots results in greater shoot

Table 1. Effect of PGR application and N rates on morphological and physiological traits of irrigated winter wheat at anthesis.

Treatment	Spike length (cm)	Plant height (cm)	Dry weight (g plant^{-1})	LAI
N rate (kg ha^{-1})				
0	7.7458a	65.704b	4.5340a	4.7617a
100	7.9792a	70.975b	4.6000a	4.4850a
200	7.8258a	68.392ab	4.9082a	4.7617a
PGR treatment				
None	6.8000b	70.00a	3.9157b	3.6200b
Ethephon	8.3208a	68.458b	5.0088a	4.6600a
CCC	8.4300a	67.279b	5.1177a	5.4142a

Means within each column with the same letters are not significantly different using LSD (0.05).

uniformity within the plant giving a higher rate of tiller survival (Figure 1 and Table 2). These findings are consistent with the results reported by other researchers (e.g., Humphries, 1968; Ma and Smith, 1991; Emam *et al.*, 1997).

Effects of PGRs and Nitrogen on Grain Yield and Its Components

Among the N rates, the highest grain yield was obtained from plots top dressed with 200 kg N ha^{-1} (Table 2). The higher grain yield was the result of a higher grain number which, in turn, was due to more fertile tillers m^{-2}. Such higher grain yield was also attributed to both a higher biological yield and number of grains per plant (Table 2).

Our results appear to substantiate the conclusions of Moes and Stobbe (1991) who suggested that the increase in spikes per square meter with ethephon treatment was due to a delay in the senescence of early tillers. In the plots which received no top dressed nitrogen, the number of fertile tillers was lower (Table 2). Nitrogen fertilizer prolonged the vegetative growing period of irrigated winter wheat and, consequently, delayed the heading date. Such a delay was intensified at higher rates of N application (data not presented). These results are in agreement with previous findings of other workers such as Tisdale and Nelson (1975) and Turk and Tawaha (2002).

Ethephon and chlormequat chloride (CCC) increased the grain yield of winter wheat plants at all nitrogen levels. However, the highest grain yield was obtained from plots which received CCC and 200 kg N ha^{-1} (Table 2). This yield increase was the result of an increase in grain number per plant which was, in turn, due to the increased spike number per plant (Table 2), confirming results reported by others (Stokes *et al.*, 1986; Emam and Karimi, 1996). On the other hand, ethephon treated wheat had the highest spikes per square meter (931.9 spikes m^{-2}) and grains per plant (253.3 grains plant^{-1}) (Table 2) whereas untreated plants produced the lowest spikes per square meter (880.3 spikes m^{-2}) and grains per plant (144.7 grains plant^{-1}) (Table 2). The apparent increase in grains per plant with the ethephon application for late appearing shoots, compared with an untreated control, was due to

a) **b)** **c)**

Figure 1. In each figure, the section a, b and c are shown: PGRs (CCC, 2.20 kg ha^{-1} and ethephon, 0.28 kg ha^{-1}) and N rates (N_1=0, N_2=100, N_3=200 kg ha^{-1}) on a number of fertile tillers/plant compared with control plants. (Scale measurement is 20 cm).

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the increased appearance and promoted growth of tillers rather than to a direct increase of grains spike^{-1}. An increase in spikes per square meter has also been reported for spring barley following ethephon application (Bahry, 1988).

Ehephon application increased the 1,000-grain weight (Table 2). The grain weight gain could have been due to higher rates of photosynthesis and photo-assimilate partitioning to the grains, or longer periods of grain filling or both (Turk and Tawaha, 2002).

In this study, it was shown that the yield and yield components of winter wheat could be affected by a foliar ethephon and CCC application at (ZGS) 25 and (ZGS) 39 under different N rates. The foliar treatment of both plant growth regulators can play an important role in the winter wheat growth indices, and attributed grain yield components. The results also indicated that the yield response of wheat to PGRs would vary under different N rates. The interaction effects of N rates and PGR (CCC and ethephon) applications were significant with respect to grain yield (Table 3). Plants treated with PGRs (CCC or ethephon) under different N rates showed higher grain yield compared with the control plants. Although application of both PGRs increased the grain yield, in CCC treated plants this increase in yield was the result of increased spikes m^{-2} due to increased tiller survival.

It might therefore be concluded that these chemicals could effectively decrease plant height in winter wheat and change the rate of photosynthesis and photo-assimilate partitioning to the grain. However, the inconsistency of these effects with regard to the rate and time of PGR application, cultivar, N rate, and environment indicate the need for a better understanding of the uptake and activity of these chemicals. Hence, further inves-

Table 2. Effect of PGRs application and N rates on yield and yield components in irrigated winter wheat.

Treatment	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Spike m^{-2}	Harvest index (%)	1000 grain weight (g)	Spike plant^{-1}	Grains plant^{-1}
N rate (kg ha^{-1})							
0	5.3525b	13.958b	756.4c	38.922a	41.8383a	5.167b	174.1b
100	9.2892a	22.421a	898.3b	42.491a	42.8883a	5.750b	204.8b
200	9.8908a	25.471a	1109.0a	39.158a	42.2383a	7.167a	264.5a
PGR treatment							
None	7.2667c	19.583a	88o.3b	37.573b	41.7517b	4.083b	144.7b
Ethephon	8.2850b	21.254a	931.9a	39.421ab	42.7642a	7.167a	253.5a
CCC	8.9808a	21.013a	946.8a	43.579a	42.4492a	6.833a	245.3a

Means within each column with the same letters are not significantly different using LSD (0.05).

Table 3. Interaction effect of PGRs application and N rates on (t ha^{-1}) grain yield (of irrigated winter wheat.

Treatment	N rate (kg.ha^{-1})			
PGR treatment	0	100	200	Mean
None	4.655e	8.497c	8.648c	7.2667C
Ethephon	5.247de	9.430bc	10.30ab	8.2850B
CCC	6.155d	9.940ab	10.85a	8.9808A
Mean	5.3525B	9.2892A	9.8908A	

Means with the same letters are not significantly different using LSD (0.05).

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tigation is required to understand better the mechanism of beneficial effects of both plant growth regulators (CCC and ethephon) on wheat cultivars under different N rates and the different agro-climatic conditions of Iran.

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تأثیر کود نیتروژن و تنظیم کننده رشد برعملکرد گندم رقم شیراز

آ. شکوفا و ی. امام

چکیده

تنظیم کننده‌های رشد (PGRs) عمدتاً برای کنترل خوابیدگی در گندم زمستانه‌یی که درسطوح بالای نیتروژن رشد یافته است، به کار می روند. هرچند معرفی رقم های پاکوتاه گندم، عمدتا مشکلات ناشی از ورس را کم کرده است، اما شواهد نشان می‌دهد که در حال حاضر نیزتنظیم کننده های رشد مثل سایکوسل (CCC) و اتفان (۲- کلرو اتیل فسفونیک اسید) با هدف افزایش عملکرد از راه تغییر جهت‌گیری تسهیم مواد پرورده به کار می روند. هدف مطالعه‌ی حاضربررسی اثرات تنظیم کننده‌های رشد در حضور سطوح مختلف کود نیتروژن، بر رشد و عملکرد گندم می باشد. این پژوهش در قالب آزمایشی مزرعه‌ای در ایستگاه تحقیقاتی دانشکده کشاورزی، دانشگاه شیراز واقع در باجگاه در سال زراعی ۸۴-۱۳۸۳ انجام شد. طرح آزمایشی به صورت کرت‌های یک بار خرد شده در قالب بلوک کامل تصادفی با چهار تکراراجرا گردید، سطوح نیتروژن (صفر، ۱۰۰، ۲۰۰ کیلوگرم در هکتار) در کرت های اصلی، تنظیم کننده‌های رشد شامل (سایکوسل (CCC)، ۲/۲۰ کیلوگرم در هکتار ماده موثره ، اتفان (۲- کلرواتیل فسفونیک اسید)، ۰/۲۸ کیلوگرم در هکتار ماه موثره و شاهد بدون اعمال تنظیم کننده) در کرت‌های فرعی قرار گرفتند. نیتروژن در قالب کود اوره (۴۶ درصد نیتروژن) در دو قسمت، نیمی درآغاز به ساقه رفتن و

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نیم دیگر در اوایل گلدهی اعمال شد. تنظیم کننده رشد CCC در مرحله ی رشد ۲۵ =ZGS و اتفان در مرحله ی رشد ۳۹ = ZGS ، به صورت برگ پاش بکار رفتند. نتایج حاصله نشان داد که، هر دو تنظیم کننده رشد اتفان و CCC ارتفاع بوته‌ها را کاهش دادند. این کاهش ارتفاع، انتقال مواد پرورده را در شرایط افزایش نیتروژن، به نفع اندام‌های زایشی و در نهایت عملکرد دانه تغییر داد. اعمال CCC ، باعث افزایش معنی داری در عملکرد نهایی دانه، نسبت به تیمار اتفان وشاهد شد و بیشترین عملکرد دانه، بدون مشاهده خوابیدگی، دربالاترین سطح کاربرد نیتروژن (۲۰۰ کیلوگرم در هکتار) و اعمال CCC، بدست آمد.

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