The Effects of Foliar Application of Plant Hormones at Booting Stage on Wheat Yield Components

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Abstract

The grain number is one of the important components in final harvested yield of wheat and it is closely related to number of florets initiation during stem elongation and number of survived florets before anthesis specially at booting stage. A split-plot experiment using a randomized complete block design with three blocks was used to study the effects of different plant growth regulators [3-Indoleacetic acid (IAA), 6-Benzyalaminopurine (6-BAP) and IAA × 6-BAP] compared with control on two wheat genotypes (Sivand and Pishtaz), at booting stage. This study was conducted at Campus of Agriculture and Natural Resources of Razi University during 2012-2013. The results showed that there was not significant different between the genotypes for the yield and yield components of wheat. But the effects of hormones were significant on grain yield, number of grains per spike and harvest index. The application of IAA × 6-BAP had greatest effect on these traits. However, the interaction effect between the genotypes and hormones was not significant for traits. The number of grains per spike had a positive and significant correlation with the wheat grain yield. The increasing in the grain yield could be attributed to increasing of grain numbers per spike that had been earned by application of two growth hormones (IAA × 6-BAP) at booting stage.

Keywords: auxin, cytokinin, floret initiation, grain yield

Introduction

Forthousands of years the wheat (*Triticumae stivum* L.), has provided the majority daily of the world's population. This plant due to high adaptation with different environmental climates has a wide distribution and land area in the world. Grain yield of wheat depends on the number of grains per unit area and average weight of them (Acreche and Slafer, 2006; Itoh et al., 1998). However, the grain yield is closely related to the number of grains. The final grain number harvested is significantly correlated with the number of fertile florets developed before anthesis (Li et al., 1999). In fact the potential of grain number per spike is determined during the last part of stem elongation stage at booting stage. Shortly before the formation of the terminal spikelet differentiation of the florets are shaped and will be continued to the anthesis stage. Within few days at around booting one to two thirds of them abort suddenly because at this time, nutritional requirements reach to the highest level and competition causes floret abortion (Kirby, 1988; Bancal, 2009). There are many factors that influence on florets primordia survivor. Longer duration of the spike growth, from terminal spikelet to anthesis, increases spike dry weight that enhances floret survival (Slafer et al., 2001). Modified duration of stem elongation in a controlled environmental had been showed that short photoperiods increased duration of stem elongation and with increasing spike dry weight the

number of fertile floret increased (Miralles et al., 2000; Gonzalez et al., 2003). Also the comparing effects of shade and photoperiods were studied by Gonzalez et al. (2005). They reported that shade and photoperiods could attribute to unfavorable source: sink balance. Also floret abortion will be increased by biotic and abiotic stress such as water and salt stress (Jian-Chang et al., 2008; Ghorbani et al., 2011). However, relationship between the endogenous plant growth regulators is one of the important factors in determining grain set in cereal.

Numerous studies have implied that plant hormones regulate a variety of growth and development processes. Among the plant growth regulators auxins, cytokinins, gibberllic acid and polyamines play an important role in hormonal activity for flower production in plants (Kaur-Sawhney et al., 2003). Increasing ABA levels in leaves and spikelets of wheat under water deficit reduced the number of seed (Wilkinson and Davies, 2002). Auxins are stimulus in flower induction and fruit development (Davies, 2004; Aloni et al., 2006). Also IAA and cytokinins are a factor in stimulating transport of assimilates for seed development (Darussalam et al., 1998; Lejeune et al., 1998). Application of gibberellins levels increased the level of this hormone at the flowering and could control the reproductive development of plant (Milyaeva and Romanov, 2002; King and Evans, 2003). Zeatin and gibberellic acid improved the number of fertile florets. Inhibition of abscisic acid not only observed at thestage ofmeiosis but also has been observed at the time offlorets initiation and floret death (Wang et al., 2001).

Since the plant hormones regulate a variety of growth and development processes, current study was conducted to study the effects of exogenous indol-acetic acid (IAA), cytokinin (6-BAP) and interaction of them (IAA × 6-BAP) at booting stage on grain yield and yield components of two wheat genotypes.

Materials and Methods

This study was conducted in 2012-13 cropping season at the Research Farm of Campus of Agriculture and Natural Resources of Razi University, Kermnshah (coordinates: 34˚ 21′ N and 47˚ 9′ E; and with elevation of 1319 AMSL), Iran. The experiment was carried out into a split-plot based on a Randomized Complete Block Design with three blocks. The factors consisted of (i) two wheat (*Triticumae stivum* L.) genotypes (Sivand and Pishtaz) in main plots and (ii) foliar application of different plant growth regulators [3-Indoleacetic acid (IAA), 6-Benzyalaminopurine (6-BAP) and IAA × 6-BAP] compared with control in sub plots. These genotypes have optimum yield and area cropping in the Kermanshah province. The foliar application of hormones was done at booting stage of wheat growth.To ensure absorption of plant growth regulators, foliar application was done three days after sunset (to prevent their degradation by sun light). The control plants also will be treated by distilled water + Teepol. The planting density was 400 seed m^{-2} and space between planting rows was 25 cm.

At harvest stage, one square meter of each plot was considered to measure of the traits of biological yield and grain yield. The number of grains per spike was also calculated from 20 spikes per plot. The harvesting index was calculated by dividing the grain yield on the biological yield as percentage.

The all analyses i.e., normal test, analysis of variance and mean comparisons were performed by using the statistical software's of SPSS 16.0 and SAS 9.1.

Results and Discussion

Effects of hormones: The effect of hormones was significant on traits of grain yield, number of grains per spike and harvest index. But the effect of hormones was not significant on the biological yield and 1000-grains weight (Table 1). The highest rates of grain yield (757 kg m^{-2}), number of grains per spike (37.9) and harvest index (54 percent) were related to application of IAA × 6-BAP at booting stage (Table 2).

The number of grains per spike, harvest index and biological yield had positive and significant correlation with grain yield (Table 3).

Effects of genotypes: In this study, there was not significant different between two genotypes for traits of grain yield and yield components of wheat (Table 1).

Table 1 Analysis of variance (MS) for foliar application of plant hormones at booting stage on yield and yield components of two wheat genotypes.

S.O.V	df	Grain yield	Biological yield	Number of grain per spike	1000-grains weight	Harvest index
R	2	24929.2^{ns}	155752.0*	1.1^{ns}	1.7^{ns}	12.7^{ns}
G	1	6016.7^{ns}	1872.7^{ns}	1.1^{ns}	0.003^{ns}	15.0^{ns}
R×G	2	12454.2^{ns}	23390.8^{ns}	0.6^{ns}	1.3^{ns}	15.2^{ns}
H	3	33601.1*	17406.5^{ns}	8.7*	0.7^{ns}	70.0*
G×H	3	13916.7^{ns}	18936.3^{ns}	4.1^{ns}	1.5^{ns}	15.0^{ns}
C.V. (%)	-	15.2	13.1	4.2	4.2	7.5

ns, * and ** not significant and significant at the 0.05 and 0.01 percent levels of probability, respectively. R: Replication; G: Genotype; H: Hormone

Table 2 Mean comparisons of yield and yield components of two wheat genotypes for different application of plant hormones at booting stage.

Hormone	Grain yield (kg m^{-2})	Biological yield (kg m^{-2})	Number of grain per spike	1000-grains weight (g)	Harvest index (%)
IAA	613.3^{b}	1288.0^{a}	35.9^{b}	40.3^{a}	48.0^{b}
6-BAP	605.0^{b}	1270.5^{a}	35.7^{b}	40.7^{a}	48.0^{b}
IAA×6-BAP	757.0^{a}	1382.2^{a}	37.9^{a}	40.9^{a}	54.3^{a}
Control	604.3^{b}	1269.0^{a}	35.2^{b}	40.2^{a}	48.0^{b}
LSD	123.5	231.9	1.9	2.1	4.7

Means at least one common letter in each column, based on Least Significant Different (LSD) test at 5% level are not significant

Table 3 Simple correlation coefficients between the traits

Traits	Grain yield	Number of grain per spike	1000-grains weight	Biological yield	Harvest index
Grain yield	**1.0**				
Number of grain per spike	0.6**	**1.0**			
1000-grains weight	0.1^{ns}	0.4^{ns}	**1.0**		
Biological yield	0.8**	0.4*	0.1^{ns}	**1.0**	
Harvest index	0.7**	0.4*	0.0^{ns}	0.2^{ns}	**1.0**

ns, * and ** not significant and significant at the 0.05 and 0.01 level of probability, respectively

The studies show that the final numbers of harvested grains have significant relationship with the developed fertile floret before the anthesis (Li et al., 1999). Wang et al. (2001) showed that injection of zeatin during floret development (anther-lobe formation) promoted floret development and significantly increased the number of fertile florets as well as grain set. Also zeatin increased the concentration of sugar in spikes at anthesis. But IAA not only inhibited the development of whole spike but also decreased all florets in the spikelets such that grain loss occurred. Whereas the number of fertile florets increased by injection of GA_3 especially when used at terminal spikelet formation. Wei-Xing et al. (2000) in study of regulating role of endogenous plant hormones in florets development and degeneration showed that the sharp decreased level of ABA and GA_{1+3} in ears from antherlobe formation to meiosis and lowest maintenance can be favorable for fertile floret development and enhancement grain set in wheat.

As results show, the foliar application of plant growth regulators at booting stage of wheat growth can increase the grain yield of wheat. Increasing in the grain yield could be attributed to increasing of grain numbers per spike that had been earned by use of two growth hormones (IAA × 6-BAP) at booting stage. In fact application of IAA × 6-BAP at booting stage could probably be affecting on florets survival fallowed by the number of grains per spike increase. (This study was a pre-experiment of Ph. D thesis of author).

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References

Acreche, M.M. and G.A. Slafer. 2006. Grain wheat responses in number of grains in wheat in a Mediterranean area. Field Crop Res. 98: 52-59.

Aloni, R., E. Aloni., M. Langhansans and C.I. Ullrich. 2006. Role of auxin in regulating *Arabidopsis* flower development. Planta. 223: 315-328.

Bancal, P. 2009. Early development and enlargement of wheat floret primordia suggest a role of partitioning within spike to grain set. Field Crops Res. 110: 44-53.

Darussalam, M., M.A. Cole and J.W. Patrick. 1998. Auxin control of photoassimilate transport to and within developing grain of wheat. Aus. J. Plant Physiol. 25: 69-77.

Davies, P.J. 2004. Plant hormones. Biosynthesis, signal transduction action. Kluwer, Dordrecht. pp. 18-35.

Ghorbani, J.M., A. Sorooshzadeh., S.A. Mohammad ModarresSanavy, I. Allahdadi and F. Moradi. 2011. Effects of exogenous application of auxin and cytokinin on carbohydrate accumulation in grains of rice under salt stress. Plant Growth Regul. 65: 305-313.

Gonzalez, F.G., G.A. Slafer and D.G. Miralles. 2003. Grain and floret number in response to photoperiod during stem elongation in fully and slightly vernalized wheat. Field Crop Res. 81: 17-27.

Gonzalez, F.G., G.A. Slafer and D.G. Miralles. 2005. Floret development and survival in wheat plants exposed to contrasting photoperiod and radiation environments during stem elongation. Funct. Plant Biol. 32: 181-188.

Itoh, H., K. Ueno and K. Yamazaki. 1998. Analysis of spike development of three spring wheat genotype under various cultural conditions. Plant Prod. Sci. 1: 258-263.

Jian-Chan, Y., L. Kai., Z. Shen-Feng., W. Xue-Ming and W. Zhi-Qin. 2008. Hormones in rice spikeletes in responses to water stress during meiosis. Acta Agronomica Sinica 34: 111-118.

Kaur-Sawhney, R., A.F. Tiburcio, T. Altabella and A.W. Galston. 2003. Polyamines in plants: an overview. J. Cell Mol. Biol. 2: 1-12.

Kirby, E.J.M. 1988. Analysis of leaf, stem and ear growth in wheat from terminal spikelet stage to anthesis. Field Crop Res. 18: 127-140.

King, R.W. and L.T. Evans. 2003. Gibberellins and flowering of grasses and cereal: prizing open the lid of the "florigen" black box. Ann. Rev. Plant Biol. 54: 307-328.

Lejeune, P., E. Prinsen., H. Van Onckelen and G. Bernier. 1998. Hormonal control of ear abortion in a stress-sensitive maize inbred. Aust. J. Plant. Physiol. 25: 481-488.

Li, C., W. Cao., T. Dai and Z. Wang. 1999. Dynamic characteristics of floret primordia development in wheat. Acta. Agron. Sin. 32: 98-100.

Milyaeva, E.L. and G.A. Romanov. 2002. Molecular genetics returns to basic postulates. Russ. J. Plant Physiol. 49: 438-444.

Miralles, D.J., R.A. Richards and G.A. Slafer. 2000. Duration of stem elongation period influences the number of fertile florets in wheat and barley. Aus. J. Plant Phys. 27: 931-940.

Slafer, G.A., L.G. Abeledo., D.G. Miralles., F.G. Gozalez and E.M. whitechurch. 2001. Photoperiod sensitivity during stem elongation as an avenue to raise potential yield in wheat. Euphytica 119: 191-197.

Wang, Z., W. Cao, T. Dia and Q. Zhou. 2001. Effects of exogenous hormones on floret development and grain set in wheat. Plant Growth Regulator 35: 225-231.

Weing-Xing, C., W. Zhao-Long and D. Ting-Bo. 2000. Changes in levels of endogenous plant hormones during floret development in wheat genotypes of different spike sizes. Acta Botanica Sinica 42: 1026-1032.

Wilkinson, S. and W.J. Davies. 2002. ABA-based chemical signaling: the co-ordination of responses to stress in plants. Plant Cell Environ. 25: 195-210.

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