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THE INFLUENCE OF PLANT GROWTH REGULATORS ON CHLOROPHYLL CONTENT, PHOTOSYNTHETICALLY ACTIVE RADIATION ABSORPTION AND PRODUCTIVITY OF TWO WINTER WHEAT VARIETIES

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Abstract

Plant growth regulators (PGR) are used in an intensive farming system to control lodging in cereals. It is supposed that PGR have potential to modify cereal growth additional to their primary target of stem elongation. To estimate the influence of plant growth regulators on PAR absorption capacity of winter wheat plants, chlorophyll content and winter wheat grain yield, field trials were conducted at the Lithuanian Institute of Agriculture's Department of Soil and Plant Management during 2005-2006. Laboratory experiments were carried out at the Lithuanian University of Agriculture in the "Tempus" laboratory of agronomical and zoo-technical analyses. The soil of the experimental site is drained soddy gleyic, light loam. The stands of winter wheat varieties 'Ada' and 'Zentos' were sprayed with the gibberellin bio-synthesis inhibitors chlormequat chloride (CCC), trinexapac - ethyl (TE) or with ethylene releasing mepiquatchloride + ethephon (MQEH) and ethephon (ETH) four times at BBCH 27-29, BBCH 32-33, BBCH 37-39, and BBCH 39-45.

Plant growth regulators exerted an unequal effect on the chlorophyll content in winter wheat. The effect depended on winter wheat varieties. In var. 'Ada' chlorophyll content and PAR increased in treated plots, while in var. 'Zentos' there were found trends of decrease. Grain yield of winter wheat var. 'Ada' in treated plots tended to increase and in the plots, treated twice with CCC a significant increase in grain yield was obtained.

Key words: PGR, winter wheat, grain yield, chlorophyll a and b and PAR absorption.

Introduction

Nitrogen fertilizer and high precipitation favour stem elongation and increase risk of lodging /Berry et al., 2000/. Plant growth regulators (PGR) are chemical compounds that regulate stem elongation through inhibiting biosynthesis of gibberellins or releasing ethylene. PGR have been mainly used in modern high input cereal management to shorten straw and thereby increase lodging resistance /Gianfagna, 1995; Rajala, Peltonen - Sainio, 2000/. Anti-gibberellic plant growth regulators (CCC, trinexapac-ethyl) used for shortening cereal stems inhibit gibberellin biosynthesis at different stages of the metabolic pathway /Adams et al., 1992; Rademacher, 2000/.

Winter wheat productivity is limited by many factors, the most important of which is the ability of the plants to absorb photosynthetically active radiation (PAR) /Šlapakauskas, Ruzgas, 2005/. Sabo et al. (2002) investigated chlorophyll and photosynthetic productivity of two genotypes of winter wheat, and found a significant correlation between the leaf area and chlorophyll a. Plant breeders have directed cereal biomass distribution from the straw to the grains, resulting from tall cultivars to shorter, more lodging resistant /Evans, 1993, Peltonen - Sainio, 1999/. The relevance of PGRs is legitimate to ask if the principal aim is to shorten the stems or if PGRs can in other way be used to modify cereal growth.

Among the most commonly observed plant responses from UV-B exposure are changes in biomass and biomass allocation, flowering pattern, plant height, and leaf thickness /Bornman, 1989; Tevini and Teramura, 1989; Teramura and Sullivan, 1991/. More than 50 models for simulating radiation - vegetation interactions have been proposed in the literature /Goel, 1988; Myneni et al., 1989/. As a result of the high diffuse fraction, the sky view through gaps in the canopy is the greatest single factor in defining the UV-B irradiance /Brown et al., 1994; Grant, Heisler, 1996/ and the distribution of the sky radiance in those gaps may become important in estimating the irradiance. Sky radiance distribution is probably not important in modelling such dense crop canopies /Gao et al., 2003/.

Many research papers suggest that plant growth regulators have potential to modify cereal growth additional to their primary target of stem elongation /Novickienė, Merkys, 1998/. Banevičienė et al. (1987) proposed that CCC influenced winter wheat growth: in the plots treated with CCC leaf area and grain number per ear increased, leaf vegetation continued longer and grain yield was higher than in the untreated even in those cases when winter wheat had not lodged. Similar results were received at the Lithuanian Institute of Agriculture. In the PGR - treated plots a trend of grain yield increase was recorded, as well as greater chlorophyll content in leaves /Auškalnienė, 2005/. PGR initiate more heads per plant and direct improvement in grain yield /Naylor, Saleh, 1987, Ma, Smith, 1992/. Tillering enables faster canopy closure, which improves interception of radiation and reduces transpiration /Peltonen - Sainio, 1999/.

The aim of our investigation was to evaluate the influence of PGR on chlorophyll content and PAR absorption and productivity of two winter wheat varieties.

Materials and methods

To estimate the efficiency of plant growth regulators field trials were conducted at the Lithuanian Institute of Agriculture's Department of Soil and Plant Management in the two winter wheat varieties: 'Ada' and 'Zentos'. The soil of the experimental site is drained soddy gleyic, light loam. The seed rate was 4 million viable seed per hectare, $N_{180}P_{80}$ K_{80} fertilization was applied. Conventional soil tillage technology - deep ploughing was employed. The winter wheat stands were sprayed with the gibberellin biosynthesis inhibitors CCC (chlormequat chloride CCC), Modus (trinexapac - ethyl) or with ethylene releasing Terpal C, and Cerone four times at BBCH 25-29 (tillering) - CCC; BBCH 32-33 (stem elongation) CCC, Moddus, BBCH 37-39 (flag leaf stage) -

Terpal C, Cerone and BBCH 39-45 (early boot stage) Cerone. The trial design was a randomized block with four replicates. The plot size was 25 m^{-2}.

Absorbed PAR was measured by a digital luminance PAR irradiance quantum - photo - radiometer HD 9021 in each plot in three places and in each place three times: over plant canopy, in the middle of plant canopy and on the soil surface – nine measurements per each plot in μ mol (m^2 s^{-1}). In total 504 measurements were made per two trials.

The chlorophyll analyses were made at the Lithuanian University of Agriculture, in the "Tempus" laboratory of agronomical and zoo-technical analyses one month after the last PGR application.

The estimation of chlorophyll a and b content was related to the estimation of optical density of the extracts: chlorophyll a (663 nm), chlorophyll b (645 nm), carotenoids (440.5 nm) (According to "Metody biochimičeskogo analiza rastenij", 1978).

The vegetative plant mass was melted in a porcelain plate with acetone and calcium carbonate, and the solute was filtrated. Segregation of pigments was made with small amounts of acetone. Later the filtrate was diluted up to an optical density of 0.1 to 0.8. The concentration of pigments (mg L^{-1}) was calculated according to the formulae:

Ca = 9.784D662 - 0.99D644

Cb = 21.426D644 - 4.650D662

Ca + Cb = 5.134D622 + 20.436D644

Ckar = 4.695D440.5 - 0.268(Ca + Cb)

Where: Ca – concentration of chlorophyll a mg L^{-1}

Cb – concentration of chlorophyll b mg L^{-1}

Ckar – concentration of carotenoids

Amount of pigments (mg 100g^{-1}) was calculated according to the formula:

X = CVV2 ++*100/nV1*1000

C – concentration of pigments mg L^{-1},

V – original amount of extract ml

V1 – original amount of extract taken for dilution ml

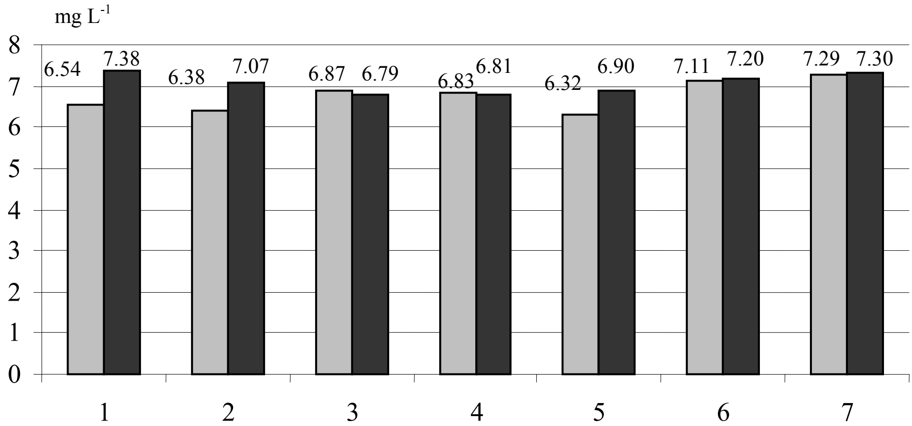
V2 – amount of diluted extract, ml

n – mass

The experimental data were compared by using an analysis of variance (ANOVA) and, where the F-ratio was significant, the least significant difference (LSD) was calculated for $P<0.05$.

Results and discussion

The content of chlorophyll a and b (mg L^{-1}) was evaluated in each plot. The amount of chlorophyll a and b in most winter wheat var. 'Ada' plots treated with PGR was higher compared with the untreated (Fig. 1-2), especially in the treatments with trinexapac – ethyl (TE) (3), ethephon (ETH) at BBCH 39-45 (6) and CCC twice (7). Significant increases in chlorophyll content were obtained in treatments 6 and 7 – BBCH 27-29 CCC and ETH at BBCH 39-45 and twice CCC – at BBCH 27-29 and BBCH 32-33.



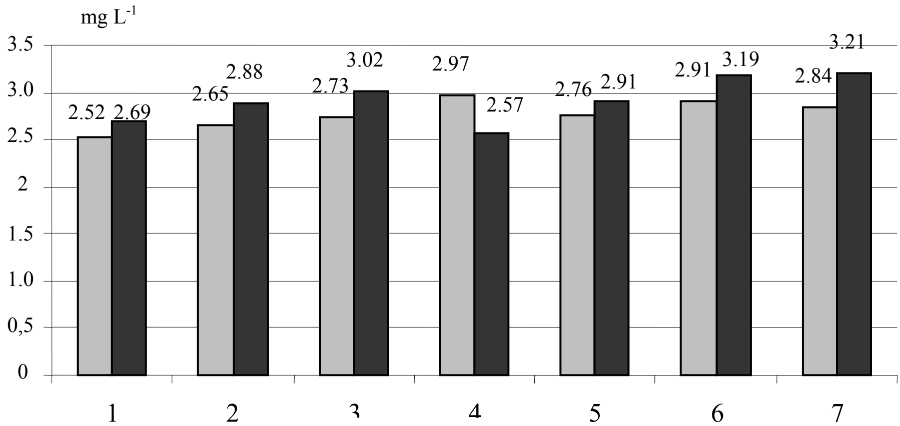
Treatment / *Variantas*

LSD_{05} / R_{05} – 0.552 (‘Ada’)

‘Ada’ ‘Zentos’

LSD_{05} / R_{05} – 0.412 (‘Zentos’)

Figure 1. The amount of chlorophyll a mg L^{-1} in the winter wheat ‘Ada’ and ‘Zentos’
1 paveikslas. *Chlorofilo a kiekis mg L^{-1} žieminiuose kviečiuose ‘Ada’ ir ‘Zentos’*



Treatment / *Variantas*

LSD_{05} / R_{05} – 0.295 (‘Ada’)

‘Ada’ ‘Zentos’

LSD_{05} / R_{05} – 0.28 (‘Zentos’)

Figure 2. The amount of chlorophyll b mg L^{-1} in the winter wheat ‘Ada’ and ‘Zentos’
2 paveikslas. *Chlorofilo b kiekis mg L^{-1} žieminiuose kviečiuose ‘Ada’ ir ‘Zentos’*
1. Untreated / *Nepurkšta*; 2. CCC 1.5 L ha^{-1} 25-29 DK (T1); 3. T1 and TE 0.4 L ha^{-1} 32-33; 4. T1 and MQET 0.7 L ha^{-1} 37-39; 5. T1 and ETH 0.5 L ha^{-1} 37-39; 6. T1 and ETH 0.5 L ha^{-1} 39-45; 7. T1 and CCC 0.5 L ha^{-1} 32-33

Conversely, in the crops of winter wheat ‘Zentos’ almost in all plots treated with PGR, the content of chlorophyll a was lower than in the untreated. Significant decrease in chlorophyll a content was obtained in treatments 3, 4 and 5 – CCC for the first application and TE (3), MQC (4) and ETH BBCH 37-39 (5) for the second (Fig. 5). The changes in the amount of chlorophyll b had different trends: in treatments 3 (TE for the second application), 6 (ETH BBCH 39-45) and 7 (CCC twice) the amount of chlorophyll b was significantly higher than in the untreated plots.

The sum of chlorophyll a and b in winter wheat 'Zentos' was significantly lower only in treatment 4 (MQC for the second application) (Fig.3).

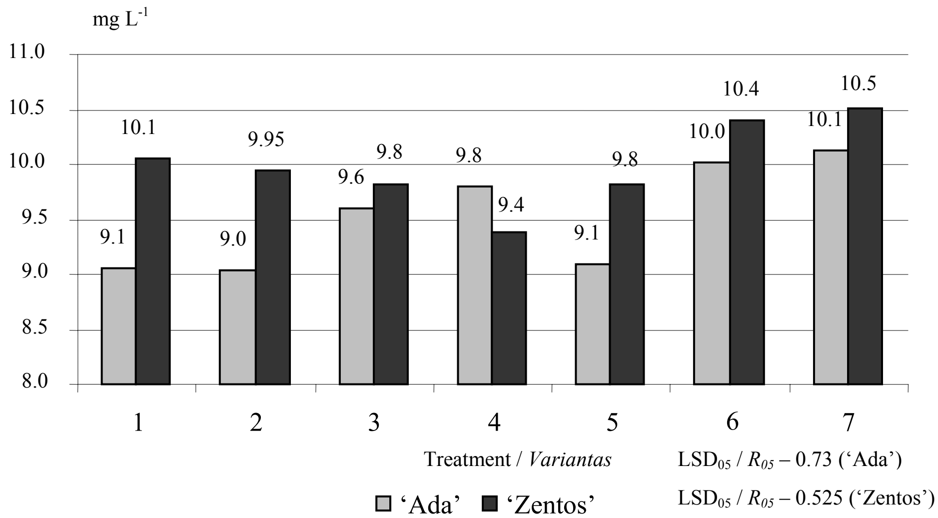


Figure 3. Sum of chlorophyll a and b mg L^{-1} in winter wheat var. 'Ada' and 'Zentos'
3 paveikslas. *Chlorofilo a ir b suma žieminiuose kviečiuose 'Ada' ir 'Zentos' mg* L^{-1}
1. Untreated / *Nepurkšta*; 2. CCC 1.5 L ha^{-1} 25-29 DK (T1); 3. T1 and TE 0.4 L ha^{-1} 32-33; 4. T1 and MQET 0.7 L ha^{-1} 37-39; 5. T1 and ETH 0.5 L ha^{-1} 37-39; 6. T1 and ETH 0.5 L ha^{-1} 39-45; 7. T1 and CCC 0.5 L ha^{-1} 32-33

In the other treatments significant differences in chlorophyll a and b sum were not found. In winter wheat 'Ada' in treated with PGR plots the sum of chlorophyll a and b was higher, compared with untreated.

The chlorophyll a and b ratio in winter wheat 'Ada' was significantly lowest in treatments 4 and 5 – with (MQET) and ETH for the second application (Fig.4).

Similar situation was obtained in winter wheat 'Zentos' stands - the ratio of chlorophyll a and b in all treated plots was significantly lower than in the untreated.

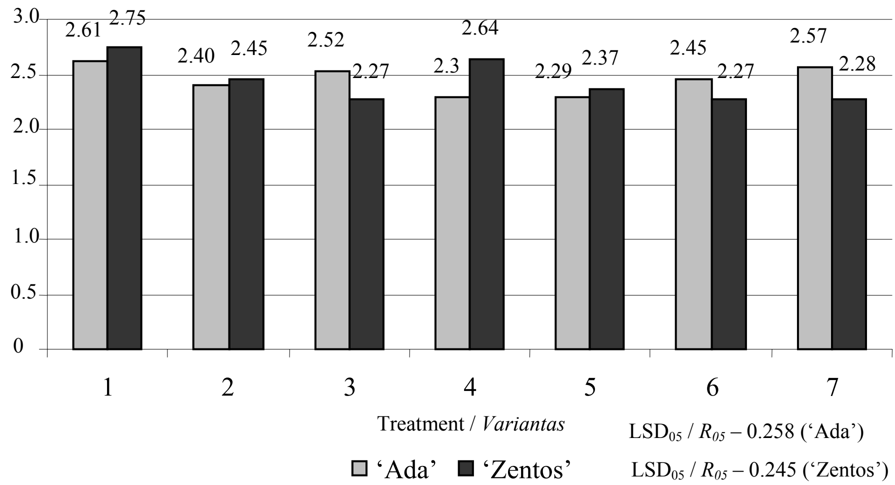


Figure 4. Ratio of chlorophyll a and b in winter wheat var. 'Ada' and 'Zentos'
4 paveikslas. *Chlorofilo a ir b santykis žieminiuose kviečiuose 'Ada' ir 'Zentos'*
1. Untreated / *Nepurkšta*; 2. CCC 1.5 L ha^{-1} 25-29 DK (T1); 3. T1 and TE 0.4 L ha^{-1} 32-33; 4. T1 and MQET 0.7 L ha^{-1} 37-39; 5. T1 and ETH 0.5 L ha^{-1} 37-39; 6. T1 and ETH 0.5 L ha^{-1} 39-45; 7. T1 and CCC 0.5 L ha^{-1} 32-33

In all treatments PAR absorption were measured in three levels of canopy in two places per plot. There were found differences not only between treated and untreated plots, but also between winter wheat varieties. In all treated plots of winter wheat 'Ada' the amount of PAR in the middle of the plot was significantly higher than that in the untreated, whereas in 'Zentos' the differences between the treated and untreated plots were not significant (Fig. 5). There were found differences between varieties in response to PGR. A greater effect of PGR on the ability to absorb PAR was identified for the variety 'Ada'. In all PGR - treated plots of winter wheat 'Ada' the amount of absorbed PAR in the middle of plots was significantly higher than in the untreated. The differences in PAR amount on soil surface between the treated and untreated plots were not significant for both varieties (Fig. 6).

There were found some differences in the grain yield of winter wheat. Grain yield differed between the varieties: 'Ada' produced a higher grain yield compared with 'Zentos'. The grain yield of winter wheat var. 'Ada' tended to increase under the influence of PGR (Fig.7). In the treatment with twice - applied CCC (7) an increase in the grain yield was significant, whereas the grain yield of the winter wheat 'Zentos' in PRG - treated plots tended to decrease. The decrease in 1000 grain weight of winter wheat 'Zentos' in most plots treated with PGR was significant (Fig. 8).

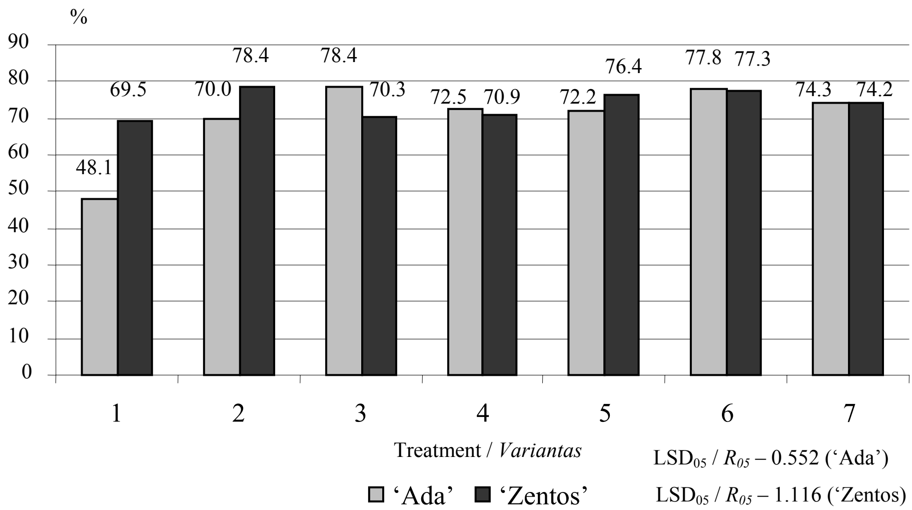


Figure 5. The amount of absorbed PAR in w. wheat ‘Ada’ and ‘Zentos’ (measured in the middle of the canopy hight)

5 paveikslas. *Žieminių kviečių ‘Ada’ ir ‘Zentos’ absorbuotos FAR kiekis (matuota pasėlio viduryje)*

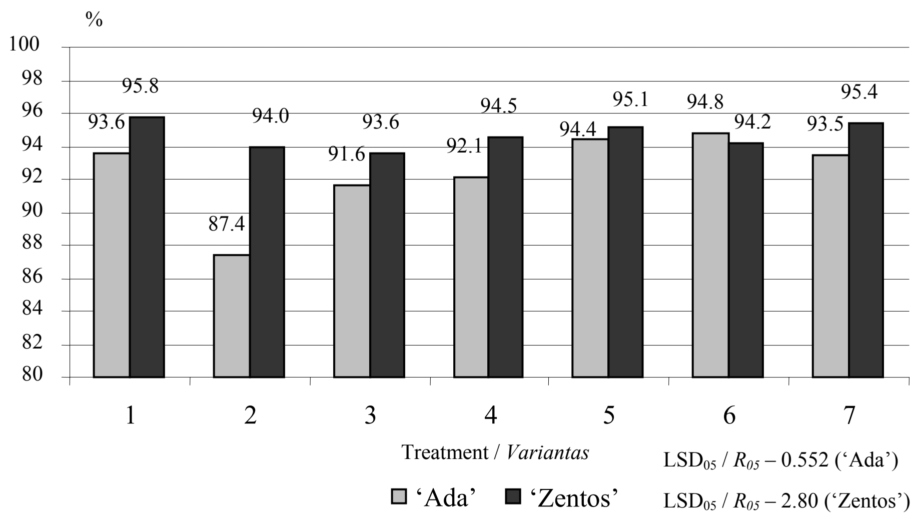


Figure 6. The amount of absorbed PAR in w. wheat ‘Ada’ and ‘Zentos’ (measured on soil surface)

6 paveikslas. *Žieminių kviečių ‘Ada’* ir *‘Zentos’ absorbuotos FAR kiekis (matuota dirvos paviršiuje)*

1. Untreated / *Nepurkšta*; 2. CCC 1.5 L ha^{-1} 25-29 DK (T1); 3. T1 and Modus 0.4 L ha^{-1} 32-33; 4. T1 and Terpal C 0.7 L ha^{-1} 37-39; 5. T1 and Cerone 0.5 L ha^{-1} 37-39; 6. T1 and Cerone 0.5 L ha^{-1} 39-45; 7. T1 and CCC 0.5 L ha^{-1} 32-33

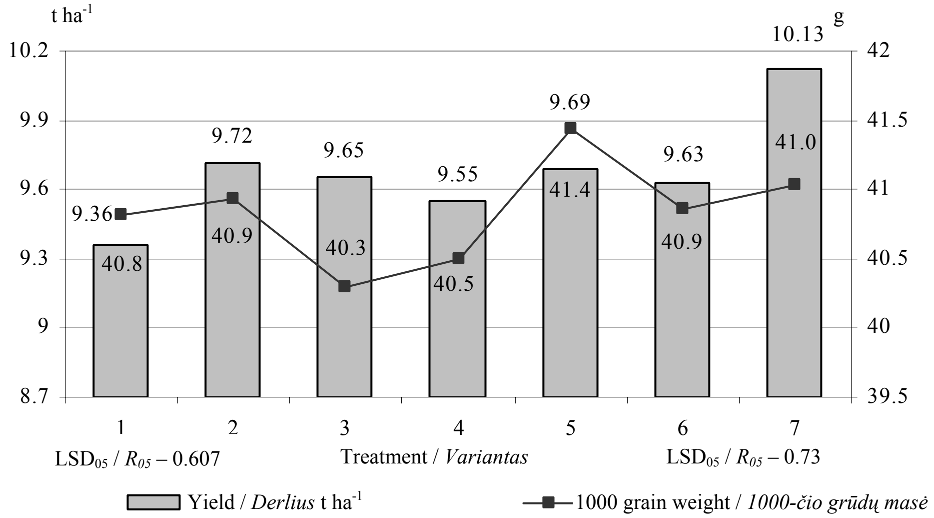


Figure 7. The grain yield t ha^{-1} and 1000 grain weight of winter wheat var. 'Ada' in different PGR treatments

7 paveikslas. *Žieminių kviečių 'Ada' grūdų derlius ir 1000-čio grūdų masė, naudojant skirtingus augimo reguliatorius*

1. Untreated / *Nepurkšta*; 2. CCC 1.5 L ha^{-1} 25-29 DK (T1); 3. T1 and Modus 0.4 L ha^{-1} 32-33; 4. T1 and Terpal C 0.7 L ha^{-1} 37-39; 5. T1 and Cerone 0.5 L ha^{-1} 37-39; 6. T1 and Cerone 0.5 L ha^{-1} 39-45; 7. T1 and CCC 0.5 L ha^{-1} 32-33

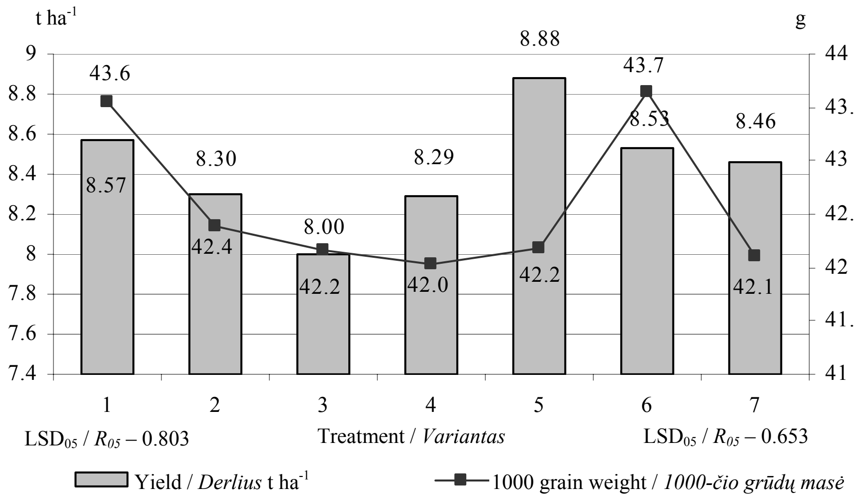


Figure 8. The grain yield t ha^{-1} and 1000 grain weight of winter wheat var. 'Zentos' in different treatments of PGR

8 paveikslas. *Žieminių kviečių 'Zentos' grūdų derlius ir 1000-čio grūdų masė, naudojant skirtingus augimo reguliatorius*

1. Untreated / *Nepurkšta;* 2. CCC 1.5 L ha^{-1} 25-29 DK (T1); 3. T1 and Modus 0.4 L ha^{-1} 32-33; 4. T1 and Terpal C 0.7 L ha^{-1} 37-39; 5. T1 and Cerone 0.5 L ha^{-1} 37-39; 6. T1 and Cerone 0.5 L ha^{-1} 39-45; 7. T1 and CCC 0.5 L ha^{-1} 32-33

It can be concluded that PGR affected chlorophyll content, PAR absorption and grain yield formation of winter wheat.

These results agree with the results obtained by other authors /Banevičienė et al., 1987; Novickienė, Merkys, 1998; Peltonen - Sainio, 1999/. However, the effect depended on winter wheat varieties.

There was not found any relationship between grain yield of both winter wheat varieties and chlorophyll a, chlorophyll b amount and the sum of chlorophyll a and b. Weak but significant correlation was identified between the amount of chlorophyll a and b.

Conclusions

1. PGR affected chlorophyll content, PAR absorption and grain yield formation of winter wheat, but the effect of PGR on different winter wheat productivity indicators was ambiguous and depended on the winter wheat varieties.

2. The grain yield of winter wheat var. 'Ada' tended to increase under the influence of PGR. In the treatment applied with CCC twice an increase in grain yield was significant, while the grain yield of winter wheat 'Zentos' in the PRG - treated plots tended to decrease. The reduction in 1000 grain weight of winter wheat 'Zentos' in most PGR - treated plots was significant.

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AUGIMO REGULIATORIŲ ĮTAKA CHLOROFILO KIEKIUI AUGALUOSE, FAR ABSORBCIJAI BEI ŽIEMINIŲ KVIEČIŲ PRODUKTYVUMUI

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Santrauka

Augalų augimo reguliatoriai (AAR) naudojami intensyviai auginant javus jų išgulimui išvengti. Be tiesioginės paskirties – javų stiebų trumpinimo - augimo reguliatoriai veikia ir derliaus formavimąsi. Augimo reguliatorių bei jų mišinių ir derinių įtakai chlorofilo kiekiui žieminiuose kviečiuose, jų absorbuojamos fotosintezės aktyviosios radiacijos (FAR) kiekiui nustatyti Lietuvos žemdirbystės instituto Dirvožemio ir augalininkystės skyriaus sėjomaininiuose laukuose 2005-2006 metais daryti du lauko bandymai. Dirvožemis – giliau karbonatingas sekliau glėjiškas rudžemis, lengvas priemolis, drenuotas, neutralaus rūgštumo. Javai – žieminiai kviečiai 'Ada' ir 'Zentos'. Bandymuose buvo naudoti giberalinų sintezės inhibitoriai chlormekvat-chloridas (CCC) ir trineksapak - etilas (TE) bei etileno sintezę skatinantis etefono ir mepikvat-chlorido mišinys (MQET) ir etefonas (ETH). Augimo reguliatoriai naudoti pagal numatytą schemą keturiais terminais: BBCH 27-29 (krūmijimasis) BBCH 32-33 (bamblėjimas). BBCH 37-39 (paskutinio lapo pasirodymas) BBCH 39-45 (visiškai išsivystęs paskutinis lapas). Laboratorinės analizės buvo padarytos LŽŪU Agronominių ir zootechninių tyrimų laboratorijoje „Tempus".

AAR turėjo nevienodą įtaką chlorofilo kiekiui žieminiuose kviečiuose – ji priklausė nuo žieminių kviečių veislės. Žieminių kviečių 'Ada' augaluose, purkštuose AAR, chlorofilo ir absorbuotos FAR kiekis didėjo, palyginus su nepurkštais, tuo tarpu kviečių 'Zentos' turėjo tendenciją mažėti. Žieminių kviečių 'Ada' grūdų derlius purkštuose laukeliuose turėjo tendenciją didėti, o laukeliuose, kurie CCC buvo purkšti du kartus, šis padidėjimas buvo esminis.

Reikšminiai žodžiai: AAR, žieminiai kviečiai, grūdų derlius, chlorofilo a ir b kiekis, FAR.