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Alleviation the negative effect by growth regulators of winter wheat under water deficit on the physiology and grain yield parameters

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Abstract
Plant pressure from salinity and water deficit have a good deal in common (Munns, 2002a), however how the plant responds to the mixture of stresses remains unresolved. Pressure from water deficit may additionally predominate in the upper part of the basis sector even as salt pressure may additionally predominate in the lower part. Water deficit became induced artificially via the usage of remote shelters inside the period between biotin and late milk ripeness. Under study conditions, water deficit is practically unavoidable since the land-water content varies temporally and spatially throughout the season. The problem of boom regulators become evaluated in two comparison years in terms of yield formation (2015–2016). In each years, the water deficit caused an extensive decrease of grain manufacturing. The poor end result of water deficit was in part relieved by means of software of increase regulators. On the contrary, within the year with appropriate conditions for tillering (2015), the alleviating impact became most apparent in software of chlormequate-chloride. The packages of trinexapac-ethyl and ethephon confirmed small reduction of terrible event of water deficit consistently in each years. Osmotic adjustment turned into incomplete in leaves of water-stressed vegetation in comparison to salt-harassed plants. Decrease leaf-tiger in water-pressured flowers led to decreased transpiration, CO2 absorption quotes and increase conductance were recovered mainly by using applications of chlormequate-chloride and azoxystrobin. Chlorophyll content and chlorophyll fluorescence parameters were greater moved by water deficit in 2014, and the alleviating effect of increase regulators corresponded with yield reaction.

Keywords: water limitation, development, salinity stress, growth parameters, spike productivity, photosynthesis, number of spikes

1. Introduction

Wheat can be processed into flour that's used within the manufacture of breakfast meals, alcohol, dextrose and as animal feed. The essential duration for impact of water deficit on wheat grain yield and quality is defined particularly by way of the ranges among stem elongation and early ripening (Entz and Fowler 1988) [7]. Water deficit decreases the boom of plant life, affects various physiological and biochemical processes together with photosynthesis, breathing, metabolism of vitamins and so forth. Excessive water stress may additionally bring about the cessation of photosynthesis, disturbance of metabolism and sooner or later the demise of flora. The wheat straw presents valuable fodder and is also used for making baskets, hats, bedding in hen runs and as substrate e.g. in mushroom manufacturing.

So one can meet the venture of multiplied frequency and severity of drought occasions, the ag-RI culture is pressured to implement a number of adaptation measures that might be capable of alleviate the bad impacts of water dilemma during crucial boom levels. Such measures may be divided into three important categories: (i) the choice and breeding of genotypes with progressed drought tolerance; (ii) an increase within the soil retention capability and discount of evaporation from soil surface, and (iii) cultivation measures enhancing the green use of water by plant life, which consist of, as an instance, the usage of boom regulators. In standard, the boom regulators can make a contribution to enhancing powerful use of water specially by way of growing the rooting depth or root water extraction from soil (Marcum and Jiang 1997), increasing the basis: shoot ratio (Rajala and Peltonen-Sainio 2001) [2], lowering leaf region (Beasley *et al*. 2007) [13] and accumulation of osmoregulatory substances (Akram *et al*. 2012) [14], increasing the buildup of antioxidants (Wu and von Tiedemann 2001) [1], helping stomatal law (Bingham and McCabe 2006) [9], reducing rate of leaf senescence (Cromey *et al*. 2004) [8] etc.

In order to curb the experiment of soil fertility, most people of industrial and communal wheat farmers use soil applied fertilizers, each organic and inorganic to increase growth and yield. But, very regularly contradictory results of plant regulators on plant physiology and yield formation beneath water deficit are mentioned (e.g. Kasele *et al*. 1994) [5]. And the soil carried out fertilizers are frequently associated with ephemeral nutrient deficiency which results in deficiencies of vitamins in the course of durations of critical needs. according to available statistics, contrast of the alleviating effects of various increase regulators which belong to the institution of gibberellin biosynthesis inhibitors (chlormequate-chloride [CCC], trinexapac-ethyl), liberation of ethylene (ethephon) and promoting cytokinin biosynthesis (strobilurins) under water limiting conditions has now not been accomplished in wheat to this point.

Material and Methods

The sector trials have been executed at the sector experimental station in Žabčice, Czech Republic (49°01'22"N, sixteen°

37'04"E) placed in a warm vicinity with transitional weather (average annual rainfall 482 mm and temperature 9.3°C). The soil kind is fluvi-eutric gley soil, and soil texture is clay-loam. The soil reaction within the arable horizon of the soil is impartial, pH is 6.1 and the content of humus is 2.26%. The wintry weather wheat cv. Matylda was sown on October 15th, 2013 and November, 2015 in sowing density of 450 germinating seeds/m2. The usual crop protection measures were executed to ensure weed and sickness manipulate for the duration of the vegetation season. The whole nitrogen dose was two hundred kgN/ha. Growth regulators were sprayed (spray volume 300 L/ha) using wheeled small plot sprayer. The growth regulator treatments were randomized in blocks (3 replications). Within the experiment following growth regulators were applied: 1355 g/ha chlormequat-chloride (Retacel extra R68, Lučební závody Draslovka a.s., Kolín, Czech Republic) at growth stage 31 BBCH, 110 g/ha trinexa-pac ethyl (trinexapac; Moddus, Syngenta Crop Protection AG, Basel, Switzerland) at 33–35 BBCH, 290 g/ha ethephon (Cerone 480 SL, Bayer S.A.S., Lyon, France) at 38–48 BBCH and 210 g/ha azoxystrobin (Amistar, Syngenta Supply AG, Basel, Switzerland) at 50–56 BBCH. The measurements of physiological parameters were done at the end of water deficit period (July 10th, 2015 and July 28th, 2015). An open gasoline exalternate system Li-6400 XT (Li-Cor, Lincoln, u.s.a.) changed into used to estimate the mild-saturated (1200 μmolphotons/m2/s) carbon dioxide assimilation rate (Amax) and stomatal conductance (gs). Simultaneously, measurements of maximum quantum yield of chlorophyll fluorescence (Fv/Fm) and a parameter 1-Vj in dark-adapted leaves were made by Fluor Pen FP one hundred (PSI, Brno, Czech Republic). Chlorophyll content material was measured by way of transmittance approach the use of the device Dualex 4 Flav (force-A, F, Orsay). All physiological measurements were carried out on flag leaves of 3 flora in line with each replication.

After wheat ripening assessment of yield and yield shape has been achieved. The wide variety of spikes turned into calculated on the location of one m2; then the location of one m2 from the significant part of every plot turned into manubest friend harvested and the grain changed into threshed using the plot harvester Sampo 2010 (Sampo Rosenlew, Pori, Finland) on August 7th, 2015 and July tenth 2016. The two-way ANOVA accompanied by means of the Fisher's LSD put up-hoc check was finished the use of the Statistical 12.

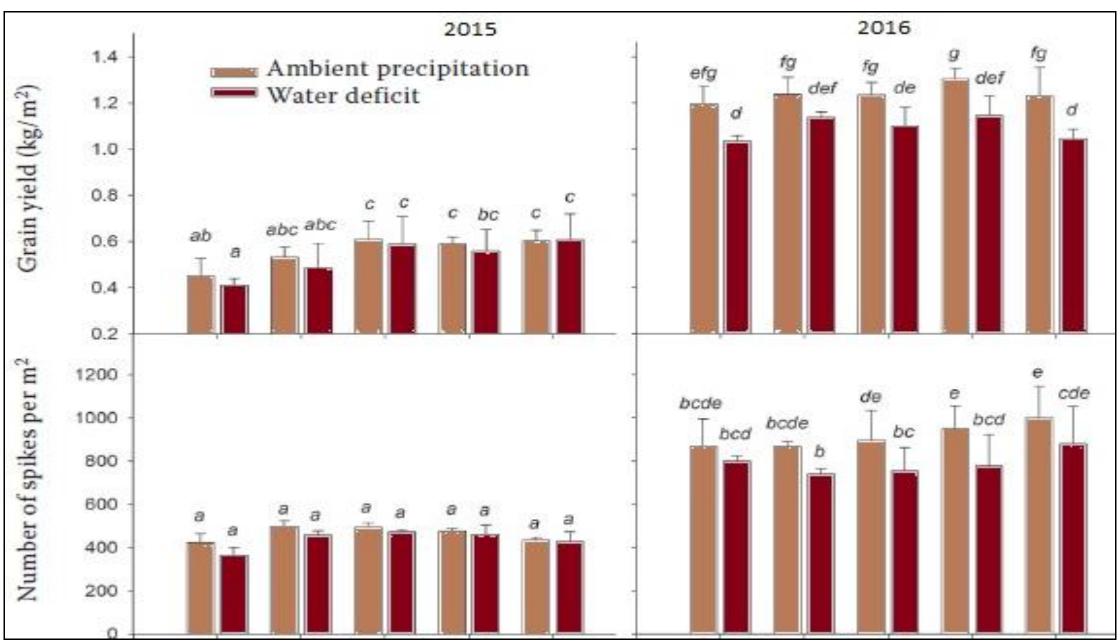
Results and Conclusion

Grain yield &Yield Parameters

Grain yield and yield parameters studied (number of spikes and spike productivity) were affected significantly by year ($P < 0.01$; Table 1). The year 2014 was characterized by generally lower yield levels and spike numbers per unit area show in fig. 1

Table 1: The average daily temperature and sum of precipitation per month in the main vegetation period of the year 2015 and 2016

Months	Temperature (°C)					Precipitation (mm)				
	long-term average (1990–2013)	2015	difference	2016	difference	long-term average (1990–2013)	2015	difference	2016	difference
3rd	4.9	8.7	3.8	5.4	0.5	33.5	5.7	- 27.8	28.3	- 5.2
4th	10.8	11.6	0.8	10.3	- 0.2	30.6	11.3	- 19.3	9.5	- 21.1
5th	15.7	14.4	- 1.3	14.6	- 1.1	51.3	62.9	11.6	33.6	- - 17.7
6th	18.7	18.5	- 0.2	19.2	0.5	59.8	43.6	- 16.2	22.5	- 37.3
7th	20.6	21.4	0.8	22.8	2.2	73.4	85.3	11.9	22.6	- 50.8



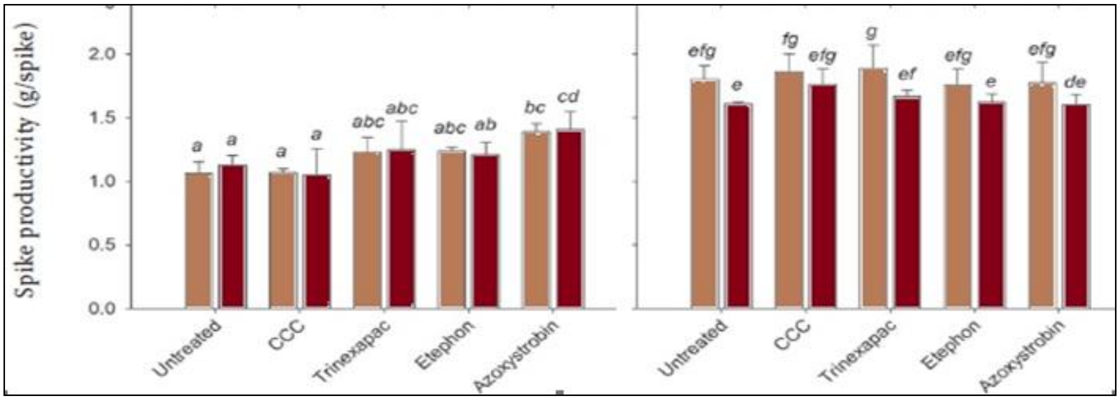


Fig 1: Effects of water deficit in period between booting and late milk ripeness and application of growth regulators on yield parameters (grain yield, number of spikes and spike productivity) in years 2015 and 2016. Means (columns) and standard deviations (error bars) are presented (*n* = 3).

The highest differences in grain yield between the years were recorded in the untreated control and CCC, whereas the lowest inter-annual differences were found for growth regulators azoxystrobin and trinexapac-ethyl. These results suggest that the growth regulators, particularly azoxystrobin and trinexapac-ethyl, were able to partially eliminate the adverse effect of the year 2014, which was characterized by lower formation of productive tillers. Relatively dry weather and high temperatures during tillering in 2015 (Table 1) were probably the cause of accelerated plant development and reduced number of strong tillers able to form productive stems (Křen *et al*. 2014) [4].

Table 2: Results of three-way ANOVA for effects of water deficit, growth regulators and year on yield characteristics, gas exchange parameters (Amax, gs), chlorophyll content and chlorophyll fluorescence (1-Vj, Fv/Fm) parameters.

	Degrees of freedom	Grain yield		Number of spikes		Spike productivity		Amax		g_s		Chlorophyll content		1-Vj		Fv/Fm	
		F	P	F	P	F	P	F	P	F	P	F	P	F	P	F	P
Year (Y)	1	1037.6	<0.001	344.2	< 0.001	298.3	< 0.001	374.8	< 0.001	17.5	< 0.001	60.8	<0.001	1659.2	< 0.001	537.2	<0.001
Growth regulators (GR)	4	5.2	<0.002	1.2	0.308	2.8	0.045	6.2	< 0.002	8.8	< 0.001	4.2	0.008	3.6	0.016	16.6	< 0.002
Water deficit (WD)	1	20.5	<0.002	12.4	0.002	5.9	0.019	200.3	< 0.002	111.1	< 0.001	68.5	<0.001	29.5	<0.002	3.3	0.080
Y × GR	4	2.6	0.006	2.5	0.068	6.2	< 0.001	3.8	0.008	2.4	0.082	0.5	0.786	3.2	0.03	10.7	<0.001
Y × WD	1	10.2	0.004	5.2	0.031	8.2	0.008	0.01	0.989	0.8	0.362	29.5	< 0.001	27.8	<0.001	1.7	0.210
Y × GR × WD	4	0.4	0.867	0.4	0.866	0.4	0.70	1.2	0.34	1.1	0.429	0.9	0.492	2.2	0.095	0.7	0.689

These results confirm the hypothesis, that the alleviation of water deficit effect by growth regulators is modulated by year. The positive effect on reduction of water deficit impacts was observed in both years also in applications of trinexapac-ethyl and ethephon, however, this effect was relatively low and statistically insignificant. Trinexapac-ethyl exhibits both an indirect effect on drought tolerance through reduction of aboveground biomass and increasing the root length and area (Beasley *et al*. 2005) [15] and the direct effect increasing the efficient use of water, reducing transpiration and greater osmotic adjustment (Bian *et al*. 2009) [12].

Physiological parameters.

The gas exchange parameters Amax and gs were statistically significantly affected by all three factors, year, water deficit and growth regulators at $P < 0.01$ (Table 2). Similarly to the grain yield, the gas exchange parameters were statistically significantly lower in 2014 (Figure 2). In contrast to yield parameters the effect of water deficit was in Amax and gs significant also for comparison within individual growth regulator treatments ($P < 0.05$; Figure 2). The Amax decline under water deficit was mostly alleviated by application of azoxystrobin and CCC. Several studies have shown increases of CO2 assimilation rate after application of strobilurin fungicides (e.g. Grossmann *et al.* 1999), which is often associated with delayed senescence and an increase of antioxidant activity (Wu and von Tiedemann 2001) [1]. All the growth regulators acted positively to $g_s$decrease under water deficit but the differences between distinct types of growth regulators were relatively low. The chlorophyll content and chlorophyll fluorescence parameter 1-Vj were both affected significantly at $P < 0.01$ by year and water deficit and at $P < 0.05$ by growth regulators (Table 2). In contrast, Fv/Fm was not

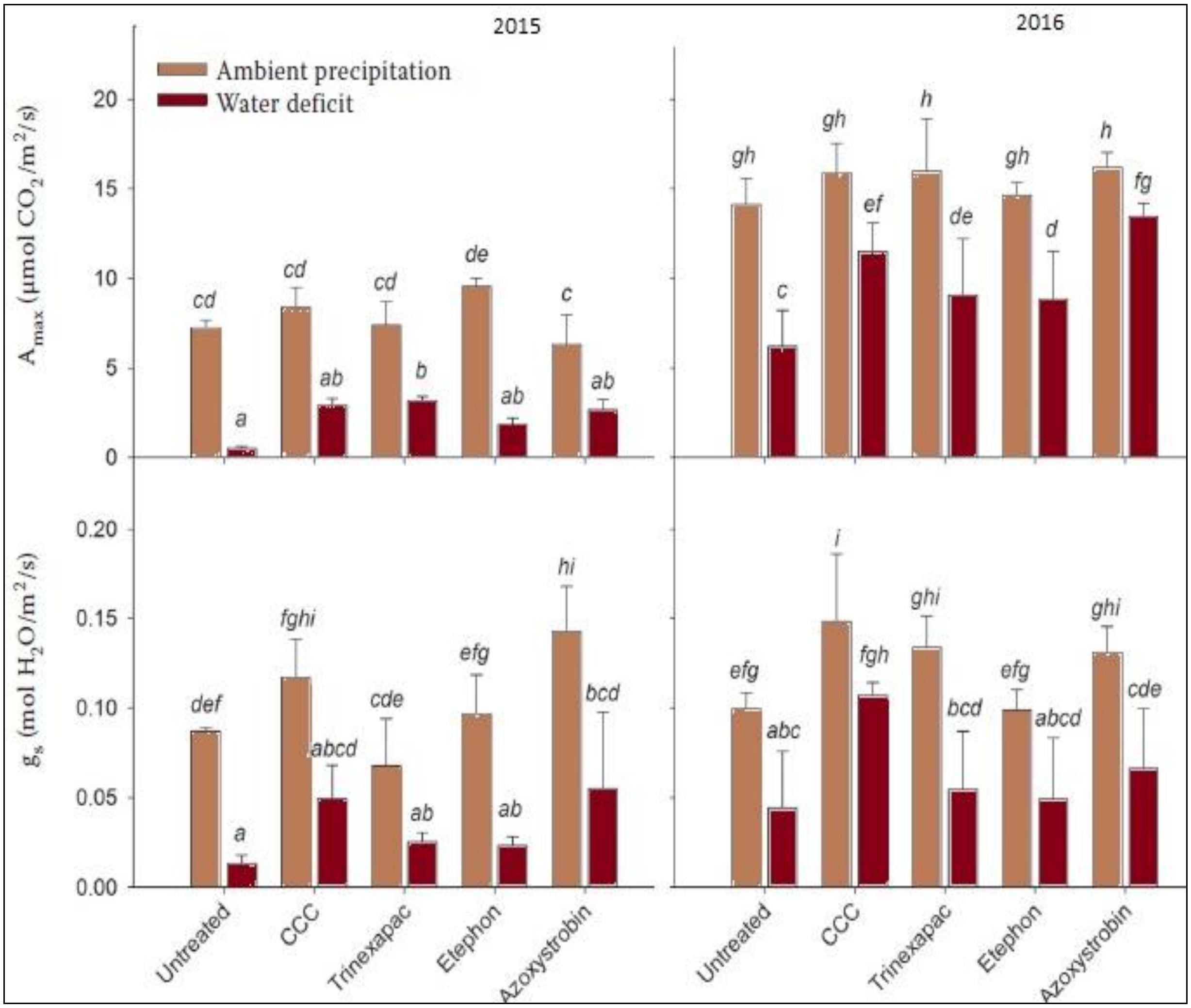
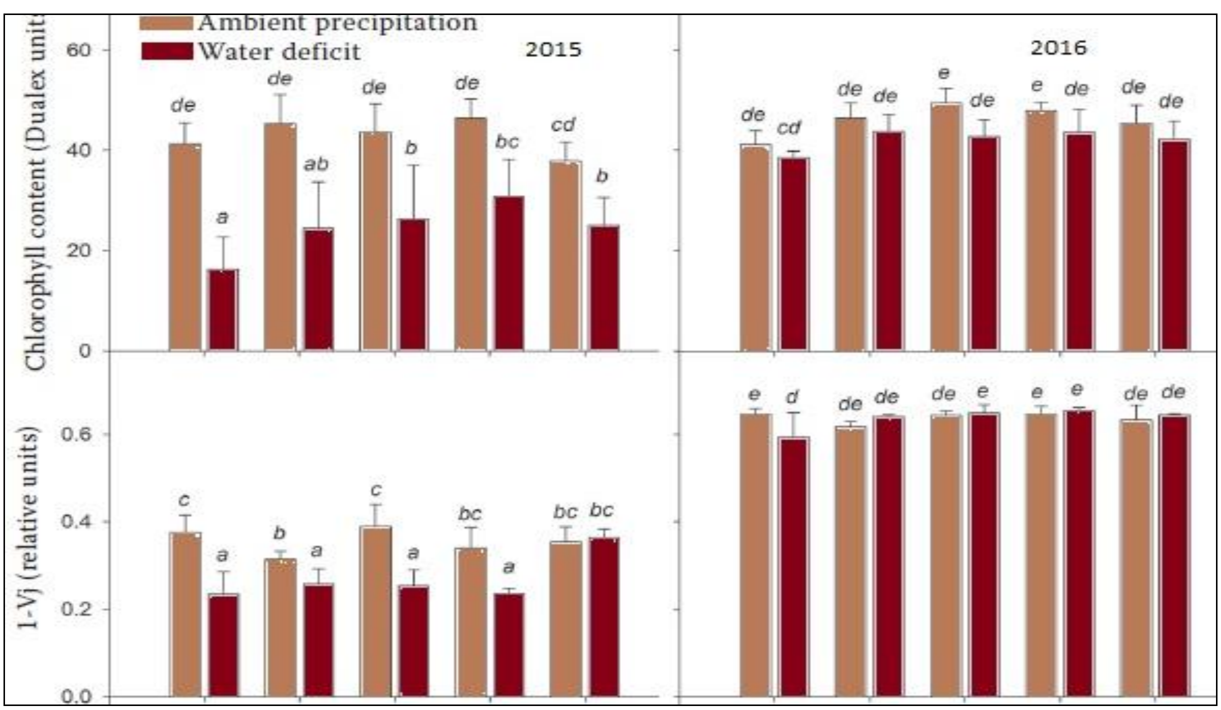


Fig 2: Effects of water deficit in period between booting and late milk ripeness and application of growth regulators on gas exchange parameters light saturated CO2 assimilation rate (Amax) and stomatal conductance (gs) measured at the end of water deficit period on the flag leaf.



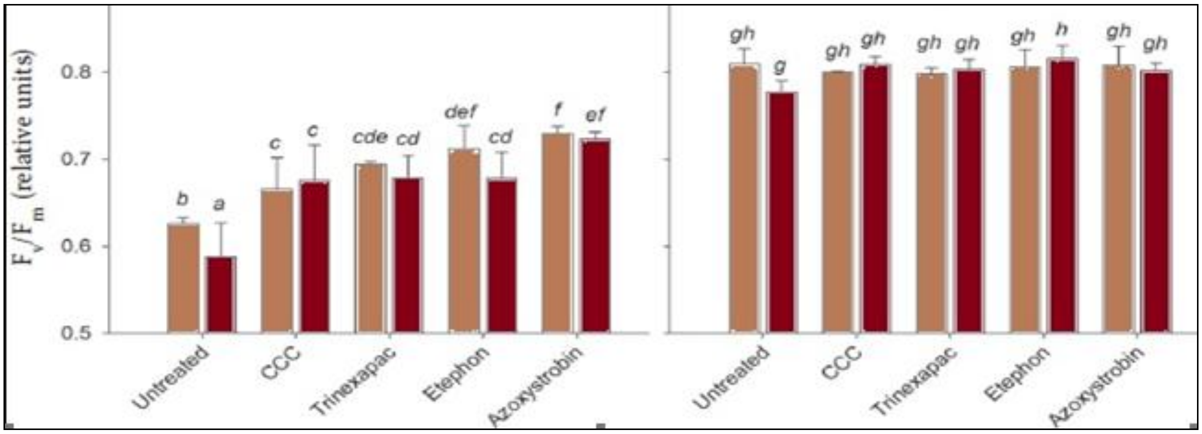


Fig 3: Effects of water deficit in period between booting and late milk ripeness and application of growth regulators on *in vivo* chlorophyll content and chlorophyll fluorescence parameters 1-Vj (variable chlorophyll fluorescence at wave J) and Fv/Fm (maximum quantum yield of photosystem II photochemistry) measured at the end of water deficit period on the flag leaf. Means (columns) and standard deviations (error bars) are presented (n = 3).

The comparison of differences between individual growth regulators and water deficit treatments (Figure 3) shows that the content of chlorophyll changed in 2016 only little, whereas in 2015 it declined significantly under water deficit. The decrease in chlorophyll content caused by water deficit was alleviated particularly by applications of etephon and azoxystrobin.

It can be concluded that growth regulators can alleviate the negative effect of water deficit both on plant physiology and grain yield. This effect, however, varies according to the conditions for yield formation. In the year with lower tillering and favorable conditions for grain filling the best effect was achieved with late applied azoxystrobin. On the other hand, in the year with favorable conditions for tillering a positive effect was observed in early applied CCC.

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