Electronic Journal of Polish Agricultural Universities is the very first Polish scientific journal published exclusively on the Internet, founded on January 1, 1998 by the following agricultural universities and higher schools of agriculture: University of Technology and Agriculture of Bydgoszcz, Agricultural University of Cracow, Agricultural University of Lublin, Agricultural University of Poznan, Higher School of Agriculture and Teacher Training Siedlce, Agricultural University of Szczecin, and Agricultural University of Wroclaw.

ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2001
Volume 4
Issue 2
Series AGRONOMY

PRUSIŃSKI J., BOROWSKA M. 2001. IMPACT OF SELECTED GROWTH REGULATORS AND EKOLIST ON YELLOW LUPIN SEED YIELD (*Lupinus luteus* L.) **Electronic Journal of Polish Agricultural Universities**, Agronomy, Volume 4, Issue 2.
Available Online http://www.ejpau.media.pl

IMPACT OF SELECTED GROWTH REGULATORS AND EKOLIST ON YELLOW LUPIN SEED YIELD (*Lupinus luteus* L.)

Janusz Prusiński, Magdalena Borowska

Department of Seed Production, University of Technology and Agriculture, Bydgoszcz, Poland

ABSTRACT

A strict, two-factor field experiment in split-block design with the control was carried out at the Mochełek Experiment Station over 1997–1999. Plants of 'Teo', traditional yellow lupin cultivar, were treated with varied doses of growth regulators and Ekolist (macro- and micro-nutrient fertiliser) at the beginning of plant flowering. The following growth regulators were applied: auxin – indole-3-butritic acid (A), cytokinin – 6-benzyloaminopurine (C), gibberellin (gibberellic acid) (G), A+C, A+G, A+C+G and Ekolist, all of them applied in three doses: low, medium and high. Over the successive research years the plants were sprayed on June 25, 14 and 14. Over full flowering, 20 control-plot plant flowers on the main stem and branches were counted. Before harvest 20 plants were sampled from each plot to determine the seed yield components. The growth regulators and Ekolist applied limited the unfavourable abscission of generative organs, which resulted in a significantly higher, than the control, yellow lupin seed yield. Out of all the treatments, auxin and Ekolist showed most favourable to seed yielding and cytokinin and auxin with cytokinin – less favourable; the effect of all the substances on seed yield was most visible for high doses. There was recorded a favourable impact of auxin, cytokinin, and auxin with cytokinin on the number of pods and seeds and on the seed weight per main stem and per plant. There was observed neither a direct impact nor any negative effect of gibberellin and its mixtures with the other growth regulators on yellow lupin yielding. Gibberellin enhanced the weight of 1000 seeds and the number of pods and of seeds from lateral branches. A favourable impact of increasing Ekolist doses was noted on most seed yield components defined for a single plant and main stem and on the number and weight of seeds on branches.

Key words: yellow lupin, growth regulators, Ekolist, seed yield and its components

PRINT

INTRODUCTION

Flower and fruit abscission is a common phenomenon, especially under stress conditions, however also under optimal conditions for plant growth and development, and in legumes it remains the main reason for low and varied seed yields. Selective flower and fruit abscission is due to changes in a small cut-off zone at the bottom and is considered one of the most interesting questions to be addressed in biology. The reports available show a comprehensive character of abscission, which can result from insufficient amount of and quality of pollen, lethal and sublethal genes, insufficient availability of assimilates and nutrients and/or plant hormone economies [23].

Bangerth [4] developed two models supplementing each other to explain the abscission of generative organs. The competition model assumes that developing fruit and seeds, assimilates acceptors, compete with vegetative organs for resources. Under extreme circumstances insufficient supply of generative parts with nutrients can lead to abscission and under less extreme circumstances – to disturbed development of fruit and seeds both in terms of quality and quantity. Powerful and high- capacity acceptors are more successful competing for N and therefore higher and higher flowering coincides with competition among generative organs for N compounds led by flowers which have developed earliest, at the bottom of inflorescence, and pods which develop from them. Over their development, pods show such a high demand for N that the plant is incapable of supplying the adequate N amount with its root system [3]. Nalborczyk [18] relates the generative organ abscission to competition for energy sources within the plant observed between C and N metabolisms. The physiological mechanism responsible for intensified pod abscission comes from the competition between a fast and continuously growing stem growth gemmule and seeds developing in pods. Mazur [17] does not answer the question whether fixed N_2 meets the N demand of legumes, while most authors suggest that under optimal development conditions the answer is positive. However, it is well known that over generative phase the effectiveness of N_2 fixation is diminished due to a decline in the activity of nitrogenase. For the N_2 fixation it is crucial that undisturbed inflow of assimilates, being the substrate for the carboxylic acid cycle in bacteroids and providing carbon chains for amino acids and amides synthesis, from host leaves to nodules is secured [24]. Legumes show a higher demand for P, Co and Mo than plants which do not fix N, which is due to their greater activity in N_2 fixation.

The dominance model assumes that generative abscission is regulated by plant hormones. Seeds and fruit developed first are capable of inhibiting the development of those developed later. According to Bangerth [4], auxin – indole-3-acetic acid (IAA) is a hormone which is directly responsible for abscission of generative organs. A big mobility of IAA from the first developed, dominant, organ inhibits the withdrawal of IAA from fruit and seeds developed later. Such inhibition most likely stimulates the development of cut-off zone and generative organ abscission. Addicot [1] relates young fruit and leaves abscission to auxin gradient; the cut-off is observed when the level of auxin below the zone is higher than its concentration above it.
The results of research conducted so far into the impact of growth regulators on legume yielding varied; significant faba bean [6,19], yellow lupin [9,21], narrow-leaf lupin [2], bean [15], soybean [22] increase in seed yield through no yield increase in faba bean seed yield [7,12,13,14]. All this coincided with a varied impact of respective growth regulators on seed yield and its components. Additionally some of the experiments were carried out under controlled conditions which, even with extremely favourable results, did not lead to a wide application of growth regulators in legume cultivation. Similarly foliar application of micronutrients increased seed yield significantly [8] or did not affect the yellow lupin seed yield [16].

The present hypothesis assumes that intensive abscission is limited or inhibited by higher hormones concentration and the application of growth regulators mixture enhances their activity. Additionally, plant fertilisation with Ekolist meets the plant demand for some macro- and micronutrients over lowering symbiosis activity and prolongs plant green vegetation in seed filling period.

MATERIAL AND METHODS

A strict, two-factor field experiment in split-block design in 4 reps with the control was carried out at the Mochełek Experiment Station over 1997–1999. Plants of ‘Teo’, traditional yellow lupin cultivar, were treated with growth regulators and Ekolist (macro- and micro- nutrient fertiliser) at the beginning of plant flowering. The growth regulators and Ekolist were applied as follows:

– auxin – indole-3-butritic acid (A) – 20, 40, 60 mg·dm^{-3},
– cytokinin – 6-benzyloaminopurine (C) – 20, 40, 60 mg·dm^{-3},
– gibberellin (gibberellic acid) (G) – 40, 80, 120 mg·dm^{-3},
– A+C – 20+20, 40+40, 60+60 mg·dm^{-3},
– A+G – 20+20, 40+40, 60+60 mg·dm^{-3},

– C+G – 20+40, 40+80, 60+120 mg·dm^{-3},
– A+C+G – 20+20+40, 40+40+80, 60+60+120 mg·dm^{-3},
– Ekolist, – 3, 6, 9 dm^{3}·ha^{-1}.

Indole-3-butritic acid (IBA) and 6-benzyloaminopurine (BAP) were obtained from SIGMA-ALDRICH CHEMIE Gmbh, gibberellic acid in Gibrescol from POLFA Kutno, and Ekolist Standard from PPHU EKOPLON S.A. Kielce. 1 dm^{3} of Ekolist includes 120 g of N, 65 g of K, 20 g of Mg, 0.5 g of Ca, 5 g of S, of B and of Cu, 3 g of Zn, 1g of Fe, 0.5 g of Mn, 0.02 g of Mo as well as trace quantities of colloidal silicate, Co, Ti and V.

Each experiment was set up after corn on a good rye soil suitability complex, IVb soil quality class. 80 kg of P_2O_5 and 120 kg of K_2O per ha was applied in spring. Soil conditions over successive years were favourable for lupin development and yielding. (Table 1); a slightly too high soil pH and very low B and Cu contents. Straight before sowing active-*Rhizobium lupini*-strains-containing Nitragina was applied. Seeds dressed with Funaben were sown on April 3, 4 and 4, respectively, over successive years 2–3 cm-deep and with 20 cm row spacing. The sowing plot covered 18 m^{2}, while harvest plot area – 14.4 m^{2}. Straight after sowing Afalon 50 WP was applied at the dose of 1.25 l·ha^{-1} in 300 l of water, and after plant emergence – Goltix 70 WP at the dose of 4 kg·ha^{-1} in 500 l of water. Each year after emergence the plots were harrowed. In 1998 there was used a mixture of Ronilan 50 WP and Merpan 50 WP at the dose of 2 kg·ha^{-1} and in 1999 – Sarfun 500 SC at 0.7 l·ha^{-1} against anthracnose. In 1998, due to heavy rainfall and prolonged plant vegetation period, lupin plants were desiccated with 3 l·ha^{-1} of Reglone.

Table 1. Chemical soil analysis

Year	pH in 1M KCl	mg·100 g^{-1} of soil		mg·kg^{-1} of soil				
		P	K	B	Cu	Mn	Zn	Fe
1997	6,1	3.8	16.6	0.3	1.4	172	7.1	568
1998	6.8	5.2	16.2	0.3	1.4	164	5.7	597
1999	6.9	7.5	18.1	0.4	1.7	197	5.7	722

Content				
very low	low	medium	high	very high

Plant spraying at the beginning of plant flowering over respective research years coincided with June 25, 14 and 14. The doses fixed corresponding to 400 l of water per ha were applied with constant- pressure sprayer. Over full flowering, flowers were counted on main stem and branches of 20 control plot plants and before harvest 20 plants were collected from each plot to determine seed yield components. The results obtained were verified with the Puławy Institute of Plant Cultivation and Soil Science software. Dunnet's test allowed for comparing the impact of doses of the substances used against the control, while the results were given as a percentage, while the Tukey test, at p=95%, – for estimating the significance of the other relationships. The research-years impact of doses is presented on the graphs adopting the following scale: control, low dose, medium dose and high dose. Trend lines have been developed with STATISTICA for Windows StatSoft. Inc. [1997].

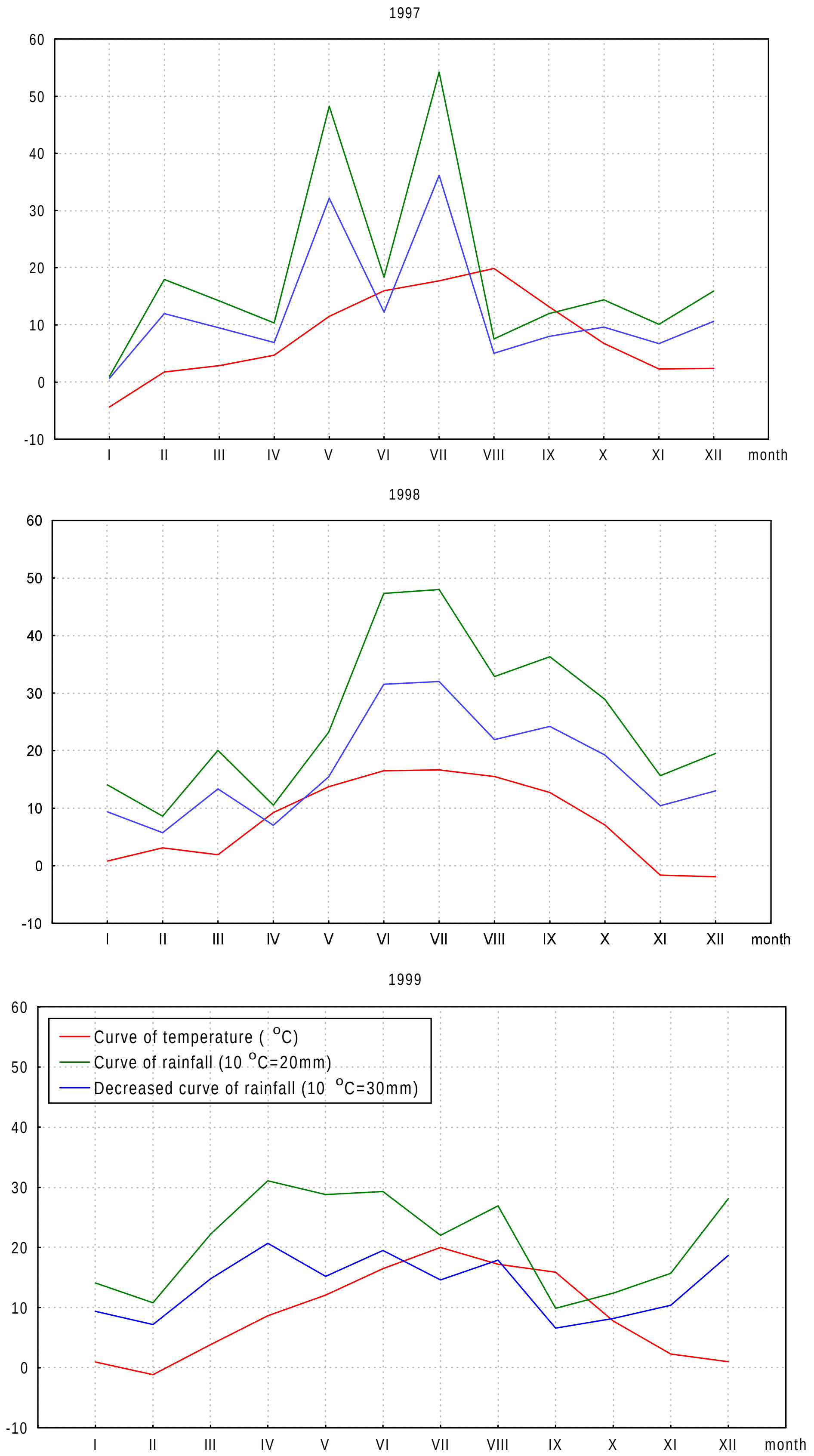
RESULTS

The research period showed weather conditions which were generally favourable for yellow lupin (Fig. 1). Chilly and moderate-rainfall April of 1997 delayed plant emergence, while considerable May rainfall prolonged the vegetative development and plant flowering until June 21, 78 days after sowing. Warm and rainy end of June enhanced plant flowering, however changeable rainfall in July and August did not help plant ripening; the plants were harvested as late as early September, after 156 days of vegetation. Warm April and its moderate rainfall in 1998 was favourable for even and early emergence 22 days off the sowing date. Similar conditions recorded in May enhanced the vegetative development and an earlier, than in the preceding year, flowering (June 10), after 66 days off the sowing date. A considerable rainfall over summer month not only enhanced flowering and pod-setting but also intensified anthracnose, which led to desiccating plants prior to harvest and their harvest on August 20, after 137 days of vegetation. In April of 1999 high rainfall and the temperature higher than the research-years mean were favourable for field emergence recorded after 23 days and flowering – after 66 days off the sowing date. Semi-drought at the end of June and the first decade of July did not disturb flowering and July, which was warm and dry, made the lupin harvest coincide with August 20, like in 1998, after 137 days of vegetation. To recapitulate, the distribution of rainfall and temperature enhanced especially the plant vegetative

PRINT

development over 1997 and 1999, flowering over 1997 and 1998, and ripening over 1997 and 1999. The evaluation of anthracnose intensity recorded in 1998 (over 1997 and 1999 symptoms of anthracnose were incidental) revealed no impact of the substances applied on plant infection with *Colletotrichum gloeosporioides* Penz.

Fig. 1. Weather conditions recorded by the Mochełek Experiment Station



PRINT

The effect of the substances on yellow lupin seed yield components is presented separately for the main stem, branches and plant as a whole. The average number of flowers developed on a single main stem was 35, 30 and 30 for successive years. On average, over the research period after the application of all the substances tested, the main stem (Table 2) produced 12.6 pods and their number did not differ significantly from the number of pods collected from the control plants (11.6). Similar insignificant differences were observed in the number of seeds per pod (3.79 and 3.75) and in the seed weight (5.19 g and 5.04 g). The number of seeds collected from the main stem of plants treated was the only one significantly higher (45.8) than the control (42.4). The evaluation of the substances used revealed that the number of pods and seeds as well as the seed weight per main stem were most enhanced by Ekolist, auxin and its mixture with cytokinin and cytokinin and most unfavourable affected by gibberellin and its mixture. The number of seeds per pod developed on the main stem was the only one unaffected by the substances applied.

Table 2. Effect of growth regulators/Ekolist on yellow lupin seed yield components defined for main stem

Growth regulator/Ekolist	Pod number	Seed number	Seed number per pod	Seed weight, g
Auxin (A)	14.6a	50.2ab	3.51a	5.96a
Cytokinin (C)	13.4a	50.2ab	3.93a	5.48a
Gibberellin (G)	10.8b	41.4c	3.96a	4.51b
Auxin+Cytokinin (A+C)	13.9a	50.0ab	3.75a	5.91a
Auxin+Gibberellin (A+G)	11.2b	43.0bc	3.96a	4.57b
Cytokinin+Gibberellin (C+G)	11.1b	41.4c	3.85a	4.65b
Auxin+Cytokinin+Gibberellin (A+C+G)	10.7b	39.3c	3.82a	4.48b
Ekolist (Ek)	15.0a	51.0a	3.60a	5.95a
Mean for growth regulator/Ekolist	12.6A	45.8A	3.79A	5.19A
Control	11.6A	42.4B	3.75A	5.04A

Means followed by the same letters did not differ significantly at p=95% with Tukey test

The average number of flowers developed on branches of a single yellow lupin plant over successive years was as follows: 48, 50 and 40; an average of 2.02 pods, 5.95 seeds and 2.87 seeds per pod and 0.74 g of seeds were collected when plants were sprayed with the substances tested and 2.22; 6.51; 2.99 and 0.72 g from control branches (Table 3). Neither in the synthesis nor in successive years there were observed significant differences in the impact of the substances tested on seed yield compounds defined for branches. Gibberellin showed slightly more favourable effect than the other regulators applied.

Table 3. Effect of growth regulators/Ekolist on yellow lupin seed yield components defined for branches

Growth regulator/Ekolist	Pod number	Seed number	Seed number per pod	Seed weight, g
Auxin (A)	2.24a	6.74a	2.93a	0.82a
Cytokinin (C)	1.86a	6.35a	3.37a	0.67a
Gibberellin (G)	2.61a	7.34a	2.43a	0.91a
Auxin+Cytokinin (A+C)	1.62a	4.55a	2.85a	0.54a
Auxin+Gibberellin (A+G)	1.79a	4.92a	2.74a	0.57a
Cytokinin+Gibberellin (C+G)	1.97a	5.64a	2.56a	0.68a
Auxin+Cytokinin+Gibberellin (A+C+G)	1.85a	5.52a	2.79a	0.68a
Ekolist (Ek)	2.11a	6.52a	3.07a	0.81a
Mean for growth regulator/Ekolist	2.01A	5.95A	2.87A	0.74A
Control	2.22A	6.51A	2.99A	0.72A

Means followed by the same letters did not differ significantly at p=95% with Tukey test

The number of flowers developed per yellow lupin plant was 78, 80 and 70 over respective years. The impact of the substances applied on seed yield components defined for a single plant, as compared against the control, was also insignificant (Table 4). The number of pods was 14.6 and 13.8, the seed number – 51.9 and 48.9, the number of seeds per pod – 3.56 and 3.59 and the seed weight – 5.92 and 5.76 g, respectively. The weight of 1000 seeds collected from plants treated (123 g) was the only one significantly higher than the control (117 g). Spraying yellow lupin plants with Ekolist, auxin and its mixture with cytokinin helped the plants keep the most significant number of pods and heaviest seeds. Of all the substances, gibberellin and its mixtures with other hormones decreased the number of pods and seeds per plant and enhanced the number of seeds per pod.

Table 4. Effect of growth regulators/Ekolist on yellow lupin seed yield components defined for single plant

Growth regulator/Ekolist	Pod number	Seed number	Seed number per pod	Seed weight, g	1000 seed weight, g
Auxin (A)	16.9a	56.9ab	3.29bc	6.77a	121ab
Cytokinin (C)	15.4b	56.5ab	3.62ab	6.15ab	123ab
Gibberellin (G)	13.4c	48.6b	3.73ab	5.43b	129a
Auxin+Cytokinin (A+C)	15.5b	54.6ab	3.48ab	6.45ab	116ab
Auxin+Gibberellin (A+G)	13.0cd	47.9bc	3.77a	5.14b	122a
Cytokinin+Gibberellin (C+G)	13.0cd	47.1bc	3.66ab	5.32b	123ab
Auxin+Cytokinin+Gibberellin (A+C+G)	12.6d	44.8c	3.68ab	5.14b	125a
Ekolist (Ek)	17.1a	58.5a	3.24c	6.98a	121ab
Mean for growth regulator/Ekolist	14.6A	51.9A	3.56A	5.92A	123A
Control	13.8A	48.9A	3.59A	5.76A	117B

Means followed by the same letters did not differ significantly at p=95% with Tukey test

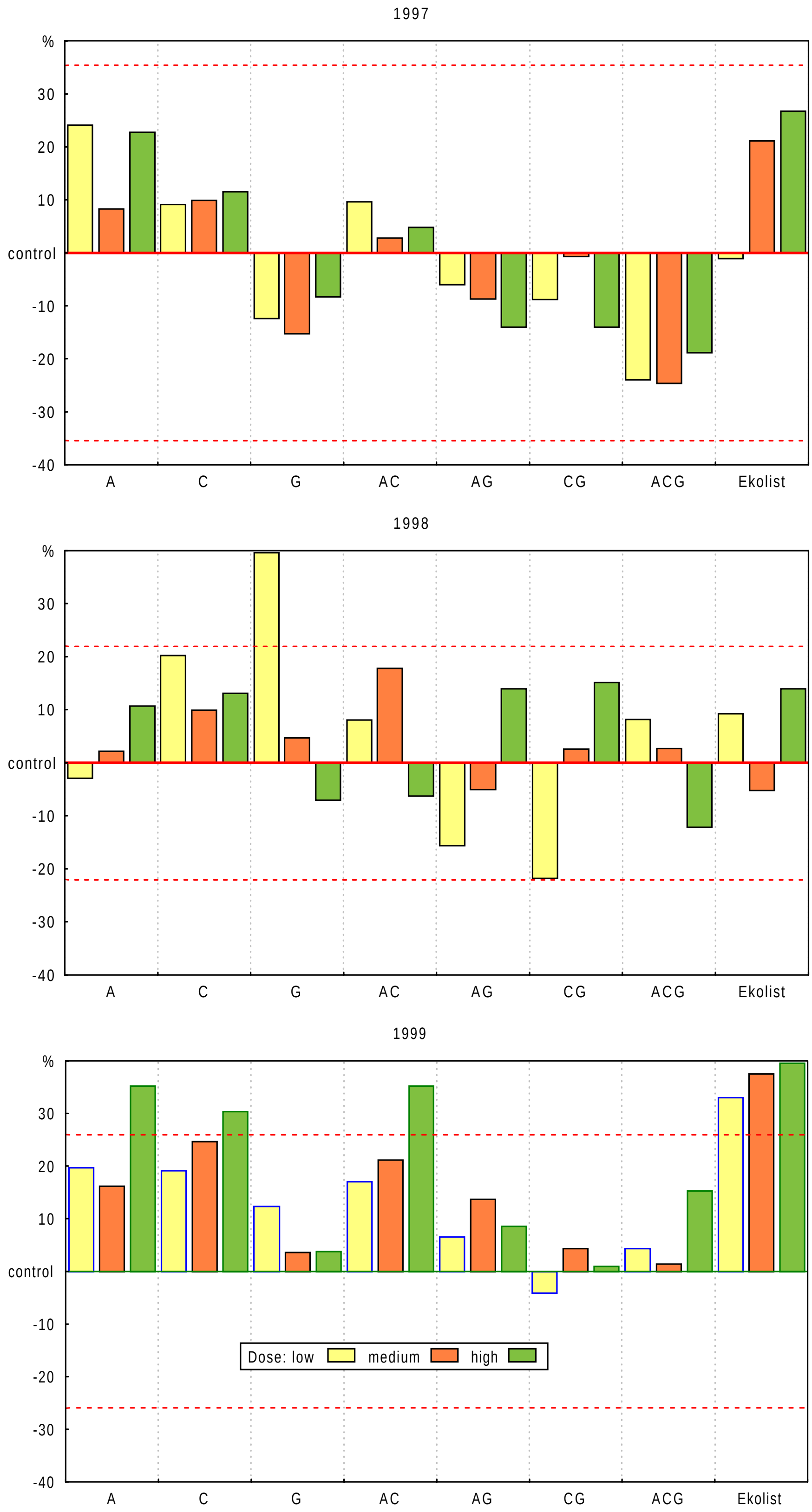
The impact of doses on yellow lupin seed yield components defined for a single plant varied across years. In 1997 a high dose of Ekolist was the only one to increase significantly the pod number per plant, while gibberellin and all its mixtures showed the tendency to decrease that number (Fig. 2). In 1998 the number was not significantly affected by any substances, while in 1999 all the doses of auxin, auxin with cytokinin and Ekolist as well as an average and high dose of cytokinin significantly increased the number of pods collected from a single yellow lupin plant. The number of seeds collected from a single plant treated with the tested doses of plant hormones and Ekolist in 1997 did not differ significantly from the number of seeds collected from the control (Fig. 3). In 1998 the high dose of gibberellin only resulted in a significantly greater number of seeds than from the control. The same effect in 1999 was recorded for high doses of auxin, cytokinin and auxin with cytokinin and all the doses of Ekolist. A comparison of the effect of the doses tested revealed over respective years no significant differences in the number of seeds per pod collected from the plants tested and the control (Fig. 4). A high dose of Ekolist in 1997 and all its doses in 1999 increased the weight of seeds collected from a single plant (Fig. 5). Similar results were noted in 1999 when all doses of auxin, cytokinin and auxin with cytokinin were applied. However in 1998 a medium dose of auxin with gibberellin and a low dose of cytokinin with gibberellin significantly decreased, as compared with the control, the weight of seeds collected from a single plant. The weight of 1000 seeds significantly higher than the control was observed in seeds from all the experiment objects in 1997 (Fig. 6), while in 1998 low and medium doses of auxin, low dose of cytokinin and medium and high doses of both as well as low dose of the three regulators were significantly lower than the weight of 1000 control seeds. The 1999 showed a significant increase in the 1000 seed weight due to high dose of gibberellin, as compared with the control.

PRINT

Fig. 2. Number of pods per yellow lupin single plant affected by growth regulators/Ekolist doses. Relative deviations from the control. Dashed line represents Dunnet's confidence interval

PRINT

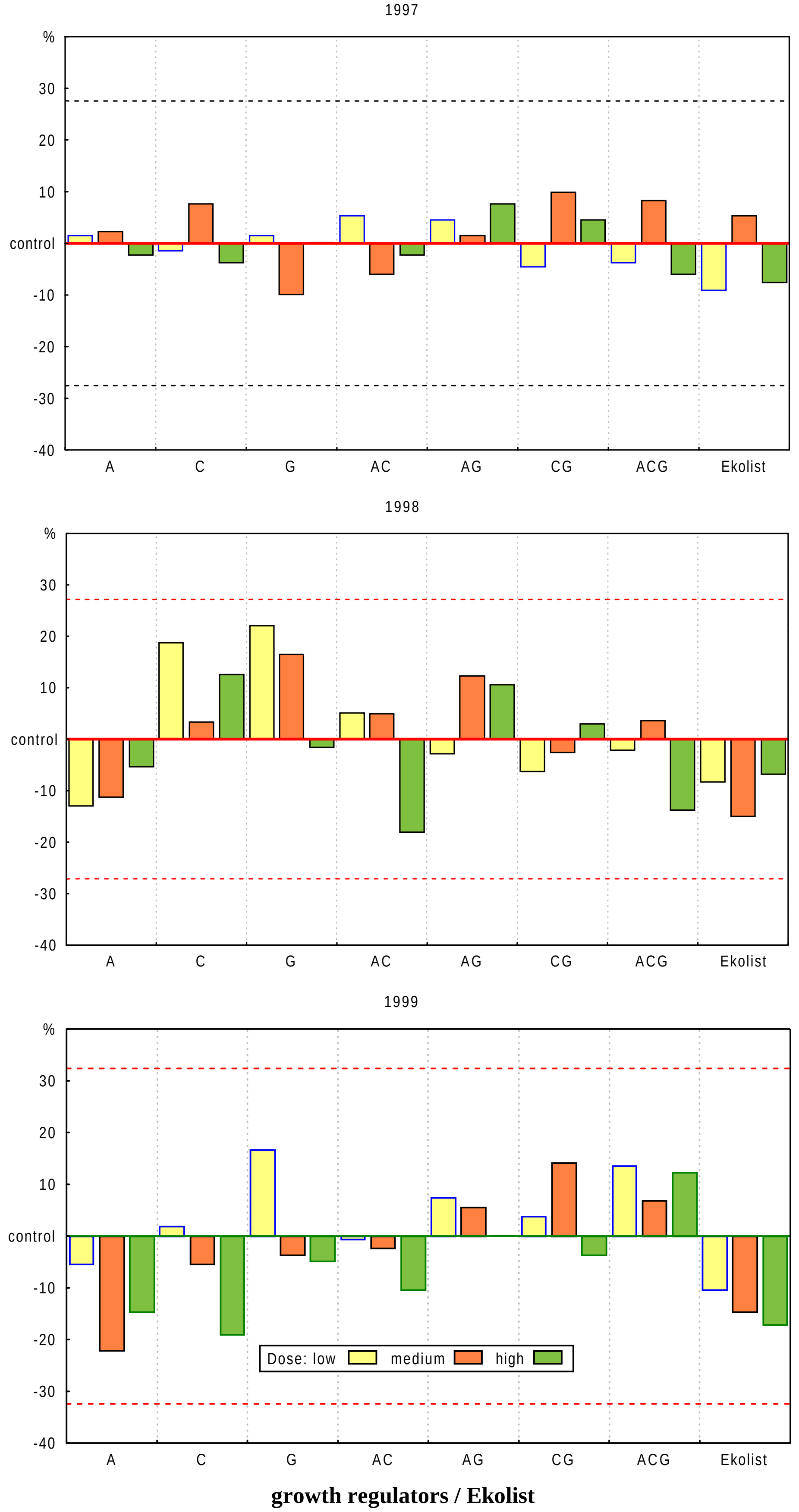
Fig. 3. Number of seeds per yellow lupin single plant affected by growth regulators/Ekolist doses. Relative deviations from the control. Dashed line represents Dunnet's confidence interval



growth regulators / Ekolist

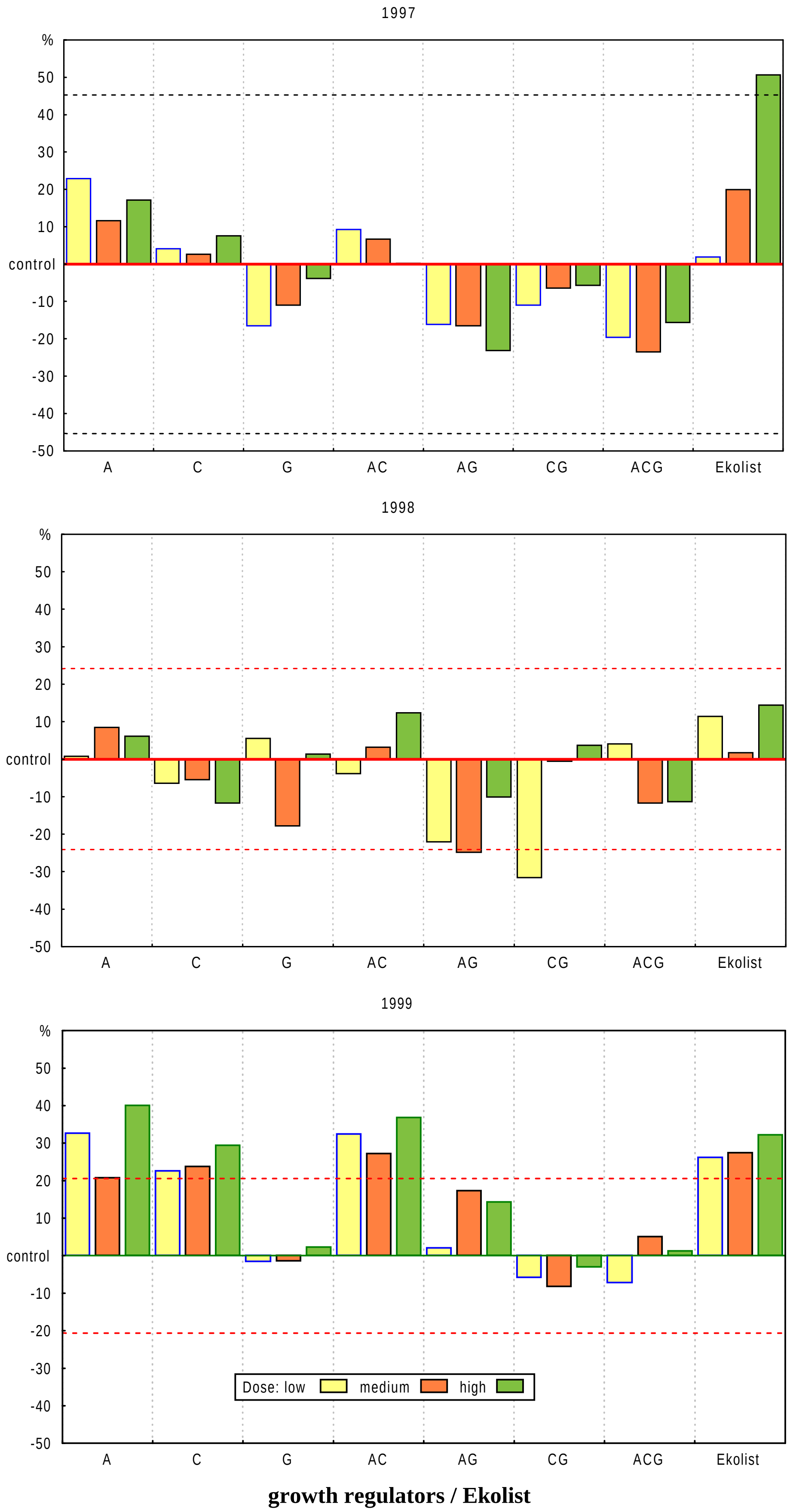
PRINT

Fig. 4. Number of seeds per pod from yellow lupin single plant affected by growth regulators/Ekolist doses. Relative deviations from the control. Dashed line represents Dunnet's confidence interval



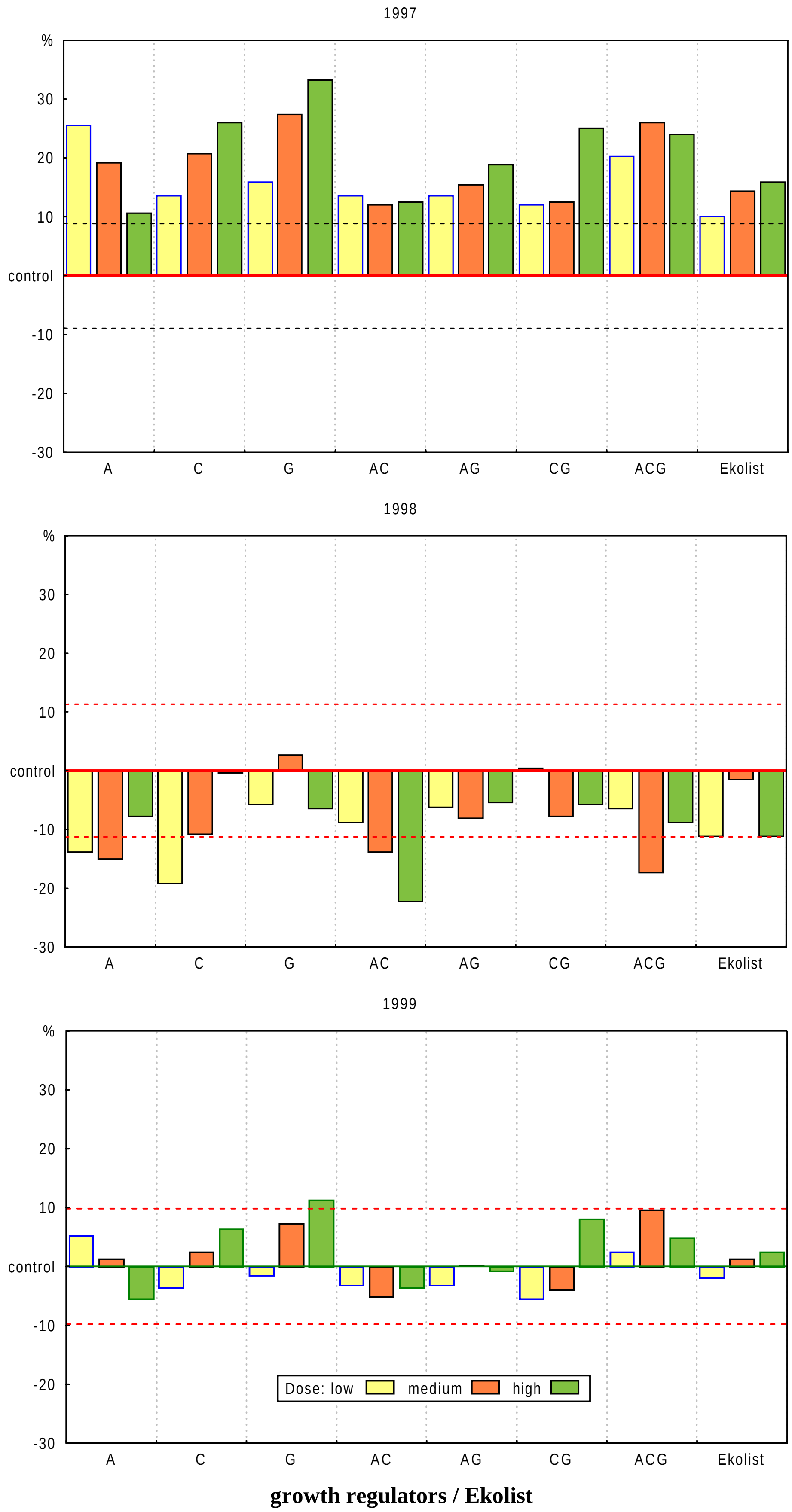
PRINT

Fig. 5. Seed weight per yellow lupin single plant affected by growth regulators/Ekolist doses. Relative deviations from the control. Dashed line represents Dunnet's confidence interval



PRINT

Fig. 6. 1000 seed weight from yellow lupin single plant affected by growth regulators/Ekolist doses. Relative deviations from the control. Dashed line represents Dunnet's confidence interval



PRINT

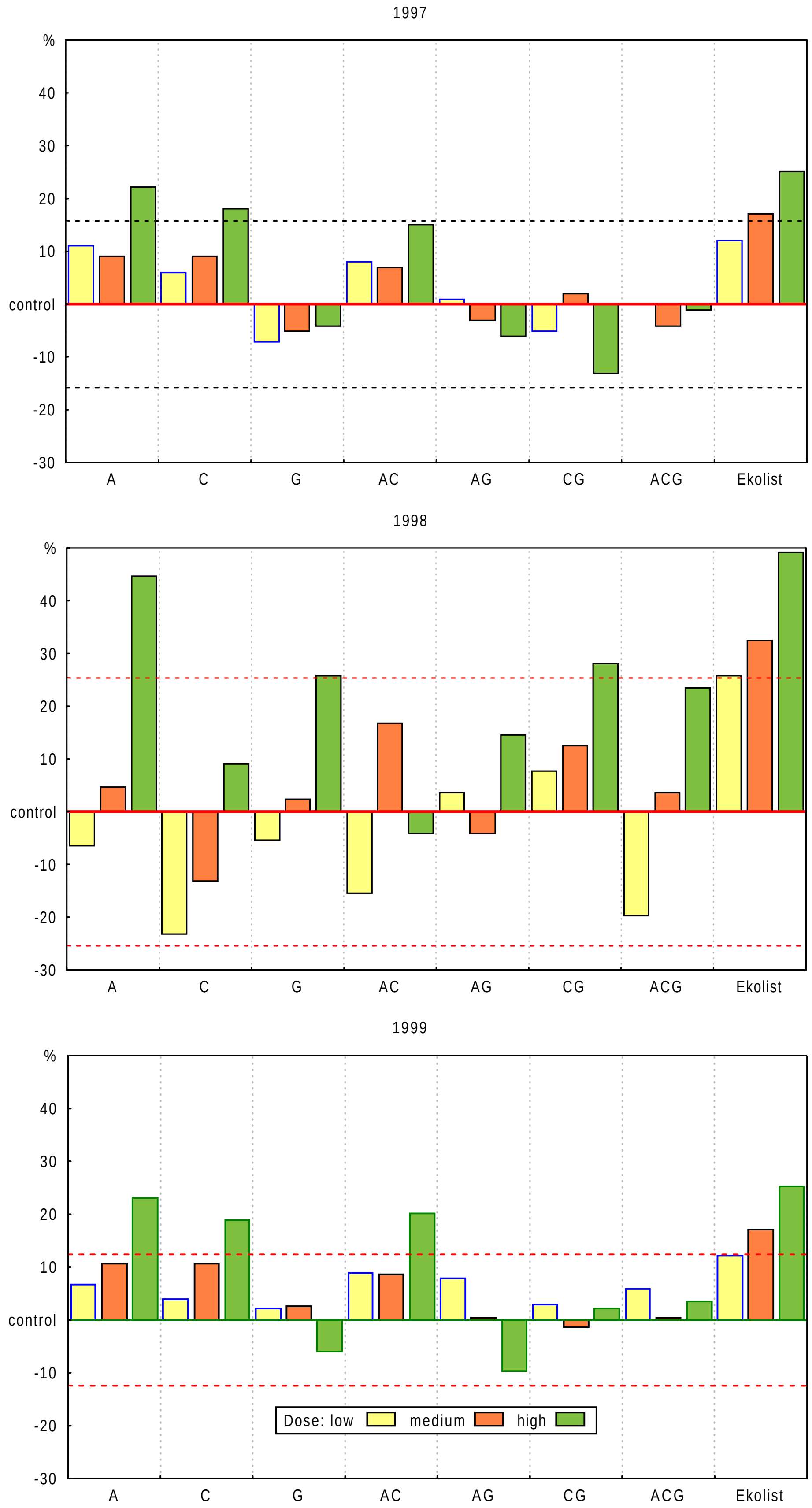
An average yellow lupin seed yield following spraying plants with growth regulators and Ekolist amounted to 1.86 t·ha^{-1} and was significantly higher (by 7.5%) than the control yield (1.73 t·ha^{-1}) (Table 5). Over respective years the difference in seed yield obtained from plants tested and control accounted for 5.2%, 8.9% and 7.3%. Treating plants with Ekolist gave a significantly higher seed yield than the application of growth regulators and/or their mixtures (except for auxin). No significant differences were observed for the effect of the growth regulators and their mixtures tested on yellow lupin yielding for the research period. As for successive years, the highest yields were obtained from plants sprayed with auxin and auxin with cytokinin (1991 and 1999) and with Ekolist (1997,1998, 1999). The yield-generating effect of the doses applied changed with years (Fig. 7). In 1997 seed yields significantly higher than the control were obtained due to application of high doses of auxin and cytokinin and medium and high of Ekolist, while in 1998 – high dose of auxin as well as gibberellin and gibberellin with cytokinin and all the doses of Ekolist. However in 1999 higher yields than the control were recorded for high doses of auxin, auxin with cytokinin and all doses of Ekolist. The analysis of the trend line for results covering the research period showed a clear favourable effect of increasing doses of auxin and Ekolist and unfavourable of auxin with gibberellin (Fig. 8) on yellow lupin yielding. A similar trend line analysis for yellow lupin seed yield components is presented in Figs. 9–13. The main stem and the yellow lupin plant itself treated with increasing doses of Ekolist and auxin and slightly less considerably also with cytokinin, and auxin with cytokinin showed a tendency to increase the number of pods (Fig. 9), number of seeds (Fig. 10) and the seed weight (Fig. 11) and to decrease the number of seeds per pod (Fig. 12). The weight of 1000 seeds (Fig. 13) tended to grow due to increasing doses of gibberellin, and slightly less due to cytokinin and cytokinin with gibberellin. No such clear-cut effect of increasing doses of the substances applied on yellow lupin seed yield components defined for branches was recorded.

Table 5. Effect of growth regulators/Ekolist on yellow lupin seed yield, t·ha^{-1}

Growth regulator/Ekolist	Year			Mean
	1997	1998	1999	
Auxin (A)	1.96a	1.78b	2.18a	1.98ab
Cytokinin (C)	1.91a	1.42c	2.13ab	1.82b
Gibberellin (G)	1.63b	1.68b	1.91b	1.74b
Auxin+Cytokinin (A+C)	1.89a	1.55bc	2.16a	1.87b
Auxin+Gibberellin (A+G)	1.67b	1.63b	1.91b	1.74b
Cytokinin+Gibberellin (C+G)	1.63b	1.81ab	1.94b	1.79b
Auxin+Cytokinin+Gibberellin (A+C+G)	1.69b	1.60b	1.98b	1.76b
Ekolist (Ek)	2.03a	2.12a	2.27a	2.14a
Mean for growth regulator/Ekolist	1.81A	1.70A	2.06A	1.86A
Control	1.72A	1.56A	1.92B	1.73B

Means followed by the same letters did not differ significantly at p=95% with Tukey test

Fig. 7. Yellow lupin seed yield affected by growth regulators/Ekolist doses. Relative deviations from the control. Dashed line represents Dunnet's confidence interval



growth regulators / Ekolist

PRINT

Fig. 8. Trend lines for growth regulator/Ekolist doses – related yellow lupin seed yield

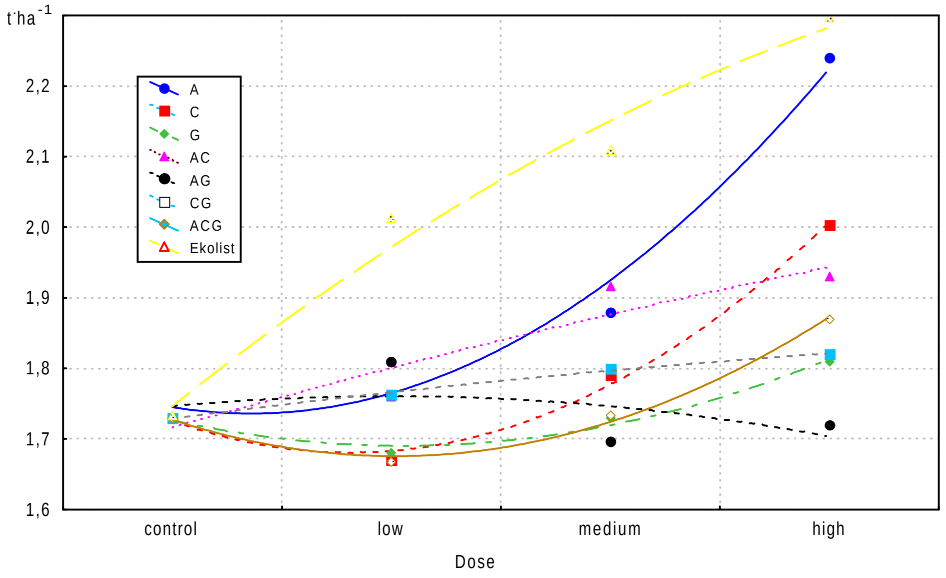
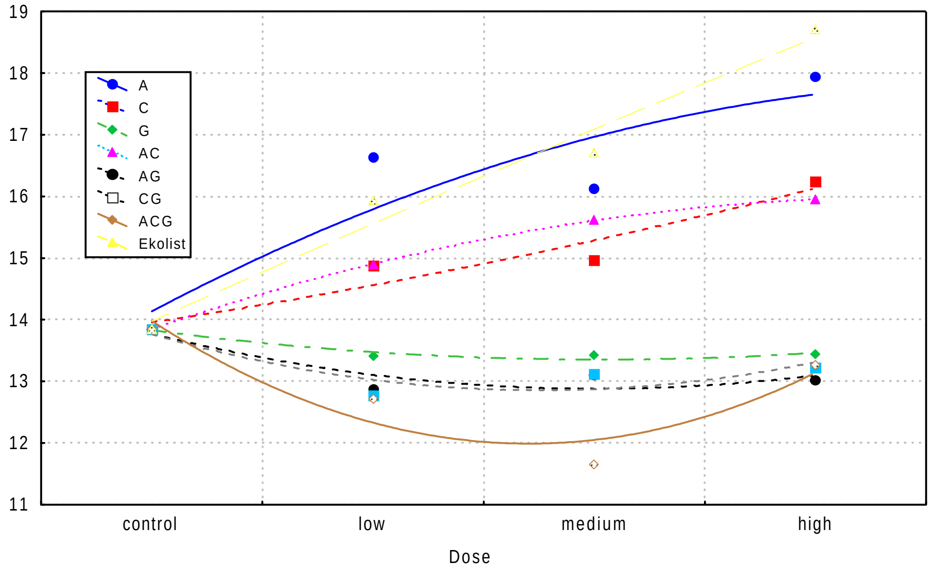


Fig. 9. Trend lines for growth regulator/Ekolist doses – related number of pods per yellow lupin plant



PRINT

Fig. 10. Trend lines for growth regulator/Ekolist doses – related number of seeds per yellow lupin plant

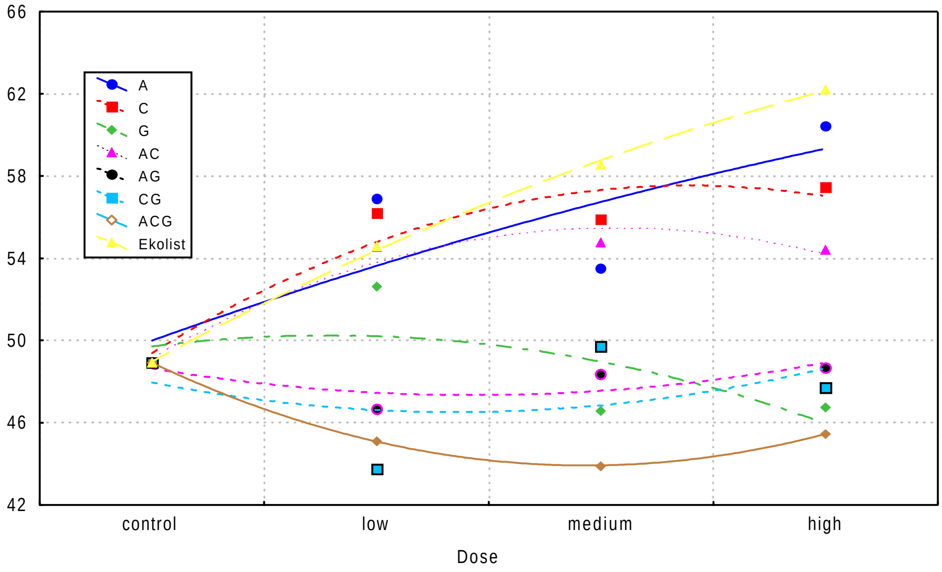
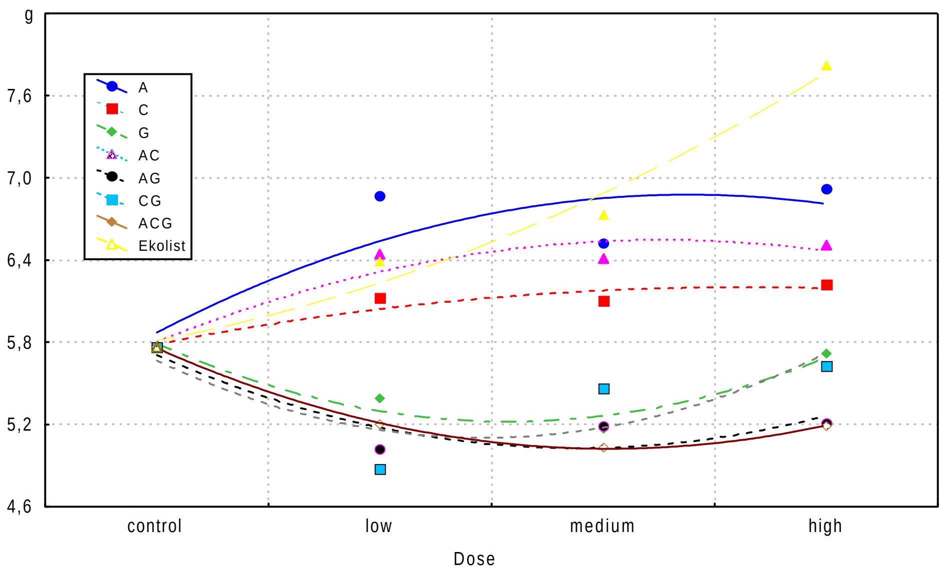


Fig. 11. Trend lines for growth regulator/Ekolist doses – related seed weight per yellow lupin plant



PRINT

Fig. 12. Trend lines for growth regulator/Ekolist doses – related number of seeds per pod of yellow lupin plant

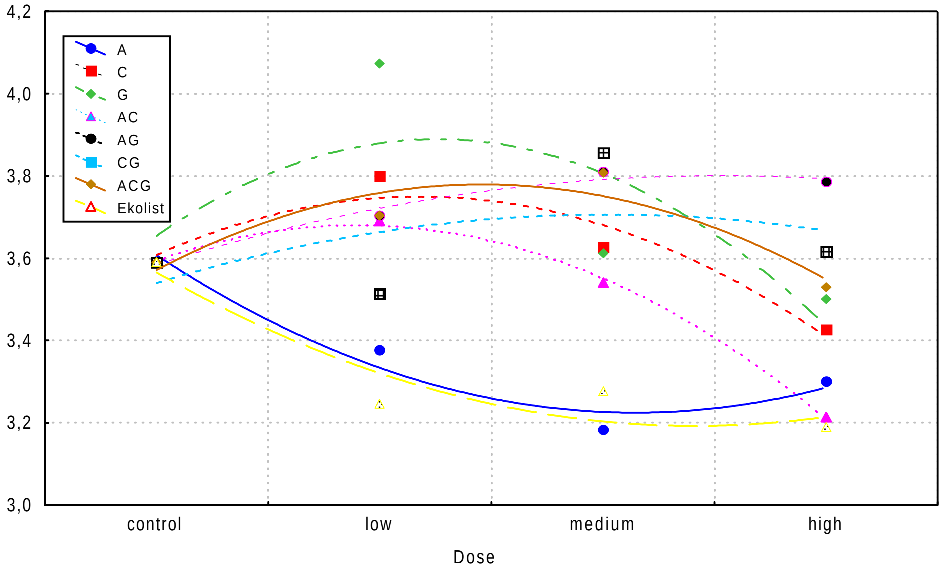
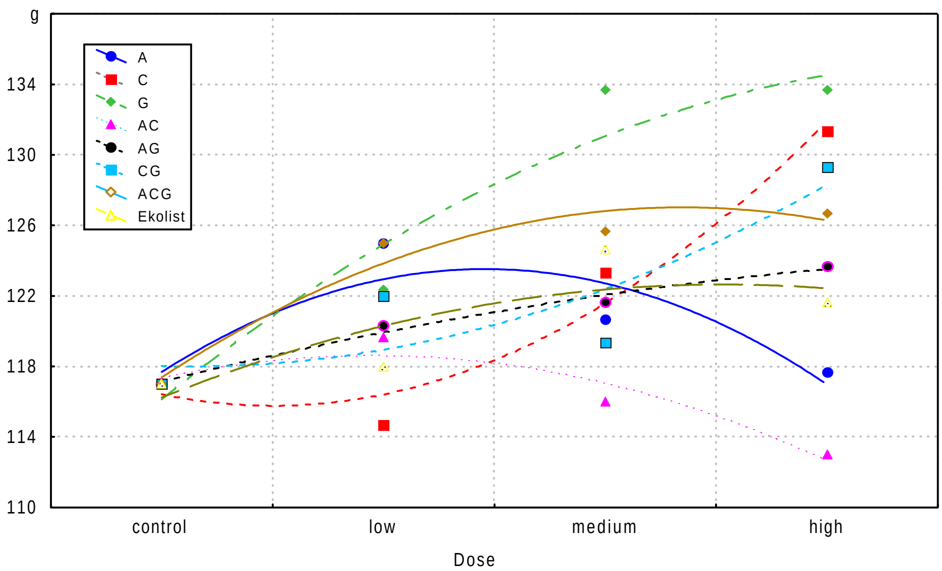


Fig. 13. Trend lines for growth regulator/Ekolist doses – related 1000 seed weight from yellow lupin plant



DISCUSSION

Yellow lupin yielding is most affected by weather and, slightly less considerably, by agricultural conditions and then by cultivar properties [5]. The rainfall optimal for yellow lupin over vegetation period ranges from 350 mm to 400 mm, while the greatest water requirements, excluding seed germination, coincide with flowering and pod setting. The weather conditions over successive years did not differ considerably from the multi-year records for the region. The greatest rainfall over vegetation, especially in its second part, over generative plant development was recorded in 1998 – 324 mm. The seed yields obtained in this year were, however, lowest for the research period: 1.56 $t{\cdot}ha^{-1}$ (control) and 1.70 $t{\cdot}ha^{-1}$ (experimental objects), which could have been due to high intensity of anthracnose. A newly recorded in Poland fungal disease afflicted by *Colletotrichum gloeosporioides* Penz. causes flower dying and considerable yield losses recorded on lupin seed plantations, yellow and white lupin, especially [11]. The rainfall over vegetation period in 1997 and 1999 was lower (278 mm and 265 mm, respectively) which, with no symptoms of infection with *C. gloeosporioides* Penz., generated higher seed yields: 1.72 $t{\cdot}ha^{-1}$ – 1.81 $t{\cdot}ha^{-1}$ in 1997 and 1.92 $t{\cdot}ha^{-1}$ – 2.06 $t{\cdot}ha^{-1}$ in 1999; by 7% in 1997 and by 20% in 1999 higher than those recorded by the Centre for Cultivar Testing [26].

PRINT

Most crop species shows very big biological reserve – the number of flowers considerably exceeds the number of developed and matured fruit. The share of fruit developed against the number of flowers accounts for 25% in faba bean and soybean, 30–70% in bean, while in alfalfa – 20–70% [23]. In the present research an average ratio of the number of pods developed to the number of control flowers accounted for 17.7%, 37% per main stem and only 4.8% on branches. In 1997, which was most favourable for lupin generative development, the ratio was 25%, 42% and 11%, in 1998, which was most affected by anthracnose, – 13%, 33% and 1% and in 1999 – 15%, 33% and 1.7%. Byszewski and Szklarska [9] and Pawłow et al., [21] observed as little as 20% of flowers produced matured pods. The results obtained confirmed a considerable effect of weather conditions and flower abortion on the use of biological lupin plant potential.

Yield instability, typical for legumes, depends also on changes in the content of endogenous growth regulators [1,4] whose role in flower abortion is defined with the dominance model. The application of growth regulators to enhance legume productivity has been covered by numerous research. Yellow lupin seed yields significantly higher than the control were recorded by Byszewski and Szklarska [9] as a result of auxin application and by Pawłow et al., [21] – cytokinin. Similarly Nowak et al., [19] reports on faba bean seed yield being enhanced by auxin and cytokinin. An increase in seed yield due to IAA was also observed for bean [15], IBA for narrow-leaf lupin [2], BAP for soybean [22] and gibberellin for faba bean [6,12,19] and bean [15]. The present research recorded a favourable, yet varied, effect of growth regulators on yellow lupin yielding. In 1997 and 1999 spraying plants with high-dose auxin increased the seed yield by 22%, and in 1998, when exposed to high intensity of *C. gloeosporioides* Penz., by almost 45%, as compared with the control. In 1997 and 1998 lupin yielded higher than the control also following the application high-dose cytokinin (by 18% and 18.7%) and auxin with cytokinin (by 15% and 20%, respectively). A 50% increase in yellow lupin seed yield due to cytokinin application, as reported by Pawłow et al., [21], was not obtained. In general, mixed growth regulators did not increase the yield considerably, as compared with the control, and quite frequently lower seed yields were noted than those obtained from plants treated separately with auxin or cytokinin. In the present research lupin yielding, just like faba bean yielding reported by Burkhard and Keller [7] and Klasa et al., [14], was not enhanced by application of gibberellin.

Legume seed yield components which are most critical in seed yielding include, besides plant density, the number of pods and seeds and seed weight per plant as well as 1000 seed weight. The application of auxin to spraying flowering lupin plants in the experiment reported by Byszewski and Szklarska [9] resulted in an increased number of pods and increased ratio of pod-to-flower developed. A greater number of pods per plant was also observed after the application of auxin in faba bean [19] and bean [15], cytokinin in narrow-leaf lupin [2], soybean [22] and faba bean [25], gibberellin in faba bean [6,19], and mixture of the three growth regulators - auxin, cytokinin and gibberellin in bean [15]. The present research showed that in 1999 exclusively, despite rainfall being lower than optimal for lupin, a significantly higher number of pods per plant was observed due to the treatment with auxin (by 35%), cytokinin and auxin with cytokinin (by 20%).

Few researchers broke down the number of pods from the main stem and from branches, which can be due to a low, about 5%, share of pods and seeds from branches in the total yellow lupin yield [20]. An increased number of pods per main stem reported in the present research coincided with 1997 and 1999 due to application of auxin (by 27% and 33%, respectively), cytokinin (by 21% and 19%) and auxin with cytokinin (by 24% and 19%). The number of pods and seeds per main stem and from single plant showed an almost linear increase with an increase in the dose of growth regulators and their mixtures. In 1998 there was recorded no favourable effect on the number of pods and seeds due to the treatment and clearly unfavourable effect of gibberellin and its mixtures with other hormones in 1997. In 1998 and 1999, however, there was noted a considerable increase in the number of pods produced by branches following the application of gibberellin (by 86% and 42%). An increasing number of pods following the application of auxin and its mixture with cytokinin seems to confirm the essential role of this regulator in flower and fruit abortion [4].

The seed weight per faba bean plant increased due to auxin, as reported by Klasa et al., [13], and due to auxin and cytokinin, as reported by Nowak et al., [19]. In 1999 in the present research the seed weight per plant was enhanced by auxin (a 31% increase as compared with the control), cytokinin (25%) and auxin with cytokinin (32%). Similar results were obtained analysing the seed weight per main stem. None of the substances studied, however, affected the seed weight produced by branches significantly, although there was a growth tendency with an increase in gibberellin doses. The present application of growth regulators, both individually and in mixtures, seems not to have overcome the inhibitory effect of primary organs on the development of secondary organs on branches, which is defined by the dominance model [4] explaining the role of growth regulators in generative organs abortion.

PRINT

For 'Teo' an average weight of 1000 seeds, being an essential indicator of seed quality, reported by COBORU has amounted to 149 g over the last couple of years [26], while in the present research – 123 g. A higher value can be obtained exposing the flowering yellow lupin plants to solutions of cytokinin and heteroauxin [21], although numerous results show no such effect [13,14,19], which is confirmed by varied present results. In 1997 the weight of 1000 seeds from control plants was very low (104 g) but it grew by 18.2% following the application of all growth regulators and their mixtures, however 1998 observed a negative effect of the substances tested on yellow lupin 1000 seed weight.

Generative organs which develop in the second part of the vegetation period are acceptors of nutrients and compete for them both among one another and with vegetative organs [4,18]. Nutrient deficiency over greatest demand can result in plant starvation and no nutritive balance, leading to lower yielding. Byszewski and Sadowska [8] observed favourable and Księżak et al., [16] – neutral effect of microelements on yellow lupin yielding. The present research yellow lupin seed yield increased by almost 50% following the application of Ekolist in 1998, which coincided with a high intensity of anthracnose infection, which could have been partly due to Ekolist fungicidal properties. The application of Ekolist at the dose of 3 $l \cdot ha^{-1}$ corresponded to the supply of 360 g of N, 78 g of P, 99 g of K, 1.5 g of Ca and Mn, 15 g of S, B and Cu, 3 g of Zn, 1 g of Fe i 0.06 g of Mo. One shall highlight that foliar application of microelements improves their effectiveness 10–20 times, as compared with soil application and that low and medium content of microelements defined in soil at the Mochełek Station. In 1997 and 1999 Ekolist increased seed yield by an average of 20%, as compared against the control, and the number of pods per plant (by over 35%) and main stem (by 34%) as well as seed weight per plant by respective 24% and 28% and, finally, seed weight per main stem by respective 20% and 27%. At large, Ekolist enhanced seed yield and its components along with increasing doses.

Abscission of generative plant parts seems to be leading naturally to a seed yield decrease. The rule of nutrient allocation introduced by Harper [23] suggests that over its life span, plant has limited nutrient resources which are allocated to varied functions, including growth and propagation. One can assume that a greater consumption related to one function limits the resources allocated to the other one. Providing plants with adequate nutrients at the right time and at the right quantity as well as regulating plant hormone economy can change the resource allocation in order to ensure an enhanced use of the biological potential of yellow lupin in farming.

CONCLUSIONS

1. Growth regulators and Ekolist applied limited the unwanted effect of generative organ abscission in yellow lupin. Additionally the use of production potential by plants was closely related to weather conditions and the intensity of anthracnose.
2. The total number of flowers developed by a single plant produced an average of 17.7% pods; 37% per main stem and only 4.8% on branches.
3. Out of all substances tested, lupin yielding was most enhanced by auxin and Ekolist and less considerably by cytokinin and mixture of auxin with cytokinin; their favourable effect on seed yield was most visible for high doses.
4. There was recorded a favourable effect of auxin, cytokinin and auxin with cytokinin on the number of pods and seeds and the weight of seeds per main stem and per single plant.
5. The number of pods, seeds as well as the number of seeds per pod and seed weight obtained from branches depended on neither the kind nor the dose of growth regulators and Ekolist researched.
6. There was recorded no or unfavourable effect of gibberellin and its mixtures on yellow lupin seed yield, except for the weight of 1000 seeds and the number pods and seeds developed on branches.
7. Increasing doses of Ekolist significantly enhanced most of the yield components for a single plant, the main stem and branches (seed number and weight).
8. The application of Ekolist at the dose of 9 l per ha at the beginning of plant flowering showed most cost-effective in increasing yellow lupin productivity. The treatment of plants with growth regulators, mainly due to their higher price and lower increases in seed yield, seems to be less justifiable.

REFERENCES

1. Addicott F., T., 1982. Abscission. Univ. California Press, Berkeley.
2. Atkins C. A., Pigeaire A., 1993. Application of cytokinins to increase pod set in *Lupinus angustifolius* L. Aust. J. Agr. Res. 44 (8), 1799–1819.
3. Aufhammer W., Nalborczyk E., Geyer B., Götz J., Mack C., Paluch S., 1989. Interactions between and within inflorescence in relation to the storage capacity of field beans (*Vicia faba*). J. Agr. Sci. 112, 419–424.

PRINT

4. Bangerth F., 1989. Dominance among fruits/sinks and the search for correlative signal. Physiol. Plant. 76, 608–614.
5. Barbacki S., 1972. Łubin. PWRiL Warszawa [in Polish].
6. Bellucci S., Keller E.R., Schwendimann F., 1982. Effect of GA_3 on the development and yielding of faba bean (*Vicia faba* L.). Part I. Effect of GA_3 on yield components. Angew. Bot. 56, 35–53 [in German].
7. Burkhard J., Keller E.R., 1983. Influence of plant density, gibberellic acid and site of the yield and yield components of different faba bean growing types. FABIS Newslet. 7, 37–39.
8. Byszewski W., Sadowska A., 1976. Impact of Wuxal foliar application on yellow lupin seed yield (*Lupinus luteus* L.). Zesz. Probl. Post. Nauk Rol. 184, 49–59 [in Polish].
9. Byszewski W., Szklarska J., 1969. Effect of spraying and defoliation on yellow lupin flower abscission. Rocz. Nauk Rol. 95A (2), 1–13 [in Polish].
10. Czuba R., 1992. Effect of microelement fertilisers in plant foliar application. Mat. VII Symp. Mikroelementy w rolnictwie. AR Wrocław, 155–157 [in Polish].
11. Frencel I., 1998. Anthracnose – to be or not to be for lupin in Poland. Mat. konf. Łubin w rolnictwie ekologicznym, PTŁ w Bydgoszczy, Przysiek, 24–30 [in Polish].
12. Kellerhals M., Keller E. R., 1984. Effect of plant growth regulators on faba bean development and yield components. FABIS Newslet. 2, 36–45.
13. Klasa A., Nowak G. A., Wierzbowska J., Gotkiewicz M., 1996. Effect of some growth regulators and their mixtures on faba bean yielding and chemical composition. Part I. Effect of auxin transport inhibitor (TIBA) and synthetic auxins (IBA ans NAA) on yielding and N and P economies. Biul. IHAR 197, 235–245 [in Polish].
14. Klasa A., Nowak G. A., Wierzbowska J., Gotkiewicz M., 1996. Effect of some growth regulators and their mixtures on faba bean yielding and chemical composition. Part II. Pactobutrazol and gibberellic acid (separately and in mixtures) on growth, yielding and N and P economies. Biul. IHAR 197, 247–255 [in Polish].
15. Koter M., Czapla J., Nowak G., Nowak J., 1983. Research into growth regulators potential in farming. Effect of GA_3, IAA and kinetin on growth and development of bean, corn and flax. I. Zesz. Nauk. ART Olsztyn, Rolnictwo 36, 17–27 [in Polish].
16. Księżak J., Podleśny J., Lenartowicz W., 1993. Foliar applications of microelements in legumes. Fragm. Agron. 4, 195–196 [in Polish].
17. Mazur T., 1991. Nitrogen in arable soil. PWN Warszawa [in Polish].
18. Nalborczyk E., 1993. Biological characteristics critical in legume productivity. Fragm. Agron. 4, 147–150 [in Polish].
19. Nowak G. A., Klasa A., Wierzbowska J., Gotkiewicz M., 1997. Yielding and content of microelements following the applications of growth retardants and fitohormones. Part I. Plant yielding. Biul. IHAR 201, 289–294 [in Polish].
20. Paprocki S., Mikołajczyk J., 1974. Yellow lupin seed production. W: Nasiona roślin strączkowych źródłem białka. Red. J. Mikołajczyk, PWRiL Oddział w Poznaniu, 168–171 [in Polish].
21. Pawłow A. N, Duchanin A. A., Sawienkow Ł. M., 1981. Causes of yellow lupin pod abscission Sielskochoziajstwiennaja biołogija, XVI, 6, 827–831 [in Russian].
22. Peterson C. M., Williams J. C., Kuang A. X., 1990. Increased pod set of determinate cultivars of soybean (*Glycine max*.) with 6-benzyloaminopurine. Bot. Gaz. 151 (3), 322–330.
23. Podlaski S., 1993. Causes, mechanisms and effects of selective generative organ abscission and varied seed development. Mat. konf. Znaczenie jakości materiału siewnego w produkcji roślinnej. SGGW Warszawa, 41–48 [in Polish].
24. Ruszkowska M., 1991. Role of microelements in biological N_2 fixation. Mat. VI Symp. “Mikroelementy w rolnictwie”. AR Wrocław, 5–13 [in Polish].
25. Ryllot P., D., Smith M., L., 1990. Effect of applied growth substances on pod set in broad beans (*Vicia faba* var. *major* L.) J. Agr. Sci. 111, 41–47.
26. Wiatr K., 2001. Trial result syntheses. Legumes. COBORU, Słupia Wielka, 1174 [in Polish].

Submited:

Janusz Prusiński
Department of Seed Production
University of Technology and Agriculture
Kordeckiego 20, 85-225 Bydgoszcz, Poland
e-mail: prusin@atr.bydgoszcz.pl

PRINT

Magdalena Borowska
Department of Seed Production
University of Technology and Agriculture
Kordeckiego 20, 85-225 Bydgoszcz, Poland
e-mail: borowska@atr.bydgoszcz.pl

Responses to this article, comments are invited and should be submitted within three months of the publication of the article. If accepted for publication, they will be published in the chapter headed 'Discussions' in each series and hyperlinked to the article.