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Chlormequat chloride and ethephon affect growth and yield formation of conventional, naked and dwarf oat

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Plant growth regulators (PGRs) are not usually applied to oat (*Avena sativa* L.) crops. This study was designed to test whether the antigibberellin chlormequat chloride (CCC) and ethylene-releasing ethephon sprayed on to oat foliage represent potential agents for manipulation of yield formation under northern growing conditions. Effects of these PGRs on yield components and tiller growth and productivity were examined in detail. This study included a long-strawed landrace, a modern standard height cultivar, two naked (*A. sativa* ssp. *nuda* L.) and two dwarf oats. Field experiments were conducted at Viikki Experimental Farm, University of Helsinki, in 1995 and 1996. Chlormequat chloride was sprayed at the two-node stage and ethephon when the flag leaf ligule was just visible on the main shoot. Various traits characterizing growth and yield formation were assessed. Chlormequat chloride increased grain yield by 0% to 13% depending on cultivar and year, while ethephon most often decreased it by up to 17%. No lodging occurred and the recorded increase in grain yield of CCC treated plants was not therefore due to prevention of lodging. However, CCC treatment resulted in more panicles per square meter and in 1995 tillers contributed more to grain yield. Ethephon treated plants had less grains per main shoot panicle, lower panicle filling rate (PFR) and parallel decreased harvest index (HI). Stem elongation of dwarf oat was enhanced by CCC, in contrast to that of conventional and naked cultivars.

Key words: Antigibberellins, *Avena sativa*, cultivars, ethylene, crop yield, harvest index, tillering, yield components

Introduction

Plant growth regulators (PGRs) are not commonly used to shorten straw and manipulate yield formation in oat (Rajala and Peltonen-Sainio 2000) as they are for barley (*Hordeum vulgare* L.) and wheat (*Triticum aestivum* L.). Oat is often regarded as a secondary crop that does not require inputs additional to those for basic crop management.

Not only do PGRs reduce straw length and lodging sensitivity, but they may also directly enhance grain yield production through im-

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proved yield components built up from excess photosynthate not used for stem elongation. For example, in several studies with barley and wheat, PGR treatments resulted in more grains per ear (Humbries et al. 1965, Naylor 1989, Ma and Smith 1992a, Börnel and Meinel 1993). Furthermore, in studies of Ma and Smith (1991) both chlormequat chloride (CCC) and ethephon treatment, reduced abortion of spikelet primordia in barley. Oat might, however, represent even greater potential for such manipulation, because the inflorescence rather than an ear is likely to be more responsive to environmental factors and crop management that favour yield formation (Peltonen-Sainio 1999). There have been few experiments with PGR-treated oat (Peltonen-Sainio and Peltonen 1997, Pietola et al. 1999, Rajala and Peltonen-Sainio 2000, Rajala et al., unpublished results), but some tentative evidence exists for oat responding to PGR treatments. For example, oat treated with CCC at two to three tiller stage (growth stage, GS22-23, Zadoks et al. 1974) had more grains per panicle than control plants (Peltonen and Peltonen-Sainio 1997). In addition to increasing grain number per ear in cereals, PGRs, CCC in particular, have enhanced tillering – especially production of head-bearing tillers (Naylor et al. 1989, Ramos et al. 1989, Khan and Spilde 1992, Peltonen-Sainio and Peltonen 1997). This may also have a positive impact on yield formation.

The effect of PGRs on yield formation may range from yield enhancement to yield reduction depending on growing conditions (Simmons et al. 1988, Ma and Smith 1992a, 1992b, Peltonen and Peltonen-Sainio 1997, Rajala and Peltonen-Sainio 2000). Genotypic differences in response to PGRs have also been reported. These are principally due to differences in straw length, but also due to genotypic differences in yield components and source to sink interaction. For this reason different oat types were included in this study. The landrace is a long-strawed, lodging-sensitive cultivar with a relatively low grain to straw ratio (i.e., harvest index, HI) compared with other husked cultivars (Peltonen-Sainio 1990). Naked oat lines are often characterised by a low number of spikelets per panicle, associated with a high number of grains per spikelet and hence, reduced yielding ability (Peltonen-Sainio 1994). Furthermore, dwarf lines with the *Dw6* gene have increased tillering ability, but not necessarily increased grain yield as tillers are not able to compensate for the lower main shoot panicle weight recorded under northern growing condition (Mäkelä et al. 1996). As this dwarfing gene is likely to express reduced ability to produce gibberellic acid, the response of such lines to antigibberellins, such as CCC, and to ethephon may differ from that of the lines lacking *Dw6*.

This study was designed to test whether foliar application of CCC and ethephon result in yield increases for reasons other than solely preventing lodging, including better combination of yield components and increased tiller formation and productivity. Furthermore, we tested whether there is genotype x PGR interaction for various morpho-physiological traits.

Material and methods

Field experiments were carried out at Viikki Experimental Farm, University of Helsinki, Finland (60°N13’N) in 1995 and 1996. The trials were sown on 9 May in 1995 and 22 May in 1996. Net plot size was 10 m^2 (1.25 × 8 m, 12.5 cm between rows) and sowing rate 500 viable seeds m^{-2}. Soil type was tentatively classified as sandy clay. 80 kg of N ha^{-1} as NH_4NO_3 was applied. Weeds were controlled with MCPA [(4-chloro-2-methylphenoxy) acetic acid] at 600 g a.i. ha^{-1} and dichlorprop at 600 g a.i. ha^{-1} after double ridge stage to avoid herbicide injuries on developing apices (Andersen 1954, Loubser and Cairns 1989). A split-plot design with four replicates was used, in which PGR treatments were applied to main plots and oat lines were split across them.

Two PGR treatments, CCC and ethephon, in addition to a control were included in the de-

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sign. CCC [(2-chloroethyl)-trimethylammonium chloride] was sprayed on to the plant foliage at 1.5 kg a.i. ha^{-1} (at 300 l ha^{-1}) when the second main shoot node was evident (GS32), 35 and 40 days after sowing in 1995 and 1996, respectively. Ethephon (2-chloroethylphosphonic acid) at 240 g a.i. ha^{-1} (at 300 l ha^{-1}) was applied when the flag leaf ligule was just visible on the main shoot (GS39), 42 and 45 days after sowing in 1995 and 1996, respectively.

Six oat lines were included in the experiments: two were Finnish conventional lines (Jalostettu maatiainen, a long-strawed landrace released in 1921, and Virma, a cultivar released in 1988), two were naked lines (Å 89106 from Norway and Rhiannon from UK), and two were dwarf lines with the *Dw6* dwarfing gene (Grane from Norway and Pal from Minnesota, USA).

The following morpho-physiological traits were measured on plants from each plot: 1) grain yield (g m^{-2}, calculated at 15% moisture), 2) days from sowing to heading, 3) days from sowing to yellow ripeness, 4) length of grain-filling period (d) from heading to yellow ripeness, 5) length of visible peduncle (cm) at maturity, 6) panicle length (cm) at maturity, 7) plant height (cm) from soil surface to panicle tips at maturity, 8) lodging (%) at harvest, 9) number of panicles m^{-2} measured from 3 rows $plot^{-1}$, each 0.5 m long, 10) tillers main $shoot^{-1}$ (no.), 11) panicle-bearing tillers on main shoot (no.), 12) main shoot phytomass (g), 13) phytomass of tillers (g main $shoot^{-1}$), 14) main shoot vegetative phytomass (g), 15) vegetative phytomass on tillers (g main $shoot^{-1}$), 16) main shoot panicle weight (g) as a total weight of grains per panicle, 17) total weight of grains on tillers (g main $shoot^{-1}$), 18) contribution of tillers to grain yield (%) as proportion of grain yield per plant produced by panicle-bearing tillers, 19) HI (%) as a proportion of total grain weight of grains per plant over total phytomass per plant, 20) single grain weight (mg), 21) number of grains per main shoot panicle, 22) panicle-filling rate (PFR, mg $panicle^{-1}$ d^{-1}), 23) grain-filling rate (GFR, mg $grain^{-1}$ d^{-1}), and 24) phytomass growth rate (PHGR, g m^{-2} d^{-1}) as an average over the whole growth period from seedling emergence to yellow ripeness. Traits 10 to 21 were measured from 40 randomly sampled mature plants in each plot.

Statistical significance of differences between years (random factor), PGR treatments, and oat lines (fixed factors) for grain yield and morpho-physiological traits were established with ANOVA. Least Significant Difference (LSD) or Student-Neuman-Keuls pairwise comparison (SNK) at $P = 0.05$ was used for separating significantly different means (SAS Institute Inc. NC, USA).

Results

Treatments with plant growth regulators, CCC and ethephon, affected grain yield, days to heading and maturity, plant height characteristics, HI, and number of grains and filling rate of main shoot panicle ($P \leq 0.045$). Year x PGR treatment interaction was statistically significant for grain yield, length of grain-filling period, days to maturity, number of tillers per main shoot and panicles per square meter, HI, plant height ($P \leq 0.034$) and contribution of tillers to grain yield ($P = 0.063$). Treatment with CCC resulted in increased grain yield by 0% to 13% depending on cultivar and year, and with ethephon in most cases decreased grain yield by up to 17% compared with the control (Table 1). There was no lodging and PGR induced changes in grain yield did not therefore result from differences in lodging sensitivity. Both CCC and ethephon increased contribution of tillers to grain yield in 1995, and treatment with CCC also resulted in more panicles per square meter (Table 2). Number of grains per panicle, PFR and HI (in 1995) were, however, reduced through ethephon treatment.

Oat line x PGR interaction was statistically significant for grain yield, the length of different growth phases and plant height characteristics ($P \leq 0.029$). Treatments with CCC, in particular, tended to slightly delay heading and ma-

Table 1. Plant growth regulator effects on grain yield, growth duration, and plant height characteristics of conventional, naked, and dwarf oat in 1995 and 1996.

Line and Treatment	Grain yield ($g\ m^{-2}$)		Days to heading		Days to maturity		Grain-filling period (d)		Length of visible peduncle (cm)		Panicle length (cm)		Plant height (cm)	
	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996
Landrace:														
Control	425	562	57	53	89	95	32	42	19	28	14	13	104	120
CCC	454	572	59	54	90	96	31	42	14	23	14	12	96	113
Ethephon	369	521	58	54	89	95	32	41	22	27	13	12	100	118
Virma:														
Control	501	588	57	53	89	96	32	43	14	20	14	13	92	103
CCC	541	589	59	55	90	96	31	41	9	17	15	13	84	96
Ethephon	416	553	58	54	90	95	33	41	13	18	12	13	82	98
Å 89106:														
Control	393	321	55	50	85	93	30	44	18	22	15	12	92	106
CCC	401	317	55	52	85	94	30	42	13	19	11	13	81	101
Ethephon	344	302	55	51	85	94	31	43	17	24	13	12	86	106
Rhiannon:														
Control	389	329	61	56	91	97	30	41	13	18	10	11	80	95
CCC	439	323	62	56	92	98	31	42	9	15	13	11	76	89
Ethephon	345	327	61	56	91	97	30	41	15	20	11	11	77	92
Grane:														
Control	549	459	62	56	90	95	28	39	6	10	13	12	71	81
CCC	563	585	61	56	90	96	29	40	8	10	11	12	75	85
Ethephon	520	538	62	57	90	96	29	39	8	9	13	11	72	81
Pal:														
Control	378	501	53	50	86	97	33	48	12	15	11	9	70	77
CCC	419	505	53	50	87	97	33	47	13	16	11	10	74	79
Ethephon	373	517	53	51	86	96	33	46	11	15	10	10	66	76
CV (%)	8.7	7.5	1.1	1.2	0.7	0.6	2.7	2.2	7.1	9.9	11.3	6.4	4.0	2.0
$SNK_{5\%}$	18.9	17.4	0.3	0.3	0.3	0.3	0.4	0.5	0.5	0.9	0.9	0.4	1.7	1.0

CCC, chlormequat chloride
CV, coefficient of variation
SNK, Student-Neuman-Keuls multiple range test at the 0.05 probability level

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Table 2. Plant growth regulator (PGR) effects on total weight of grains from tillers, tiller contribution to grain yield, harvest index, number of grains per panicle, and panicle filling rate (PFR). Data for years are shown separately when year x PGR interaction was statistically significant for the trait.

Trait and year	Control	CCC	Ethephon	LSD5%
Panicles m^{-2}:				
1995	582	635	609	51.4
1996	682	669	720	67.6
Tiller contribution to grain yield (%):				
1995	4.7	6.7	6.9	1.56
1996	21.7	21.4	19.4	2.44
Harvest index (%):				
1995	46.4	47.2	43.2	2.46
1996	41.4	40.1	40.1	1.77
Grains panicle^{-1} (no):	32	33	29	2.0
PFR (mg panicle^{-1} d^{-1}):	28.0	28.7	25.8	2.24

CCC, chlormequat chloride
LSD, least significant difference at the 0.05 probability level

turity in some oat lines, whereas effects of ethephon on duration of main growth phases were more inconsistent (Table 1). Elongation of the visible part of the peduncle tended to slow clearly more following CCC application than following ethephon when compared with the control, but only in conventional and naked lines. Similar effects were recorded on plant height, whereas no consistent effect on panicle length was established. Furthermore, dwarf cultivars, Grane and Pal, differed from other cultivars in their response to PGRs. Application of CCC resulted in increased plant height and increased elongation of the visible part of the peduncle.

No PGR effect, PGR x cultivar or PGR x year interaction were registered for number of tillers and panicle-bearing tillers per square meter, production of vegetative phytomass, total weight of grains on main shoot and tiller panicles, single grain weight and filling rate nor for PHGR. All of the measured traits ($P < 0.001$) except total weight of grains per tillers ($P = 0.114$) differed significantly among oat lines. Year x oat line interaction was recorded for traits ($P \leq 0.037$) other than number of tillers ($P = 0.096$) and panicle-bearing tillers per main shoot ($P = 0.165$) and panicle length at maturity ($P = 0.300$). Large genotypic variation in morpho-physiological traits was recorded (Table 3).

Discussion

Spraying CCC at the two-node stage of oat increased grain yield by 0% to 13% depending on cultivar and year. This was not due to reduced lodging. CCC induced enhancement of yielding ability was recorded especially in 1995, when high temperature and low precipitation occurred at pre-anthesis (Table 4), and resulted in production of less vegetative phytomass and grains (Table 3). Ethephon applications at flag leaf emergence had a contrary effect to CCC, and yield reduction was most often recorded (Table 1). Our findings are thereby consistent with those recorded for other cereals, for which CCC increased grain yield by 0% to 20% (De et al. 1982, Ma and Smith 1992a, Börnel and Meinel 1993) and ethephon effect ranged from a 64% yield reduction up to 13% yield increase depending on growing conditions (Simmons et al. 1988, Taylor et al. 1991, Ma and Smith 1992a). Slight yield

Table 3. Differences among oat lines in yield components that were unaffected by plant growth regulator application in 1995 and 1996. Means followed by a different letter in each row within a year are significantly different ($SNK_{5\%}$).

Trait#	1995						1996					
	Landrace	Virma	Å 89106	Rhiannon	Grane	Pal	Landrace	Virma	Å 89106	Rhiannon	Grane	Pal
Tillers (no. main shoot^{-1})	0.31a	0.27a	0.28a	0.36a	0.27a	0.58b	0.77ab	0.65a	1.00bc	0.93bc	0.87bc	1.08c
Panicle-bearing tillers (no. main shoot^{-1})	0.10a	0.04a	0.07a	0.19b	0.08a	0.37c	0.48b	0.34a	0.55b	0.58b	0.51b	0.75c
Main shoot phytomass(g)	2.11cd	2.26d	1.65b	1.98c	2.13cd	1.25a	2.46c	2.51c	2.41c	2.12b	2.01b	1.05a
Phytomass on tillers (g main shoot^{-1})	0.12a	0.07a	0.09a	0.24b	0.09a	0.24b	0.80b	0.63ab	0.75b	0.83b	0.65ab	0.43a
Main shoot vegetative phytomass (g)	1.22c	1.18c	0.97b	1.17c	1.00b	0.63a	1.34c	1.35c	1.54c	1.42c	1.12b	0.53a
Vegetative phytomass on tillers (g main shoot^{-1})	0.08a	0.04a	0.06a	0.15b	0.05a	0.13b	0.49bc	0.39b	0.54bc	0.61c	0.43b	0.26a
Main shoot panicle weight (g)	0.89b	1.08c	0.67a	0.81b	1.13c	0.62a	1.12d	1.16d	0.86c	0.71b	0.90c	0.52a
Total weight of grains per tillers (g main shoot^{-1})	0.04a	0.02a	0.03a	0.09b	0.04a	0.11b	0.32c	0.24b	0.21a	0.22ab	0.23ab	0.17a
Single grain weight (mg)	31.8b	31.5b	23.5a	24.4a	31.7b	32.0b	33.3d	29.4c	21.7b	19.1a	34.8e	40.4f
GFR (mg grain^{-1} d^{-1})	1.01c	0.99c	0.78a	0.82b	1.12d	0.97c	0.80d	0.71c	0.51b	0.46a	0.89e	0.87e
PHGR (g m^{-2} d^{-1})	14.8ab	16.5ab	14.0a	17.4b	15.7ab	14.6ab	25.5b	23.4b	23.2b	23.0b	21.5b	15.3a

GFR, grain-filling rate
PHGR, phytomass growth rate
SNK, Student-Neuman-Keuls multiple range test at the 0.05 probability level

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Table 4. Monthly mean temperature and precipitation for growing seasons 1995 and 1996 and the long-term means (1961–1990) at Kaisaniemi Meteorological Station, Helsinki.

Month	Mean temperature (°C)			Precipitation		
	1995	1996	Long-term	1995	1996	Long-term
May	8.8	8.6	9.7	66	68	31
June	17.3	13.3	15.0	31	58	41
July	15.8	15	17.0	28	122	60
August	16.3	18.1	15.7	51	1	74
September	11.9	9.8	11.1	67	28	73

increases following CCC application were due to alterations in yield components, as differences between PGR treatments in length of the main growth phases were modest and inconsistent (i.e., most often one day delay if any).

Traits contributing to CCC induced yield increase

Although PGR applications enhanced tillering in barley and wheat (Naylor et al. 1986, 1987, Woodward and Marshall 1988, Craufurd and Cartwright 1989, Taylor et al. 1991, Khan and Spilde 1992, Ma and Smith 1992a), the response is likely to be limited under northern growing conditions. This is because tillering, especially production of head bearing tillers, is inhibited by long-day-induced hormonal signals that maintain apical dominance (Peltonen-Sainio and Järvinen 1995). In this study, the number of panicle-bearing tillers was frequently far less than one per main shoot and was highest in the dwarf line Pal (Table 3). However, CCC tended to increase the total weight of grains per tiller panicle ($P = 0.056$) and in 1995, when tiller contribution to grain yield was much lower than in 1996, tillers of CCC treated plants contributed more to grain yield than did those of the controls (Table 2). Also more panicles per square meter was recorded in CCC treated plants. Yielding ability of tillers was not enhanced at the expense of the main shoot, even though it occurred under growing conditions that did not favour tiller growth in general (Table 4), as CCC did not alter the number of grains per panicle, PFR, GFR or single grain weight on main shoot (Tables 1 and 2). We estimated that the recorded 2% unit increase in tiller contribution to grain yield in 1995 averaged 90 kg more grain ha^{-1}. When comparing the PGR effects on panicle yield in naked and husked oats, our results did not suggest that PGRs have potential for modifying yield formation of naked oat through enhancing spikelet and grain set. High number of grains per spikelet and low numbers of spikelets per panicle are associated with lower productivity in naked oat compared with conventional oat (Peltonen-Sainio1994).

The slight effects of CCC on growth and productivity may result from decreased intra-plant competition for photoassimilates, as spraying with CCC resulted in shorter stems. Peltonen-Sainio and Peltonen (1995) showed that numerous sinks, such as tiller growth, stem elongation and floret set, simultaneously demand assimilates at late pre-anthesis. The finding of Knapp et al. (1987) further supports a decrease in intra-plant competition. They found that both CCC and ethephon increased the total amount of water-soluble carbohydrates in wheat culm, which may indicate enhanced accumulation of reserved assimilates in stems. In this study, the length of the visible part of the peduncle was reduced by 14% to 36% with CCC in conventional and naked oat cultivars depending on year, whereas the corresponding decrease in plant height from soil surface to panicle tip was 5% to 12% (Table 1).

Thus, our results indicate that the CCC effect was predominantly on the uppermost internode and no statistically significant PGR effect on panicle length (P = 0.105) was recorded in this study.

By enhancing rather than inhibiting stem elongation the response of dwarf cultivars to CCC differed from that of conventional and naked oat (Table 1). For example, the visible peduncle was up to 33% longer and plants were 3–6% higher at maturity when compared with the untreated control. Rajala and Peltonen-Sainio (2001) also reported this phenomenon. The authors hypothesise that CCC resulted in abundant accumulation of gibberellin (GA) biosynthesis precursors in addition to those resulting from the expression of the dominant *Dw6* gene. This overdose of GA precursors possibly served subsequently as an abundant source for GA synthesis in CCC treated plants. As a consequence of this stem elongation of CCC treated plants exceeded that of the control plants. Enhanced stem elongation in dwarf cultivars following CCC treatment was already recorded at late pre-anthesis (data not shown). This finding, however, contradicts that of Burrows (1986) who found that treatment with GA_3, enhanced peduncle elongation in dwarf oat. Furthermore, contrary to our results concerning the *Dw6* gene of oat, Beharav et al. (1994) reported *Rht* alleles in wheat to reduce sensitivity to endogenous and exogenous GA, and also to inhibitors of GA synthesis, including CCC. Evidently, further experiments are needed to test our hypothesis. Meanwhile, antigibberellins cannot be recommended for manipulation of yield formation in dwarf oat as they may stimulate rather than inhibit stem elongation.

Traits modified with ethephon

In contrast with CCC, ethephon most often reduced grain yield of oat (Table 1). This was evident as fewer grains per panicle was set. PFR was reduced by 8%, and in 1995 HI lowered by 3 percentage units. Reduction of grain number by three per main shoot panicles is likely to be the predominant factor contributing to yield reduction following ethephon application. It is also possible that in 1995 especially, recorded tendency of enhanced tiller productivity through ethephon treatment was biologically inefficient for the plant, resulting in reduced HI. The risk of ethylene stimulated yield reduction in oat is hence similar to that reported for barley and wheat (Simmons et al. 1988, Taylor et al. 1991, Ma and Smith 1992b). Yield losses often occur in unfavourable growing conditions and are therefore suggested to result from an overdose of ethylene in plant tissues. In addition to exogenously applied ethylene released from ethephon, endogenous ethylene production is stimulated by stresses.

In conclusion, the results from our studies showed that yield formation of oat was responsive to PGR treatments. The antigibberellin CCC enhanced growth, whereas application of ethylene-releasing ethephon resulted in yield losses in oat. Increased grain yield attributable to CCC application resulted from more panicles per square meter and higher contribution of tillers to grain yield. Yield reduction caused by ethephon was associated with fewer grains per main shoot panicle, reduced PFR and higher contribution of tillers to grain yield. Stem elongation of dwarf oat was enhanced by CCC application in contrast to that of naked and conventional cultivars.

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SELOSTUS

Kasvunsääteiden vaikutukset tavanomaisen, paljasjyväisen ja kääpiökauran kasvuun ja sadonmuodostukseen

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Ohra- ja vehnäkasvustojen lako torjutaan kasvunsäätein kauraa yleisemmin. Myös tutkimus on keskittynyt näihin ensin mainittuihin viljalajeihin. Kaura saattaa kuitenkin reagoida tähkällisiä viljoja herkemmin kasvuoloissa tapahtuviin muutoksiin, myös kasvunsäädekäsittelyihin. Siksi tutkimme kasvunsääteiden vaikutuksia kauran sadonmuodostukseen Suomen kasvuoloissa mittaamalla jyväsadon lisäksi 24 kasvuston rakennetta ja sadonmuodostusta kuvaavaa ominaisuutta. Peltokokeet järjestettiin Helsingin yliopiston Viikin koetilalla vuosina 1995 ja 1996. Tavanomaisen kauran lisäksi tutkimme kasvunsääteiden vaikutuksia paljasjyväisen ja kääpiökauran sadontuottoon. Tutkittujen kasvunsääteiden vaikutus perustuu kasvien hormonitoiminnan muutoksiin. Klormekvattikloridi (CCC) ehkäisee gibberelliinihapon biosynteesiä ja etefoni lisää etyleenin tuotantoa.

Kaurakasvustojen käsittely CCC:lla kaksisolmuasteella lisäsi satoa parhaimmillaan 13 %, kun etefoni-käsittely lippulehden kielekkeen tultua esille yleensä vähensi satoa. Koska kaurakasvustot eivät lakoontuneet, kasvunsääteet vaikuttivat sadonmuodostukseen muuttamalla kasvustorakennetta. Kumpikin kasvunsääde lyhensi tavanomaisten ja paljasjyväisten kauralajikkeiden kortta, erityisesti näkyvää osaa ylimmästä nivelvälistä. Kääpiölajikkeiden korsi kuitenkin piteni CCC-käsittelyn seurauksena. CCC lisäsi röyhyjen määrää neliöllä ja versojen tuottamaa osuutta sadosta. Myös etefoni-käsittely lisäsi versojen merkitystä sadontuottajina, mutta tämä oli seurausta lähinnä pääverson heikentyneestä sadontuottokyvystä. Etefoni-käsiteltyjen kaurojen pääversoissa oli vähemmän jyviä ja röyhyn täyttymisteho sekä satoindeksi jäivät kontrollikasveja alhaisemmiksi.

Tutkimustemme mukaan tilanteissa, joissa kasvunsääteillä ei ensisijaisesti lakoa ehkäisemällä pyritä turvaamaan sadontuottoa, antigibberelliinikäsittelyin (CCC) voitaneen vähissä määrin parantaa kauran sadonmuodostusta. Etefonia käytettäessä riski satotappioille on ilmeinen. Edullisetkaan vaikutukset sadontuottokykyyn eivät olleet riittäviä, jotta käsittelyiden voisi arvioida olleen taloudellisesti kannattavia tilanteessa, jossa lakoa ei esiinny.