Influence of gibberellin and β -indole-acetic acid on plants of yellow and white lupine

Part I — The growth and the development of plants

Wpływ gibereliny i kwasu β -indolooctowego na rośliny łubinu żółtego i białego

Cz. I. Wpływ na wzrost i rozwój roślin

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In some earlier investigations on lupines (Birecka, Szymańska, Ścibor-Marchocka 1960, Birecka, Szklarek, Mazan 1960), we noticed a marked relationship between the content of alkaloids and the growth rate of plants as well as their nitrogen content (apart from the also significant influence of the development phase). Among the many researches on the influence of gibberellins on growth and development of plants there are relatively few concerning the influence of these substances on the accumulation of nitrogen in papilionaceous plants or on the alkaloid content in plants rich in these compounds. Moreover the results of those researches are discordant (they will be discussed in greater detail in Part II) depending on the species under investigation or the stage of plant development at which gibberellin was applied. Therefore, some experiments were undertaken, in which the influence of gibberellin on lupine plants was considered. In most cases β -indole-acetic acid was also applied.

Preliminary experiments were carried out in spring 1960 on a population of bitter white lupine (Czechnicka var.). On the 17th day of growth in pots gibberellin was applied in doses of 2.10, or 30 μ g per plant either by spraying the leaves or through the petiole after cutting off the lamina. The plants were harvested 17 days later. No influence of gibberellin on their growth or on their alkaloid content was observed.

This part of the report deals with the results obtained in subsequent experiments concerning mainly the processes of growth and development, whereas the results referring to the nitrogen and alkaloid contents will be dealt with in Part II.

METHODS

The 1960 experiments.

The plants were grown in the greenhouse in Wagner's pots on a mixture of sand and soil (7 + 2 kg.). The following nutrients were supplied before sowing: 50 mg $N(NH_4NO_3)$, 300 mg $K_2O(K_2SO_4)$, 300 mg $P_2O_5(NaH_2PO_4)$, 615 mg $MgSO_4 \cdot 7H_2O$, 5 mg H_3BO_3 , 5 mg $MnSO_4$, 0.2 mg $CuSO_4$, 0.2 mg $ZnSO_4$, 0.5 mg $(NH_4)_6Mo_7O_{24}$, and 1 g $CaSO_4 \cdot 2H_2O$.

Bitter yellow lupine. Germinated seeds were planted on July 30; complete sprouting was recorded on August 2 and the same day the plants were inoculated with a *Rhizobium* strain*. On September 16, i.e. on the 45th day of growth the plants were thinned to five in each pot and sprayed in the afternoon with solutions of either gibberellin (potassium salt of gibberellic acid), or β -indole-acetic acid, or a mixture of these two substances; in all cases two different concentrations were applied. About 1 ml of solution was used for every plant. On the same day some of the plants were decapitated. Spraying with the same solutions was repeated on September 20 and 24. The controls were sprayed with distilled water. At the time of spraying the soil in the pots was covered with cotton-wool. The plants (from four pots per treatment) were harvested 18 days after the first spray, i.e. on October 4.

Medium-early, bitter white lupine (Czechnicka variety). Germinated seeds sown out on August 18 sprouted on August 20 and were inoculated with *Rhizobium* on the same day. On September 16, i.e. on the 27th day of growth, the plants were thinned to five per pot the subsequent experimental procedures being exactly the same as with yellow lupine.

The 1961 experiments.

In addition to the populations used in the preceding year two other populations of white lupine were experimented with. They were the eighth generation** from crosses of two varieties of lupine, i.e. White I ♀ $\times$ White Przebędowski medium-early ♂. One of the hybrids (119-1-3) was a bitter homozygote and the other (E-7/DB₂) was a low-alkaloid homozygote. The alkaloid level was 0.81 per cent in the seeds of the hybrid 119-1-3, about 0.01 in the seeds of the hybrid E-7/DB₂, and 2.10 per cent in the seeds of the Czechnicka variety.

The seeds of the yellow and the white lupines — the latter were checked under a UV lamp (Latawiec, 1958) — were sown at the

* Cultures of the appropriate *Rhizobium* strains were supplied by Professor J. Ziemięcka, to whom I wish to express my very sincere gratitude.

** I am indebted to Doctor J. Mikołajczyk for supplying the seeds of these populations; the symbols denoting these hybrids are his.

end of April into pots with analogous soil — sand mixture and nutrients as in the 1960 experiments. The sprouting of all plants was observed on May 2. On the same day the plants were inoculated with the suitable *Rhizobium* strain. On June 10 all the plants were additionally given 0.3 g. of K_2O and 0.3 g. of P_2O_5 per pot.

On the 28th day some of the plants (previously thinned to six per pot) were decapitated. On the same day gibberellin and heteroauxin were applied for the first time (Spraying Time I) — mainly on leaves and apex (the decapitated plants were treated only with solutions of higher concentration of these substances). The spray was repeated after 3, 10, and 18 days.

A part of the plants of yellow lupine and of the white Czechnicka variety was first sprayed on the 46th day of growth (Spraying Time II). The treatment was subsequently repeated twice at intervals of two days and for the third time on the 64th day of growth. Three or four pots per treatment were harvested on the 28th *, 46th, and 64th day of vegetation; on this last date also the decapitated plants were cropped.

The last harvest of white lupine was at the stage of full maturity. Yellow lupine was harvested somewhat earlier, i.e. on the 105 th day, the stems of these plants having been attacked by *Rhizoctonia aderholdi*; in all treatments the degree of infection was the same; the plants were harvested two days after the morbid symptoms appeared. The plants were always harvested in the afternoon.

RESULTS

Yellow lupine

The 1960 experiments.

On the 45th day of growth the number of leaves on the main stems was 9—10. At the time of harvest in all treatments their number was 20—21, on the developing, still rather small side shoots the total number of leaves was 13—14. The growth of the side shoots of the decapitated plants was somewhat more vigorous than of the controls, but the leaves of the main stems of these plants did not differ in the intensity of greenness.

A few days after spraying with A_3 or with a mixture of IAA and a high concentration of A_3 the internodes of the main stems were already significantly longer than those of the controls. This difference was increasing until the end of the experiment. The effect of IAA was

* At that time a good many of nodules on the roots of plants of both species were noticed.

Tabela 1 — Table 1
Weight of bitter yellow lupine
(Experiment 1960)
Ciężar roślin łubinu żółtego gorzkiego
(doświadczenie 1960)

Plant treated with Stosowane substancje*	Concen- tration Stężenie g/l	Dry matter content % of fresh weight Zawartość suchej masy** — %		Dry matter g per plant Ciężar rośliny — g s. m.			
		blades blaszki liściowe	stem łodyga	leaves liście	stem łodyga	total razem	roots korzenie
Control	0	15.5	7.9	1.64	0.37	2.01	0.40
		after 18 days po 18 dniach		increase after 18 days przyrost po 18 dniach			
Control	0	16.0	9.1	1.73	0.69	2.42	0.27
A ₃	10 ⁻²	16.1	9.5	1.90	1.02	2.92	0.33
A ₃	5 × 10 ⁻¹	16.0	9.4	1.88	1.07	2.95	0.37
IAA	10 ⁻⁵	14.7	8.3	1.46	0.84	2.30	0.65
IAA	10 ⁻³	14.9	8.3	1.50	0.78	2.28	0.65
A ₃ }	10 ⁻²	14.3	8.8	1.44	0.75	2.19	0.71
IAA }	10 ⁻³						
A ₃ }	5 × 10 ⁻¹	16.5	9.5	1.54	1.02	2.56	0.45
IAA }	10 ⁻⁵						
Decapit.	0	15.9	10.1	1.02	0.66	1.68	0.32
μt (p-0.05)				0.14	0.13		0.12

* A₃ — potassium salt of gibberellic acid, IAA — β-indole-acetic acid.

A₃ — sól potasowa kwasu gibberelinowego, IAA — Kw.B-indolooctowy.

** The dry matter content in leaf stalks ranged 10.0—10.8 per cent and their weight ranged 0.25—0.28 g d.m.
Zawartość w ogonkach liściowych wahała się w granicach 10.0—10.8%, a ich ciężar — 0.25—0.28 g s.m.

much weaker (the laminae sprayed with this substance were even somewhat smaller). No influence of the substances applied on the growth of the side shoots was observed.

The weight increments 18 days after the first spray are listed in Table 1. During that period the weight of the aerial part of the controls was doubled. The stimulating influence of A₃ in both doses, was manifested, mainly by the increased weight of the stems and to a lesser degree of leaves. The plants treated with IAA only showed a weight increment of leaves smaller and of stems slightly higher (in the case of the higher dose — not statistically proved) than the controls. An analogous lower increment of the weight of leaves showed the plants treated with both substances, regardless of their concentration. Only in the case, when the dose of IAA was small and the dose of A₃ large, the weight increment of the stems was the same as after treatment with A₃ alone.

Worth noting was the greater water content of both leaves and stems under the influence of IAA. All the plants treated with this substance manifested a more vigorous growth of the roots than in all other treatments. The only difference between the decapitated plants and the controls was the weight of leaves (apart of course from their number), which was higher in the latter case.

The 1961 experiments.

At the age of 28 days the number of leaves on the main stem was 8—9. At the age of 46 days their number was 18 in the controls, 20 in plants sprayed with IAA and 22* in plants sprayed with A_3 (regardless of the concentration). Plants treated at Spraying Time I began to form buds between the 45th and the 48th day of growth, earlier after A_3 and later after IAA.

Plants sprayed at Spraying Time II showed bud formation between the 50th — 51st day independently of what substance was applied (i.e. 4—5 days after spraying). The controls began budding on the 53rd — 54th day of growth. The flowers of these plants developed rapidly and in all treatments the formation of pods began between the 65th and the 67-th day. Flower buds on the side shoots (4 with a total of 18—20 leaves per undecapitated and 6—7 with 42—45 leaves — per decapitated plant) began to appear on the 62nd or the 63rd day independently of the treatment. Single pods were formed on the side shoots of only a few plants and they still were very small at the time of the last harvest.

The influence of the applied substances on the growth of main stems is illustrated by the data in Table 2 and by photopraghs 1, 2, 3, 4. and 5.

During 18 days after the first spray both substances caused a greater elongation of the stems, but the effect of A_3 was stronger than of IAA. The differences due to the various concentrations of these substances were insignificant. During the following 18 days the stimulating effect on the growth of stems was manifested only by the larger doses but now the effect of IAA was equally strong as of A_3 .

These two substances sprayed first at Spraying Time II also appreciably stimulated the elongation of main stems, the magnitude of this effect being also in this case the same independently of the substance applied and its concentration (the difference in the treatment A_3 5×10^{-4} g/l is not statistically proved). However, the observations of the plants showed that the rate of elongation of the side shoots was signi-

* This number of leaves on the main stem was the highest and the same for all these plants at the beginning of bud formation. The numbers in all the three cases are the averages with ± 0.5 of variation.

Fig. 1. Yellow lupine at the age of 44 days: pots No. 122 — controls, No. 143 — Spraying Time I: $A_3 10^{-2}$ g/l, No. 139 — Spraying Time I: $A_3 5 \times 10^{-1}$ g/l

Fig. 2. Yellow lupine at the age of 44 days: pots No. 121 — controls, No. 168 — Spraying Time I: IAA 10^{-5} g/l, No. 160 — Spraying Time I: IAA 10^{-3} g/l

Fig. 3. Yellow lupine at the age of 62 days: pots No. 121 — controls, No. 145 — Spraying Time I: A_3 10^{-2} g/l, No. 136 — Spraying Time I: A_3 5×10^{-1} g/l

Fig. 4. Decapitated yellow lupine at the age of 44 days: pots No. 121 — undecapitated controls, No. 172 — decapitated controls, No. 173 — decapitated sprayed with A_3 5×10^{-1} g/l, No. 176 — decapitated sprayed with IAA 10^{-3} g/l

ificantly greater after A_3 than after IAA (but unfortunately no accurate measurements were made). In the later stages of development the differences between the plants treated with A_3 and IAA on one side and the controls on the other gradually disappeared, so that at the time of the last harvest they already were insignificant.

Table 2 — Tabela 2
Height of the main stem of yellow lupine (cm.)
Wysokość pędu głównego łubinu żółtego (cm)

Treatment Zastosowane substancje	Concen- tration Stężenie g/l	Plants — Rośliny w wieku 46 days old — 46 dni* 64 days old — 64 dni					
		treated on the 28th day opryskane w 28 dniu				treated on the 46th day opryskane w 46 dni	
		height wysokość	Δ	height wysokość	Δ^{**}	height wysokość	Δ^{**}
Control	0	7.6		43.5			
A_3	10^{-2}	18.5	+10.9	52.8	-1.6	57.3	+13.8
A_3	5×10^{-2}	20.7	+13.1	66.0	+9.4	60.0	+16.5
IAA	10^{-5}	12.2	+4.6	51.5	+3.4	57.0	+13.5
IAA	10^{-3}	13.6	+6.0	59.4	+9.9	56.8	+13.3

* At this time the decapitated controls and the decapitated, heteroauxin treated plants were only just at the end of the rosette stage; the height of the stems of the decapitated gibberellin treated plants was 12—14 cm.

Rośliny dekapitowane, kontrolne, jak i opryskane heteroauksyną zaczęły w tym okresie wychodzić zaledwie z fazy rozetki, natomiast opryskane gibereliną miały łodygi (przy znacznie mniejszej ilości międzywęzli niż nie dekapitowane) wysokości około 12—14 cm.

Δ^{**} increment as compared to controls
przyrost w porównaniu z kontrolą

The influence of A_3 on the decapitated plants was manifested by a much greater elongation of the main stems and the simultaneous much weaker growth of the side shoots as compared to the control. On the other hand, the influence of IAA was mainly manifested by a larger area of the leaf laminae and their deeper green colour.

Table 3 lists the weights of plants at the age of 28, 46, and 64 days. The results obtained for the 46th day of growth show that: 1) A_3 in both concentrations caused a marked increase in the weight of the stems as compared to the controls, but the increment after the higher dose was somewhat smaller. It seems that the larger dose applied at that stage was too strong, as it had a distinctly negative effect on the weight of leaves and side shoots. 2) the differences caused by IAA in the weight of leaves and side shoots were near the L.S.D. In this experiment IAA had no significant effect on root growth. (Similarly, it did not affect the water content in the aerial organs). On the 64th day of growth there were no significant differences between treatments in

Table 3 — Tabela 3
Weight of yellow lupine plants (per plant)
(Experiment in 1961)
Ciężar roślin łubinu żółtego w czasie wegetacji (w przeliczeniu na 1 roślinę)
(Doświadczenie 1961 r.)

Plants treated with Stosowane substancje	Concentration Stężenie g/l	Time of treatment Czas stosowania	Weight — g d.m.			Ciężar — g s.m.			Aerial parts Część nadziemna	Roots Korzenie
			main shoot pęd główny			lateral shoots pędy boczne				
			leaves liście	stem łodyga	flowers kwiaty	leaves* liście	stems łodygi	flowers kwiaty		
			in the 28th day of growth — w wieku 28 dni							
	control		0.42	0.02					0.44	0.12
			plants on the 46th day of growth rośliny w wieku 46 dni							
A ₃	10 ⁻²	on the 28th day	1.29	0.16		0.04			1.49	0.69
A ₃	5 × 10 ⁻¹	of growth	1.39	0.37		0.05			1.81	0.59
IAA	10 ⁻⁵	w 28 dniu	1.10	0.30		0.01			1.41	0.59
IAA	10 ⁻³	wzrostu	1.15	0.21		0.04			1.40	0.75
μt (p—0.05)			1.20	0.20		0.06			1.46	0.65
			0.10	0.04						
			on the 64th day of growth — w wieku 64 dni							
A ₃	control 10 ⁻²	on the 28th day	2.31	1.13	0.20	0.40	0.08		4.12	1.27
A ₃	5 × 10 ⁻¹	of growth	2.11	1.38	0.26	0.38	0.06		4.19	1.21
IAA	10 ⁻⁵	w 28 dniu	2.04	1.64	0.22	0.48	0.07		4.45	1.26
IAA	10 ⁻³	wzrostu	[1.97	1.29	0.24	0.42	0.10		4.02	0.82]
			2.26	1.52	0.28	0.64	0.12		4.82	1.41
decapit	0		0.40	0.22	—	2.02	1.13	0.06	3.83	0.95
decapit. +A ₃	5 × 10 ⁻¹		0.43	0.43	—	1.56	0.62	0.02	3.06	0.77
decapit. +IAA	10 ⁻³		0.69	0.30	—	2.16	0.96	0.04	4.15	1.36
A ₃	10 ⁻²	on the 46th day	2.37	1.60	0.29	0.76	0.18		5.20	1.22
A ₃	5 × 10 ⁻¹	w 46 dniu	2.21	1.48	0.27	0.58	0.17		4.71	1.04
IAA	10 ⁻⁵		2.38	1.53	0.25	0.55	0.09		4.80	1.22
IAA	10 ⁻³		2.19	1.49	0.26	0.53	0.13		4.60	1.05
μt (p—0.05)			0.25**	0.14	0.058	0.14	0.04**			

* The weight of leaves for undecapitated plants is stated jointly with the weight of flowers, which in various treatments ranged 0.01—0.02 g.

Ciężar liści roślin (nie dekapitowanych) w wieku 64 dni podany jest z masą kwiatów, wahającą się w granicach 0.01—0.02 w różnych kombinacjach.

** In calculating the L.S.D. the plants sprayed on the 28th day with IAA of 10⁻⁵ g/l concentration were disregarded.

Błąd obliczony z pominięciem roślin opryskanych heteroauksyną w stężeniu 10⁻⁵ g/l w 28 dniu wzrostu.

*** In calculating the L.S.D. the decapitated plants were disregarded.

Błąd obliczony z pominięciem roślin dekapitowanych.

the weight of leaves* of the main stems, except for the persisting, but not increasing negative effect of A_3 at the higher concentration. When not the weight of the stems at the time under consideration, but the increment of the weight during the last 18 days is considered, it is to be seen that this increment was higher than in the controls only after large doses of A_3 or IAA. The higher concentration of the latter substance caused a greater weight increment of side shoots, specially of their leaves.

The application of the two substances at Spraying Time II had no significant effect on the weight of leaves of the main shoot, but caused equally for both substances an appreciably greater increment of the weight of the main stems. The magnitude of this increment (similarly to the magnitude of the elongation of stems) in this case, thus, depended neither on the nature of the growth substance nor on its concentration. On the other hand, A_3 had a greater effect on the side shoots, in particular on their stems than IAA.

The decapitated plants sprayed when still young with the higher dose of A_3 showed after 36 days as compared to the controls, 1) a greater increment of the weight of main stems, and 2) a simultaneous lesser growth of the side shoots. The effect of the higher dose of IAA was manifested by a greater increase of the weight of leaves of the main stem and of the roots.

The yields from the last harvest will be discussed in Part II.

White Lupine

The 1960 experiments.

The number of leaves developed by the 27th day of growth was eight on each plant. In the second week after spraying the leaf laminae were somewhat larger than in the controls, specially after treatment with IAA. Somewhat more rapid elongation of the internodes was observed only after treatment with the higher concentration of A_3 . The leaf laminae of the decapitated plants were appreciably broader and of deeper green colour.

On the day of the harvest the plants had 16—17 leaves each and had not yet developed side shoots — this was true also in the case of the decapitated plants — but were already beginning to bud and this process was equally advanced in all treatments.

* The weight of the whole plants (and not only of the leaves) treated with IAA at the concentration of 10^{-5} g/l was not reliable: replications showed a high discrepancy of results caused by an accidental flooding of two pots.

Table 4 — Tabela 4

Weight of bitter white lupine (Experiment 1960)
Ciężar roślin łubinu białego gorzkiego (doświadczenie 1960)

Plant treated with Stosowane substancje*	Concentration Stężenie g/l	Dry matter content% of fresh weight Zawartość suchej masy**—0/0		Dry matter g per plant Ciężar rośliny — g s. m.			
		blades blaszki liściowe	stem łodyga	leaves liście	stem łodyga	total razem	roots korzenie
Control	0	14.4	9.0	0.58	0.12	0.70	0.20
		after 18 days po 18 dniach		increase after 18 days przyrost po 18 dniach			
Control	0	13.8	11.0	0.69	0.54	1.23	0.16
A ₃	10 ⁻²	14.3	11.2	0.82	0.50	1.32	0.16
A ₃	5 × 10 ⁻¹	13.3	11.1	0.87	0.65	1.52	0.24
IAA	10 ⁻⁵	15.5	12.1	0.87	0.51	1.38	0.17
IAA	10 ⁻³	15.3	12.0	0.90	0.54	1.44	0.21
A ₃ }	10 ⁻²	15.3	11.8	0.91	0.53	1.44	0.16
IAA }	10 ⁻³						
A ₃ }	5 × 10 ⁻¹	14.5	11.1	0.76	0.45	1.21	0.15
IAA }	10 ⁻⁵						
decapit.	0	14.5	12.5	0.48	0.28	0.77	0.29
μt (p=0.05)				0.10	0.09	0.14	

* A₃ — potassium salt of gibberellic acid, IAA — β-indole-acetic acid.

A₃ — sól potasowa kwasu giberelinowego, IAA — kwas β-indolooctowy.

** The dry matter content in leaf stalks ranged 11.0—12.2 per cent (the higher values correspond to the IAA treatments).

Zawartość suchej masy w ogonkach ilościowych wahała się w granicach 11.0—12.0% (wyższe wartości w komb. z IAA).

The increment of the plant weights on the 18th day after the first spraying are listed in Table 4. The response of white lupine to the applied substances differed in many respects from the response of yellow lupine at the same period. The following differences as compared to the controls are worth noting: 1) the smaller water content of leaves and shoots under the influence of IAA, 2) greater increment of leaves of plants treated with A₃ as well as with IAA, 3) the lack of any influence of IAA on the root growth, and 4) the relatively weak influence of A₃ on the weight of stems only apparent for the higher concentration of this substance and when it was applied without IAA.

The 1961 experiments.

On the 28th day the plants of all populations had 9—10 leaves each. With regard to the character of development the bitter Czechnicka variety resembled greatly the fodder hybrid E-7/DB₂: in both cases budding began on the 34th day when 16 leaves had developed, full blossom of the main shoots occurred on the 45th day, and the side shoots (in the fodder hybrid they developed earlier than in the bitter variety) began flowering on the 53rd day; the plants matured on the 128th day of growth. On the other hand, the development in the bitter hybrid 119—1—3 was retarded 7 days for the beginning of bud forma-

Fig. 5. White lupine of the bitter Czechnicka variety at the age of 44 days: pots No. 4 — undecapitated controls, No. 74 — decapitated controls, No. 76 — decapitated sprayed with $A_3 \ 5 \times 10^{-1} \text{ g/l}$, No. 81 — decapitated sprayed with $IAA \ 10^{-3} \text{ g/l}$

tion on the main shoots, 5—6 days for full blossom, and 11 days for the beginning of flowering of the side shoots; these plants matured on the 136th day of vegetation. The 119—1—3 hybrid differed from the others by the greater number of leaves on the main shoot (20 instead of 16) and on the side shoots (30 instead of 20), and by the greater height of the main stem, this last distinguishing trait did not appear till between the 50th and the 55th day of growth and was maintained to the stage of maturity. On the other hand the response to decapita-

tion of the two populations of bitter lupine was similar and differed from the response of the population of fodder lupine: the growth of bitter lupines was more intense and the number of leaves on the side shoots was higher (28 as compared to 20). The decapitated plants of all the experimental populations had, similarly as in the earlier experiments, much larger leaf laminae and were of a deeper green than in the controls.

In the undecapitated plants no influence was observed of the applied substances on the height of stems, the size and the number of leaves, and the rate of development; this was true at all stages of development and of all experimental populations. On the other hand, the decapitated plants showed a more rapid elongation of the main stems already a few days after spraying with A_3 .

Photograph 5 illustrates the plants of the Czechnicka variety on the 45th day of growth; the plants of other varieties showed also analogous differences. Table 5 lists the heights of stems on the 64th day. As is to be seen from the data obtained the decapitated plants did not react to IAA. No other differences, besides those already mentioned, were observed in the behaviour of the decapitated plants under the influence of the two substances applied.

As no significant influence of either A_3 or IAA on the weight of the particular plant organs of white lupine was observed — the only exception here was a slight increase of the weight of the main stems of decapitated plants after treatment with A_3 — only the yields of the

Table 5 — Tabela 5

Height of the main stem (cm) of 64 days old plants of white lupine

Wysokość pędu głównego roślin łubinu białego (cm) w wieku 64 dni

Treatment Zastosowane substancje	Concentra- tion Stężenie g/l	Height of stem (cm) Wysokość łodygi (cm)		
		bitter — var. Czechnicka odm. gorzka Czechnicka	bitter hybrid ród gorzki 119—1—3	fodder hy- brid ród pastewny E 7/BD ₂
Control		56.0	65.8	54.1
decapit.	0	20.7	19.5	21.1
decapit. + A_3	5×10^{-1}	26.1	24.7	27.4
decapit. + IAA	10^{-3}	18.0	21.0	21.6

Table 6 — Tabela 6
Weight of white lupine plants (Experiment 1961)
Ciężar roślin łubinu białego (doświadczenie 1961 r.)

Kind of population Populacje	Treatment Kombinacje	Weight g d.m. per plant — ciężar 1 rośliny g s.m.							
		main stem — pęd główny			lateral shoots — pędy boczne			total razem	roots, korzenie
		leaves liście	stem łodyga	podstrąki	leaves* liście	stems łodygi	podstrąki		
on the 28th day of growth — w wieku 28 dni									
Bitter Czechn. v. gorzka Czechn. Bitter hybrid Ród gorzki 119—1—3 Fodder hybrid Ród past. E 7/DB ₂	0	0.58	0.23					0.81	0.18
	0	0.67	0.27					0.94	0.26
	0	0.57	0.26					0.83	0.24
on the 46th day of growth — w wieku 46 dni									
Bitter Czechn. v. gorzka Czechn. Bitter hybrid Ród gorzki 119—1—3 Fodder hybrid Ród past. E 7/DB ₂	0	1.40	1.19	0.13	0.26			2.98	1.11
	0	1.41	1.06	0.09	0.03			2.59	1.01
	0	1.04	0.98	0.13	0.14			2.29	0.70
on the 64th day of growth — w wieku 64 dni**									
Bitter Czechn. v. gorzka Czechn. Bitter hybrid Ród gorzki 119—1—3 Fodder hybrid Ród past. E 7/DB ₂	0 decap.	1.43 0.69	2.13 1.02	0.75	1.32 1.99	0.63 1.70		0.15 5.55	1.78 1.79
	0 decap.	1.56 0.75	2.19 1.02	0.34	1.14 1.96	0.45 1.59		0.19 5.42	1.38 1.74
	0 decap.	1.25 0.74	1.93 1.01	0.91	1.20 1.26	0.52 1.24		5.81 4.37	1.62 1.62

* The weight increment for the 46th day of growth refers to the whole side shoots and on the 64th day to the side shoots leaves and the flowers jointly; the weight of flowers was 0.01—0.03 g. and was the lowest in the bitter hybrid 119—1—3. W 46 dniu — ciężar odnosi się do całych pędów bocznych, w 64 dniu podano ciężar liści wraz z kwiatami.

** The weights of the main stems of decapitated plants sprayed with A₃ were 1.18, 1.23, and 1.24 g. (the order of listing is the same as in the table).

Ciężar łodygi pędu gł. roślin dekapitowanych, opryskanych A₃ (wg kolejności podanej w tabeli): 1.18; 1.23; 1.24 g.

controls are listed in Table 6. (The yields at the stage of full maturity reported in Part II were also the same in all treatments).

The observed differences in the development rate between the particular populations are reflected mainly in the weight of pods.

Although, the Czechnicka variety resembled the fodder hybrid in the rate of growth of the vegetative organs and differed in this respect from the bitter hybrid, it manifested a closer similarity to the bitter hybrid in the weight of leaves and of the main stems.

DISCUSSION

In the experiments here reported two substances were applied, the influence of which on the processes of growth and development have been the subject of numerous investigations, which however have not always given unambiguous results; this is why different, sometimes even contradictory hypotheses were advanced to explain the mechanism of the action of these substances. This circumstance also makes more complicated the interpretation of the results presented here. It seems, therefore, useful to review briefly the earlier researches on this problem, but only so far as they are relevant to the present considerations.

The influence of auxins, among them also of IAA, and of gibberellins on the growth processes may be manifested, when the concentration of these substances are suitable, by the increase of cell size and too by the more vigorous cell division processes (A u d u s 1959). These substances, in particular gibberellin, may cause an increase of the surface area of leaves and also of their dry matter content (Alvin 1960, Brian 1958, Humphries 1958 a and b, Kenzer 1960, Smith and Sciuchetti 1958), but very often there is no increase in the weight of leaves after treatment with gibberellin and sometimes their weight may even drop (Ergle 1958, Humphries 1961, Lockhart 1956, Masuda and Hamur 1959). According to Humphries and Wheeler (1960) in darkness gibberellin stimulates both the cell-division processes and the elongation of cells, but in light only the elongation. The influence of IAA on the growth of roots largely depends on its concentration; when the concentrations are low this substance may stimulate the growth of roots e.g. of lupine (Fries 1960, Maelt and Grumbein 1939), whereas at higher concentrations it very clearly inhibits the root growth this effect having been observed in many experiments. As has been demonstrated in many researches, for a very wide range of concentrations gibberellin is without stimulating influence on the root growth (Brian, Hemming and Radley

1955, Ergle 1958, Kato 1961), but sometimes it may have an inhibitory effect (Albin 1959, Smith and Sciuchetti 1959).

Much attention has been centred on the influence of both these substances on the process of the elongation of stem internodes and on the generative development of plants. Here are some of the results from investigations on the elongation of internodes. According to Galstone and Baker (1951) the stems of a tall variety of pea responded very weakly or not at all to IAA, whereas the isolated segments of the stems reacted very strongly. Brian and Hemming (1955) experimenting with various varieties of pea with different rates of stem growth, in particular in the first stage of vegetation, found that in all the varieties (at the age of between 24 and 48 days) the stem elongation response to IAA was much weaker than to gibberellin. The response to both substances of the dwarf forms was stronger than of the tall ones. But, whereas after treatment with gibberellin the stems of the dwarf forms could equal the height of the tall forms, after treatment with IAA the increase of the height was much smaller. (IAA had little or no effect on the tall forms). Subsequent researches of those workers (Brian and Hemming 1955, 1958, Brian 1959) on the dwarf forms of pea indicated that the isolated segments of the stems strongly reacted to IAA, whereas the reaction of the internodes in intact plants was much weaker (this last statement is based on the results of earlier investigations of those workers). The opposite response was obtained with gibberellin; the positive effect of A_3 on the elongation process was primarily manifested by intact plants, whereas the isolated segments either did not respond or responded very weakly. Since the elongation of internodes cut off from a plant was greater, even if no growth substance had been supplied, than of the analogous segments in an intact plant, Brian and Hemming supposed that the reduced growth in intact plants was the result of an inhibitor or inhibitors transferred to the internodes from some other parts of the plant. In their experiments with decapitated plants IAA strongly stimulated the elongation of stems, whereas stimulation by gibberellin was very weak. The stimulation by the latter substance was strong only when it was applied jointly with IAA.

Brian and Hemming stressed the synergic character of the action of the two substances in the experiments with the decapitated plants and with the isolated segments. They very emphatically connected the possibility of gibberellin action with the presence of auxins in the plant tissue itself.

This opinion is opposed by other workers (Hillman and Purves 1961, Kato, 1961, Purves and Hillman 1959), who stress, on the ground of experiments with isolated stem segments, the additive

nature of the effect of these substances and the lack of relationship between them in the influence they exert.

The influence of the two substances, especially of gibberellin, is manifested in various plants by the acceleration of the process of internode elongation i. e. by the shorter time needed for this process. The response of younger plants is stronger than of older ones; in the later stages of development the differences of gibberellin stimulated growth disappear (Brian, Hemming and Lowe 1958, Góra 1960, Stowe and Yamaki 1959).

The degree of the influence exerted on the elongation of stems largely depends on the photoperiodic reaction of plants and on the photoperiodic conditions. On the whole the effect of auxins and gibberellins is much stronger under short-day than under long-day conditions (Chaylakhyan 1957, Burk and Tso 1958, Liverman and Lang 1956, Wittwer, Bukovac and McVey 1959). The strong response under short-day conditions is primarily manifested by long-day, in particular rosette plants. According to Lang (1961, also Sachs and Lang 1961) without significantly affecting the cell division processes in the apical meristem of these plants gibberellin causes renewed cell divisions in the subapical zone where normally the cells do not divide when the plant is in the rosette stage. Lang and others think that at least during the first few days after the application of gibberellin the elongation of stems is the result of this stronger mitotic activity. Analogous, though slower changes in the subapical zone occur when under the influence of environmental conditions, but without gibberellin, the stems begin to „shoot”.

The reactions of growth are very often accompanied by developmental reactions; e. g. long-day plants treated with IAA may pass to the generative stage under short-day conditions. A similar influence is also exerted by gibberellins (besides the authors already mentioned Bunsow and Harder 1957, Brian 1958, Kenzer 1960, Weijer 1959). These substances may, moreover, accelerate the flowering of long-day plants even under long-day conditions and too of some neutral plants (Chaylakhyan 1957, Wittwer, Bukovac and Sell 1957, Rappaport 1957), but they have not the same positive effect on short-day plants under long-day conditions.

The explanation of the above mentioned effects is all the more important as compounds physiologically resembling gibberellin were found in many higher plants (Kitzel 1957, Radley 1958, Wheeler 1960), also in lupine seeds (Phinney and West 1960). Noteworthy in this connexion are the researches on auxin oxidase *. In many

* Strictly speaking the oxidase of β -indole-acetic acid.

researches (Galston 1957, Galston and Warburg 1959, Pilet 1957a and b, Weijs 1958) a reverse relation was found between the activity of this enzyme and the auxin content of the plants. The often observed lower level of these hormones in plants exposed to short-day conditions than in those in long-day conditions (Bonner 1949, Chaylakhyan and Zdanow 1939, Lang, 1954, Liverman and Lang 1956) is to be explained by the greater activity of oxidase when the light period is short. From white lupine an auxin oxidase was isolated (Stutz 1957), the activity of which underwent similar changes depending on the photoperiodical conditions. (Garay et al. 1959, Sagi and Garay 1951a, b). The changes in the activity of this enzyme are attributed to the changes in the level of its inhibitor, which may be represented by phenolic compounds.

The long day stimulates the synthesis of the inhibitor, whereas the short day has the opposite effect especially when night temperatures are low (besides the authors already mentioned also Galston 1957, Watanabe and Stutz 1960). The character of the photoperiod has a strong influence in very young plants, but its influence in older ones is almost nil: according to Sagi and Galston the level of phenolic compounds in the leaves of young, 14-day plants of white lupine is low, but it greatly rises during the following 56 days of growth.

The investigations on the influence of gibberellin on the oxidase-inhibitor system have yielded contradictory results. Galston (1957, 1959) and Pilet (1957b) think that gibberellin causes an increase of the amount of auxin in plants and that this increase is the result of the higher level of the auxin oxidase inhibitor. A similar conclusion was reached by Watanabe and Stutz in experiments with white lupine. On the other hand, Sagi and Garay (1961a) working with the same species found that independently of the photoperiod gibberellin influenced neither the activity of oxidase nor the content in phenols, though it significantly stimulated the growth process, the stimulation being stronger under short-day and weaker under long-day conditions.

Four hypotheses may be mentioned here to explain the mechanism of gibberellin action on the growth.

According to the first of these hypotheses (Pilet, Stutz, and others) gibberellins having no direct influence on growth, act indirectly through the auxin „sparing” system (phenol $\rightarrow$ oxidase), the rate of growth being determined by the level of auxins. A different hypothesis was advanced by Brian and Hemming, who found no influence of A_3 on the activity of oxidase in etiolated pea seedlings; according to those workers gibberellin itself cannot be an auxin, since its effects

are manifested only in the presence of auxins. Its action, like the action of similar compounds found in plants, consists in the neutralization of the inhibitor or inhibitors of the auxin stimulated growth process. It is to be stressed that Brian and Hemming think gibberellin to be a substance influencing the elongation of cells and not their division.

According to still another hypothesis (Hillman, Purves, and Kato) gibberellin is a growth substance of a different nature than the auxins and in its action it is not dependent on the system associated with them. The manifestations of the interaction between gibberellin and auxin have essentially a secondary character and are caused by the fact that growth is the result of many processes. The action of the two substances may occur at different spaces in the tissue.

Finally, a fourth hypothesis (Lang) leaving aside the action of auxins takes into account only the growth processes of stems. In this approach the sub-apical zone of the stem, the "sub-apical meristem", plays a major role in the stem growth of "rosette" plants as well as of nonrosette plants. (In plants which form no rosettes the sub-apical zone resembles, in so far as the cell-division rate is concerned, the sub-apical zone of rosette plants treated with gibberellin). Gibberellin, and gibberellin-like endogenic substances play an important part in the stem formation process. In plants, which do not form a rosette, these compounds are present in amounts allowing the optimum mitotic activities (treatment with gibberellin has no significant influence on cell division in the sub-apical zone), whereas in rosette plants the amount of these substances at the rosette stage is lower and is, thus, a factor limiting mitotic activity.

There are also many varying opinions on the mechanism underlying the influence of auxins and gibberellins in the generative development. Some of these opinions are worth considering here.

1. According to one hypothesis the transition of plants to the generative stage depends on the auxin level. In the long-day plants — as opposed to the short-day ones — the process would be conditioned by a high content of these hormones (Liverman and Lang 1956). This explanation in connection with the hypothesis according to which gibberellin acts through the mechanism of the „auxin sparing system" would, thus, also account for gibberellin.

2. Another hypothesis (Lang 1961, Rappaport 1957, Stowe 1959, Wittwer et al. 1957) assumes that gibberellins accelerate the flowering of plants only by accelerating the elongation of stem internodes and the formation of a necessary number of leaves, since these factors condition the transition of plants into the generative phase. (This hypo-

thesis would, therefore, apply to long-day plants, in particular rosette plants, and partly to neutral plants).

3. In Chaylakhyan's (1958) hypothesis the florigen complex in all plants consists of two groups of compounds, a) of gibberellins necessary for stem formation and growth, and b) of anthezins required for flower formation. Flowering would then be the result of the interaction between the two groups of substances.

4. Finally, according to Brian (1958) in leaves exposed to light a hormone resembling gibberellins is formed through the intermediate, slightly active compound "P". In darkness this hormone is again transformed into the compound "P". For the generative development of long-day plants a large amount of this hormone is necessary, whereas in short-day plants a small amount is sufficient. In neutral plants the synthesis of this hormone is independent of the photoperiod.

The two species of lupine used in the above described experiments differed in that yellow lupine, as opposed to white lupine, is a rosette plant. The opinions about the photoperiodic reaction of these two species are not consistent; according to some authors they are long-day plants and others think they approach more the neutral type, since considerable differences between the particular varieties are possible (Barbacki 1952). The question whether the populations in this work were long-day or neutral can be answered only by comparing the differences in their behaviour in the autumn and the spring-summer experiments, but as the length of day was not the only difference this may be somewhat misleading, all the more so as the time of sowing in autumn was not the same for both species*. Bitter white lupine sown in the spring began budding at the age of 32—35 day and yellow lupine at the age of 53—54 days**. The white lupine sown in the autumn began forming buds only till on the 44—45th day; yellow lupine was still in the vegetative phase on the 63rd day of growth; in both species the generative development was delayed (when plants of the same age in the spring and autumn experiments are compared it becomes apparent that the leaf formation process was also delayed). It is impossible to say what would be the behaviour of yellow lupine at a later stage; the earlier sowing made possible the transition of the plants to the stage of stem elongation.

* One of the reasons why yellow lupine was sown earlier was the wish to investigate the plants at a stage when the intensity of alkaloid synthesis is relatively high.

** This also was the case in other experiments at this laboratory.

In spite of the delay — though admittedly it was not long* — in the generative development neither gibberellin** nor IAA accelerated the process of bud formation in white lupine. Under normal conditions of vegetation these substances did not significantly affect even the growth of plants***, though there were as many as three different populations of this species.

The response of yellow lupine was different. Under normal conditions of growth the rate with which it passed to the generative stage distinctly depended on the time and the degree of the influence that the applied substances had on the stem elongation. We may suppose, therefore, that the investigated varieties of white lupine were more closely related to the neutral than to the long-day type of plants and that, so far as the generative development is concerned, they belonged to the group of plants, which did not respond to gibberellin. (In this group gibberellin supplied from outside has no influence — from the point of view of the possibilities of differentiation of generative organs in the meristem — on the formation of internodes or of the necessary number of leaves). It must be added that these lupines do not respond either to IAA (probably for analogous reasons). On the other hand, yellow lupine would belong to the group of plants in which the acceleration of the generative development by gibberellin was primarily caused by the gibberellin stimulated acceleration of the internode elongation. A point to be stressed in this connection is that the IAA accelerated bud formation was also correlated with the acceleration by this substance of the stem elongation. The two substances were, therefore, very similar in their influence on the generative development, at any rate in the case of the populations of the two species in these experiments. Their action or its absence depended only on the characteristic properties of the plants.

Without going into the causes of the differences between the two species in the way in which they reacted by their growth and their

* The population of white lupine in the experiments of Garay et al. (1959) flowered 28—30 days later under short-day than under long-day conditions and leaf formation was also retarded.

** The gibberellin acid A₃ used in these experiments is generally considered as the most effective in the acceleration of stem formation and flowering among the known gibberellins A₁, A₂, and A₄ (Bukovac and Wittwer 1958, 1961).

*** The results of the autumn experiments indicate that the lack of response to heteroauxin as well as to gibberellin under normal conditions of vegetation cannot be interpreted as the absence of any influence of these substances on the growth processes in the populations under investigation.

development to gibberellin and heteroauxin, the following question can be put: how do these two substances act on the stem elongation process?

The response of yellow lupine indicated that the differences in the concentration of the applied substances were — except for the time that the influence lasted — without significant effect and similarly without effect was their possibly different degree of penetration and translocation. Although in young plants the magnitude of the influence exerted by the two substances was different, between the 46th and the 64th day of growth, i.e. at the time when in the controls the stems were rapidly elongating, their influence was equal and very strong* regardless of the time when spraying was started. It is, thus, difficult to accept, as does Brian, that the stimulation of the elongation of stems in intact plants by the auxins is weaker than by gibberellin. If we accept the hypothesis advanced by that author to explain the observed responses of yellow lupine, then many additional, highly conjectural assumptions would have to be made. The same applies also to the hypothesis of the "auxin sparing system".

Similarly, the results now obtained for the influence of A_3 and IAA on the elongation of stems in decapitated plants did not fully agree with the investigations of Brian and Hemming. The decapitated plants of white lupine reacted to A_3 but did not react to IAA, whereas according to those authors the contrary response was to be expected. A reaction similar to that in the present experiments was also observed by Kaufman and Twedie (1958) in rice. In yellow lupine A_3 stimulated the elongation of decapitated stems much more strongly than β -indole-acetic acid, which, contrarily to A_3 , significantly affected the growth of roots and leaves.

It seems that in the present experiments with lupine gibberellin influenced both the processes of cell elongation (evidence in support of this statement is supplied by the decapitated plants) and the intensity of cell division (this was shown by Lang's work). As to the question whether IAA stimulated the mitotic activity or not, a definite answer is difficult. (On the whole auxins are rather known as substances mainly increasing the size of cells). A possibility, which must be considered, is that the greater influence of A_3 than of IAA on the elongation of the main stems in young plants of yellow lupine (and of

* The disappearance at the later stage of differences between the plants treated with A_3 or IAA on one hand and the controls on the other indicates that also β -indole-acetic acid only accelerates the process of stem growth without influencing the final height of stems.

side shoots in older plants) was the result of, among others, the differences in the action of these compounds on the cell division processes.

Hypotheses advanced to explain the mechanism of action of the two substances studied in this work, and in particular the interaction between them, were in most instances based on the behaviour of one organ only. The drawing of general conclusions without accounting for the responses of various organs and for the interaction between them seems, however, to be a procedure not deprived of risk. If all these factors are also accounted for in the case of the present experiments with lupine, then the differences in the nature of the action of these two substances, and probably also in the underlying mechanism, become well marked, though the results actually produced may sometimes be rather similar.

In support of this last statement the following results of the autumn experiments may be here quoted in addition to those already mentioned.

1. After treatment with IAA the root growth of yellow lupine was greatly enhanced, and this was probably one of the reasons why — as compared to the control — the growth increase of stems was small and the weight of leaves was lower. At the same time the water content of the both aerial organs was much higher. On the other hand, without affecting the growth of roots A_3 stimulated the growth of stems and leaves, but left unchanged the water content of these organs. When two substances were applied jointly the nature of their influence was different in the various organs; in leaves the influence of only IAA was manifested, in stems the manifestation of the influence of either IAA or A_3 depended on the concentration, and in roots in one instance the action was additive (but not synergic).

2. In white lupine the influence of A_3 and IAA on the root growth was nil, their influence on the growth of leaves was positive and equal, but different on the water content of these organs. Far from synergic was the effect of A_3 applied jointly with IAA.

The conclusions from the experimental results reviewed in the discussion seem to be that: 1) the two substances are to a great extent independent in their action, 2) the hypothesis advanced by Brian (gibberellin $\rightarrow$ inhibitor $\rightarrow$ growth $\leftarrow$ auxins) to explain the mechanism of action of these substances is rather slightly probable, and 3) the view advanced by Hillman, Purves, and Kato probably would explain more accurately than any other the actual state of things.

Nothing has been said in the discussion about the considerable differences in the influence of gibberellin and auxins on the metabolic processes, though these processes have a great influence on the size and the division of cells.

We must bear in mind, however, that to say "the action of these substances is different" is no explanation of the mechanism of their action.

Conclusions

1. The following results were obtained with plants of yellow lupine growing under normal vegetation conditions:

a. The treatment with gibberellin and β -indole-acetic acid accelerated the process of the elongation of stems. At the time when the growth of stems was slow the influence of IAA was weaker than that of A_3 and at the stage of intense growth the influence of both substances was the same.

b. Both substances also caused an increase in the weight of the stems, the magnitude of this increase largely depending on the magnitude of their influence on stem elongation.

c. A_3 and IAA accelerated the transition of plants to the generative stage.

d. Decapitated plants reacted with respect to stem elongation more strongly to A_3 than to IAA. The latter substance caused a more intense growth of the main shoot leaves and of the roots.

2. Plants of yellow lupine growing in autumn treated with A_3 manifested a more intense growth not only of stems but also of leaves. On the other hand, the influence of IAA was manifested by a greater growth of roots, a weak stimulation of stem elongation and a decrease in the weight of leaves. Plants treated with heteroauxin had a greater water content in their aerial organs.

3. When the three examined populations of white lupine were grown under normal conditions of vegetation, neither A_3 nor IAA had any effect on the processes of their growth or development. The only response of decapitated plants to A_3 was the greater growth of the main stems, whereas even here the influence of IAA was nil.

4. In white lupine of the Czechnicka variety grown in autumn the treatment with either of these substances caused a more intense growth of leaves. The influence on the stem growth was very weak and appeared only after treatment with a high concentration of A_3 .

5. The confrontation of the results obtained with the various existing hypotheses concerning among other things, the interaction of gibberellins and β -indole-acetic acid (or auxins in general) indicates that the two substances are largely independent of each other in their action and that the manner in which they act may differ.

STRESZCZENIE

W latach 1960—1961 przeprowadzono kilka doświadczeń w kulturach wazownych nad wpływem gibereliny — A_3 i kwasu β -indolooctowego na wzrost i rozwój łubinu żółtego gorzkiego oraz białego gorzkiego (odmiany Czechnickiej). W doświadczeniach 1961 r. dodatkowo badano dwie populacje krzyżówek dwóch form pastewnych (Biały I ♀ $\times$ Biały Przebędowski, średniowczesny ♂). Jeden z rodów był homozygotą gorzką, drugi zaś homozygotą niskoalkaloidową.

Doświadczenia 1960 r. (oprócz wstępnego, przeprowadzonego wiosną tegoż roku) założono z łubinem żółtym 30.VII, z łubinem zaś białym 18.VIII. Dn. 16.IX. opryskano rośliny obu gatunków roztworami: 1) gibereliny (w stężeniach 10^{-2} lub $5 \times 10^{-10}/o$), 2) kwasu β -indolooctowego (w stężeniach 10^{-5} lub $10^{-30}/o$) 3) roztworami zawierającymi obie te substancje wzrostowe. Tegoż dnia część roślin dekapitowano. Łubiny sprzątnięto po upływie 18 dni.

W doświadczeniach 1961 r. założonych wiosną (nasiona obu gatunków wysiano równocześnie) w 28 dniu wzrostu część roślin dekapitowano. W tymże czasie zastosowano po raz pierwszy (termin I) giberelinę względnie heteroauksynę. Oprysk tych samych roślin powtórzono po upływie 3, 10 i 18 dni. Część roślin łubinu żółtego i białego odm. Czechnickiej opryskano po raz pierwszy dopiero w 46 dniu wegetacji (termin II). Zabieg ten następnie powtórzono dwukrotnie w odstępach dwudniowych i po raz trzeci w 64 dniu wzrostu. Zbioru dokonywano w 28, 46 i 64 dniu wegetacji. Łubiny białe po raz ostatni sprzątnięto w fazie pełnej dojrzałości, natomiast łubin żółty nieco wcześniej, w 105 dniu wzrostu.

1. U roślin łubinu żółtego w normalnych warunkach wegetacji stwierdzono, że:

a) giberelina i kwas β -indolooctowy przyspieszają proces wydłużania łodyg; w okresie słabego ich wzrostu wpływ heteroauksyny jest mniejszy niż gibereliny, natomiast w fazie intensywnego wydłużania — jednakowy;

b) oba te związki powodowały również zwiększenie ciężaru łodyg w stopniu zależnym w dużej mierze od wielkości wpływu na proces wydłużania;

c) zarówno giberelina, jak i heteroauksyna przyspieszyły przejście roślin w fazę rozwoju generatywnego;

d) rośliny dekapitowane reagowały pod względem wydłużania łodyg silniej na giberelinę niż na kwas β -indolooctowy; ta ostatnia substancja wywołała intensywniejszy wzrost liści pędu głównego oraz korzeni.

2. Rośliny łubinu żółtego rosnące jesienią wykazały pod wpływem gibereliny intensywniejszy wzrost nie tylko łodyg, ale i liści. Działanie zaś kwasu β -indolooctowego przejawiało się w większym wzroście korzeni i słabej stymulacji wydłużania łodyg oraz w zmniejszeniu ciężaru liści. Rośliny traktowane tą substancją wykazały większą zawartość wody w organach nadziemnych.

3. U badanych populacji łubinu białego w normalnych warunkach wegetacji zarówno giberelina, jak i kwas β -indolooctowy nie mają wpływu ani na proces wzrostu, ani też rozwoju. Reakcja roślin dekapitowanych na zastosowaną giberelinę przejawiała się tylko w większym wzroście łodygi pędu głównego, natomiast kwas β -indolooctowy nawet i pod tym względem nie wykazał żadnego wpływu.

4. U łubinu białego (odm. Czechnicka), rosnącego jesienią, obie substancje wywołały intensywniejszy wzrost liści. Wpływ — i to niewielki — na wzrost łodyg przejawiał się jedynie w przypadku zastosowania gibereliny w dużym stężeniu.

5. Uzyskane wyniki w konfrontacji z istniejącymi hipotezami dotyczącymi m.in. interakcji między gibereliną i heteroauksyną (lub też auksynami w ogóle) wskazują, iż obie te substancje w swym działaniu są w dużym stopniu niezależne od siebie i że charakter ich działania może być różny.

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