Management of sunflower stand height using growth regulators

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ABSTRACT

Influence of growth regulators chlormequat chloride, ethephon, trinexapac-ethyl, and a combination of chlormequat chloride and ethephon on decreasing sunflower height was examined in the years 2006–2009. Height was reduced by as much as 63 cm by double application of chlormequat chloride (915 g/ha) + ethephon (465 g/ha) at early and later growth stage (BBCH 32 and 50). Trinexapac-ethyl (375 g/ha) did not affect the height. One-time application of chlormequat chloride (1440–2160 g/ha), chlormequat chloride (458 g/ha) + ethephon (233 g/ha) (BBCH 30 or 50), or ethephon (480 g/ha) (BBCH 30) was sufficient for a ca 30 cm reduction during flowering, but this effect did not last until harvest. With double application (BBCH 30 and 50), reduction lasted until harvest. For ethephon (480 g/ha), application at BBCH 50 reduced height by as much as 35 cm and lasted until harvest. Combining a lower rate of ethephon with ammonium sulfate was effectively equivalent to using a full rate. Flower head diameter at maturity showed no significant negative influence compared to the control. In 2008 and 2009, a delay in flowering onset was observed after applying growth regulators.

Keywords: growth inhibition; chlormequat chloride; ethephon; trinexapac-ethyl

Plant growth retardants are synthetic compounds that are used to reduce the shoot length of plants. This is achieved primarily by reducing cell elongation, but also by lowering the rate of cell division. In their effect on the morphological structure of plants, growth retardants are antagonistic to the gibberellin and auxin plant hormones that are primarily responsible for shoot elongation (Rademacher 2000).

The sunflower is a plant disadvantaged by its tall growth despite its relatively limited root system. This disadvantage is manifested in its tendency toward uprooting, especially on irrigated areas and in locations with strong wind currents during flower head maturation. It is therefore desirable to reduce sunflower height, which would also facilitate fungicide and desiccants application and mechanized harvest (Weiss 2000).

From a physiological viewpoint, the regulation of root growth and germination depends on gibberellin and its antagonist (2-chloroethyl) trimethylammonium chloride, or CCC (Bianco et al. 1996). Although germination is not itself inhibited in the first CCC phase, once the elongation phase occurs, CCC's presence manifests itself in an inhibitory manner and also in relation to root growth. The same experiments yielding the same results were already conducted in the USA (Jones and Phillips 1966).

There is very little information on possibilities for using growth regulators in sunflowers. Nevertheless, in order to achieve an economical and stable yield, as well as to maintain oil quality, it is often necessary to treat plants with a fungicide after flowering or use a desiccant before harvest. Considering that the normal sunflower height between flowering and harvest is 160–200 cm, these operations cannot be performed without damaging the stand.

In cereals and oil crops, a number of substances with growth regulating effect are widely used. In winter rape, metconazole and tebuconazole are most frequently used (Balodis and Gaile 2009) to improve overwintering by application in autumn

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and to decrease rape height in spring. In cereals, for example, chlormequat chloride and ethephon are used (Rajala and Peltonen-Sainio 2001) to support tillering and prevent wheat and barley from lodging.

The aim of our study was to determine whether it is possible to decrease the height of sunflower plants by application of selected growth regulating substances and whether this will have a negative effect on the crop and yield.

MATERIALS AND METHODS

The field experiments were conducted at a location having one of the most fertile soils in the Czech Republic. The country is located in the Central European climatic zone (Loc: 49°17'13.708''N, 17°22'13.296''E). The location is in a warm and slightly humid area with mean annual temperature of 8.7°C and total annual precipitation of 599 mm. Figure 1 show the course of weather for the different experimental seasons. By its FAO classification, the soil at the site belongs to the type Luvi-Haplic Chernozem with deep, structural, clay loam topsoil.

The experiments were conducted in 2006–2009. Sunflowers were sown using a HEGE 95 seeder to the final spacing of 21 cm. Plot area was 20 m^2 and the plots were randomly arranged within the test area. Each plot was comprised of 4 rows with a distance of 0.75 m between them, and there were 4 replications for each treatment. Sunflower varieties sown for the experiment were Pilar in 2006, Pilar and Alexandra in 2007, and Alexandra in 2008 and 2009. The treatments applied and their combina-

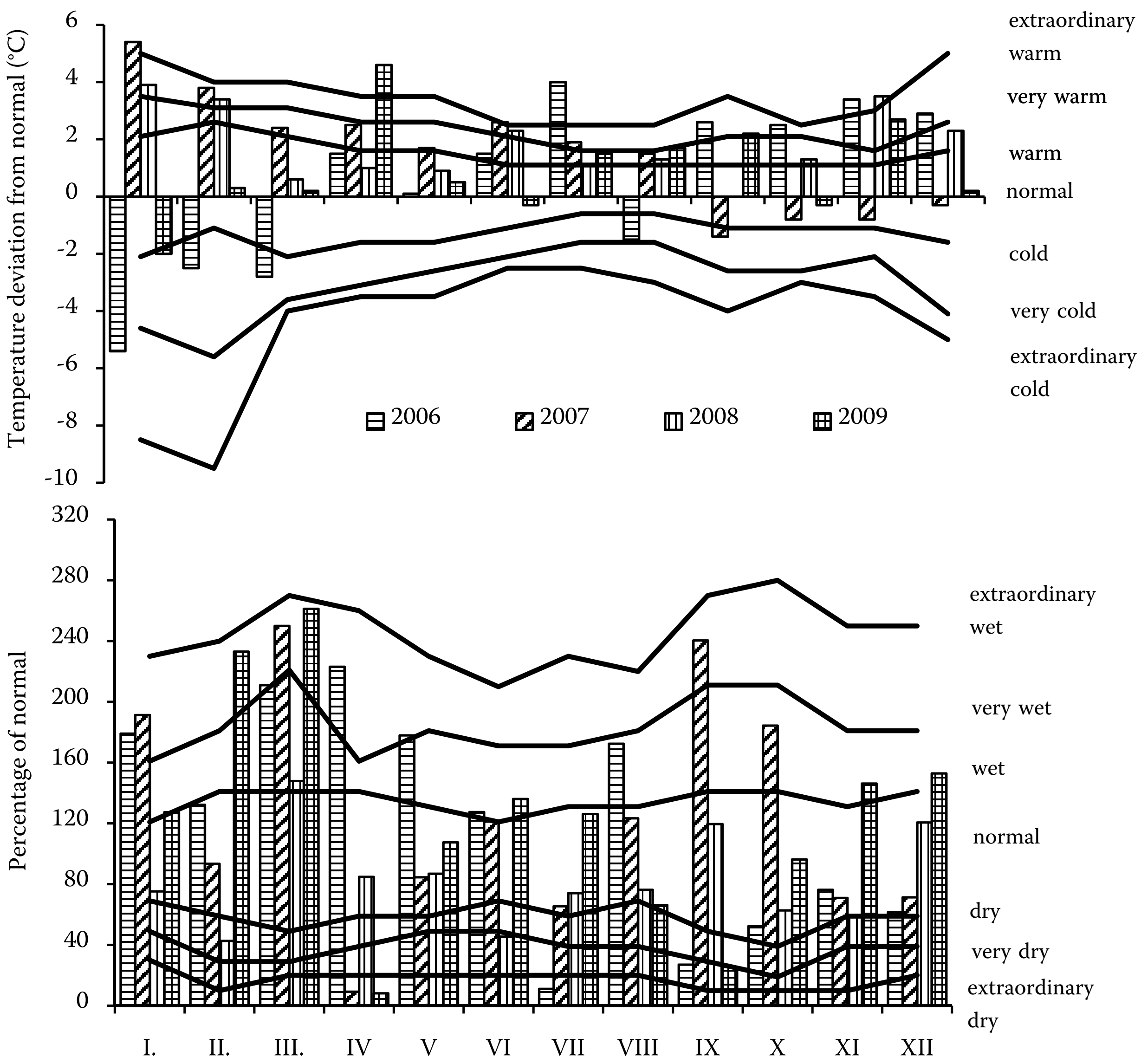

Figure 1. Temperature and precipitation at the Research Institute Agrotest fyto, Ltd. Kroměříž

tions are presented in Tables 1–4. Experimental applications in 2006 were made at only one time, BBCH 51 (40–50 cm of sunflower height, bud in axils of upper leaves 2–3 cm in diameter). Two applications were made in 2007, 2008, and 2009, the earlier at BBCH 32 (2 visibly extended internodes) and the later at BBCH 50–51. Also in the years 2008 and 2009, double applications were made at the same rates at BBCH 32 and at BBCH 51. In 2009, ammonium sulfate $(NH_4)_2SO_4$ (AS) was added into the experimental applications to examine if it could be possible to reduce the application rate for growth regulator. Applications were made using a small plot backpack sprayer by R & D Sprayers. Water application rate was 350 L/ha, pressure 0.3 kPa, nozzle type – flat fan XR Teejet 8002VS. For experiments in individual years, the following materials were used: Retacel Extra R68 (chlormequat chloride 720 g/L) in 2006–2009, Terpal C (chlormequat chloride 305 g/L + ethephon 155 g/L) in 2006–2009, Moddus (trinexapac-ethyl 250 g/L) in 2006 and 2007, and Cerone 480 SL (ethephon 480 g/L) in 2008 and 2009.

Evaluation was based upon measurements of plant height and differences from control following the individual applications. The height of sunflowers was measured in the flowering stage (BBCH 61–69) and before harvest. Given the weather condition occurring in each year, there were small differences in the times of evaluation: in 2006, full flowering (BBCH 65) and during ripening (BBCH 85); in 2007, at the beginning of flowering (BBCH 61), after flowering (BBCH 70) and before harvesting (BBCH 89); in 2008 and 2009, at the beginning of flowering (BBCH 61) and before harvesting (BBCH 89). Plant height was measured at five places on each plot.

Achenes were not harvested for technical reasons. Instead, before harvesting the diameters of the flower heads were measured for each treatment of the experiment. For each repetition, the diameters of 20 consecutive plants in one of the two central rows within the plot were measured. Peripheral plants were excluded.

The plant height and flower head diameter data were statistically analyzed using multifactor analysis of variance (ANOVA) with subsequent verification based on the Tukey's test. The data were processed using Statistica 7.0.

The entire experimental area was uniformly treated at preemergence against weeds using a combination of the herbicides acetochlor 1152 g/ha + flurochloridone 375 g/ha.

RESULTS AND DISCUSSION

The results for 2006 are summarized in Table 1. Growth was reduced by 14 cm using Retacel Extra and by 27 cm using Terpal C, as evaluated at the end of vegetation. Pilar is among the shorter varieties, and the untreated control measured 175 cm when evaluated before harvest. When Terpal C was used, unlike the case with Retacel Extra, less chlorosis of leaves was observed after application. This symptom of phytotoxicity occurred ca 5 days after application and very quickly subsided. Moddus did not reduce the sunflower height.

Flower head diameter measurements showed no marked negative effect of the applied growth regulators. Only in the case of Terpal C alone at the rate of 1.25 L/ha there was a moderate decrease in diameter of flower head, but this was not significant.

The results for 2007 are summarized in Tables 2a and 2b. Applying Retacel Extra as well as Terpal C achieved a decrease in plant height of 25–30 cm.

Moddus did not reduce the height of sunflower. Flower head diameter measurements for the experimental variants before harvesting showed

Table 1. Experimental findings for 2006

	Rate (L/ha)	Application time	Assessment – plant height (cm)				Flower head diameter	
			BBCH 63		BBCH 85			
			cm	dif.	cm	dif.	cm	dif.
Height of control			156		175		15.2	
Retacel Extra R68	3.50	27 Jun BBCH 50	145	–12	160	–14*	15.2	0
Modus	0.30	27 Jun BBCH 50	156	0	165	–9	15.2	0
Terpal C	1.25	27 Jun BBCH 50	130	–26**	147	–27**	14.6	–0.6

BBCH 50 – 10 mature leaves, height of sunflower ca 40–50 cm, bud in axil of the upper leaves 2–3 cm in diameter; *$P < 0.05$; **$P < 0.01$

Table 2a. Experimental findings for 2007

	Rate (L/ha)	Application time	Height diference vs. control (cm)			Flower head diameter	
			BBCH 61 25 Jun	BBCH 69 6 Aug	BBCH 89 18 Sep	cm	dif.
Height of control			125	187	180	14.8	
Retacel Extra R68	2.00	31 May BBCH 32	–11	–24**	–10	15.4	0.5
Retacel Extra R68	4.00	31 May	–25**	–24**	–19*	14.6	–0.2
Moddus	1.50	31 May	–3	–23**	–15*	14.7	–0.2
Moddus	1.00	31 May	–4	–6	11	13.9	1.0
Terpal C	1.25	31 May	–22**	–21**	–11	14.3	–0.5
Retacel Extra R68	2.00	15 Jun BBCH 50	–5	–25**	–7	14.9	0.0
Retacel Extra R68	4.00	15 Jun	–12*	–25**	–28**	15.1	0.3
Moddus	1.50	15 Jun	–1	–5	5	16.0	1.2
Moddus	1.00	15 Jun	4	–8	–2	14.5	–0.3
Terpal C	1.25	15 Jun	–12*	–22**	–17*	15.1	0.3

BBCH 32 – 2 visibly extended internodes; BBCH 50 – 10 mature leaves, ca 40–50 cm, bud in axil of the upper leaves 2–3 cm in diameter. $^{*}P < 0.05$; $^{**}P < 0.05$

that the application of growth regulators did not negatively affect yield.

The results for 2008 are summarized in Table 3. Applying growth regulators led to significant height of sunflower reduction. With one-time application at the early or later term, shortening of sunflower stems from Retacel Extra R68 was in a range of 13–28 cm during flowering and 11–18 cm before harvesting. It was also confirmed that applications at BBCH 32 lead to better results than did later applications. Cerone and Terpal C achieved better shortening results by several centimeters, with reductions of 27–41 cm during flowering and 13–31 cm before harvesting.

Greatest shortening was achieved by double applications at both times, when reductions were in the range 32–63 cm during flowering and 25–51 cm before harvest.

The results for 2009 are summarized in Table 4. Reduced growth after application of growth regula-

Table 2b. Experimental findings for 2007

	Rate (L/ha)	Application time	Height diference vs. control (cm)			Flower head diameter	
			BBCH 61 25 Jun	BBCH 69 6 Aug	BBCH 89 18 Sep	cm	dif.
Height of control			135	194	198	14.7	
Retacel Extra R68	2.00	31 May BBCH 32	–31**	–19*	–21*	16.3	1.6
Retacel Extra R68	4.00	31 May	–33**	–23**	–18*	15.7	1.0
Moddus	1.50	31 May	–12	–5	–4	15.9	1.2
Moddus	1.00	31 May	–5	–15*	–17*	15.4	0.7
Terpal C	1.25	31 May	–25**	–23**	–18*	15.5	0.7
Retacel Extra R68	2.00	15 Jun BBCH 50–51	–23**	–11	–25**	16.9	2.1
Retacel Extra R68	4.00	15 Jun	–28**	–23**	–27**	15.6	0.9
Moddus	1.50	15 Jun	–13	2	–3	17.2	2.5
Moddus	1.00	15 Jun	2	–9	0	16.1	1.3
Terpal C	1.25	15 Jun	–17*	–12	–16*	15.7	1.0

BBCH 32 – 2 visibly extended internodes; BBCH 50–51 – 10 mature leaves, ca 40–50 cm, bud in axil of the upper leaves 2–3 cm in diameter; $^{*}P < 0.05$; $^{**}P < 0.01$

Table 3. Experimental findings for 2008

	Rate (L/ha)	Application time	Height diference vs.control (cm)				Flower head diameter BBCH 89		Flowering BBCH 60 (%)
			BBCH 61		BBCH 89				
			cm	dif.	cm	dif.	cm	dif.	
Height of control			175		172		17.3		50
Retacel Extra R68	2.0	6 Jun BBCH 32	147	–28**	156	–16*	17.9	0.6	5
Retacel Extra R68	4.0	6 Jun	149	–26**	154	–18*	17.1	–0.2	4
Cerone 480 SL	1.0	6 Jun	150	–25**	156	–16*	17.2	–0.1	15
Cerone 480 SL	1.5	6 Jun	148	–28**	153	–20*	16.3	–1.1	10
Terpal C	1.5	6 Jun	150	–26**	153	–19*	17.7	0.4	5
Terpal C	3.0	6 Jun	142	–33**	150	–22*	19.4	2.1	3
Retacel Extra R68	2 × 2.0	6 Jun. 25 Jun BBCH 32 and 50	143	–32**	147	–25**	18.8	1.5	0
Retacel Extra R68	2 × 4.0	6 Jun. 25 Jun	133	–43**	145	–27**	17.1	–0.2	3
Cerone 480 SL	2 × 1.0	6 Jun. 25 Jun	133	–43**	126	–46**	19.1	1.8	20
Cerone 480 SL	2 × 1.5	6 Jun. 25 Jun	121	–55**	121	–51**	19.0	1.7	15
Terpal C	2 × 1.5	6 Jun. 25 Jun	124	–51**	134	–38**	18.8	1.5	3
Terpal C	2 × 3.0	6 Jun. 25 Jun	112	–63**	119	–53**	17.3	0.0	3
Retacel Extra R68	2.0	20 Jun BBCH 50	147	–28**	159	–13	19.1	1.8	3
Retacel Extra R68	4.0	20 Jun	162	–13	161	–11	16.8	–0.5	20
Cerone 480 SL	1.0	20 Jun	140	–35**	148	–24**	17.7	0.4	4
Cerone 480 SL	1.5	20 Jun	134	–41**	141	–31**	18.3	0.9	10
Terpal C	1.5	20 Jun	148	–27**	159	–13	16.4	–0.9	10
Terpal C	3.0	20 Jun	135	–40**	145	–27**	18.6	1.3	0

BBCH 32 – 2 visibly extended internodes; BBCH 50 – 10 mature leaves, ca 40–50 cm, bud in axil of the upper leaves 2–3 cm in diameter; *$P < 0.05$; ** $P < 0.01$

tors was similarly pronounced as in the experiments of the previous year. For one-time application at either the early or later time the height reduction by Retacel Extra R68 ranged around 24 cm during flowering and 10 cm before harvesting. Again, a more notable result was achieved by applications at BBCH 32 than at later times. Decreasing the amount of active ingredient and combining with AS did not lead to the same or a better result. Cerone and Terpal C again achieved even better shortening results by several centimeters: 15–28 cm during flowering and 20 cm before harvesting. Decreasing the amount of active ingredient and combining with AS led to a better result only in the case of Cerone (33 cm).

The greatest reduction of sunflower height was achieved by applications at both application times. Shortening was in the range 26–47 cm during flowering and 33–40 cm before harvesting. Positive effect from using a combination with AS was observed only for Cerone.

Applying growth regulators in 2008 and 2009 affected the beginning of flowering compared to the untreated control (Tables 3 and 4). Delayed onset of flowering was recorded most frequently in the case of Terpal C but also for Retacel Extra, while the delay was more pronounced at higher rates and two applications per season.

From the results of experiments performed during 2006–2009, it is evident that it is possible to reduce height in sunflower plants by some growth regulators. A single application per season can reduce height of sunflower by 20–30 cm, depending on the growth regulating substance used and the time of application. With using two applications per season, shortening by 20–60 cm is possible. In experiments by Lovett and Campell (1973) CCC increased stem and petiole width, and

Table 4. Experimental findings for 2009

	Rate (L, kg/ha)	Application time	Height diference vs. control (cm)				Flower head diameter BBCH 89		Flowering BBCH 60 (%)
			BBCH 61		BBCH 89				
			cm	dif.	cm	dif.	cm	dif.	
Height of control			183		190		15.8		30
Retacel Extra R68	2.0	15 Jun BBCH 32	159	–24*	180	–10	18	2.2	30
Retacel Extra R68 + AS	1.5 l + 1.5	15 Jun	171	–12	180	–10	17.9	2.2	30
Cerone 480 SL	1.2	15 Jun	168	–15*	170	18.9	18.9	3.2	30
Cerone 480 SL + AS	0.6 l + 1.5	15 Jun	166	–17*	158	17.9	17.9	2.2	30
Terpal C	1.5	15 Jun	155	–28**	170	17.3	17.3	1.5	10
Terpal C + AS	0.75 l + 1.5	15 Jun	164	–19*	175	18.4	18.4	2.7	10
Retacel Extra R68	2 × 2.0	6 Jun. 25 Jun. BBCH 32 and 50	157	–26**	155	–35**	19.4	3.6	5
Retacel Extra R68 + AS	2 × 1.5 l + 1.5	6 Jun. 25 Jun		–20*	178	–13	16.9	1.2	1
Cerone 480 SL	2 × 1.2	6 Jun. 25 Jun	136	–47**	158	–33**	16.6	0.8	10
Cerone 480 SL + AS	2 × 0.6 l + 1.5	6 Jun. 25 Jun	123	–60**	130	–60**	16.1	0.3	5
Terpal C	2 × 1.5	6 Jun. 25 Jun	145	–38**	150	–40**	19.2	3.5	3
Terpal C + AS	2 × 0.75 l + 1.5	6 Jun. 25 Jun	144	–39**	150	–40**	17.6	1.8	0
Retacel Extra R68	2.0	20 Jun BBCH 50	175	–8	185	–5	15.7	–0.1	30
Retacel Extra R68 + AS	1.5 l + 1.5	20 Jun	183	0	185	18.4	18.4	2.6	30
Cerone 480 SL	1.2	20 Jun	156	–27**	165	15.4	15.4	–0.4	10
Cerone 480 SL + AS	0.6 l + 1.5	20 Jun	170	–13	175	–15*	16	0.2	30
Terpal C	1.5	20 Jun	176	–7	170	14.8	14.8	–0.9	30
Terpal C + AS	0.75 l + 1.5	20 Jun	163	–20**	175	–15*	16.3	0.6	30

BBCH 32 – 2 visibly extended internodes; BBCH 50 – 10 mature leaves, ca 40–50 cm, bud in axil of the upper leaves 2–3 cm in diameter. AS – ammonium sulfate; *$P < 0.05$; ** $P < 0.01$

decreased length of internodes, head diameter and photosynthetic area. Identical results were reported also by Koutroubas et al. (2004), the influence of three growth regulators – paclobutrazol, mepiquat chloride and chlormequat chloride – on sunflower plants height, on yield, and on the number of achenes in flower heads was investigated. Mepiquat chloride and paclobutrazol reduced the plant height after application until maturity. The height reduction was very pronounced, ranging from 9.5 to 11.7% compared to the untreated control. Shortening occurred due to a reduction in internodes length. Use of these two growth regulators was accompanied by a decrease in achene yield by 26 and 29%. Using chlormequat chloride at a rate of 3 kg/ha brought a decrease in achene yield, but when used at rates of 1.5 kg/ha and 4.5 + 4.5 kg/ha (two application times) it was higher than in the untreated control and with a concurrent decrease in height by 12–15 cm.

Due to technical difficulties, the yield was not evaluated, but this was replaced by measuring the diameters of the flower heads at the mature harvest period. In measuring the flower head diameter there was detected no notable negative (or positive) influence on this parameter. It can therefore be judged that the application of chlormequat chloride, chlormequat chloride + ethephon, and ethephon at the application rates reported does not directly affect the yield. In a study by Baylis and Dicks (1983), a combination of mepiquat chloride and ethephon retarded sunflower stem growth very well. That was in contrast to daminozide, which had a very uneven effect. The application time for growth regulator is considered very important, as it may affect the yield.

In accordance with the observations by Koutroubas et al. (2004), our experiments also recorded chlorotic spots on the leaves after application of chlormequat chloride which were visible for several days. These spots very quickly faded away. After applying ethephon (480 g/ha), a slight change in plants' appearance was visible. The plants visibly slowed down the growing, leaves turned down, and new leaves had shorter petioles. Axillary buds were lighter in color. These symptoms gradually subsided. Damage to sunflower plants (i.e. flower deformation) grown in a hydroponic solution was reported by Wanderley et al. (2007) when higher rates of the paclobutrazol active ingredient were used.

In 2008 and 2009, growth regulators affected the beginning of flowering compared to the untreated control. Side effects of growth regulation substances are described by Rademacher (2000). He mentions influence, for example, on biosynthesis of sterols, carotenoids, cytokinins, and abscisic acid. The slower onset of flowering recorded in the experiments resulted from metabolic reactions to the application of active ingredients, more so in the case of chlormequat chloride than ethephon.

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