Effect of exogenous application of growth regulators on the physiological parameters and the yield of winter wheat under drought stress

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Abstract: The field trial aimed to evaluate the effect of different growth regulators in winter wheat under growth stress was conducted in 2013/2014. Within this experiment following growth regulators and fungicide with growth regulation effect were used: Retacel extra R68 (chlormequat chloride 720 g/l), Moddus (trinexapac-ethyl 250 g/l), Cerone (ethephon 480 g/l), Amistar (strobulirin 250 g/l). These growth regulators were applied at growth stages between BBCH 31 and BBCH 59. The aim of the experiment was to determine the impact of these regulators on the growth, development and yield of winter wheat when simulating the drought stress using experimental rain-out shelters. The attention was paid to assess the effect of exogenous application of growth regulators on the physiology and the yield of selected varieties of winter wheat under drought stress. From our preliminary results it can be concluded that almost all growth regulators increase the rate of CO_2 assimilation and the stomatal conductance. Definitely positive effect on water use efficiency was found in fungicide treatment with growth regulation effect - azoxystrobin. Under drought stress the decrease of chlorophyll content in leaves was found. Growth regulators CCC and trinexapac mitigate the decline of chlorophyll content caused by drought in the upper leaves but rather increased the impact in older (lower) leaves. Fungicide azoxystrobin alleviates the decrease of chlorophyll caused by drought in all leaves. The results show that all regulators increased yield, which demonstrate a positive effect under dry conditions because the vegetation season was very dry and lodging did not occur. Furthermore, the most pronounced mitigation of drought stress was found for strobilurin and partly also trinexapac. Results of field experiments can contribute to mitigating the impact of drought on yield formation and quality of winter wheat production in the realization of biological potential of wheat genotypes.

Key-Words: plant growth regulators, winter wheat, drought stress

Introduction

Drought still belongs to the most significant environmental factors which negatively influences plant growth. Drought stress in winter wheat is evidently more significant in Central Europe than in other regions, it is also supposed that according to the model of climate prediction periods of drought are going to be more often [1].

Period of drought during the early phase of growing season can have serious consequences for crop production, excess of water in this period has negative influence as well on the production and quality of crops because it increases the risk of infection by certain diseases, it leads to root anoxia and tillage is more difficult. Drought decreases the growth of plants, influences various physiological and biochemical processes such as photosynthesis, respiration, metabolism of nutrients and growth stimulators [2, 3]. Partial elimination of environmental stress can be reached by application of growth regulators.

Growth regulators can improve water use efficiency by closing stomata. They also have effect on increase of ratio roots: above ground biomass and can also influence the accumulation of antioxidants that protect plants during stress conditions. For agricultural purposes the growth regulators are such substances which have effect on physiological processes in metabolism of plants and thereby they positively influence the yield and the quality of production.

This mostly concerns increase of cold resistance, limitation of lodging, tiller levelling, reduction of apical dominance, higher deployment of generative organs, more effective use of nutrients, decrease of harvesting losses and facilitating harvest [4]. Drought – lack of water or water stress - is the most limiting stressor for plants, it decreases the activity of all enzymes in the plant, slows down the growth of the plant, leads to closing stomata and reduction of CO_2 assimilation [5, 6].

By applying growth regulators we can affect levelling of productive tillers and prolongation of leaf area activity. Greenhouse research proves that growth regulators can decrease evapotranspiration by 29% [7]. Some studies are pointing out that growth regulators can, in fact, increase rooting [8]. Previous studies proved that plants with slow growth can survive longer period of drought than fast growing plants [9]. By using phytohormones or synthetic regulators we might achieve a partial elimination of environmental stress effect or help plants with regeneration after active stress. Theoretically, it is possible to suppose that the regulator itself causes increase or decrease of yield because its activity is in correlation with the influence of all other parameters of the environment.

The aim of the experiment was to evaluate positive and negative impacts of growth regulators on physiology and winter wheat yield in conditions of drought, to choose suitable types of regulators and the time of applying in order to improve tolerance to drought.

Fig. 1 Sheds over the experimental area of winter wheat

Material and Methods

The experiment was carried out at the field experimental station in Žabčice with winter wheat variety Matylda.

The experimental station is situated in Southern Moravia (the Czech Republic). Moderate soils are dominant type in this region. The location is considered to be one of the hottest areas in the Czech Republic [18].

Sowing of the variety Matylda was carried out on October 15th, 2013 in three replications randomly distributed on selected plot with sowing rate of 4MGS/ha. Variety Matylda belongs to the set of early varieties. The variety has a medium plant length with an average resistance to lodging. Variety Matylda has a very high yield potential. During the growth phase by the end of stem elongation period BBCH 39 there were over the half of the experimental area built short-termed rain out shelters providing induction of drought stress. Measuring of physiological parameters (water use efficiency, CO_2 assimilation rate (Fig. 4) and the chlorophyll content in leaves (Fig. 5) was done in the middle of drought stress (May 26th, 2014), and at the end of drought stress effect.

After wheat ripening evaluation of yield (Fig. 6) and yield structure has been done. For evaluation of CO_2 assimilation rate, transpiration and stomatal conductivity gas exchange system LI 6400 XT with a assimilation chamber equipped with LED light source has been used. The measurement took place at constant temperature, relative air humidity, CO_2 concentration and at saturation light intensity. The observed parameters allowed calculation of water use efficiency (WUE) and indirect parameter of water use efficiency A/Gs.

As an additional parameter for evaluation of primary phase of photosynthesis measuring of chlorophyll fluorescence by the apparatus FluorPen has been done. Parameters of the maximal and actual quantum yield PS II were evaluated. The content of chlorophyll and flavonols was determined in vivo by the method of transmittance and UV screening of chlorophyll fluorescence by the instrument Dualex4 FLAV. The individual regulators were applied in the following phenophases and in amounts according the Table 1.

Table 1

Number of variants	Name of product	The planned dose		The term application
		product ha (l, kg)	water ha (l)	
1	**KONTROLA**			
2	CCC (Retacel)	1,88 l	300 l	3.4.2014 BBCH 31
3	TRINEXAPAX-ETHYL (Moddus)	0,4 l	300 l	23.4.2014 BBCH 32-35
4	ETHEPHON (Cerone 480SL)	0,6 l	300 l	7.5.2014 BBCH 45
5	AZOXYSTROBIN (AMSTAR XTRA)	0,8 l	300 l	13.5.2014 BBCH 59

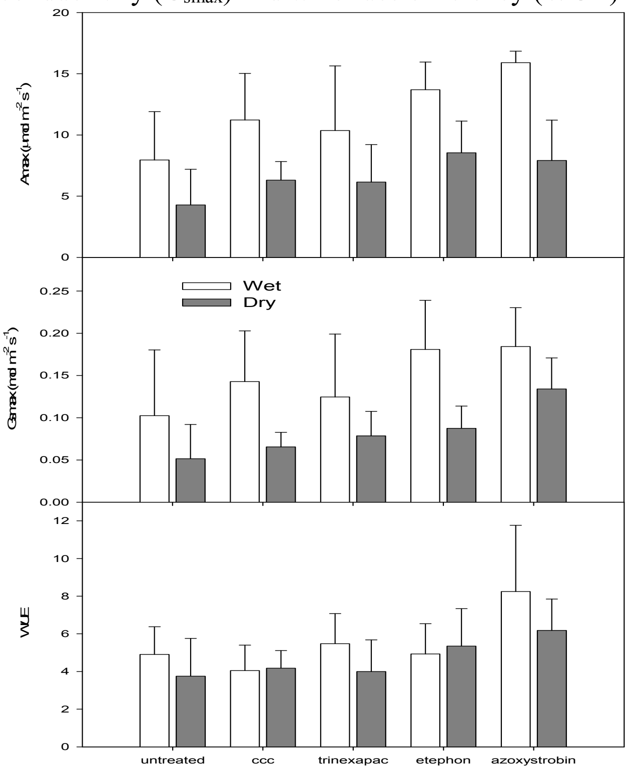
Fig. 2 Aplication of CCC (4.4.2014)

Fig. 3 Aplication of trinexapax-ethyl (23.4.2014)

Results and Discussion

The results indicate a negative effect of drought on the CO_2 assimilation rate (A_{max}) and stomatal conductance (G_s). In the untreated control were A_{max} and G_s reduced by almost 50%. The application of growth regulators increased CO_2 assimilation rate in both treatments with ambient rainfall and drought stress, with the highest increase recorded after application of azoxystrobin and etephon. Relative differences between dry and wet treatment, however, changed relatively little. The decrease of relative reduction of A_{max} due to drought stress occurred mainly after application of etephon and trinexapac-ethyl. In the case of G_s the decreased reduction was noted after the application of azoxystrobin and trinexapac-ethyl. The most significant effect on increasing water use efficiency (WUE), was found following the application of azoxystrobin both in dry and wet variants. The effect of drought was also reflected in the decrease of chlorophyll content in individual leaves within vertical profile. This decrease was mitigated mainly by application of azoxystrobin. In the case of applications of trinexapac-ethyl the effect of drought on the chlorophyll content was reduced in upper leaves but enhanced in bottom leaves. Yield results showed a positive effect of all applications of growth regulators, with the highest impact of the trinexapac-ethyl, etephon and azoxystrobin. All three treatments also reduced the negative impact of drought on yield.

Fig. 4 CO_2 assimilation rate (A_{max}), stomatal conductivity (G_{smax}) and water use efficiency (WUE)



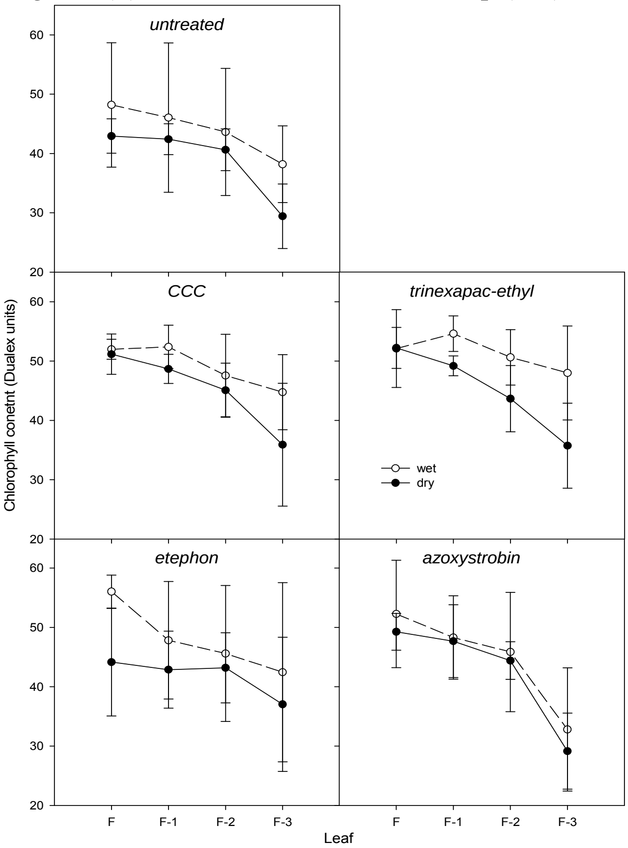
Definitely positive influence on water use efficiency was caused only by fungicide with regulatory effects - azoxystrobin.

Conclusion

The use of growth regulators is accompanied with a number of positive effects, especially in the conditions of water deficit.

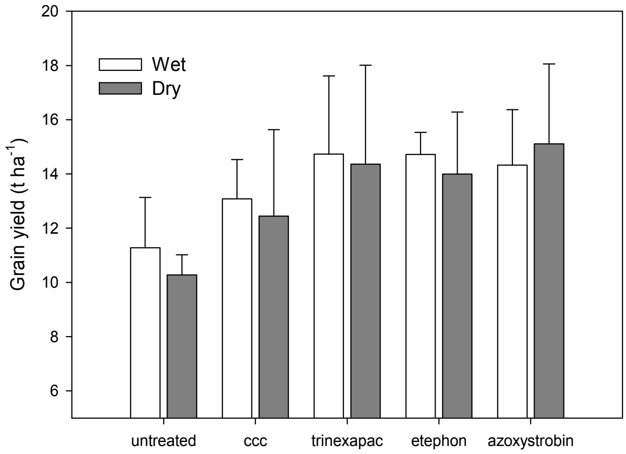
By applying growth regulators we can reach a partial elimination of environmental stress effect. Growth regulators can improve water use efficiency. They also have influence on increase of roots: above ground biomass ratio and can also influence the accumulation of antioxidants that protect plants during stress conditions. According to our preliminary results it is possible to be stated that, practically, all growth regulators used increase the CO_2 assimilation rate and stomatal conductance.

Fig. 5 Chlorophyll content in leaves in order from flag leaf (F) to the fourth leaf from the top (F-3)



Regulators CCC and trinexapac reduce decrease of chlorophyll caused by drought at upper leaves but on the other hand they increase it at older lower leaves.

Fig. 6 Effect of drought and growth regulators application on grain yield



The biggest reduction of drought stress influence (shed) on yield was evident at strobilurin and partially at trinexapac as well.

- Unambiguously positive influence on water use efficiency had mostly fungicide with regulatory effects - azoxystrobin.
- Due to drought activity there is decrease of chlorophyll content in leaves. Regulators CCC and trinexapac reduce decrease of chlorophyll caused by drought at upper leaves but on the other hand they increase it at older lower leaves.
- Fungicide azoxystrobin reduces decrease of chlorophyll caused by drought at all the leaves.
- It is evident from the measurements that all the regulators increased the yield and which it itself proves the positive effect during the drought because it was a very dry year and the canopy did not lodge. Furthermore, the biggest reduction of drought stress effect on yield was evident in strobilurin and partially at trinexapac-ethyl application as well.

The results of field experiments can significantly contribute to reduction of drought impact on yield formation and quality of production of winter wheat in realization of biological potential of varieties.

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