THE BEHAVIOR OF SOME WINTER WHEAT GENOTYPES UNDER PLANT GROWTH REGULATORS TREATMENT AND INCREASED NITROGEN APPLICATIONS

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Abstract. *Plant Grow Regulators (PGR) are used widely to reduce the risk of lodging in winter wheat (Triticum aestivum L.) grown at high nitrogen rates. A field experiment was conducted during 2015-2016 winter wheat growing season at Agricultural Research and Development Station Turda to evaluate the effect of PGR on plant height, lodging, internodes length, grain yield and grain protein content of seven winter wheat genotypes tested at different rates of applied nitrogen fertilizer, in combination with foliar treatment with trinexapac-ethyl- based Plant Growth Regulator sprayed over the foliage. Results showed that high rates of applied nitrogen fertilizer and high rainfall stimulated stem elongation and increase the risk of cereal lodging. The PGR application on wheat cause shorter plants due to the reduction of the internodes length and less lodging. The response depends on factors like: wheat variety, amount of nitrogen fertilizer applied and the weather conditions. PGR applications significantly reduced lodging but didn't necessarily completely eliminate it, some genotypes even after PGR treatment still lodged. On yield and grain protein content nitrogen fertilization had a bigger influence than the trinexapac-ethyl treatment so these technology elements are not exclusive to each other.*

Keywords*: winter wheat, lodging, PGR, nitrogen fertilization, yield, grain protein content.*

INTRODUCTION

Wheat (Triticum aestivum, L.) is one of the main cereal crops in the world as well as in Romania. Improvement of wheat yield is the primary concern of plant physiologists and plant breeders. The grains of wheat contain large amounts of carbohydrates, proteins, in addition to some minerals and vitamins (MUNTEAN ET AL., 2014). For the economic value of wheat, efforts aiming for further increase in wheat production are still going on, and devoted for wheat production. Increasing plant productivity either in the form of dry weight or yield, is one of the main targets in agricultural policy, this could be achieved through fertilization and/or plant growth regulators treatment including retardants (ORABI & SADAK, 2015).

The term growth retardants is used for all chemicals that retard cell division and cell elongation in shoot tissues and regulate plant height physiologically without formative effects (GÂDEA ŞTEFANIA, 2009, ORABI & SADAK, 2015).

From all the agronomic factors, nitrogen fertilization plays a major role in increasing yield, because this factor has an important role in synthesis of amino acids, proteins and nucleic acids, it determines the number of tillers, it increase the photosynthetic area which induce a better use of sunlight energy. An adequate amount of nitrogen in the soil has a positive influence on spikelet size and the number of spikelets per spike, number of flowers and the percent of fertile flowers from spikelet (HARASIM ELZBIETA ET AL., 2016).

High rates of applied nitrogen fertilizer and high precipitation favor stem elongation and increase risk of cereal lodging. In high input agriculture application of plant growth regulators (PGR) has become common practice to prevent lodging. They are used to shorten straw of cereals and thereby increase lodging resistance (AUSKALNIENE ONA ET AL., 2008).

Lodging in cereals refers to the displacement of the stem from its vertical position and leaning towards the soil. Stem lodging is usually caused by the weight of water accumulated in the mature ears, wind, and low stem resistance, among other factors (TAIZ & ZEIGER, 2004).

In general, lodging has been controlled by restricting nitrogen fertilizer application and/or using short cultivars. Growth retardants can also be used to solve this problem (ESPINDULA ET AL., 2009).

MATERIAL AND METHODS

The experiments have been carried out at the Agricultural Research and Development Station Turda (46°35’ N latitude and 23°47’ E longitude, 345-493 m altitude from Adriatic Sea).

The climate is temperate continental, with the annual average temperature about 9,0°C.

Meteorological data from the winter wheat vegetation period (October 2015-July 2016) are presented in table 1. Comparing long-term average temperature values and the monthly average during winter wheat vegetation period, we notice that in this period the temperatures were higher than the long term average.

Rainfall was high during the winter wheat growing season 2015-2016, occasionally excessive, except in December. The year 2016 was the wettest year from the past 59 years. A large amount of rainfall occurred at the end of winter wheat vegetation period in June and July which increase the risk of cereal lodging.

Table 1

Temperature and rainfall values registered in the winter wheat period of vegetation 2015-2016 and long-term averages for that region

Months	2015-2016 Monthly average		59 years average	
	Temperature (^{0}C)	Rainfall (mm)	Temperature (^{0}C)	Rainfall (mm)
October	9.7	45.4	9.6	33.6
November	6.1	32	3.9	28.2
December	0.7	6.9	-1.4	27.5
January	-2.8	25.0	-3.4	20.8
February	4.6	23.8	-0.8	18.4
March	5.9	47	4.5	19.3
April	12.4	62.2	9.9	44.4
May	14.3	90.4	15	67.1
June	19.8	123.3	17.8	83.4
July	20.5	124.9	19.7	72.9
Average	9.12		7.48	
Total		580.9		415.6

The experimental design consists in subdivided plots in a three factorial experimental system. The experimental factors were:

Plant growth regulators (PGR): A- untreated with PGR (control)
B- treated with PGR

Nitrogen fertilization (F), doses of active substances:

-F1 N50P50 kg ha^{-1}(control);
-F2 N50P50+ N50 kg ha^{-1};
-F3 N50P50+ N100 kg ha^{-1};
-F4 N50P50+ N150 kg ha^{-1}.

Genotypes (G): Arieşan, Apullum, Andrada, Dumitra, Taisa, Crişana and Bezostaia.

The wheat was sown in third trimester of October 2015 at a seeding rates of 550 germinate seeds per square meter.

Before sowing the wheat, nitrogen and phosphorus fertilizers were applied in every plot at the following rates: N 50 kg ha^{-1} and P 50 kg ha^{-1}. Beside the fertilization applied in autumn nitrogen fertilization was applied on crop at boot stage (BBCH 40-49) at different rates 50 kg ha^{-1} (F2), 100 kg ha^{-1} (F3), 150 kg ha^{-1} (F4). The variant F1 was considered as control and nitrogen fertilizer was not applied on crop.

The PGR foliar treatment included trinexapac-ethyl on dose of 0,4 l ha^{-1} sprayed over the foliage at BBCH 32.

At final stage of maturity the plant height was measured and notes were given for lodging resistance to every genotype. Thirty plants treated with PGR and thirty untreated with PGR from every genotype were taken before harvest and the length of the internodes were measured.

Winter wheat from the experimental plots was harvested with Wintersteiger plot combine; each plot having five harvestable square meters. The yield was reported at standardized moisture 14% for winter wheat. The grain protein content was determined using the Inframatic 9500 Grain Analyzer.

The results were investigated by analysis of variance and tested using the F-test.

RESULTS AND DISCUSSIONS

F test demonstrated that wheat height was significantly influenced by nitrogen fertilization, by the genotype and by the interaction between PGR treatment and genotype. PGR treatment had a small influence on plats height, but statistically significant (table 2).

Table 2

Plant height and F test for seven winter wheat genotypes in a three factorial experimental system

Rates of nitrogen		Plant height (cm)							
		F_1 (N50)		F_2(N100)		F_3(N150)		F_4(N200)	
No.	Genotype	A(Ct.)	B	A(Ct.)	B	A(Ct.)	B	A(Ct.)	B
1.	Arieşan	107	99^{00}	113	100^{000}	115	101^{000}	118	102^{000}
2.	Apullum	108	99^{00}	110	99^{000}	111	100^{00}	111	104^{0}
3.	Andrada	99	94	97	95	99	93^{0}	99	95
4.	Dumitra	107	98^{00}	108	99^{00}	109	102^{0}	111	100^{00}
5.	Taisa	97	93	97	95	100	95^{0}	101	96^{0}
6.	Crişana	103	101	107	100	107	102^{0}	107	100^{0}
7.	Bezostaia	115	104^{000}	117	108^{00}	118	108^{00}	122	112^{00}
LSD (5%) 5.12 LSD (1%) 7.11 LSD (0.1%) 10.37									
F Test									
PGR Treatment (T)				449.325*					
Nitrogen fertilization (F)				6.262***					
Genotype (S)				96.743***					
TxF				0.301					
TxS				7.598***					
FxS				1.074					
TxFxS				0.853					

A- without PGR treatment

B- with PGR treatment

Ct. – Control

The plant height decreased after the PGR treatment records MATYSIAK in 2006 and ESPINDULA ET AL in 2009. The plant height of the seven genotypes treated with PGR in comparison with the ones untreated (control) showed that all the genotypes had decreased plant height, but the difference was not the same for all cultivars (fig.1). All the genotypes had significantly reduced plant height after PGR treatment in comparison with the control (without PGR treatment), but Arieşan had the biggest reduction of plant height which was 13 cm.

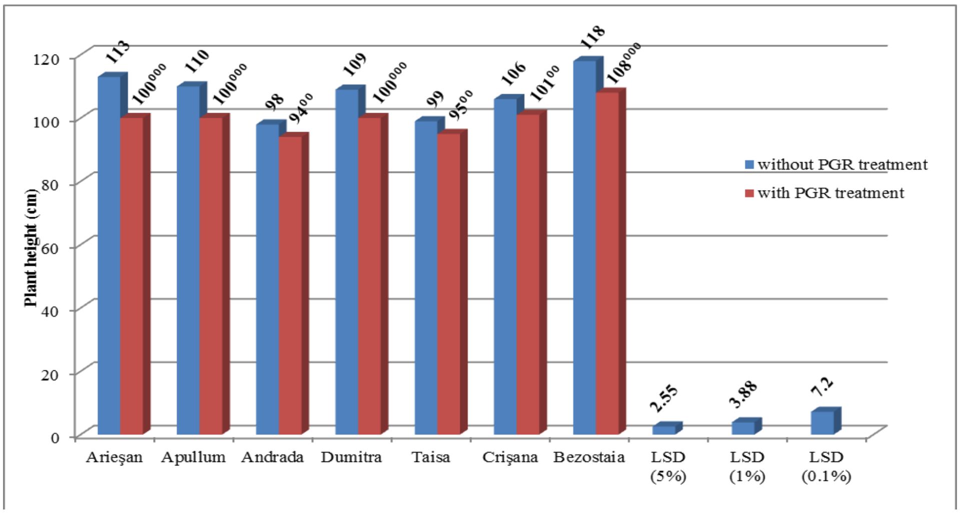

Figure1. The influence of PGR treatment on plant height

From table 3 we can see the effect of the PGR by reducing internode length, mostly the upper internodes showed higher differences from the untreated variant. Not all the genotypes had the same response to the PGR treatment. Reduction in plant height as a consequence of PGR treatment is associated with the reduced elongation of internodes, the uppermost internodes in particular are shortened (RAJALA, 2003).

According to F test genotype had significantly influence the internode length from all the internodes, while PGR treatment significantly influence the length of third, fourth, fifth and sixth internodes.

Table 3

The influence of plant growth regulators treatment on internodes length and F Test for seven winter wheat genotypes

Genotype		Internode length (cm)					
		L_1	**L_2**	**L_3**	**L_4**	**L_5**	**L_6**
Arieşan	A	3.07	10.80	12.10	17.95	21.30	46.20
	B	2.97	9.36	10.86	15.45	19.33	40.90
Apullum	A	3.69	7.91	12.73	15.39	23.20	46.90
	B	3.33	8.83	12.33	13.89	19.39	39.81
Andrada	A	3.53	6.85	10.35	14.15	20.60	40.25
	B	3.35	7.45	10.90	14.20	19.70	36.65
Dumitra	A	4.05	8.40	11.40	15.25	20.10	40.55
	B	4.04	8.30	10.17	13.75	18.40	37.64
Taisa	A	5.66	9.55	10.95	13.66	18.90	39.50
	B	5.85	8.95	10.20	13.05	18.40	32.95
Crişana	A	3.58	7.95	12.55	15.47	21.65	42.95
	B	3.42	6.55	11.15	14.05	19.90	40.60
Bezostaia	A	3.31	10.10	14.35	19.90	25.68	46.16
	B	3.30	10.30	11.45	15.50	21.20	39.20
F Test							
PGR Treatment (T)		0,598	0,996	22,756***	34,361***	62,398***	88,337***
Genotype (S)		12,839***	7,903***	5,048***	19,228***	11,966***	12,149***
TxS		0,258	1,114	1,602	4,266***	2,659**	1,524

A- without PGR treatment B- with PGR treatment

There are many factors that contribute to the process of lodging, the most predominant of these include: wind, rain, topography, soil type, crop husbandry practices, crop disease and an abundant supply of nutrients in the soil (BERRY ET AL., 2004).

Nitrogen fertilization rates increase the risk of lodging as showed in table 4 and similar information were obtained by RAJKUMARA in 2008. The genotypes from this study have different height and stem strengths that increase or decrease lodging risk. Arieşan, Crişana and Bezostaia genotypes are taller and had a higher lodging risk which cannot be corrected even after the PGR treatment. Dumitra, Taisa and Andrada showed medium lodging risk and the variants treated with PGR did not lodge.

According to F test PGR treatment and genotype had a significant influence on lodging and nitrogen fertilization had a small influence on this trait but statistically significant (table 4).

Table 4

Observation of lodging risk scored on a 1-7 scale ant F test

Rates of nitrogen		F1		F2		F3		F4	
No.	Genotype	A	B	A	B	A	B	A	B
1.	Arieşan	6	4	7	4	7	4	7	4
2.	Apullum	4	2	3	2	5	2	6	2
3.	Andrada	1	1	1	2	3	1	3	1
4.	Dumitra	3	1	3	1	3	1	5	1
5.	Taisa	1	1	4	1	5	1	5	1
6.	Crişana	4	3	4	3	5	2	5	4
7.	Bezostaia	6	4	7	5	7	5	7	5
F Test									
PGR Treatment (T)				283,102 ***					
Nitrogen fertilization (F)				23,759 *					
Genotype (S)				214,196 ***					
TxF				15,470 *					
TxS				11,166 *					
FxS				4,176 **					
TxFxS				6,128 **					

1 no lodging occurs — A-without PGR treatment
2 a light bending of the plants — B-with PGR treatment
3-4 medium lodging risk (20% - 40% from the field is affected by lodging)
5-6 high lodging risk (50% - 70%from the field is affected by lodging)
7 very high lodging risk (80% - 100% from the field is affected by lodging)

F test demonstrated that wheat yield was significantly influenced by the nitrogen fertilization and by the genotype (table 5).

Because winter wheat has a weak radicular system and the demand for nutrients is highest between stem extensions and ripening, deficiency in this period has a negative influence on yield (AXINTE ET AL., 2006, MUNTEAN ET AL., 2008). Mineral fertilizers are the most important factor for increasing winter wheat grain yield (HARASIM ELZBIETA ET AL., 2016). Comparing the average grain yield from all four rates of nitrogen fertilization (table 5), shows that the highest grain yield was obtained when the amount of nitrogen fertilizer was higher.

Table 5

Grain yield and F Test for seven winter wheat genotypes in a three factorial experimental system

Genotypes	A				B			
	F1 (Ct.)	F2	F3	F4	F1 (Ct.)	F2	F3	F4
Arieşan	6500	6770	7200**	7620**	7030	7730**	7730**	7820**
Apullum	6920	7320	7930***	7820***	7500	7980*	8130**	8120**
Andrada	7350	7430	7750	7970**	7120	7580	8180***	8230***
Dumitra	7080	7650*	8120***	7720**	7320	8130***	8630***	8620***
Taisa	7000	7130	7500*	7680**	7320	7920*	8120***	8350***
Crişana	6770	7280*	7370*	8020***	6630	7150*	7820***	7750***
Bezostaia	5300	6000**	6000**	5770*	5780	6270*	6730***	6870***
LSD (5%) 460 LSD (1%) 610 LSD (0.1%) 800								
F Test								
PGR Treatment (T)	22,887							
Nitrogen fertilization (F)	197,550***							
Genotype (S)	102,252***							
TxF	3,646*							
TxS	4,346***							
FxS	0,856							
TxFxS	1,383							

A- without PGR treatment

B- with PGR treatment

Ct. – Control

There was significant PGR Treatment x Genotype interactions for grain yield as shown in fig. 2. Five (Arieşan, Apullum, Dumitra, Taisa, Bezostaia) from seven winter wheat genotypes of this study had significantly higher yield after receiving PGR treatment in comparison with the ones that were not treated with PGR (control ones). The production increased with 430-640 kg ha^{-1} in the treated variants in comparison with the untreated ones.

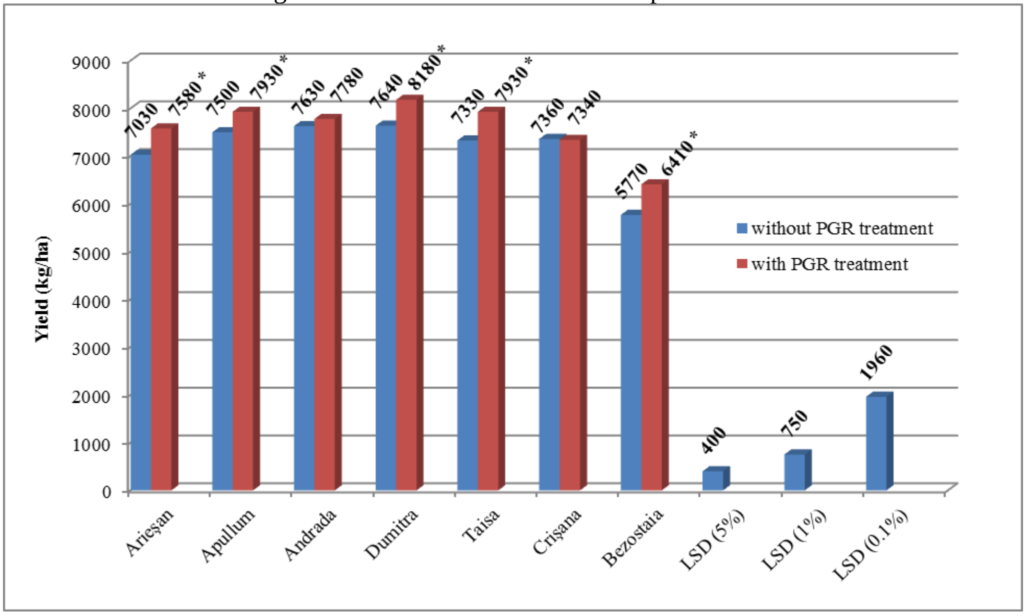

Figure 2. The influence of the PGR Treatment and on yield

Nitrogen fertilization and genotype influence significant grain protein content, while PGR treatment had non-significant influence on this trait and F test proved the same (table 6).

Table 6

Grain protein content and F Test for seven winter wheat genotypes in a three factorial experimental system

Genotypes	A				B			
	F1 (Ct.)	F2	F3	F4	F1 (Ct.)	F2	F3	F4
Arieşan	12.20	14.27***	15.50***	15.97***	11.77	13.93***	15.87***	15.87***
Apullum	10.70	11.70*	12.90***	13.67***	10.33	11.87**	13.20***	13.60***
Andrada	10.77	12.30**	13.50***	14.10***	10.60	12.33***	13.50***	13.77***
Dumitra	10.97	12.03*	12.73***	13.30***	10.50	11.63*	13.10***	13.57***
Taisa	10.40	11.47*	12.90***	13.37***	10.37	12.23***	13.37***	13.83***
Crişana	11.27	12.27*	13.50***	14.13***	11.10	12.23*	13.30***	14.23***
Bezostaia	12.43	13.80**	15.07***	15.73***	12.63	14.37***	15.60***	16.13***
LSD (5%) 089 LSD (1%) 1.23 LSD (0.1%) 1.67								
F Test								
PGR Treatment (T)	5,918							
Nitrogen fertilization (F)	79,299***							
Genotype (S)	182,145***							
TxF	0,366							
TxS	2,675*							
FxS	2,249***							
TxFxS	0,592							

A- without PGR treatment

B- with PGR treatment

Some authors proved a positive influence of retardants on protein content but others show an opposite action of retardants on this trait (MATYSIAK KINGA, 2006). As shown in figure 3 from all the genotypes used in this study only two (Taisa, Bezostaia) had higher grain protein content after receiving PGR treatment in comparison with the variants untreated with PGR.

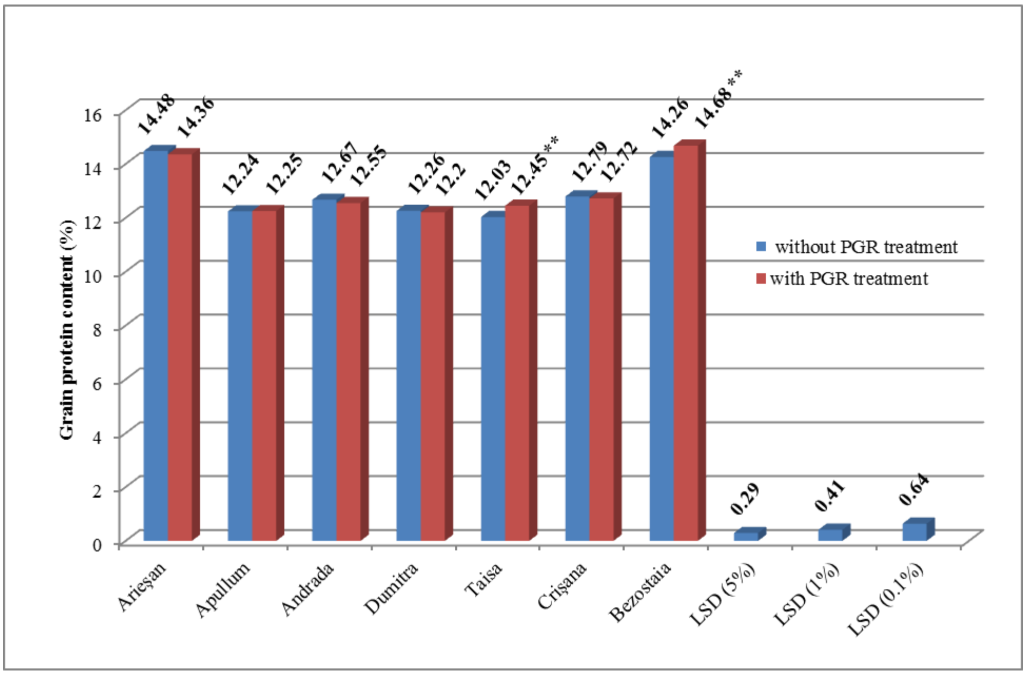

Figure 3. The influence of the PGR treatment on grain protein content

Many researchers have reported associations between plant height, number of internodes and internode length with lodging (KELBERT ET AL, 2004).

As shown in table 7 plant height and yield was correlated with lodging from both treated and untreated variants. Lodging scores were also correlated with grain protein content from the variants which were treated with PGR. The length of the first and fourth internode from the variants treated with PGR, and the length of the third, fourth and sixth internode from the variants which were not been treated with PGR, were correlated with lodging.

Table 7

Spearman rank correlations between lodging scores and plant height, yield and grain protein content for 7 winter wheat genotypes, Turda 2016

	Lodging scores (1-7)	
	Without PGR treatment	With PGR treatment
Plant height (cm)	0.879*	0.923*
Yield (kg/ha)	-0.770*	-0.822*
Grain protein content (%)	0.660	0.815*
First internode length	-0.605	-0.778*
Second internode length	0.679	0.518
Third internode length	0.826*	0.481
Fourth internode length	0.917*	0.778*
Fifth internode length	0.715	0.635
Sixth internode length	0.770*	0.741

CONCLUSIONS

Results showed that high rates of applied nitrogen fertilizer increased the risk of cereal lodging. The PGR application on wheat cause shorter plants (internodes) and less lodging. PGR applications significantly reduced lodging but didn't necessarily completely eliminate it.

Winter wheat height was significantly influenced by PGR treatment. Reduction in plant height as a consequence of PGR treatment is associated with the reduced elongation of internodes. PGR treatment improved the crop resistance to lodging.

Five genotypes (Arieşan, Apullum, Dumitra, Taisa, Bezostaia) from seven of this study had higher yield after receiving PGR treatment in comparison with the ones that were not treated with PGR .The production increased with 430-640 kg·ha^{-1} in the treated variants in comparison with the untreated ones.

On grain protein content nitrogen fertilization had a bigger influence than the trinexapac-ethyl treatment.

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