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ARTIFICIAL HORMONES AND WEED CONTROL IN OIL FLAX CULTIVATIONS

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TIKKURILA, FINLAND

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Preface

At Central Agricultural Experiment Station, Department of Agronomy, Tikkurila, Finland, field experiments and investigations with artificial hormones were started in 1946. The investigations continued in summers 1947 and 1948. Principal attention was paid to the effect of these new chemical compounds on different weeds and on the possibilities of using them in crop production. Sprays have proved more effective than dusts, but shortage of sprayers has for the present limited the use of artificial hormones in Finland. As artificial hormones are of great importance in oil flax cultivations, where growth is greatly impeded especially by annual weeds, several experiments have been carried out on oil flax. This book is the first publication of the investigations hitherto carried out at my department, and it is based on the experiments conducted by Dr. J. Paatela during the growth season 1948.

Tikkurila, January 1949.

Otto Valle

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Introduction

Oil flax is a rather small cultivated plant, which does not give much shade, and its development is at first slow. Therefore oil flax cultivations are often heavily infested with weeds. Oil flax cultivation is successful only if the soil is free from weeds, and in rotation oil flax is usually grown after grass land, potato or root vegetables.

At the beginning of the current decade it was discovered in England that some organic acids,β-indoleacetic acid (plant hormone called earlier heteroauxin), and α-naphtaleneacetic acid with different structure from the former, applied in solutions at suitable concentrations kill many broad-leaf weeds, but have no injurious effects on the growth of cereals. Soon after this it was observed in England and U. S. A. that some other synthetic coumpounds, such as 2-methyl-4-chloro-, 2,4-dichloro, or 2,4,5-trichloro-phenoxyacetic acid (2M-4K, 2,4-D, and TCP), and their salts and esters, exert similar selective effects. All monocotyledonous plants, however, are not resistant, nor are all herbaceous plants sensitive. Oil flax is a herbaceous cultivated plant, which is much more susceptible than cereals but which is more resistant than many of the most sensitive weeds. Therefore it is possible to use artificial hormones [1]) for weed control in oil flax cultivations. As the safety margin between resistance and injury in oil flax is much smaller than in cereals (wheat, oats, rye, barley), it is very important to know the most significant factors affecting the effectiveness of artificial hormones and to use these substances for weed control in oil flax in such a manner that as effective control as possible is exerted but the amount or quality of the crop of oil flax is not damaged. Such significant factors are, for instance, treatment at the right stage of development, right amount of suitable artificial hormones, and climatic and edafic factors.

Oil flax is one of the most important oleiferous plants in the world, and therefore weed control in oil flax is a question worth investigating. As it has not hitherto received much attention, the purpose of this study is to contribute to the solution of this important question. In my work I have been assisted by students HELVI MARJANEN and AILI HÄNNINEN, to whom, as well as to Miss ARMI AILAS, who has translated the manuscript into English, I want to express my thanks in this connection.

[1]) By artificial hormones or growth regulators we mean in this study synthetic organic compounds, whose effect is similar to that of phytohormones (auxins) but which are not found in plants.

I. Earlier investigations

The possibilities of using artificial hormones for weed control in oil flax have been so far little investigated in Finland. According to the experiments conducted at the Central Agricultural Experiment Station, Department of Agronomy, in summers 1947 and 1948 (so far unpublished) oil flax resisted well e. g. the amounts of 1 kg. of 2M-4K per hectare applied at the rate of 800—1 000 l. per hectare. BREITENSTEIN (4) observed in practice that oil flax was not injured by the English dust *Agroxon* [1]) or by the Finnish dust *Hormotox* [2]) applied at the rate of 200—250 kg. per hectare. This amount was sufficient to kill some weeds satisfactorily.

This question has received a little more attention in other countries. The experiments conducted in Denmark have shown that careful application of artificial hormones does not reduce the crop of oil flax, and that it is better to use methoxon-compounds than 2,4-D-compounds (13, 16). RASMUSSEN (14) mentions two experiments with 0.5 and 1 % *Agroxon* [3]), applied at the rate of 1 000 l. per hectare. The average yield from untreated plots, containing 24 % of weeds, was 1 640 kg. of seeds and 3 210 kg. of stems per hectare. In the treated plots the proportion of weeds was only 1.0 and 0.5 % and the increase in yield obtained from these plots was on the average 90 kg. and 10 kg. of seeds and 51 kg. and 58 kg. of stems per hectare.

Also in Sweden artificial hormones have been used for weed control in oil flax cultivations. Thus JACOBSON and BJÖRKLUND (8), who report the results of the experiments conducted in Denmark, Sweden, and Norway, recommend for oil flax 5—7 l. of *Agroxon* or *P46* [4]) per hectare. 2,4-D compounds have proved more dangerous than methoxon compounds and are not suitable for oil flax. The lowest amount (5 l. per ha.) is recommended by them for control of *Brassica campestris, Sinapis arvensis, Raphanus raphanistrum, Thlaspi arvense,* and *Chenopodium album.* If other weeds occur, such as *Cirsium arvense,* the highest amount (7 l. per ha.) is recommended. Spray applications must never be made later than to plants which have attained the height of 7—10 cm. Spraying at a later stage of development may prove very dangerous, and at a very late stage, when buds appear, spraying must not be given, for it may result in the destruc-

[1]) Contains 1 % of 2M-4K.
[2]) Contains 0.5 % of sodium salt of 2,4-D.
[3]) Contains 10 % of 2M-4K.
[4]) Prepared in Denmark and contains 10 % of 2M-4K.

tion of the whole crop. According to them spraying at the right moment has no effect on the oil content of seeds. — ÅBERG, HAGSAND and VÄÄRTNÖU (22) have investigated the effect of artificial hormones on the fibre flax *Concurrent*, which is much more sensitive than oil flax. They observed among other things that even such small amounts as 0.5 kg. of *Wormosan G*[1]) and 5 l. of *Agroxon* applied at the rate of 1 000 l. per hectare greatly reduced the amount of both seed and stem crop. The weight per 1 000 seeds seemed to decrease, if the applied amount (4—6 kg. of *Wormosan G* and 20—40 l. of *Agroxon* per ha.) of artificial growth regulators significantly exceeded the normal amount, whereas these large amounts had no effect on the germination of seeds. Spray applications made at different times with sodium salt solution of 2,4-D (0.6 and 1.1 kg. per ha.) to plants at different stages of development had no effect on the weight per 1 000 seeds, germination of seeds or on their chemical structure, which, however, was significantly affected by some other compounds. So, for instance, spraying with 0.5—1 % *Weedone*[2]) increased the crude protein content of the seeds by 2—3 %, spraying with *Agroxon* by 0.6—0.9 %, while the oil content decreased correspondingly by 3.4—5.3 % and by 0.5—0.9 %. — Weed control in oil flax cultivations by means of artificial hormones is most successful, if chiefly methoxon compounds (*Agroxon* and *P* 46) are used and applied at the rate of 6—8 l. per hectare, or 60—80 % of the normal amounts given to cereals (22, 23).

Experiments with artificial hormones conducted in England (3) show that methoxon compounds may be sprayed on oil flax without danger up to a concentration of 0.2 % of the pure compound at the rate of 100 gallons per acre or about 1 100 l. per hectare. Sodium salt or acid suspension of 2,4-D must not be used in higher concentration than 0.1 %, and ester-oil emulsions are quite unsuitable for oil flax. These maximum concentrations can be applied only when the plants have attained the height of 3—4 inches (= 7.5—10 cm.), and before they have attained the height of 12 inches (= 30 cm.). Spraying applied at right time has no injurious effect on the amount or quality of the seed crop, whereas spray applications made too early or too late may prove dangerous. Dusts, which are less effective than sprays, are recommended by BLACKMAN and HOLLY to be used only where no sprayer is available, water is scarce, or when the most sensitive weeds are eradicated. Dusts must be applied at the rate of a little over 2 lb. of the active compound per acre (= about 2.2 kg. per hectare).

1) Contains 40 % of amino salt of 2,4-D.
2) Contains 9.6 % of 2,4-D.

II. Present investigations

A. Methods

The experiments, which were all conducted during the growth season 1948 at the Department of Agronomy of the Central Agricultural Experiment Station at Tikkurila, were sown in rows with sowing-machine, with 12—15 cm. spaces between the rows. The variety used was the Finnish *Tikkurila oil flax* (former name *Ti* 0774, weight per 1 000 seeds about 5 gm., period of growing short, on the average 92 days, that of Argentine oil flax being on the average 100 days). The amount sown was approximately 100 kg. per ha. The plots, 5.0—6.0 m^2, in one experiment 63.4 m^2 in size, were placed according to the usual row or block method. All experiments were carried out with four replicates. Nearly all experiments (also untreated plots) were as well as possible kept free from weeds, which were pulled off with hands. Either the Danish *Ginge* knapsack sprayer or the Swedish *TT-Favorit* horse-operated sprayer was used to apply the sprays. The solution was applied at the rate of 1 000 l. per ha., or, if the horse-operated sprayer was used, at the rate of 700 l. per ha. Dusts were applied to moistened plants in calm weather through veil bags.

Seed crops were calculated on 98 % purity and 90 % dry basis. The effect of artificial hormones on the quality of crop was examined by determining the weight proportion of sound and membranous seeds in the crop, the weight per 1 000 seeds, and, for a portion of samples, the germination and oil content of seeds, and the refractive number of oil.

Classification of seeds was conducted according to PAATELA (12, p. 10) and the results are averages of 2 samples of 2.5 gm. each. *Weights per 1 000 seeds* are averages of 4 weighings of 100 seeds, *germinations* averages of the results of 4 germinating experiments with 50 seeds. *Oil content* was determined in TWISSELMANN's apparatus by extracting for 4 hours about 2 l. ether boiling at 34° C through finely ground and dried seed samples. The results, expressed on dry basis, are averages of two determinations deviating 0.7 at the most and 0.16 on the average. *Dry basis* was determined from two seed samples of 2.5 gm. each, which were kept for

75 minutes at 120° C. *Refractive number* was determined with ABBE's refractometer (nD 20° C) from oils obtained with determinations of oil contents.

B. Effect of time of treatment and of amount of effective substance on development of oil flax, on amount of seed and stem yield and on quality of seed yield

1. *Experiments with oil flax treated at different stages of development*

Experiment 1. — The purpose of the experiment was to find out the effect of methoxon and 2,4-D compounds on oil flax, if applied at different stages of development and as sprays of different concentrations. The plots, 6 m² in size, were arranged according to row method, number of replicates 4. Treatments: *a* = untreated, *b*—*d* = sprayed with 0.05, 0.1, and 0.2 % 2M-4K (= *Agroxon)*, applied at the rate of 1 000 l. per hectare, *e*—*f*: sprayed with 0.05 and 0.1 % aqueous solution of sodium salt of 2,4-D. Spray applications were made with the *Ginge* knapsack sprayer at seven different stages of development. Dates of spray applications, the average height of plants at the time of treatment, and the mean temperature on the day of treatment and during two following days are given below:

Stage of development	Date of treatment	Average height of plants at time of treatment (cm.)	Mean temperature on day of treatment and two following days (C°)
I	June 3	2.6, cotyledon stage	16.2
II	June 9	4.6	18.8
III	June 14	7.8	14.0
IV	June 22	12.5	16.6
V	June 26	17.1	18.0
VI	July 2	30.0, bud stage	19.8
VII	July 13	41.5, flowering	16.6

After each treatment observations were made with regard to the effect of artificial hormones, expressed as different degrees of stem curvature. Notes were also made of the period, expressed in days, which passed before the plants recovered, or again attained an upright position. The observations, which are averages of 400 marked individuals in every treatment, are given in Table 1. Figures indicating the average rate of stem curvature on each observation day were obtained by multiplying the proportion of different stem curvature by the degree of curvature (0—4) and divided by 100. A greater degree of stem curvature resulted in higher figures. For methoxon sprays these figures are shown graphically in Fig. 1.

Table 1. Effect of artificial hormones on stem curvature and recovery of oil flax plants at stages I—VII of development. Rate of stem curvature shown by a scale 0—4: 0 = erect, 1 = about 45° bent, 2 = about 90° bent, 3 = drooping, more than 90° bent, and 4 = lying on the ground or dead (= cotyledon stage) or drooping on the ground (= later stages of development); cp. figures 4—7 on pp. 23—24. Stages I—VII of development are the same as on page 12.

Stage of development and date	2M-4K kg. per ha.															Sodium salt of 2,4-D kg. per ha.									
	½					1					2					½					1				
	Average percentage of degrees of stem curvature 0—4 in 400 plants																								
	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
I 3.6.	100					100					100					100					100				
5.6.	22	62	16			4	34	56	6		3	22	66	9		6	70	21	3		4	29	56	11	
6.6.	6	82	10	2		1	44	45	10		0	40	50	8	2	2	73	16	9		0	24	47	28	1
8.6.	12	82	4	2		5	68	26	0	1	0	51	43	4	2	2	57	30	11		2	31	50	15	2
10.6.	54	46				42	41	17			—	—	—	—	—	*Not completely recovered*									
12.6.	100					—	—	—			20	52	24	2	2										
15.6.						83	17				—	—	—	—	—										
16.6.						100					80	12	5	0	3										
17.6.											100														
II 9.6.	100					100					100					100					100				
10.6.	56	39	5			35	52	13			35	47	18			81	19				54	45	1		
12.6.	83	16	1			51	31	16	2		5	52	36	7		79	21				53	44	3		
14.6.	100					—	—	—			—	—	—			—	—	—	—		—	—			
15.6.						84	16				30	57	12	1		91	9				81	19			
16.6.						—	—				—	—				100					—	—			
17.6.						100					68	32									100				
21.6.											100														
III 14.6.	100					100					100					100					100				
15.6.	89	11				71	27	2			24	70	5	1		94	6				94	6			
17.6.	100					38	62				4	13	79	4		100					100				
19.6.						100					—	—	—												
23.6.											100														
IV 22.6.	100					100					100					100					100				
23.6.	5	80	15			1	42	57			0	0	45	55		92	8				83	17			
25.6.	100					81	15	4			5	34	35	26		100					100				
27.6.						100					—	—	—												
30.6.											100														
V 26.6.	100					100					100					100					100				
27.6.	0	58	38	4		0	6	88	6		0	0	0	100		100					100				
28.6.	68	24	8			17	66	17			0	0	16	84											
30.6.	100					62	34	4			0	14	78	8											
2.7.						100					19	81													
4.7.											100														
VI 2.7.	100					100					100					100[1]					100[1]				
4.7.	0	7	89	4		0	0	32	68		0	0	2	98		0	0	14	86		0	0	0	100	
5.7.	1	6	93			0	0	89	11		0	0	7	93		0	0	0	100		0	0	0	100	
8.7.	6	91	3			0	79	21			0	20	74	6		0	0	31	69		0	0	0	100	
10.7.	90	10				68	28	4			5	25	70			6	28	57	9		0	5	73	22	
14.7.	100					—	—				—	—													
18.7.						100					—	—				*Not completely recovered*									
20.7.											100														
VII 13.7.	100					100					100					100[2]					100[2]				
	100					100					100					100					100				

[1]) 1 and 2 kg. of morpholine salt of 2,4-D per ha.
[2]) ½ and 1 kg. of morpholine salt of 2,4-D per ha.

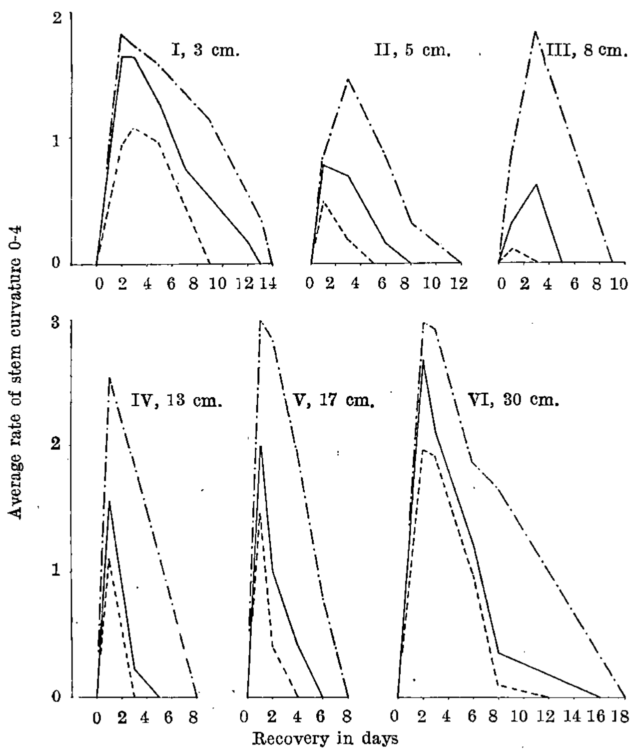

Fig. 1. Effect of methoxon sprayings applied at stages I—VI of development on average rate of stem curvature and recovery of oil flax cultivations. Broken line = ½, unbroken line = 1, and dotted line = 2 kg. of 2M-4K per ha.

The results given in Table 1 and Figure 1 are somewhat misleading, for all treated plants, especially those at cotyledon stage, did not recover completely. A number of the plants in the sprayed plots were namely completely killed, as table 2 shows. Each relative number gives the average of 400 plants in different replicate plots marked before the treatment and recounted at the time of harvesting.

Table 2. Effect of artificial hormones sprayed at stages I—VII of development on relative density of oil flax cultivations. Average density before treatment at stage I = 156, at stage II = 158 plants per row meter. Stages I—VII of development are the same as on p. 12.

Stage of development	Relative density of oil flax cultivations at the time of harvesting					
	Untreated	2M-4K kg. per ha.			Sodium salt of 2,4-D kg. per ha.	
		½	1	2	½	1
I	100	100	97	95	89	87
II	100	100	100	99	100	100
III—VII	100	100	100	100	100	100

After recovery the effect of artificial hormones sprayed at different stages of development was chiefly observed as retardation of development. Observations about the height of plants, flowering, and reaching of yellow maturity are given in Tables 3 and 4 and in Figure 2. Heights are averages of about 20 measurements.

Table 3. Effect of methoxon sprayings on the height of oil flax at stages I—VI of development.

Date	Height at time of treatment, average increase per day and final height (cm.)							
	Untreated	2M — 4K kg. per ha.			Untreated	2M — 4K kg. per ha.		
		½	1	2		½	1	2
		Stage I				*Stage II*		
3. 6.	**2.6**	**2.6**	**2.6**	**2.6**	—	—	—	—
9. 6.	+0.3	+0.2	+0.0	+0.0	**4.6**	**4.6**	**4.6**	**4.6**
14. 6.	0.6	0.1	0.3	0.0	+0.6	+0.2	+0.1	+0.1
17. 6.	0.4	0.7	0.1	0.4	0.4	0.4	0.3	0.3
22. 6.	0.7	0.7	0.8	0.4	0.7	0.6	0.2	0.1
27. 6.	1.4	1.3	1.1	0.8	1.4	1.5	1.6	1.2
29. 6.	2.4	1.7	1.0	1.6	2.4	1.8	1.4	2.7
5. 7.	1.9	2.2	1.9	1.8	1.9	2.0	1.9	1.8
11. 7.	0.8	0.8	1.5	1.6	0.8	1.2	1.6	1.6
20. 7.	0.1	0.2	0.3	0.5	0.1	0.2	0.4	0.4
	41.5	39.9	38.5	38.0	41.5	41.6	42.4	40.8
		Stage III				*Stage IV*		
14. 6.	**7.5**	**7.5**	**7.5**	**7.5**	—	—	—	—
17. 6.	+0.4	+0.2	+0.2	+0.1	—	—	—	—
22. 6.	0.7	0.6	0.5	0.1	**12.5**	**12.5**	**12.5**	**12.5**
26. 6.	—	—	—	—	+1.2	+0.8	+0.5	+0.1
27. 6.	1.4	1.4	0.9	1.1	2.3	1.0	0.8	0.1
29. 6.	2.4	2.1	1.9	1.7	2.4	2.0	1.5	2.0
5. 7.	1.9	2.0	2.1	2.0	1.9	2.1	2.2	2.0
11. 7.	0.8	1.0	1.4	1.5	0.8	1.1	1.0	1.2
20. 7.	0.1	0.2	0.2	0.2	0.1	0.1	0.3	0.3
	41.5	41.8	41.3	39.9	41.5	40.7	39.9	38.5
		Stage V				*Stage VI*		
26. 6.	**17.1**	**17.1**	**17.1**	**17.1**	—	—	—	—
29. 6.	+2.4	+1.7	+0.8	+0.2	—	—	—	—
2. 7.	—	—	—	—	**30.5**	**30.5**	**30.5**	**30.5**
5. 7.	1.9	2.2	2.1	1.9	+1.8	+0.6	+0.3	+0.2
11. 7.	0.8	0.9	1.2	1.4	0.8	1.1	1.4	0.9
20. 7.	0.1	0.0	0.1	0.1	0.1	0.3	0.3	0.5
	41.5	40.9	39.9	38.8	41.5	41.3	42.8	41.0

When the possibilities of using artificial hormones for weed control in oil flax cultivations are investigated, it is important to know, what effect such substances have on the amount and quality of the crop of oil flax, with special regard to seed crop. For the present experiment these facts are shown in Tables 5 and 6. Seed crops were expressed on 90 % dry basis and 98 % purity. Stem crops were weighed air-dry. As a significant delay in maturity was caused in many experimental plants

Table 4. Effect of artificial hormones on flowering and yellow maturity of oil flax plants at stages I—VII of development.

Stage of development and height at time of treatment cm.	Flowering in treated plants begun earlier or later (± days) than in untreated plants					Average period of flowering (days)						Treated plants entered yellow maturity earlier (+) or later (—) than untreated plants (days)				
	2M — 4K			Sodium salt of 2,4-D		Untreated	2M — 4K			Sodium salt of 2,4-D		2M — 4K			Sodium salt of 2,4-D	
	kg. per ha.						kg. per ha.					kg. per ha.				
	½	1	2	½	1		½	1	2	½	1	½	1	2	½	1
I 2.6	+1	+1	0	0	—1	11	13	14	15	13	13	0	0	0	+1	—1
II 4.6	0	—1	—2	0	0	13	13	13	13	14	14	0	—2	—2	+1	0
III 7.8	0	0	—1	0	0	13	13	14	14	12	11	0	—2	—2	+1	+1
IV 12.5	+1	+1	—1	+1	+1	11	12	14	13	12	12	0	—2	—6	0	+1
V 17.1	+1	+1	—2	+1	+1	11	13	14	13	13	12	0	—2	—5	+1	+1
VI[1]) 30.0	0	—1	—11	—19	—26	11	17	19	14	18	20	—3	—9	—13	—19	—22
VII[2]) 41.5	*Sprayed during flowering*					11	16	22	24	11	23	—11	—12	—12	—9	—11

[1]) 1 and 2 kg. of morpholine salt of 2,4-D per ha.
[2]) ½ and 1 kg. of morpholine salt of 2,4-D per ha.

by artificial hormone treatments, if applied at stages VI and VII of development — e. g. a number of green leaves were left on the stems — the stem crops of these stages are not reported here.

Table 5. Effect of artificial hormones on the yield of seed and stem [1]) of oil flax cultivations treated at stages I—VII of development. Differences printed in fat are significant at least at 5 % level of probability.

Stage of development and height at time of treatment	Untreated		2M-4K kg. per ha. ½		1		2		Sodium salt of 2,4-D kg. per ha. ½		1	
	kg. per ha.	Rel.	± kg. per ha.	Rel.	± kg. per ha.	Rel.	± kg. per ha.	Rel.	± kg. per ha.	Rel.	± kg. per ha.	Rel.
	Yield of seed											
I 2.6	1 170	100	+ **160**	113	+ **200**	117	+ 40	103	— **150**	87	— **400**	66
II 4.6	1 330	100	+ **150**	112	+ **190**	115	+ 80	106	— 10	99	+ 60	105
III 7.8	1 110	100	+ **130**	111	+ **140**	113	+ **100**	108	— 20	98	— 50	95
IV 12.5	1 160	100	+ 160	113	+ 120	110	+ 130	110	+ 70	106	+ 50	104
V 17.1	1 230	100	+ 100	108	+ 60	105	+ 10	101	± 0	100	— 20	98
2) VI 30.0	1 230	100	+ 30	103	+ 50	105	— 110	92	— **600**	52	— **850**	31
3) VII 41.5	1 100	100	— 100	91	— **260**	76	— **380**	65	— **130**	89	— **540**	51
	Yield of stem											
I 2.6	2 020	100	+ 150	107	+ 170	108	+ 40	102	— 190	91	— 340	83
II 4.6	2 090	100	+ **220**	111	+ **300**	114	+ 150	107	+ 110	105	+ 90	104
III 7.8	1 830	100	+ **190**	111	+ **200**	111	+ 120	107	+ 50	103	— 60	97
IV 12.5	1 860	100	+ **170**	109	+ **200**	111	+ **230**	**112**	+ 80	104	— 10	99
V 17.1	1 890	100	+ 30	102	+ 70	103	+ 110	106	— 30	98	— 120	93

1)

Stage of development	Minimum significant difference at 5 % level of probability kg. Yield of seed	Yield of stem	F-value Yield of seed	Yield of stem	m % Yield of seed	Yield of stem
I	164	314	16.63***	3.69*	4.8	5.2
II	120	190	4.19*	2.80(*)	2.8	2.8
III	100	138	6.14**	5.15**	2.9	2.4
IV	129	133	1.94	5.57**	3.4	2.2
V	119	171	1.25	2.29	3.2	3.0
VI	141	—	67.17***	—	4.7	—
VII	125	—	23.46***	—	4.8	—

Bonnier, G. and Tedin, O. 1940: Biologisk variationsanalys. 325 pp. Stockholm. — Handledning i försöksteknik. Lantbrukshögskolan, Jordbruksförsöksanstalten. Meddelande No. 1, 203 pp. Norrtälje 1939.

2) 1 and 2 kg. of morpholine salt of 2.4-D per ha.
3) ½ and 1 kg. of morpholine salt of 2.4-D per ha.

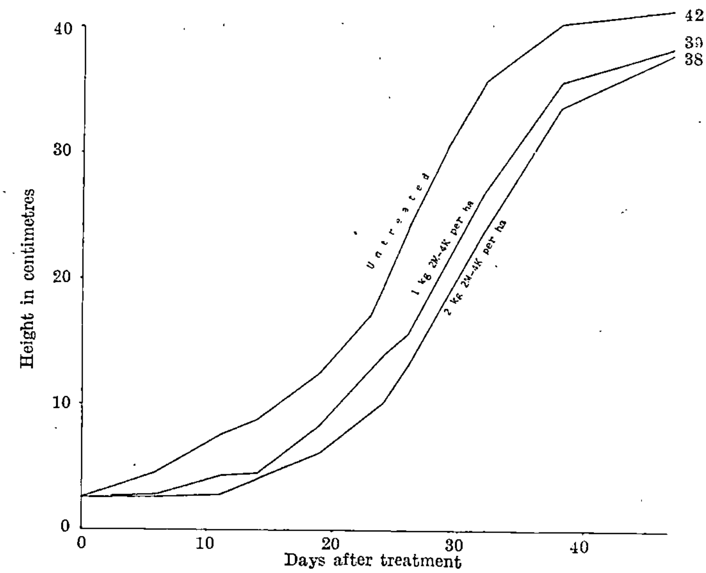

Fig. 2. Effect of methoxon sprayings (1 and 2 kg. per ha.) on height of oil flax cultivations at stage I of development.

Table 6. Effect of artificial hormones, sprayed at stages I—VII of development, on the quality of seed crop and on the yield of oil.

Stage of development and height at time of treatment cm.	Untreated		2M-4K kg. per ha.				Sodium salt of 2,4-D kg. per ha.				Untreated	2M-4K kg. per ha.		Sodium salt of 2,4-D kg. per ha.	
			1		2		½		1			1	2	½	1
	Average weight proportion of sound (= S) and membranous (= M) seeds in crop (%)											Weight per 1000 seeds gm.			
	S	M	S	M	S	M	S	M	S	M					
I 2.6	86	2	83	2	75	5	82	3	76	5	5.0	4.9	4.8	4.8	4.5
II 4.6	87	2	83	2	81	2	80	2	80	1	5.1	5.1	5.0	5.2	5.1
III 7.8	90	1	85	1	87	1	90	1	89	1	5.1	5.1	5.0	5.0	5.0
IV 12.5	87	1	90	1	87	1	90	1	88	1	5.1	5.2	4.9	4.9	4.9
V 17.1	89	1	90	1	88	1	86	1	87	0	5.1	5.2	4.9	5.1	5.1
1) VI 30.0	87	1	73	2	44	13	29	10	15	21	5.2	5.0	4.3	4.6	3.9
2) VII 41.5	90	1	41	18	31	28	75	3	11	14	5.1	4.5	4.4	5.5	4.5
	Yield of oil (kg. per ha.) and relative number										Oil content %				
I 2.6	443	100	+72	116	+ 9	102	—59	87	—158	64	42.8	42.6	42.4	42.7	42.0
III 7.8	430	100	+49	111	+30	107	—10	98	— 26	94	43.9	43.4	43.3	43.6	43.4
V 17.1	474	100	+22	105	+ 1	100	— 4	99	— 10	98	43.7	43.7	43.5	43.4	43.6

1) 1 and 2 kg. of morpholine salt of 2,4-D.
2) ½ and 1 kg. of morpholine salt of 2,4-D.

Experiment 2. — The seven different stages of development of the previous experiment were treated, as mentioned on p. 12, during about six weeks under somewhat different climatic conditions. In order to eliminate the differences in climatic conditions between different treatments, another experiment similar to experiment 1 was conducted, in which sprayings were applied simultaneously to plants being at four different stages of development. The experiment was sown in mouldy clay soil on May 22, June 1, June 11 and June 21, at ten days' intervals, at the rate of about 100 kg. of 100 % germinating and pure seed per hectare. The plants were arranged in plots of 5 m^2 in size and the treatments — *a* = untreated, *b*—*d* = ½, 1, and 2 kg. of 2M-4K given as *Agroxon*, *e* = 1 kg. of sodium salt of 2,4-D, and *f* = 1 kg. of morpholine salt of 2,4-D applied as aqueous solution at the rate of 1 000 l. per hectare — were placed in four blocks. Spray application was made by means of *Ginge* knapsack sprayer on July 1. The average height of plants at the time of treatment and temperature on the day of treatment and two following days are given below:

Stage of development	Average height of plants at time of treatment (cm.)	Mean temperature on day of treatment and two following days (C°)
I	3.0, cotyledon stage	19.5
II	5.3	19.5
III	19.2	19.5
IV	30.5, bud stage	19.5

Thus stages I—IV of development approximately correspond to the stages I, II, V, and VI in the experiment 1. — The effect of artificial hormones on the stem curvature and recovery, density, height, flowering, and yellow maturity are shown in Tables 7—10.

Table 7. Effect of artificial hormones on stem curvature and recovery of oil flax plants being at stages I—IV of development at time of treatment. Rate of stem bending expressed according to the same scale as in Table 1 on p. 13. Stages of development are the same as above.

Stage of development and date	2M—4K kg. per ha.															Sodium salt of 2,4-D kg. per ha.					Morpholine-salt of 2,4-D kg. per ha.				
	½					1					2										1				
	Average percentage of degrees of stem curvature 0—4 in 400 plants																								
	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
I 1. 7.	100					100					100					100					100				
3. 7.	.5	69	23	3		1	20	67	12		0	23	58	17	2	3	44	43	9	1	0	31	53	14	2
6. 7.	39	56	5			11	77	8	3	1	8	40	43	6	3	3	54	36	5	2	2	59	29	6	4
7. 7.	50	46	4			12	80	6	2		7	61	27	4	1	7	54	33	3	3	4	57	27	6	6
12. 7.	100					—	—	—			—	—	—			—	—	—	—		—	—	—	—	—
14. 7.						100					—	—				—	—	—			—	—	—	—	—
15. 7.											100					16	84				42	40	8	3	7
																Not completely recovered									
II 1. 7.	100					100					100					100					100				
2. 7.	59	38	3			16	71	12	1		0	4	60	36		93	7				0	29	56	15	
3. 7.	69	30	1			16	65	19			0	7	69	24		95	5				0	15	69	16	
6. 7.	100					89	11				22	70	8			—	—				13	68	19		
7. 7.						100					26	69	4	0	1	100					—	—	—		
8. 7.											58	38	4								8	80	11	0	1
12. 7.											100										—	—			
14. 7.																					100				

Stage of development and date	2M—4K kg. per ha.															Sodium salt of 2, 4-D kg. per ha.					Morpholine-salt of 2,4-D kg. per ha.				
	½					1					2					1					1				
	Average percentage of degrees of stem curvature 0—4 in 400 plants																								
	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
III 1. 7.	100					100					100					100					100				
2. 7.	6	42	51	1		0	3	82	15		0	0	0	94	6	90	10				0	0	0	85	15
3. 7.	18	79	3			17	67	15	1		0	0	9	85	6	95	5				0	0	3	79	18
4. 7.	90	10				31	61	8			0	3	29	66	2	100					0	0	17	68	15
6. 7.	100					76	24				0	6	72	22							0	3	13	84	
7. 7.						87	13				0	12	78	10							0	1	10	89	
12. 7.						100					—	—	—								—	—	—		
15. 7.											75	25									39	55	6		
21. 7.											100										—	—			
6. 8.																					100				
IV 1. 7.	100					100					100					100					100				
2. 7.	0	0	0	100		0	0	0	100		0	0	0	100		0	100				0	0	0	100	
4. 7.	27	69	4			0	2	93	5		0	0	46	54		0	97	3			0	0	2	98	
6. 7.	59	41				0	20	80			0	0	89	11		49	51				0	0	41	59	
7. 7.	91	9				0	46	54			0	0	94	6		76	24				0	0	0	100	
15. 7.	100					89	11				14	83	3			100					0	12	88		
27. 7.						100					—	—									Not completely recovered				
3. 8.											100														

Table 8. Effect of artificial hormones on the relative density of oil flax cultivations being at stages I—IV of development at time of treatment. Average density before treatment at stage I = 167, at stage II = 184 plants per row meter. Stages I—IV are the same as on p. 19.

Stage of development	Relative density of oil flax cultivations at time of harvesting					
	Untreated	2M-4K kg. per ha.			Sodium salt of 2,4-D kg. per ha.	Morpholine salt of 2,4-D kg. per ha.
		½	1	2	1	1
I	100	98	95	92	87	73
II	100	100	100	98	100	98
III—IV	100	100	100	100	100	100

Table 9. Effect of artificial hormones on height of oil flax plants being at stages I—IV of development at time of treatment. Figures printed in fat and subsequent figures indicate the real height of the plants, above fat figures the height of the bent plants.

Date	Untreated	2M-4K kg. per ha. ½	2M-4K 1	2M-4K 2	Sodium salt of 2,4-D kg. per ha. 1	Morpholine salt of 2,4-D kg. per ha. 1	Untreated	2M-4K kg. per ha. ½	2M-4K 1	2M-4K 2	Sodium salt of 2,4-D kg. per ha. 1	Morpholine salt of 2,4-D kg. per ha. 1
		Stage I						*Stage II*				
1. 7.	**3.0**	before spraying					**5.3**	before spraying				
2. 7.	—	—	—	—	—	—	8.5	7.7	6.9	4.1	8.4	4.2
4. 7.	4.1	3.6	2.9	2.7	2.8	2.7	9.7	10.0	9.6	7.3	9.6	7.4
7. 7.	5.5	4.2	4.2	3.4	3.3	3.2	12.7	**11.2**	**11.3**	9.1	**10.4**	8.0
14. 7.	13.3	**12.9**	**11.7**	9.0	6.5	4.8	22.4	21.9	21.1	**16.2**	19.6	**13.5**
17. 7.	17.8	15.5	12.9	**11.8**	9.3	—	31.2	31.1	29.1	28.3	30.3	22.1
20. 7.	27.0	28.5	20.0	17.0	10.7	5.3	39.1	39.1	38.5	35.8	37.8	27.5
23. 7.	35.7	33.6	29.7	24.9	15.7	15.8	48.4	46.8	44.2	41.8	42.8	37.3
26. 7.	45.1	39.7	39.4	33.2	18.8	23.2	51.2	50.7	50.0	47.1	47.2	45.0
29. 7.	50.7	49.2	48.0	44.2	34.5	35.2	52.5	51.2	53.0	49.0	50.8	47.8
2. 8.	56.3	55.0	54.8	51.5	44.0	45.5	52.8	51.6	53.1	50.2	51.0	48.3
7. 8.	59.1	59.2	57.8	55.0	45.9	46.2	53.0	51.8	53.2	50.9	51.1	48.8
		Stage III						*Stage IV*				
1. 7.	**18.2**	before spraying					**30.0**	before spraying				
2. 7.	22.1	20.6	16.5	15.1	22.0	14.7	33.0	30.3	28.9	28.2	33.9	28.1
4. 7.	28.5	25.4	22.3	14.6	**28.0**	14.8	39.1	35.3	31.6	28.8	38.9	28.4
7. 7.	33.2	**29.2**	24.5	18.8	30.2	17.8	42.3	37.7	33.8	29.1	40.5	28.6
14. 7.	40.9	37.9	**36.1**	29.0	37.5	23.9	43.0	41.5	38.8	35.0	42.7	31.6
17. 7.	42.1	40.8	39.6	35.0	38.8	26.6	43.5	**42.0**	39.8	38.3	**43.0**	37.0
23. 7.	44.1	42.8	43.2	**39.8**	39.2	31.1	44.1	43.0	42.0	40.6	43.4	37.4
29. 7.	46.7	45.5	47.7	45.2	40.7	38.0	44.4	45.2	**45.0**	42.0	44.0	39.2
2. 8.	47.9	46.8	47.8	45.8	43.1	38.8	44.8	45.4	45.8	42.1	45.2	39.8
7. 8.	50.0	47.0	48.2	45.9	43.6	38.9	45.1	45.5	45.8	**42.8**	45.5	39.8

Table 10. Effect of artificial hormones on flowering and yellow maturity of oil flax plants being at stages I—IV of development at time of treatment.

Stage of development and height at time of treatment cm.		Flowering in treated plants begun on the average later than in untreated plants (days)					Average period of flowering (days)						Treated plants entered yellow maturity on the average later than untreated plants (days)				
		2M — 4K kg. per ha.			Sodium salt of 2,4-D kg. per ha.	Morpholine salt of 2,4-D kg. per ha.	Untreated	2M — 4K kg. per ha.			Sodium salt of 2,4-D kg. per ha.	Morpholine salt of 2,4-D kg. per ha.	2M — 4K kg. per ha.			Sodium salt of 2,4-D kg. per ha.	Morpholine salt of 2,4-D kg. per ha.
		½	1	2	1	1		½	1	2	1	1	½	1	2	1	1
I	3.0	0	0	1	1	2	13	13	15	16	20	18	0	0	0	3	3
II	5.3	0	1	1	1	3	12	15	14	15	15	15	0	2	4	0	4
III	19.2	0	2	4	0	14	14	15	14	18	16	18	1	3	5	1	7
IV	30.5	0	1	14	0	21	11	23	21	27	16	19	3	10	18	3	20

Figures indicating the average rate of stem curvature on each observation day were obtained by multiplying the proportion of different stem curvature by the degree of curvature (0—4). For methoxon sprayings these figures are shown graphically in Figure 3.

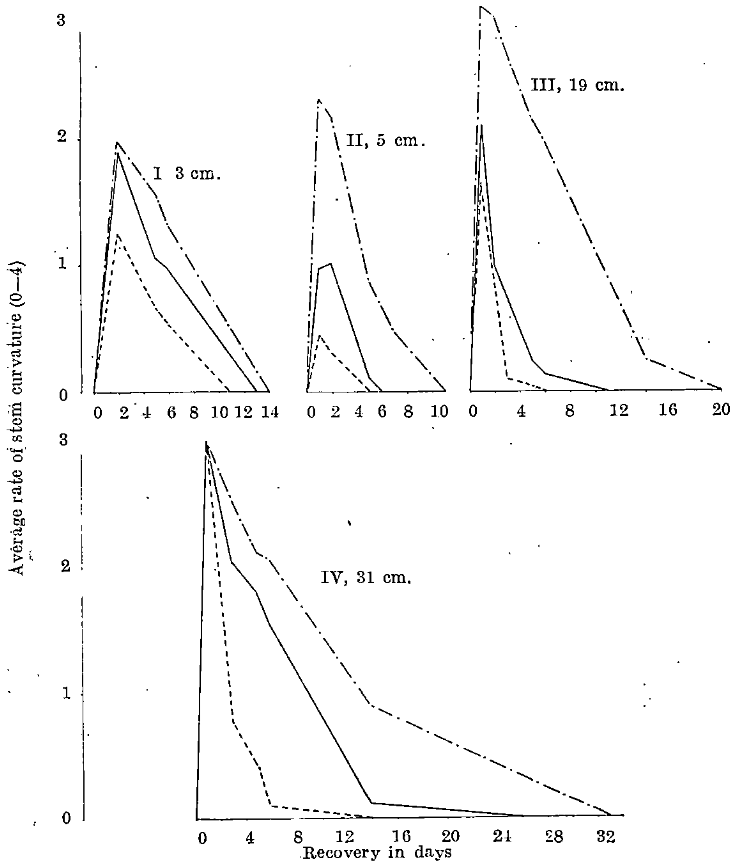

Fig. 3. Effect of artificial hormones on stem curvature and recovery of oil flax cultivations at stages I—IV of development. Figures indicate the average rate of stem curvature. Broken lin = ½, unbroken line = 1, and dotted line = 2 kg. of 2M-4K per ha.

The results reported in Tables 3 and 9 are based on usual rough measuring. They are averages of 20 individual plants selected at random in different replicate plots. In order to obtain as accurate results as possible, another experiment was conducted in connection with experiment 2, in which the effect of methoxon sprays of different concentrations on marked individuals was observed. Treatments: a = untreated, b— e = $^1/_5$, ½, 1, and 2 kg. of 2M-4K as *Agroxon* per ha. Measurings — the first measuring on July 19 at 15 just before treatment, and after treatment every morning at 9 at first, later at intervals of 2—4 days during 22 days — were made from a board placed on piles, which were hit in the ground and on a level with it. The thickness of the board was added to each result of measuring.

Figures 4—7 show best the stem bending and recovery of oil flax treated at stages I—IV of development.

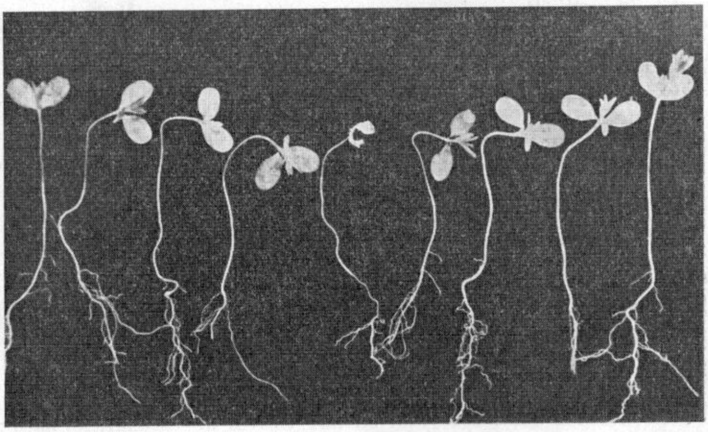

Fig. 4. Stem curvature and recovery of oil flax treated at stage I. Dying plant in the center. ½ natural size. Comparable with stage I in experiment 1.

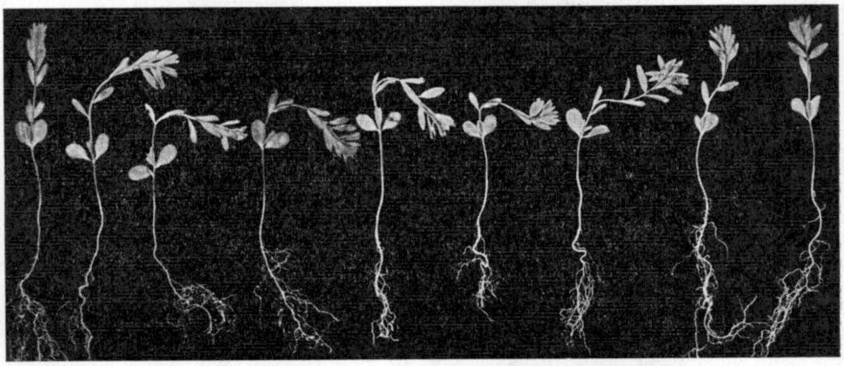

Fig. 5. Stem curvature and recovery of oil flax treated at stage II. $^1/_3$ natural size. Comparable with stage II in experiment 1.

Fig. 6. Stem bending and recovery of oil flax treated at stage III. $^1/_5$ natural size. Comparable with stage V in experiment 1.

Fig. 7. Stem curvature and recovery of oil flax treated at stage IV. $^1/_5$ natural size. Comparable with stage VI in experiment 1.

The averages of measurings, which in each plot were made for 32—34 individual plants, are given in Table 11.

Table 11. Some observations about effect of artificial hormones (applied at the rate of 1/5, ½, 1 and 2 kg. of 2M-4K per ha.) on height of oil flax.

Days after treatment	Height at time of treatment, average increase per day and final height (cm.)				
	Untreated	2M—4K kg. per ha.			
		1/5	½	1	2
0	22.7	23.6	22.4	19.0	17.8
[1]) 1	[2]) 1.3	1.6**	2.2***	1.5*	1.6**
2	2.0	1.1	0.6	0.9	0.9
3	1.8	1.7	0.7	0.4	0.2
4	1.6	1.4	1.0	0.3	0.2
5	2.0	1.9	1.7	0.6	0.4
6	1.8	2.3	1.9	1.3	0.6
7	1.8	1.5	1.4	0.9	0.8
8	1.9	2.2	2.1	1.7	0.8
9	2.8	3.3	3.0	2.7	1.7
10	2.1	2.7	2.9	2.6	2.3
11	1.7	1.8	2.1	2.3	2.5
12	1.2	1.4	1.8	2.0	2.0
14	1.2	1.3	1.3	1.8	2.1
16	0.9	1.1	1.1	1.5	1.7
18	0.6	0.6	0.7	1.0	1.0
22	0.3	0.3	0.4	0.8	1.0
31	52.9	53.8	51.7	49.7	50.2

[1]) 18 hours after treatment. Subsequent measurements after 24 hours.

[2]) Mean differences (m) on the average are: untreated = ±0.077, 0.02 % = ±0.070, 0.05 % = ±0.068, 0.1 % = ±0.072 and 0.2 % = ± 0.081.

The effect of artificial hormones on the amount of the seed, stem, and oil crop of oil flax, and on the quality of seed and oil crop for experiment 2 is shown in Tables 12—15.

Table 12. Effect of artificial hormones on yield of seed and stem [1]) of oil flax plants being at stages I—IV of development at time of treatment. Differences printed in fat are significant at least at 5 % level of probability.

Stage of development and height at time of treatment cm.	Untreated		2M-4K kg. per ha.						Sodium salt of 2,4-D kg. per ha.		Morpholine salt of 2,4-D kg. per ha.	
			½		1		2		1		1	
	kg. per ha.	Rel.	± kg. per ha.	Rel.	± kg. per ha.	Rel.	± kg. per ha.	Rel.	± kg. per ha.	Rel.	± kg. per ha.	Rel.
	Yield of seed											
I 3.0	1 480	100	+ 50	103	+ 150	110	+ 70	105	— 200	86	— **360**	76
II 5.3	1 670	100	+ 30	102	+ 40	102	— 90	95	— 140	92	— **410**	75
III 19.2	1 500	100	— 150	90	—**270**	82	—**300**	80	— 140	91	— **920**	39
IV 30.5	1 520	100	— **250**	84	—**290**	81	—**580**	62	— **420**	72	—**1 220**	20
	Yield of stem											
I	4 690	100	+ 290	106	— 90	98	—460	90	—**1 230**	74	—**1 520**	68
II	4 730	100	— 410	91	—570	88	—690	85	— **820**	83	—**1 090**	77
III	2 500	100	— 150	94	— 80	97	+ 270	111	— 170	93	— 340	86
IV	2 100	100	+ 100	105	+ **570**	128	+ **640**	131	+ 140	107	+ 300	115

[1]) Minimum significant differences for yields of seed and stem required for significance at 5 % level, F-values, and m % are given below:

Table 13. Effect of artificial hormones on the quality of yield of seed. Plants were at stages I—IV of development at time of treatment.

Treatments	Average weight proportion of sound (= S) and membranous (= M) seeds in yield								Weight per 1 000 seeds for the whole crop (= A) the sound seeds (= S), and membranous seeds (= M)							
	I 3.0 cm.		II 5.3 cm.		III 19.2 cm.		IV 30.5 cm.		I			II			III	IV
	S	M	S	M	S	M	S	M	A	S	M	A	S	M	A	A
Untreated	30	11	56	4	73	5	90	1	4.4	5.2	3.3	5.1	—	—	4.8	5.0
½ kg. of 2M-4K	30	14	50	6	73	3	83	3	4.4	5.1	3.2	5.1	—	—	4.9	5.0
1 —»—	27	13	41	4	73	4	82	5	4.6	5.1	3.2	4.8	5.1	3.3	4.8	4.6
2 —»—	27	13	37	7	67	11	66	16	4.6	5.2	3.3	4.7	5.1	3.3	4.7	4.5
1 kg. of sodium salt of 2,4-D.	15	18	29	6	79	4	83	6	4.4	5.2	3.2	4.8	5.1	3.3	5.0	5.2
1 kg. of morpholine salt of 2,4-D per ha.	13	26	20	11	23	23	19	37	4.1	5.2	3.0	4.5	5.1	3.2	3.6	3.5

Table 14. Effect of artificial hormones on oil content and yield of oil. Preparations sprayed on plants being at stages I—IV of development.

Stage of development and height at time of treatment cm.	Untreated			2M-4K kg. per ha.						Sodium salt of 2,4-D kg. per ha.			Morpholine salt of 2,4-D kg. per ha.		
				1			2			1			1		
	Oil content %	Oil kg. per ha.	Rel.	Oil content %	Oil kg. per ha.	Rel.	Oil content %	Oil kg. per ha.	Rel.	Oil content %	Oil kg. per ha.	Rel.	Oil content %	Oil kg. per ha.	Rel.
I 3.0	41.9	546	100	42.0	+ 58	111	42.4	+ 32	106	42.0	— 72	87	41.5	— 135	75
II 5.3	43.3	639	100	43.3	+ 13	102	43.3	— 36	94	43.3	— 54	92	42.0	— 172	73
III 19.2	41.7	553	100	41.9	— 98	82	41.9	— 108	80	41.9	— 51	91	40.5	— 347	37
IV 30.5	42.3	567	100	41.5	— 116	80	40.6	— 232	59	41.6	— 165	71	39.0	— 463	18

Table 15. Effect of artificial hormones on the degree of unsaturation of oil indicated by refractive numbers. Preparations sprayed on plants being at stages I—IV of development.

Stage of development and height at time of treatment	Untreated	2M—4K kg. per ha.		Sodium salt of 2,4-D kg. per ha.	Morpholine salt of 2,4—D kg. per ha.
		1	2	1	1
	Refractive number				
I 3.0	1.4839	1.4839	1.4839	1.4838	1.4835
II 5.3	39	39	40	40	40
III 19.2	32	33	32	32	31
IV 30.5	30	31	31	30	32

Stage of development	Minimum significant difference kg. Yield of seed	Minimum significant difference kg. Yield of stem	F-values Yield of seed	F-values Yield of stem	m % Yield of seed	m % Yield of stem
I	271	575	3.46*	14.33***	7.1	4.6
II	213	791	45.54***	2.02°	7.2	6.4
III	221	396	15.24***	2.39°	6.9	5.4
IV	186	441	35.86***	3.24(*)	6.6	6.1

The purpose of the two experiments reported on pages 12—26 has been to find out, whether oil flax is resistant to 2M-4K and 2,4-D compounds applied at different stages of development as sprays of different concentrations. Before the obtained results are surveyed, a third experiment is reported, in which the artificial hormones were given as dusts.

Experiment 3. — The experiment was arranged according to row method, the size of plots being 5.4 m^2, number of replicates 4. Treatments: *a* = untreated, *b*—*c* = treated by giving through veil bags 2 and 4 kg. of 2M-4K (as *Agroxon)*, the amount of carrier being 200 and 400 kg. per hectare, *d*—*g* = treated by giving 1, 2, 2, and 2 kg. of sodium salt of 2,4-D per hectare, the amount of carrier being 100, 200, 100, and 50 kg. per hectare. The average height of the plants at the time of treatment:

Stage of development	Date of treatment	Average height of plants at date of treatment (cm:)
I	June 6	3.0
II	June 11	4.2
III	June 20	7.5

The effect of dusts on the treated plants was slow at all three stages of development. Only a slight curvature was observed and buds opened in all plots almost simultaneously. Therefore, only the figures indicating yield of seed are given in Table 16.

Table 16. Effect of dust applications of artificial hormones on yield of seed. Treated at stages I—III of development, and treatments a—g are the same as above. Differences printed in fat are significant at 5 % level of probability.

Stage of development and height at time of treatment cm.	a		b		c		d		e		f		g	
	Yield of seed													
	kg. per ha.	Rel.	± kg. per ha.	Rel.	± kg. per ha.	Rel.	± kg. per ha.	Rel.	± kg. per ha.	Rel.	± kg. per ha.	Rel.	± kg. per ha.	Rel.
I 3.0	1 160	100	**+230**	120	**+200**	117	—160	86	—130	88	— 90	92	— 40	96
II 4.2	1 050	100	— 90	92	+ 90	109	+ 40	105	+ 40	104	+150	115	+ 30	103
III 7.5	1 250	100	+ 60	104	+100	107	+120	110	+110	108	+120	109	+150	111

[1]) Minimum significant differences at 5 % level of probability, F-values, and m % of yields of seed are:

Stage of developmet	Minimum significant difference (kg.)	F-value	m %
I	217	4.20	6.1
II	276	0.70	8.2
III	160	0.89	3.9

Discussion

In the three experiments reported on pages 12—27 different concentrations of methoxon and chloroxon compounds were applied to oil flax plants at different stages of development in order to find out their effects on the development of the plants, on the amount and quality of seed and stem crop, and on the quality of seed crop. These facts are of considerable value, when the importance of artificial hormones with regard to weed control in oil flax is investigated.

Effect on stem curvature and recovery

As the results given in Tables 1 and 7, and in Figures 1 and 3 indicate, the plants attained the greatest degree of stem curvature within 1—3 days after treatment. If a methoxon compound *(Agroxon)* was used, the average rate of stem curvature was usually intensified and the time needed for recovery prolonged, if the amounts of effective substance per unit surface area were increased. Significant differences in average degree of stem curvature were also observed between different stages of development. In experiments 1 and 2 the average rate of stem curvature for ½, 1, and 2 kg. of 2M-4K applied at comparable stages of development was this: I and I = 12 and 13 days, II and II = 8 and 7 days, V and III = 6 and 12 days, VI and IV = 15 and 24 days. In the experiment 2 the time needed for recovery was distinctly longer for plants at the stages III and IV than for the plants at the comparable stages V and VI in the experiment 1. At stages I and II no differences in average stem curvature of plants were observed between experiments 1 and 2. — Of 2,4-D compounds the effect of morpholine salt applied to oil flax at cotyledon or bud stage was so great that the plants did not recover completely, but remained more or less creeping on the ground. Also at other stages of development the effect of morpholine salt spray on the stem curvature was greater than that of a methoxon spray of double concentration. The recovery of oil flax was prevented by a solution of the sodium salt of 2,4-D applied at cotyledon stage. At other stages of development its effect, however, was not so great as that of a comparable amount of 2M-4K. This is probably explained so that the aqueous solution of sodium salt of 2,4-D cannot enter the plants to any considerable extent except at cotyledon stage. This question will be considered again later (cp. p. 44). — In experiment 1 none of the applied compounds caused stem curvature at stage VII of development. Experiments conducted in U. S. A. (2, 9, 10, 15, 18) have shown that growth regulators travel with assimilation products probably along the phloem into the stem causing bending in it, and that the rate of bending increases with quickened absorption and translocation of the effective substance. The quickest effect was observed under conditions favourable for photosynthesis. Treatment with 2,4-D caused no or hardly any curvature in dark, in cold, if CO_2 was lacking, or in stems treated after the leaves had been cut off. Plants treated at stage VII had already attained their final height by the time of treatment, which probably accounts for the non-curvature in these plants. — As Tables 2 and 8 show, all plants in the recovered plots, however, did not recover, but a number of them died, especially if the treatment was applied at cotyledon stage.

Effect on height

The results of the effect of artificial hormones on the height of oil flax cultivations, applied at different stages of development, are given in Tables 3, 9, and 11. Within 18 hours after treatment (Table 11), 0.02, 0.05, 0.1, and 0.2 % methoxon sprays apparently caused a distinct stimulation in the growth of oil flax treated when 20 cm. high. Especially the average height of plants treated with the 0.05 % solution increased considerably more (= 2.2 ± 0.068 cm.) than that of untreated plants (= 1.3 ± 0.077 cm.). During the next seven days, however, the average height of the plants in untreated plots increased distinctly more than the height of other plants. Also other results (Tables 3 and 9) affecting the height of plants show distinctly that, on the whole, growth during the next few days after treatment occurred at a slow rate, if high concentrations of spray applications were used. So the treated plants remained much smaller than the untreated ones. This phenomenon, however, was not permanent, for the average height of the plants treated before they had attained their final height increased considerably, and on the whole this increase was greatest in plants treated with the highest concentration of the spray. Table 11 shows for instance that 11—22 days after treatment the average height of plants treated with 0.2 % solution showed the greatest increase (= 18.1 cm.), that of the untreated plants the smallest increase (= 9.5 cm.). Thus in the reported experiments the final height of plants treated with 0.2 % methoxon spray was at the most 4 cm. lower than that of the untreated plants. If treated with a concentration of 0.1 %, they remained only 2 cm. lower, at the most. On the other hand, salt solutions of 2,4-D, particularly morpholine salt, had distinctly injurious effects on the height of oil flax.

Effect on flowering and reaching of yellow maturity

In experiment 1 flowering was delayed 2 days at the most owing to treatments applied at stages I—V of development. Treatment at bud stage, especially if 0.2 % 2M-4K and 0.1 and 0.2 % morpholine salt solutions of 2,4-D were used, resulted in a more significant delay of 11—26 days. In experiment 2 the delay caused by 2 kg. of 2M-4K and 1 kg. of morpholine salt of 2,4-D per hectare seemed to be more significant, if the applications were made shortly before opening of buds. 0.1 % methoxon spray delayed flowering for 2 days, at the most, aqueous sodium salt spray of 2,4-D for 1 day at the most (cp. p. 44).

Delay in yellow maturity also seems to have been dependent on the date of treatment, the delay being more significant, if the treatment was given shortly before opening of buds, and if the amounts of effective substance used per unit surface area was large.

Effect on the amount of seed and stem crop

The crop results of the experiments 1—3 are given in Tables 5, 12, and 16. Morpholine and sodium salt sprays of 2,4-D caused the most significant reductions in seed and stem crops. In experiment 1 no reduction in seed or stem crop was caused by treatments with sodium salt solution of 2,4-D applied at the rate of ½ and 1 kg. per hectare, if the plants were treated at stages II—V of development (= 4.6—17.1 cm.). On the other hand, at stage I, and at the comparable stage in experiment 3, as well as at all stages in experiment 2 the effect was distinctly injurious. Also other investigators (3, 8, 14) emphasize the dangerousness of 2,4-D solutions to oil flax.

The seed crop was r e d u c e d owing to methoxon treatments in experiment 1 only if given at flowering stage (= VII) in experiment 2, if given to plants which had attained the height of 19—31 cm. (= stages III and IV). Reduction in stem crop was only detectable owing to a treatment given at stage II.

The seed crop was i n c r e a s e d in experiment 1 by all methoxon treatments given at stages I—III (2.6—7.8 cm.), and in experiment 3 by treatments given at stage I (3.0 cm.). It is not certain, however, whether the increases in yield (40—80 kg. per ha.) obtained from the experimental plot *d* (= 2 kg. of effective substance per ha.) in experiment 1 at stages I and II are due to spray applications. On the other hand, the i n c r e a s e s i n y i e l d o b t a i n e d f r o m e x p e r i m e n t a l p l o t s *c* a n d *d* (= ½ kg. and 1 kg. of the effective substance applied as spray, or 1 kg.

and 2 kg. of the effective substance applied as dust) are certainly due to treatments and show a variation of 130—230 kg. per hectare, or 11—20 %, the average increase being 175 kg. per hectare, or 15 %. Also in the experiment 2 the plots treated by methoxon at stage I produced 50—150 kg. more seed per hectare than the untreated plots, though the differences cannot be considered significant.

The stem crop was increased in experiment 1 by all treatments with 0.05, 0.1, and 0.2 % methoxon sprays applied at stages I—V (2.6—12.5 cm.),[1]) though the increases obtained at stage I and with a concentration of 0.2 % at stage II and III cannot be considered significant. The proved increases were on the average 210 kg. of air-dry stems per hectare, or about 11 %. In experiment 2 the air-dry stem crop was increased by spray applications made with 0.1 and 0.2 % solution of methoxon at stage IV (30.5 cm., bud stage) with approximately 600 kg. per hectare. The development rhythm of the plants was thoroughly disturbed and their growth points at least partly destroyed owing to the treatment, but when the plants recovered, they developed numerous side branches near the growth point, and owing to these the crop increased.

Many investigations have been hitherto published dealing with the question of the importance of growth-regulating substances. More or less distinct increases in crops have been reported, but, on the whole, these increases have been attributed to the disappearance of weeds from the treated areas. The increases in yield reported above in connection with experiments 1—3 cannot, however, be due to more favourable growing conditions as a result of eradication of weeds, because all plots (also the untreated ones), as already mentioned, were as well as possible kept free from weeds, which were pulled off with hands as soon as they appeared. The increases in yield are therefore most probably due to the stimulation caused by right amounts of methoxon compounds applied at a suitable stage of development.

The thought that the growth of cultivated plants can be stimulated and their yield increased by artificial hormones is not a new one. American distributors of some of the preparations have reported, for instance, increased yields and more vigorous growth of plants as a result of growth regulator treatment, though such claims have not been hitherto confirmed (1, p. 7). ÅBERG (22, pp. 56—57) describes the increases in yield (41 and 52 %) obtained in an experiment on bean with very small amounts of methoxon and 2,4-D,[2]) and observes that they are probably due to the

[1]) The increase is probably due to a slight increase in the diameter of stems.
[2]) 1 l. of AGROXON and 0.1 kg. of WORMOSAN G per ha.

growth-stimulating effect of these preparations. Also *Seger* oats produced an increase in yield of 270—520 kg., or of 6—11 %, if 1—4 kg. of *Wormosan G* (40 % 2,4-D) per hectare was applied to an area not heavily infested with weeds. In this instance the increase in yield, therefore, could not be due to larger growth space obtained with killing of weeds.

Very interesting is the question of the effect of different growing conditions on the smaller or greater increase in yields of different plants caused by treatments with various amounts of growth-regulating substances. The answer to this question also answers the question of the real growth-reducing effect of weeds. The increases in yields reported hitherto are not necessarily due only to more favourable growing conditions caused by killing of weeds. Likewise, in experiments, in which the relative number of a crop treated with artificial hormones was e. g. 90, the growth-reducing effect of the preparation may have been greater than 10 %, but owing to the increase in yield due to more favourable growing conditions caused by eradication of weeds the final relative number of yield was 90. Valuable information with regard to these facts will be obtained in field experiments with two parallel plots, one of which will be kept free from weeds.

In experiment 1 definite increases in yield were obtained, if oil flax was treated with 0.05—0.2 % methoxon solution at early stages of development. But why were such increases not obtained, or obtained to much less extent, in experiment 2 from plants treated in the same manner and at comparable stages of development? As the results given in Tables 1 and 7 and in Figures 1 and 3 indicate, the greatest degree of average stem curvature was usually attained within 1—3 days after treatment, after which the plants began to recover. The figures below show the mean temperature prevailing on the day of treatment and during two following days in experiments 1 and 2.

Stage of development	Experiment 1	Experiment 2
I/I	16.2 C°	19.5 C°
II/II	18.8	19.5
V/III	18.0	19.5
VI/IV	19.8	19.5

The mean temperature on the day of treatment and two following days was in experiment 1 lowest for cotyledon stage (I), or 16.2° C, highest, or 19.8° C, for bud stage (VI), which was nearly the same as for all stages of development in experiment 2. Yet the results obtained in experiment 2 for cotyledon stage showed the greatest similarity to those obtained in experiment 1, and the least similarity for bud stage. Reduction in yield does not seem to be due to higher mean temperature prevalent on the day of treatment and two following days.

Figure 8 shows the curves indicating the rate of growth for untreated plants in experiments 1 and 2 during 6 days following treatment.

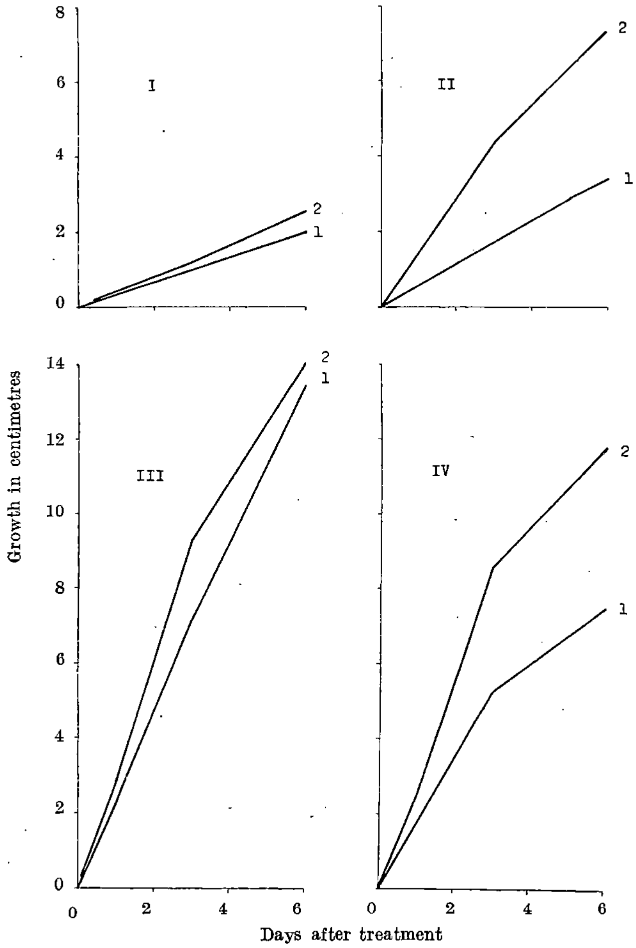

Fig 8. Average rate of growth of untreated plants in experiments 1 and 2 during 6 days following treatment cm. per day.

Figure 8 indicates that during the next few days following treatment growing occurred at a higher rate in the untreated plants of experiment 2 than in the comparable plants of experiment 1. The figures on p. 34, which give a summing up of the results reported hitherto, confirm that the potential of development must have been for the untreated plants of experiment 2 quite different from that of the comparable plants of experiment 1:

Comparable stages of development in experiments 1 and 2	Average height at time of treatment (cm.)	Average height at yellow maturity (cm.)	Time between treatment and yellow maturity (days)	Average increase in height per day between treatment and yellow maturity (cm.)	Yield of seed		Yield of stem	
					kg. per ha.		kg. per ha.	
1: I	2.6	41.5	71	0.55	1 170	100	2 020	100
2: I	3.0	59.1	74	0.76	1 480	126	4 690	232
1: II	4.6	41.5	65	0.57	1 330	100	2 090	100
2: II	5.3	53.0	67	0.71	1 670	126	4 730	226
1: V	17.1	41.5	49	0.50	1 230	100	1 890	100
2: III	19.2	50.0	58	0.53	1 500	122	2 500	132
1: VI	30.0	41.5	42	0.27	1 230	100	1 990	100
2: IV	30.5	45.2	38	0.39	1 520	124	2 100	106

The rapidity of growth at a given stage of development is determined by the joint effect of prevailing climatic and edafic factors, and it is greater under favourable conditions. Vigorous growth e. g. depends upon vivid assimilation and rapid translocation of assimilation products from leaves. Many american investigations (2, 9, 10, 15, 18) show that the artificial hormones absorbed in leaves are translocated with assimilation products probably along the phloem into the stem, and that the effectiveness of translocation depends on the number of assimilation products transferred from the leaves in one unit of time.[1] This accounts among other things for the greater influence of artificial growth regulators on plants growing at a sunny place than on plants of like species growing in the shade. Likewise for the greater susceptibility of plants to the influences of artificial hormones in spring and in summer, when their photosynthetic action is vigorous, as compared to the end of the growing season, when little food is produced by plants. The results of the present investigations reported above have shown that a definite stimulation to height was caused by artificial hormones within 18 hours after treatment, that the final yield of seed and stem from plants treated at early stages of development (2.6—12.5 cm.) increased, if growing occurred at the rate indicated in Table 3 and in the figures given above. If plants of the same height, but being otherwise in more active state of growth, were treated in the same manner, the effect was often opposite : the yield was reduced. This is probably due to the slower rate of growth in the treated plants of experiment 1 as compared to the plants of experiment 2. Thus the plants of experiment 1 had time to utilize a part of the artificial growth regulator absorbed by them to larger extent than the plants of experiment 2, and the injurious

[1]) No reserve food is transferred into the stem from very young, actively growing leaves (10).

influence of too large amounts of artificial hormones was mitigated. In experiment 2 the translocation of artificial growth regulators into the stem probably occurred more acutely and resulted in more vigorous effects. We may also think of such a possibility that the amount of hormones produced by the plants themselves was in experiment 2 at the time of treatment larger than in the plants of experiment 1, as the plants of experiment 2 were in more vigorous state of growth. Therefore also the increase in the amount of artificial hormones had a more vigorous effect.

Experiment 1 was sown at normal time (May 22), and the earliest stages of development were treated under normal conditions prevailing in Southern Finland at that time.[1]) The last plots of experiment 2, however, were sown about a month later than normal. Thus the results obtained in experiment 1 probably give the most accurate picture of the possibilities of using artificial hormones for weed control in oil flax in Southern Finland. According to experiment 1 ½—1 kg. of methoxon compound *(Agroxon)* applied as an aqueous solution at the rate of 1 000 l. per hectare to plants of the height of 2.6—12.6 cm. had no injurious effects on the yield of seed and stem, on the contrary, both increased, the former on the average by 160 kg. or about 14 % per hectare, the latter by about 210 kg. or about 11 % per hectare. As the concentration of ½ kg. per hectare is not sufficient to kill less sensitive weeds, 1 kg. per hectare is the most recommendable amount. According to the results of experiments 1 and 2 in application of artificial hormones attention must, however, not be paid exclusively to the compound applied, to the amount used, or to the height and stage of development of the treated plants, but also to the rapidity of growth, which is determined by both climatic and edafic factors. Actively growing plants are more sensitive than plants growing slowly, and thus smaller amounts of the effective substance are to be used for the former than for the latter.

The obtained results agree with those reported by Blackman and Holly (3), as far as the amount and quality of the effective substance are concerned. They declare, however, that it is of great importance to

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[1]) Average climatic conditions prevalent during growth season 1948 at Tikkurila and deviations from normal.

Month	Temperature C°		Precipitation mm.	
	Normal	1948	Normal	1948
May	8.4	+ 0.9	47	± 0
June	12.8	+ 2.0	53	— 29
July	16.1	— 0.3	70	— 28
August	13.8	+ 0.5	88	+ 21

wait until the oil flax plants are 3—4 inches (= 7.5—10 cm.) high before they are sprayed, and spraying must have ceased before they reach 12 inches (= 30 cm.). The results of the experiments conducted in Scandinavia (8) suggest that oil flax should be sprayed, when plants have attained the height of 7—10 cm., at the latest. This agrees with the results reported above. The amounts recommended to be used in Scandinavia, 5—8 l. of *Agroxon* per hectare (8, 22, 23) seem to be somewhat small for Finland. On the other hand, treatment with normal amounts of dinitro-ortho-cresol (DNOC) applied to fibre flax cultivations in Sweden in warm spring 1948 resulted in death of plants in several districts, and this warns us that in some years the safety margin between the recovery and death of rather sensitive plants treated with selective herbicides may be extremely narrow.

Effect on the quality of crop

Classification of seeds. On the whole, the reduction in the proportion of sound seeds and the increase in the proportion of membranous seeds was dependent on the concentration of the applied methoxon solution so that higher concentrations increased the proportion of membranous seeds and decreased that of sound seeds (Tables 6 and 13). Treatment exerted the most injurious effects at bud and flowering stages. Morpholine salt of 2,4-D exerted the greatest influence, whereas sodium salt had injurious effects only if applied at cotyledon stage.

Weight per 1 000 seeds. With an increase in the proportion of membranous seeds the weight per 1 000 seeds decreased correspondingly. As far as sound seeds are concerned, the treatments had no injurious effect on the weight per 1 000 seeds (Tables 6 and 13).

Oil content (Tables 6 and 14) in the crops obtained from the plots of experiment 2 treated with morpholine salt of 2,4-D showed the most significant reduction (at bud stage in some instances 2.3 %) owing to a considerable increase in the proportion of membranous seeds. Methoxon compound had no injurious effect on the oil content of seeds, except when applied at bud stage. The results do not disagree with the results reported by other investigators (8, 22).

Refractive numbers (Table 15) indicate that the degree of unsaturation of oil was reduced some units by morpholine salt of 2,4-D, if applied at cotyledon stage, which is probably due to higher temperature in vegetations thinned by treatments, as compared to other vegetations (12, pp. 12—13, 65, 70). Differences between different stages of development, on the other hand, are quite distinct and agree with the results reported earlier (12, p. 17).

With regard to the amount and quality of crop weed control in oil flax cultivations should be exercised with 1 kg. artificial hormones of methoxon type, and these substances should be applied to plants at an early stage of development (3—13 cm.).

2. *Experiments with oil flax treated at similar stage of development*

Experiment 4. — The purpose of this experiment was to find out the effect of different amounts of 2M-4K on the yield of seed, if oil flax cultivations at the same stage of development were sprayed with different amounts of 2M-4K in the morning or at dusk. The plots, 5.4 m^2 in size, were arranged according to row method, number of replicates 4. Treatments: a = untreated, b = 0.75 kg. per hectare sprayed in the morning, c = the same applied at dusk, d and e = 1½ kg. per hectare applied in the morning and in the evening, and f and g = 3 kg. per hectare. Treatment applied with *Ginge* knapsack sprayer, on July 5, the average height of plants 18 cm. The effect of the treatment on the yield of seed is shown in Table 17.

Table 17. Effect of spray aplications of 0.75, 1½, and 3 kg. of methoxon compound on yield of seed.[1]) M = *sprayed in the morning*, E = *in the evening.*

2M-4K kg. per ha.	Yield of seed kg. per ha.	Yield of seed Relative number
0	1 550 [1])	100
0.75 M	+ 90	106
0.75 E	+ 50	103
1.5 M	—340	78
1.5 E	—400	74
3.0 M	—980	37
3.0 E	—870	44

Discussion

Treatment with 0.075 % solution did not result in reduction of the yield of seed, but 0.15 and 0.3 % solutions had extremely injurious effects. Though the plants were at a very sensitive stage of development (8 days before opening of buds) at the time of treatment, and effective substance was applied at the rate of up to 3 kg. per hectare, similar treatments in the morning and in the evening did not produce different effects on the amount of yield.

[1]) Minimum significant difference at 0.05 level of probability 175 kg., F-value = 55.59***, m % = 4.9.

Experiment 5. — The purpose of the experiment was to find out, whether artificial hormones used for weed control in oil flax cultivations can be applied by means of a horse-operated sprayer. The plots, 63.4 m^2 in size, (untreated plots 31.7 m^2) were arranged according to row method, number of replicates 4. Treatments: a = untreated, b—d = treated by means of horse-operated *TT-Favorit* sprayer with 0.5, 1, and 2 kg. of 2M-4K (*P 46*) applied at the rate of 700 l. per hectare. Plants were rather high at the time of treatment, June 29, on the average 15 cm. The experimental area was not heavily infested with weeds. Their number was counted only for an area of 1 m^2 in each treatment. Results are given below:

Species of weed	2M-4K (*P 46*) kg. per ha. 0	½	1	2
	Number of weeds per m^2			
Chenopodium album	16	4	0	0
Erysimum cheiranthoides	6	2	0	0
Galeopsis sp.	2	1	1	0
Spergula arvensis	4	2	0	0
Polygonum convolvulus	3	2	2	1
Stellaria media	9	6	1	0
Viola arvensis	12	4	2	1
Polygonum lapathifolium	1	0	1	1
Together	53	21	7	3
Relative number	100	40	13	6

Also weed seeds were stored at threshing and assortment, and the average yield per hectare of weed seeds from different plots show fairly accurately [1]) the effectiveness of artificial hormones with regard to different species. The results reported above, as well as the effect of spray applications on the amount and quality of the seed crop of oil flax, are given in Tables 18 and 19.

Table 18. Effect of P 46 spray on yield of seed of oil flax. Treated by means of horse-operated Favorit sprayer

Treatments	Yield of seed: kg. per ha.	Yield of seed: Rel. number	Quality of crop: Sound seeds %	Membranous seeds %	Weight per 1 000 seeds gm.	Germination %
Untreated	[2])1 430	100	75	4	4.8	93
½ kg. of 2M-4K	+ 20	101	80	3	4.8	95
1 » —»—	+ 60	104	78	3	4.8	95
2 » —»— per ha.	+ 30	102	81	4	4.7	97

[1]) The real seed crop of weeds scattering their seeds early and easily is not always found out by means of this method.
[2]) Minimum significant difference at 5 % level of probability 43 kg., F-value 3.58°, m % 0.9.

Table 19. Effect of ½—2 kg of 2M-4K (P 46) on yield of seed of the most common weeds in experiment 5. Applications made by means of horse-operated Favorit sprayer.

Species of weed		Yield of seed kg. per ha. (= *a*), relative number (= *b*), and proportion of each species in the whole yield of weeds % (= *c*)			
		Untreated	2M—4K kg. per ha.		
			½	1	2
Chenopodium album L ...	*a*	74.20±6.84	6.00±2.03	0.13±0.03	0.16±0.06
	b	100	8	0	0
	c	62.6	20.0	1.2	2.1
Erysimum cheiranthoides L	*a*	15.65±2.70	3.00±0.01	0.53±0.14	0.25±0.15
	b	100	19	3	2
	c	13.2	10.0	5.0	3.2
Galeopsis sp.	*a*	1.97±0.46	0.40±0.13	0.02±0.01	0
	b	100	20	1	0
	c	1.7	1.3	0.2	0
Spergula arvensis L	*a*	0.53±0.21	0.25±0.04	0.05±0.02	0.05±0.02
	b	100	47	9	9
	c	0.4	0.8	0.5	0.6
Polygonum convolvulus L .	*a*	23.28±3.77	16.98±2.00	7.63±0.82	5.55±0.62
	b	100	73	33	24
	c	17.7	56.5	72.2	72.1
Stellaria media (L) Vill...	*a*	0.83±0.18	0.70±0.12	0.40±0.14	0.18±0.15
	b	100	84	48	22
	c	0.7	2.3	3.8	2.3
Viola arvensis (Murr.) Gaud.	*a*	0.58±0.09	0.65±0.16	0.18±0.03	0.07±0.01
	b	100	112	31	12
	c	0.5	2.2	1.7	0.9
Polygonum lapathifolium L	*a*	0.93±0.06	0.75±0.18	1.15±0.20	0.58±0.35
	b	100	81	124	62
	c	0.8	2.5	10.9	7.5
Fumaria officinalis L	*a*	0.48±0.01	1.25±0.09	0.43±0.00	0.80±0.10
	b	100	260	90	167
	c	0.4	4.2	4.1	10.4
Galium spurium L	*a*	0.02±0.01	0.06±0.02	0.05±0.02	0.06±0.02
	b	100	300	250	300
	c	0.0	0.2	0.5	0.8
Together	*a*	118.47	30.04	10.57	7.70
	b	100	25	9	7

Discussion

Though spray applications were made, when the average height of the plants was already 15 cm., none of the amounts used (0.5—2 kg. of the effective substance per ha.) reduced the seed crop of oil flax, or had any injurious effect on its quality. It is even probable that the seed crop increased owing to the treatment by 20—60 kg. per hectare, though the differences are not proved.

Of the weeds *Chenopodium album*, *Erysimum cheiranthoides* and *Galeopsis sp.*[1]) were eradicated or lost seeding capacity to considerable extent already owing to treatment with 1 kg., *Polygonum convolvulus*, *Spergula arvensis*, *Stellaria media* and *Viola arvensis* to less extent. The three last mentioned species are generally considered rather resistant (11). In this experiment the usual treatment with 1 kg. reduced their seed crop on the average to 1/3, treatment with 2 kg. sometimes to 1/7 of the average crop obtained from untreated plots, and the number of weeds to 1/8 and to 1/25 of the untreated plot. *Polygonum lapthifolium*, *Galium spurium*, and *Fumaria officinalis* were resistant.

This experiment confirms convincingly the results of earlier experiments, according to which it is not dangerous to use artificial hormones for weed control in oil flax cultivations, if only the treatment is given well before bud stage and effective substance is applied at the rate of 1 kg. of 2M-4K per hectare.

C. Importance of carrier to the effectiveness of artificial hormones with regard to oil flax

In connection of the survey of literature it was mentioned that oil flax, on the whole, is most resistant to methoxon compounds *(Agroxon, P 46)*, which should be applied at the rate of 0.5—1.0 kg. per hectare (8, 13, 14, 16, 23), or in some instances at the rate of 2 lb. per acre (= about 2.2 kg./ha.) (3). 2,4-D compounds are not recommended at all, or they should be applied in much smaller amounts. According to Blackman and Holly even 0.1 % solution of sodium salt or acid suspension of 2,4-D can be applied at a susceptible stage of development (= 3—4 inches to 12 inches or 7.5—10 cm. to 30 cm.), but ester-oil emulsions are quite unsuitable.

Also the results of the present experiments indicate that 2,4-D compounds had in general more injurious effects on the development of oil flax, and on the yield of seed and stem than 2M-4K compounds. A sixth experiment was conducted in order to compare the effectiveness of a methoxon compound *(P 46)* with that of a 2,4-D compound *(P 47)* with regard to oil flax.

Experiment 6. — The substances were sprayed with a *Ginge* knapsack sprayer on plants, 29 cm. in height, at bud stage (= 4 days

[1]) *G. speciosa* Mill., *G. tetrahit* L., and *G. bifida* Boenn.

before flowering) on July 9. Treatments: *a* = untreated, *b* and *d* = 0.75 and 1.5 kg. of the sodium salt of 2,4-D, *c* and *e* = 1.5 and 3.0 kg of 2M-4K per hectare. Size of plots 5.4 m^2, number of replicates 4. The effect of the sprayings on the yield of seed is given in Table 20.

Table 20. Effect of spray applications of 2M-4K and 2,4-D (P 46 and P 47) on yield of seed of oil flax.[1])

Treatments	Yield of seed kg. per ha.	Yield of seed Rel. number
a = Untreated	1 680	100
b = 0.75 kg 2,4-D per ha.	—160	90
c = 1.5 » 2M-4K » »	—130	92
d = 1.5 » 2,4-D » »	—230	86
e = 3.0 » 2M-4K » »	—460	72

The 2,4-D compound *P 47* seemed to be more effective than the 2M-4K compound *P 46*. Among the other results reported previously we also find opposite results. So, for instance, in experiment 1 1 kg. of the sodium salt of 2,4-D in aqueous solution did not result in so marked stem curvature at stages III—V than 1 kg. of 2M-4K per hectare (Table 1). In the same experiment a treatment with 2,4-D did not retard maturity when applied at stages II—V, whereas a treatment with 2M-4K caused significant retardation (Table 3). The same was observed for stages II—IV in experiment 2 (Tables 7 and 10). But at cotyledon stage 2,4-D proved more effective than methoxon in experiments 1 and 2: it resulted in thinned vegetations, in injurious effects on stem curvature and recovery, and on the yield of seed and stem. Experiment 7 was conducted in order to find out the reason for such sudden decrease in the effectiveness of artificial hormones applied at a later stage of development.

E x p e r i m e n t 7. — Experimental plots, 1.5 m^2 in size, in which the average height of the plants was about 15 cm., were sprayed on July 22 with *a* = aqueous solution of the sodium salt of 2,4-D, *b* and *c* = the same added with 1 % of emulsifying oil, *d* = aqueous solution of the morpholine salt of 2,4-D applied at the rate of 2 kg. per hectare. Two adjacent plots A and B were sprayed in each treatment. 15 minutes after treatment the plants of B-plots were irrigated by giving them an amount of water corresponding to 10 mm. heavy rain. 3 days after treatment samples showing stem curvature were taken from plots A and B in each treatment. These samples are shown in figures 9—11.

[1]) Minimum significant difference at 5 % level of probability = 137 kg., F-value = 12.65***, m % = 3.0.

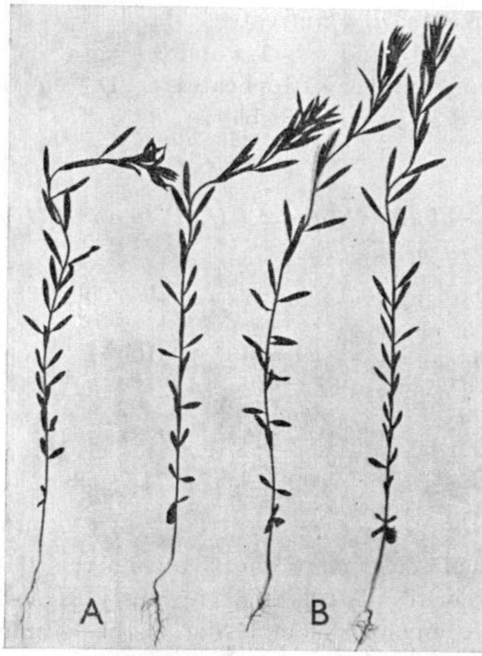

Fig. 9. Effect of aqueous solution of the sodium salt of 2,4-D on stem curvature of oil flax. Rate of application 2 kg. of compound per ha. dissolved in 1 000 l. water. Plants *B* (2 plants on the right) were subjected to 10 mm. artificial rain 15 minutes after treatment. *A* = not irrigated. Samples taken three days after treatment. $^1/_4$ natural size.

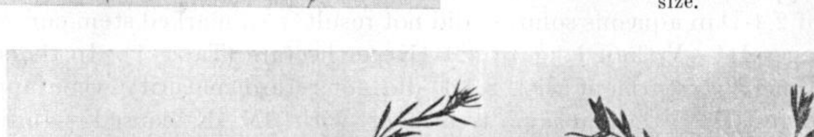

Fig. 10. Effect of aqueous solution of the sodium salt of 2,4-D, added with 1 % emulsifying oil, on stem curvature of oil flax. Rate of application 2 kg. of compound per ha. dissolved in 1 000 l. water. Plants *B* (3 plants on the right) were subjected to 10 mm. artificial rain 15 minutes after treatment. *A* = not irrigated. Samples taken three days after treatment. $^1/_4$ natural size.

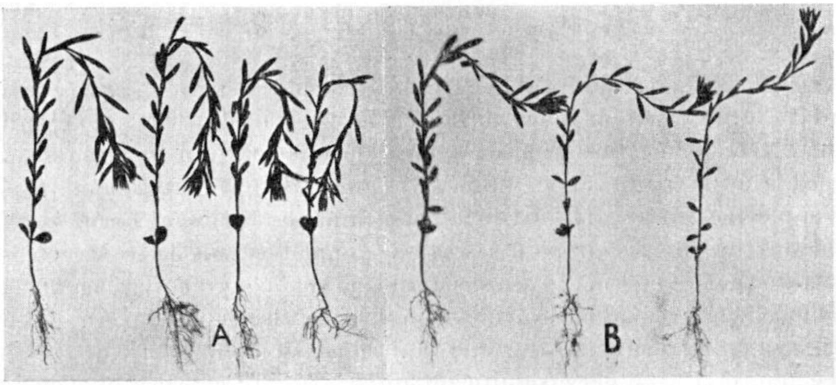

Fig. 11. Effect of aqueous solution of the morpholine salt of 2,4-D on stem curvature of oil flax. Rate of application 2 kg. of compound per ha. dissolved in 1 000 l. water. Plants B (3 plants on the right) were subjected to 10 mm. artificial rain 15 minutes after treatment. *A* = not irrigated. Samples taken three days after treatment. $^1/_4$ natural size.

The effect of sprayings on the height of oil flax is shown in Figure 12.

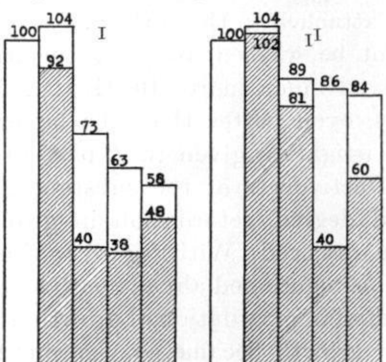

Fig. 12. Effect of 0.2 % 2,4-D spray applications on height of oil flax measured 11 days (= I) and 26 days (= II) after treatment. Treatments: *1* = untreated, *2* = aqueous solution of the sodium salt of 2,4-D, *3* = *2* + emulsifying oil *303*, *4* = *2* + emulsifying oil *Panfix*, *5* = aqueous solution of the morpholine salt of 2,4-D. Height of untreated plants 1 I 48 cm., and of 1 II 57 cm. = 100. Shaded = not irrigated, unshaded = irrigated.

Table 21 shows the effect of 2,4-D spray applications on the opening of buds.

Table 21. Effect of 2,4-D spray applications on opening of buds in plants 15 cm. in height at time of treatment.

Treatments	Flowering delayed as compared to untreated plants (days) *A* = not irrigated *A*	*B* = irrigated *B*
0.2 % aqueous solution of sodium salt of 2,4-D	1	0
Previous + 1 % emulsifying oil 303	9	3
The first + emulsifying oil *Panfix*	22	5
0.2 % aqueous solution of morpholine salt of 2,4-D	14	11

Discussion

As Figures 9—12, and Table 21 indicate, only a slight stem curvature, retardation in growth or delay in flowering was caused by 2 kg. of sodium salt of 2,4-D per hectare applied as an aqueous solution to plants, which were on the average 15 cm. high. 15 minutes after treatment *B*-plots were subjected to 10 mm. artificial rain, and the artificial hormone compound on the surface of plants was so completely washed away by the irrigation that no effect was observable. When spreading agent (1 % emulsifying oil) was added to the aqueous solution, the compound entered the tissues more easily and resulted in distinct stem curvature of the third degree (cp. p. 13), a very significant retardation in growth, and delay in flowering. The oil *Panfix* seemed to increase the effectiveness of 2,4-D compound more than *303*. An irrigation given to *B*-plot 15 minutes after treatment slightly decreased the effectiveness of the selective herbicide, as shown by stem curvature, retardation in growth, and delay in flowering, but owing to the spreader some of the herbicide, at least, was absorbed by the plant tissues or attached to the surface of the plants to such extent that all of it could not be washed away by the irrigation. Morpholine spray applications proved much more effective than comparable sodium salt spray applications, even better than the latter used together with the spreader *303*. An irrigation given to *B*-plot 15 minutes after treatment decreased the effectiveness of the substance, but a distinct stem bending of the second degree, retardation in growth and considerable delay in flowering were observed. With regard to the height of all treated plants it was observed, as mentioned already earlier (cp. p. 29) that though treatments at first resulted in retardation of growth, this was no permanent phenomenon, and later growth became so vigorous that final differences in height between treated and untreated plants were clearly smaller than a short time after treatment.

The results of this and other experiments (1, 17, 20) suggest that the low effectiveness of an aqueous solution of 2,4-D on oil flax at other than cotyledon stages, which was observed in experiments 1 an 2, may be due to the fact that the solution cannot easily penetrate the surface tissue. At cotyledon stage, when the tissue is still delicate, a 0.1 % solution of the sodium salt of 2,4-D was more effective than comparable *Agroxon* spray, at other stages much less effective.[1]) Owing to spreader the preparation is spread on the surface of the plant in a thin film, so that the liquid does not turn into drops and roll to the ground as easily as a pure water solution, which has a greater surface tension.

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[1]) In the experiment 6 the 2,4-D compound (*P* 47) was more effective than the 2M-4K compound (*P 46*); it probably contains some substance decreasing surface tension (spreader).

The preliminary experiment reported above, as well as the experiments 1, 2, and 6 indicate that with regard to the effectiveness of artificial hormones both the compound itself and the carrier used are of extreme importance. The better the spray is attached to the plant, the more evenly it is spread on the surface of the plant, and the better it is absorbed by the tissues, the more effective it seems to be. If 2M-4K and 2,4-D compounds are absorbed by the tissues with equal ease, 2,4-D compounds seem to be much more effective than methoxon compounds.[1])

[1]) In this connection a short mention may be made of the effect of isopropyl N-phenyl carbamate (IPPC) on oil flax. In a pot experiment oil flax appeared to be almost as sensitive as wheat, whereas pea resisted the substance well, and even clearly stimulated by it. The results agree with those reported by Ennis (6). Thus IPPC cannot be recommended for eradication of quack-grass *(Agropyrum repens* (L.)*)* and other graminous weeds from oil flax cultivation

Summary

1. The first detectable effect caused by artificial hormones, stem curvature, was observed to begin within ½—6 hours after treatment. The deepest degree of stem curvature was observed 1—3 days after treatment. Spray application of the morpholine salt of 2,4-D produced the most injurious effects, especially if applied at cotyledon and at bud stage, and plants remained more or less creeping on the ground. Likewise, when an aqueous solution of the sodium salt of 2,4-D was applied to plants at cotyledon stage, the plants did not recover completely, but when applications were made at other stages, it was less effective than comparable amount (= 1 kg. per ha.) of 2M-4K, which is due to the fact that aqueous solution is not easily absorbed by plant tissues. The average rate of stem curvature caused by 2M-4K compound *(Agroxon)* was at a given stage of development greater, if large amounts of the substance were sprayed to plants per unit surface area. At cotyledon and bud stages the plants were most susceptible to stem curvature, and at these stages also the time needed for recovery was longest. Plants were least susceptible to stem curvature immediately after cotyledon stage, when the average height of the plants was 5—8 cm. The plants treated at the end of flowering period did not show any stem curvature, nor was any significant curvature apparent at any stage of development, if dusts were used for treatments.

All individual plants in the recovered groups of plants, however, did not recover, but part of them died, especially if treated at cotyledon stage. The average percentage for treatments with 0.1 % methoxon spray was 4, for treatments with comparable amount of 2,4-D spray 13. Sprayings with 0.1 % compounds applied immediately after cotyledon stage did not result in any thinning in vegetations.

2. Sprayings with 0.02—0.2 % solutions, especially with 0.05 % solution, of methoxon resulted in definite stimulation in the growth of oil flax within 18 hours after treatment. — In general the rapidity of growth in the treated plants was during the days following the treatment dependent on the concentration of the spray, so that higher concentration retarded the growth and the treated plants remained much shorter than the untreated plants. Before the final height was recovered, however, the average height of the treated plants increased, and the increase was greatest for

plants treated with highest concentration. Thus the final height of plants treated with 0.1 % 2M-4K remained only up to 2 cm. shorter than that of the untreated plants, whereas the plants treated with 0.1 % aqueous solution of 2,4-D remained up to 11 cm. shorter.

3. The effect of artificial hormones on the flowering and yellow maturity of oil flax was, on the whole, very injurious, if large amounts of the compound were used per unit surface area, and if the treatment was given shortly before bud stage. 0.1 % methoxon sprays given at an early stage of development (3—13 cm.) delayed flowering for 1 day, at the most, and yellow maturity for 2 days, at the most.

4. Treatments with 0.05—0.2 % methoxon at an early stage of development (3—13 cm.) did not result in any injurious effects on the amount of the yield of seed and stem, or on the quality of seed. On the contrary, under conditions, under which the growth of oil flax during the next few days after treatment occurred at the rate of 0.3—0.6 cm. per day on the average, depending on the stage of development, especially methoxon sprays of 0.05 % and 0.1 % concentrations caused a definite increase in yield, 130—230 kg. of seed or 11—20 %, and 170—300 kg. of stem per hectare, which is probably due to stimulation. Sprayings given at a very late stage of development (= some days before appearance of buds, and especially at bud or flowering stage) had an injurious effect on the amount of yield of seed and stem, as well as on the quality of seed, especially if the treatment was given under conditions favourable for rapid growth, or if the substance used was a compound of 2,4-D.

5. The effects caused by similar amounts of artificial hormones applied on the sunny morning or on the evening of the same day did not show any differences with regard to the amount of yield.

6. In the spraying experiment, in which the amount or the quality of yield of oil flax was not injuriously affected by a treatment with 2M-4K, applied at the rate of 0.5—2 kg. per hectare, many of the weeds occurring in the experimental area were killed or lost their seeding capacity. Thus a treatment with 1 kg. of 2M-4K was sufficient for *Chenopodium album, Erysimum cheiranthoides* and *Galeopsis sp.* The seed crop of *Polygonum convolvulus, Spergula arvensis, Stellaria media* and *Viola arvensis,* which are considered rather resistant, was on the average reduced by a treatment with 1 kg. per hectare to $^1/_3$, by 2 kg. to $^1/_7$ of the average seed crop obtained from the comparable untreated plots, and their number decreased to $^1/_8$ and to $^1/_{25}$ of the untreated plot. Resistant were *Polygonum lapathifolium, Galium spurium* and *Fumaria officinalis.*

7. 1 kg. of the sodium salt of 2,4-D in aqueous solution resulted in more injurious effects than a comparable amount of 2M-4K given as *Agroxon,* if applied at cotyledon stage. At other stages it proved less effective than 2M-4K. If emulsifying oil was added to the aqueous solu-

tion of the sodium salt of 2,4-D, the effectiveness of the compound increased considerably. Owing to the added oil the compound also became more resistant to rainfall.

8. **At least in Southern Finland and in areas with similar climatic conditions artificial hormones seem to be of considerable importance with regard to weed control in oil flax cultivations. The best results are achieved by applying 1 kg. of 2M-4K per hectare at an early stage of development (3—13 cm.).**

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Suomenkielinen selostus

Maatalouskoelaitoksen kasvinviljelysosastolla Tikkurilassa ryhdyttiin professori Otto Vallen toimesta v. 1946 tutkimaan tekohormonien merkitystä rikkaruohojen torjunnassa. Kokeita on jatkettu vuosina 1947 ja 1948. Niissä on kiinnitetty päähuomio tekohormonien vaikutukseen eri rikkaruoholajeihin, varsinkin öljypellavalla tavattaviin siemenrikkaruohoihin. — Tekohormonit ovat keinollisesti valmistettuja orgaanisia yhdisteitä, jotka vaikuttavat kasveissa tavattoman pienissä määrin esiintyvien hormonien (auksiinien) tavoin, mutta joita ei ole tavattu kasveissa. Tekohormonit tuhoavat sopivan suuruisina määrinä annettuina useat rikkaruohot, mutta eivät yleensä vaikuta haitallisesti viljakasvien kasvuun eivätkä satoon, mikäli levitys on suoritettu viimeksi mainittujen ollessa nuorella kehitysasteella. Kaikki ruohomaiset kasvit eivät kuitenkaan ole yhtä herkkiä tekohormoneille. Niinpä eräät rikkaruohot tuhoutuvat varsin helposti jo ½ kg/ha suuruisella tekohormonimäärällä, kun taas eräät toiset lajit eivät tuhoudu edes 2 kg/ha suuruisella määrällä. Samankin kasvilajin kestävyys tekohormoneja vastaan saattaa kuitenkin huomattavasti vaihdella, riippuen mm. sen kehitysasteesta, kasvunopeudesta sekä käytetystä valmisteesta. — Ruohomaisista viljelykasveista öljypellava kestää melko hyvin metoksoni-tyyppisiä tekohormoneja, joilla niin ollen voidaan torjua rikkaruohoja öljypellavaviljelyksiltä. On vain selvitettävä, kuinka suuria määriä öljypellava normaalioloissa kestää tekohormoneja ilman että sen sadon määrä pienenee tai laatu huononee, ja toisaalta, kuinka pienillä määrillä rikkaruohot saadaan tuhotuiksi. Käsillä olevan tutkimuksen tarkoituksena on selvitellä lähinnä kysymyksen ensimmäistä osaa, ts. miten öljypellava kestää eri kehitysasteilla ollessaan eri suuria tekohormonimääriä. Tutkimukset on suoritettu Maatalouskoelaitoksen kasvinviljelysosastolla kasvukauden 1948 kuluessa.

Seuraavassa yhteenvedossa esitetään saavutetuista tuloksista lähinnä käytännön maanviljelijää kiinnostavat seikat, jotka hänen on syytä ottaa huomioon ryhtyessään tekohormoneilla torjumaan rikkaruohoja öljypellavaviljelyksiltään.

Ensiksikin mitä valmistetyyppiin tulee, *ovat 2M-4K- eli metoksoni-valmisteet* (esim. *Agroxone* ja *P 46) ehdottomasti suositeltavampia kuin 2,4-D-valmisteet,* jotka saattavat vaikuttaa hyvinkin haitallisesti öljypellavan siemen- ja varsisadon määrään sekä siemensadon laatuun (ss. 17, 25—26). Tekohormonien käytössä on myös erittäin tärkeätä ottaa huomioon, että käsittely suoritetaan oikeaan aikaan, sekä että tehoavaa ainetta käytetään sopiva määrä. *Suositeltavin käyttömäärä on 1 kg/ha tehoavaa ainetta* (= 10 litraa esim. *Agroxone*a tai *P 46*-valmistetta) ruiskutettuna 700—1 000 litrassa vettä. Tämä määrä on yleensä myös riittävä useimpien rikkaruoholajien tuhoamiseksi (ss. 38—40). Öljypellava kestää 2M-4K-tyyppisiä tekohormoneja parhaiten *nuorella kehitysasteella*, sts. sen ollessa 3—13 cm:n mittaista. Tosin tällöinkin käsitellyt kasvustot taipuvat, niiden väri vaalenee ja pituudenkasvu hidastuu, mutta ne ovat ohimeneviä ilmiöitä, jotka eivät vaikuta haitallisesti lopullisen sadon määrään eivätkä laatuun (ss. 13—27). Jos käsittely suoritetaan sirkkalehtiasteella (2.5—3 cm), kasvusto kärsii enemmän kuin hiukan myöhemmillä kehitysasteilla. Tämä ilmenee mm. kasvuston harvenemisena ja voimakkaampana taipumisena (ss. 13—14, 19—20, 22). Sadon määrään sirkkalehtiasteellakaan suoritettu käsittely ei kuitenkaan vaikuta haitallisesti. Liian myöhään, sts. *nuppuasteella tai hiukan ennen sitä suoritettu käsittely sen sijaan saattaa vaikuttaa erittäin haitallisesti siemensadon määrään ja laatuun* (ss. 17—18, 25—27). Näin ollen *käsittely on varminta suorittaa heti sirkkalehtiasteella tai viimeistään kun öljypellava on kasvanut 13 cm:n mittaiseksi.*

Öljypellavan rikkaruohontorjunnan kannalta on mitä edullisinta, että käsittely tekohormoneilla voidaan suorittaa jo kehityksen alkuvaiheessa. E n s i k s i k i n öljypellavakasvustot saadaan vapautumaan rikkaruohoista hetkellä, jolloin öljypellava hidaskasvuisena ja erittäin huonosti varjostavana saattaa helpoimmin joutua rikkaruohojen tukahduttamaksi. T o i s e k s i öljypellavalle jää rikkaruohojen kuoltua käytettäväksi enemmän kasvinravintoaineita ja vettä. Varsinkin viimeksi mainitun puute matalajuurisen öljypellavan ollessa nuorella kehitysasteella saattaa vaikuttaa erittäin haitallisesti sen kehitykseen. Näin ollen tekohormoneilla käsiteltyihin kasvustoihin kehittyvien kukkien lukumäärä, joka määräytyy jo varsin aikaisessa kehitysvaiheessa, tulee, samoin kuin siemensatokin, suuremmaksi kuin rikkaruohojen varjostamissa kasvustoissa. K o l m a n n e k s i, kun käsittely suoritetaan öljypellavan ollessa nuorella kehitysasteella, suurin osa ruiskutteesta tulee käytetyksi rikkaruohojen torjuntaan. Tällöin nimittäin ruiskutetta leviää enemmän rikkaruohojen lehdille ja maahan, jossa sen rikkaruohoja tappava vaikutus yleensä kestää parin kuukauden ajan, kuin jos ruiskutus tapahtuisi myöhemmin öljypellavan ollessa rehevämpää.

Tekohormonien käyttö öljypellavaviljelyksien rikkaruohontorjunnassa on kaikesta päättäen menetelmä, joka on omiaan lisäämään öljypellavan viljelyvarmuutta. Kun rikkaruohot saadaan pidetyksi kurissa, öljypellavan kasvuolosuhteet paranevat, josta johtuen sen sato saattaa, rikkaruohojen runsaudesta ja koosta riippuen, oleellisesti lisääntyä. Suoritettujen kokeiden perusteella näyttää myös siltä, että 2M-4K-tekohormonit em. sopivilla kehitysasteilla ja sopivan suuruisina määrinä annettuina *kykenevät kiihottamaan öljypellavan kasvua ja siten lisäämään öljypellavan siemensatoa* keskimäärin 175 kg/ha eli 15 % (ss. 17, 27).