EFFECT OF NON-HERBICIDAL SPRAYS OF 2,4-DICHLOROPHENOXYACETIC ACID ON THE GROWTH AND DEVELOPMENT OF BEAN PLANTS

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EFFECT OF NON-HERBICIDAL SPRAYS OF 2,4-DICHLOROPHENOXYACETIC ACID ON THE GROWTH AND DEVELOPMENT OF BEAN PLANTS

By

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CONTENTS

INTRODUCTION

The effect of growth substances has become a field of major interest in horticultural research. In a comparatively short time application of growth substances has been found to be of importance in various phases of the horticultural practice, and additional practical uses of the substances might be found when better knowledge of their functions is obtained.

In the following is presented a study of plant growth subsequent to spraying with non-herbicidal solutions of 2,4-dichlorophenoxyacetic acid. The purpose of the study is to observe responses which might indicate the function of this substance in the plant.

To facilitate the terminology, the term 2,4-D is used in the following for 2,4-dichlorophenoxyacetic acid and its common derivatives.

Review of Literature

Among a series of phenoxy compounds with the property of being able to stimulate plant growth, Zimmerman and Hitchcock (20) classified 2,4-D as a very potent growth regulator. Hamner and Tukey (4) and Mitchell and Marth (8) introduced this substance for use as a selective herbicide at a concentration of 1000 p.p.m. in water. When applied to the plant it enters into the tissues very

rapidly. According to Weaver, Minarik, and Boyd (18) the maximum amount of the substance enters the plant within six hours after treatment. Swanson (14) has demonstrated that the action of 2,4-D is systemic. The substance or a factor stimulated by it, travels some distance through the plant and induces what Beal (1,2) calls a telemorphic response. This response has been studied by several workers. Tukey, Hamner, and Imhofe (15) found that cell division was greatly increased in all cambial zones and phloem regions of the stem and rhizome of bindweed. Working with kidney bean plants Swanson (14) reports similar results.

The effect of 2,4-D is found to be influenced by the metabolic activity of the plant. Work by Beal (3) and Mitchell and Brown (10) indicates that the substance or a factor is associated with the translocation of organic material from active photosynthetic regions. When 2,4-D was applied to the cut surface of the second internode of decapitated bean plants, there was found much less response in the lower parts of the plant than when the substance was applied to the base of the blades of the primary leaves. These findings are in line with reports concerning the influence of light and temperature on the effect of 2,4-D, so far as these factors influence metabolic activity and solute translocation in the plant.

Marth and Davis (7) found that the action of 2,4-D was greatly increased by a rise in the temperature, and Weaver and DeRose (17) found much less stem curvature of shaded bean plants as compared to plants exposed to sunlight.

On the other hand, 2,4-D itself is found to influence the metabolism of the plant. Mitchell and Brown (9) sprayed plants of annual morning-glory with a solution of 1000 p.p.m. of 2,4-D and found that readily available carbohydrates (sugars, starch, and dextrin) were essentially depleted within a period of three weeks. Sugars in treated plants at first increased above the amount in the untreated ones, and they were nearly depleted during the second and third week after the treatment. Smith, Hamner and Carlson (13) studied chemical changes in bindweed also sprayed with a herbicidal concentration of 2,4-D. They found an initial rise in sugars (total) as per cent of dry weight in treated leaves before any corresponding drop in the starch-dextrins fraction. The trend was reversed, however, after the first four days, and was followed by a drop in both carbohydrate fractions and total nitrogen as the leaves became chlorotic and wilted. Changes in total sugars and starch-dextrins in the stem were similar to those in the leaves, though neither the initial increase nor final decrease was so large. The nitrogen content,

however, increased significantly above the control as would be expected from histological evidence of meristematic activity in the stem. There was, likewise, an initial rise in total sugars in the roots and rhizomes of treated plants, followed by a decrease, and an increase in total nitrogen paralleling the increasing meristematic activity.

These findings would indicate that 2,4-D causes a change in the metabolism of the plant. Leaf reserves seem to be quickly mobilized and translocated or consumed, while, on the other hand, the increasing nitrogen content and meristematic activity observed in the root following treatment indicates accelerated synthesis of proteins and growth in this part of the plant.

Statement of the Problem in the Present Study

Decreased rate of growth of the top of bean plants after treatment with 2,4-D has been found by Weaver (16) to be closely correlated with the amount of substance applied. When 2,4-D is applied in low concentrations one might, therefore, expect a less pronounced effect on the metabolism than by application of herbicidal concentrations. However, any change in the metabolism will influence the subsequent growth and development of the plant. The main object of this study is to observe, describe and measure characteristics of the growth and

development of plants treated with small amounts of 2,4-D.

Emphasis is placed upon: (1) to determine if the treatment causes a change in the chemical composition of the plants, (2) to determine if the treatment will cause a change in the rate of growth of the different parts of the plant, and (3) to observe the effect of the treatment on flowering, fruiting, maturing, and the yield of the plant.

MATERIALS, METHODS, AND RESULTS

A certified strain of red kidney bean obtained from Ferry-Morse Seed Company was used in this study. Experiments were carried out both with plants grown under greenhouse conditions during the spring and plants grown under field conditions in the summer. The greenhouse experiment was primarily concerned with part (1) and (2) of the problem, while the field experiment was thought to give the most reliable information concerning the last part.

Greenhouse Experiment

Seed was selected for uniformity and planted in four inch pots on March 27. Four seeds were planted in each pot. The pots contained equal amounts of a soil mixture consisting of equal parts of composted soil and sand, thoroughly mixed so as to give a uniform growing medium. At intervals throughout the experimental period an equal amount of a dilute and complete nutrient solution was applied to each pot. The moisture content of the soil was kept as equal as possible in the different pots, partly by means of placing the pots in a layer of peat moss. The temperature in the greenhouse varied between 65 and 80 degrees F.

The seed germinated April 2, and April 7 the seedlings were thinned to two plants per pot. The pots were then arranged in seventeen rows of eight pots each across the greenhouse bench. The plants were highly uniform. On April 17 when the first trifoliate leaves were expanding, five rows were sampled at random for chemical analysis. On the same day six rows were sprayed with a water solution of 10 p.p.m. of the sodium salt of 2,4-D using a commercial herbicide consisting of 70% of 2,4-dichlorophenoxyacetic acid and 30% sodium bicarbonate. Upon dissolving in water the sodium salt of 2,4-D is formed. The solution was acidified with one gram of citric acid per liter thus increasing the activity of the substance (6). The solution was applied as a very fine mist by means of an atomizing nozzle, and the leaves were wetted completely on both sides. After drying, the treated plants were arranged in alternating rows among the untreated ones.

On April 29, twelve days after the treatment, five treated and five untreated rows were sampled for final chemical analysis. The remaining plants were repotted in eight inch pots and kept for further study of the development.

The sampled plants were divided into: (1) Roots and epicotyl, (2) first internode, (3) primary leaves, and (4) tops, including all parts above the node of the primary leaves.

Fresh weight was recorded immediately upon sampling. Roots were washed free from soil particles by rinsing in tap water and dipping for a few seconds in a saturated solution of sodium chloride, dried in tissue paper and weighed. Fresh weight was recorded separately for each row.

Dry weights were recorded after drying in forced draft at 80-85 degrees C. Dry weights of the different plant parts were recorded for treated as a whole and untreated as a whole.

The dried material was ground in a Wiley mill, redried and kept in a desiccator. Aliquots were taken for determination of ash, Ca, P., protein, ether extract and crude fibers. The methods of A.O.A.C. (12) were followed. Ether extract and crude fibers, were determined in order to calculate nitrogen-free extract. This fraction will, according to Morrison (11), include the more soluble carbohydrates, such as starch, the sugars, the hemicelluloses, and the more soluble part of the cellulose and the pentosanes. Per cent of water ash, protein, fibers, and ether extract were merely added together and the sum subtracted from 100. The difference is given as per cent nitrogen-free extract.

The data for fresh weight are given in table 1 and 2, and for dry weight and chemical constituents in table 3.

Table 1. Fresh weights in grams per 10 plants of kidney bean at the time of spraying with a solution of 10 p.p.m. of the Na-salt of 2,4-dichlorophenoxy-acetic acid (April 12) and twelve days later (April 28).

Plant part	April 17	April 28	
		untreated	treated
Roots	40,5	81,6	94,4
First internode	8,2	9,4	9,8
Primary leaves	41,4	42,5	44,5
Top	23,0	87,6	61,8
Total	113,1	221,1	210,5

Table 2. Fresh weights in grams per row (16 plants) twelve days after spraying with a solution of 10 p.p.m. of a solution of the Na-salt of 2,4-dichlorophenoxyacetic acid.

Row	Roots		Tops	
	untreated	treated	untreated	treated
1.	128,0	165.0	112,0	102,0
2.	115,0	156,0	121,0	99,0
3.	129,0	125,0	183,0	91,0
4.	152,0	153,0	153,0	100,0
5.	149,0	156,0	130,0	103,0

Table 3. Per cent of fresh weight and total weight in grams per 10 plants of dry weight, ash, Ca, P, protein, and N-free extract at the time of spraying with a solution of 10 p.p.m. of the Na-salt of 2,4-dichlorophenoxyacetic acid (April 17) and twelve days later (April 28).

	April 17 Initial Check		April 28			
			untreated		treated	
	%	grams	%	grams	%	grams
Dry weight						
Roots	7,2	2,86	9,9	8,08	10,0	9,44
First int.	9,9	0,81	17,2	1,62	17,2	1,69
Pr. leaves	10,4	4,31	11,9	5,06	12,4	5,52
Top	12,5	1,56	14,7	12,88	15,1	9,34
Ash						
Roots	1,19	0,482	1,58	1,288	1,76	1,663
First int.	1,57	0,129	1,64	0,154	1,72	0,168
Pr. leaves	1,69	0,701	1,92	0,817	1,99	0,886
Top	1,56	0,359	1,88	1,645	1,83	1,131
Calcium						
Roots	0,049	0,198	0,076	0,620	0,076	0,717
First int.	0,034	0,028	0,063	0,059	0,051	0,050
Pr. leaves	0,162	0,648	0,234	0,995	0,223	1,037
Top	0,081	0,186	0,151	1,323	0,130	0,803
Phosphorus						
Roots	0,044	0,178	0,060	0,490	0,060	0,566
First int.	0,042	0,034	0,053	0,050	0,053	0,052
Pr. Leaves	0,061	0,253	0,054	0,230	0,056	0,249
Top	0,088	0,202	0,075	0,645	0,077	0,476
Protein						
Roots	1,62	0,656	1,40	1,142	1,47	1,388
First int.	1,57	0,129	1,09	0,102	1,11	0,109
Pr. leaves	3,07	1,271	2,11	0,897	2,20	0,979
Top	3,70	0,851	2,82	2,470	2,88	1,780
N-free extract						
Roots	2,16	0,875	4,57	3,729	4,54	4,286
First int.	3,00	0,240	8,83	0,830	9,22	0,904
Pr. leaves	4,06	1,681	5,92	2,516	6,25	2,781
Top	4,93	1,134	6,88	6,027	7,23	4,468

Results of the Greenhouse Experiment

The treatment of the young bean plants with a 10 p.p.m. solution of 2,4-D temporarily decreased the rate of top growth. The plants showed some epinasty which occurred a few hours after the treatment (fig. 1). They recovered, however, in a few days, and at the time of final sampling, there was only slight bending of stem and petioles (fig. 2). While the top of the treated plants showed less total growth twelve days after the treatment, there is an indication of larger root growth of treated plants in the same period, although an analysis of variance does not give a basis for a definite conclusion. It is, however, seen from table 2 that among the treated rows there is only one with a total fresh weight of roots not larger than any of the corresponding weights among the untreated rows.

These quantitative changes in the top-root relationship brought about by the treatment of 2,4-D is not found to be accompanied by any significant changes in the chemical composition of the different parts of the plant (table 3).

The plants which were left for further study started to flower about the first of May. At this time the treated plants were somewhat greener and some of the younger leaves of the treated plants showed an abnormal

development (fig. 3). They became dark green, mottled, dwarfed, and lanceolate, and felt thicker and stiffer than normal leaves. These leaves are henceforth referred to as abnormal leaves. There were three to five such leaves on each of the treated plants.

At the end of May there was a definite more vigorous growth of treated than of untreated plants (fig. 4). At harvesting time, in the middle of June, the treated plants had a significantly higher number of leaves per plant. There was found an average of 11,2 leaves per treated plant and only 6.6 leaves per untreated plant (exclusive primary leaves). This difference in number of leaves reflects the more extensive lateral growth of treated plants. Fig. 5 shows representative plants treated and untreated, from which all the leaves (with petioles) are removed. The better development of lateral branches from the second node of treated plants is very distinct. No weighings were made of roots and tops, but there is an indication that the weight relationship which was found twelve days after the treatment, was reversed at the time of harvesting.

On June 2, counts showed a better set of fruits on treated plants than on untreated. Of fruits which actually developed, however, there was not significantly more on treated than on untreated plants. (table 4).

Table 4. Average number and weight in grams per plant of pods and seeds of 14 untreated plants and 12 plants sprayed with a solution of 10 p.p.m. of the Na-salt of 2,4-Dichlorophenoxyacetic acid.

Plants	No. of pods	Weight of pods	No. of seeds	Weight of seeds
Untreated	3,2	9,6	10,2	7,4
Treated	4,1	10,6	11,6	7,6

A very striking difference due to the treatment was found in the time of maturing. While the untreated plants turned yellow at the beginning of June, the treated ones kept the green color for about two weeks longer. The pods were not harvested until they were completely dry and shriveled. On June 14 all pods on untreated plants were harvested, while the harvest of the pods of the treated plants was not completed until June 28 and even at that date some pods had to be removed in the green stage (table 5).

Table 5. Number of fully ripe pods of 14 untreated plants and 12 plants sprayed with a solution of 10 p.p.m. of the Na-salt of 2,4-dichlorophenoxyacetic acid.

Plants	June 14	June 23	June 28	Total
Untreated	45	0	0	45
Treated	7	30	12	49

The observations concerning yield and time of harvesting were made on a comparatively small number of

plants (12 treated and 14 untreated). This phase of the problem was, therefore, followed up more closely in the field experiment. The better growing conditions in the field were expected to give more reliable results.

Field Experiment - Methods and Results

Seed selected for uniformity was planted in the field on May 31. The soil was a fertile sandy loam. The seed germinated in about one week, and on June 17 the plants were thinned to about one foot.

On June 24 when the first trifoliate leaf was expanding, the plants were sprayed with an acidified solution of the same commercial preparation of 2,4-dichlorophenoxyacetic acid as used in the greenhouse experiment. Three different concentrations: 1, 10, and 100 p.p.m. were used and six replications as seen from the following field map. There were 30 plants in each plot. A two-gallon air compressor sprayer was used for the treatment. Only the upper side of the leaves became fully wetted.

Field Map

Block 1	Block 2	Block 3
0	III	II
III	0	I
II	I	0
I	II	III
0	III	II
III	0	I
II	I	0
I	II	III

Plots: 0 = control
I = 1 p.p.m. 2,4-dichlorophenoxyacetic acid
II = 10 p.p.m. ---
III = 100 p.p.m. ---

Each plot consists of two rows with 15 plants in each row.

The day after treatment the plants in the 100 p.p.m. plots showed pronounced epinasty (fig. 6), while only slight epinasty was observed in 10 p.p.m. plots and none at all in the 1 p.p.m. plots. The growth of the plants in the plots receiving the 100 p.p.m. solution was markedly inhibited by the treatment, and even though the plants recovered, they never became as vigorous as the plants in any of the other plots. The 10 p.p.m. solution caused only slight decrease in top growth for a short period after the treatment, and the plants became later on as vigorous as the untreated ones. No effect upon growth was observed after treatment with the 1 p.p.m. solution.

At the beginning of July abnormal leaves developed in the 100 p.p.m. plots, five to ten leaves on the lower lateral branches took on an appearance as described for abnormal leaves in the greenhouse experiment. In the 10 p.p.m. plots only a few plants developed abnormal leaves.

At the middle of July flowering began in the control plots, the 1 p.p.m. plots, and the 10 p.p.m. plots. In the 100 p.p.m. plots flowering was markedly delayed. At the end of July the growth, however, seemed to be somewhat accelerated in the 100 p.p.m. plots, no more abnormal leaves were developed, and flowering was initiated (fig. 7.).

At the time this thesis has to be completed (beginning of August) the plants are in the middle of the fruiting stage, and, therefore, no data on yield or earliness can be given.

Chemical Studies of Leaf Composition

On July 1 samples were taken from the field grown plants in order to determine if the treatments had any influence upon the content of ascorbic acid, chlorophyll, and carotene of the leaves. The first trifoliate leaf from five plants in each plot, giving a total of 30 leaves per treatment, was sampled in the morning. The samples were immediately brought to a cold storage in glass jars lined with moist filter paper, and were

weighed and macerated. Ascorbic acid was determined within half an hour after maceration. The method given by Lucas (5) was followed. The chlorophyll and carotene content were determined in the afternoon after the methods of A.O.C.A. (12).

On July 7 the same procedure of sampling and determinations was repeated, this time using the second trifoliate leaf of the same plants. Results of the determinations at both dates are given in table 6.

Table 6. Fresh weight of leaves and mgs. of ascorbic acid, carotene, and chlorophyll per 100 grams of fresh leaf tissue at two different dates after spraying with various concentrations of the Na-salt of 2,4-dichlorophenoxyacetic acid.

Sample	Fresh weight of 10 leaves	Mgs. per 100 g.		
		asc. acid	carotene	Chlorophyll
July 1				
Control	2,90	133,0	8,0	144,0
1 p.p.m.	3,50	125,0	7,0	144,0
10 p.p.m.	3,40	64,0	8,0	144,0
100 p.p.m.	2,50	68,0	6,5	122,0
July 2				
Control	4,00	123,5	5,9	135,0
1 p.p.m.	4,30	72,8	5,2	130,0
10 p.p.m.	4,25	72,0	6,0	136,0
100 p.p.m.	2,40	65,2	4,4	112,0

As seen from table 6, there seems to be an increase in the fresh weight of leaves after the 1 and 10 p.p.m. treatment as compared to 100 p.p.m. and untreated. It

should be noted that none of the leaves sampled had abnormal appearance and all were fully expanded. The content of ascorbic acid seems to be decreased even after 1 p.p.m. treatment, while carotene and chlorophyll is not affected by concentrations as high as 10 p.p.m. The treatment with 100 p.p.m. has, however, markedly decreased the content.

On July 28, 50 normal and 50 abnormal leaves in the 100 p.p.m. plots were sampled, one leaf of each from the same plant. The leaves were taken in the early afternoon on a bright, sunny day, and from nearby positions on the plant in order to have as little difference in age of the leaves as possible. The samples were brought to the laboratory in moist glass jars within half an hour after sampling, weighed, and killed at 100 degrees C for one hour. Drying was made with forced draft at 80-85 degrees C for 24 hours and the dry weight was recorded immediately after the drying process. After redrying at 110 degrees C, aliquots were weighed for determination of total sugars, starch, protein, and ash. For the determination of sugars and starch a modification of the official method of the A.O.A.C. developed at the Department of Agricultural Chemistry at M.S.C., was used. The other constituents were determined by the official methods of the A.O.A.C. Results are given in table 7.

Table 7. Fresh and dry weight of leaves and per cent of dry weight of ash, total sugars, starch and protein, of normal and abnormal leaves after spraying with a solution of 100 p.p.m. of the Na-salt 2,4-dichlorophenoxyacetic acid.

Leaves	Fresh weight of 10 leaves	Per cent dry weight	Per cent of dry weight			
			ash	Tot.sug.	starch	prot.
Abnormal	2,07	9,3	20,9	2,6	5,3	23,7
Normal	2,84	10,8	17,7	3,7	9,8	21,8

As seen from table 7 there is no great difference in the per cent of dry weight between normal and abnormal leaves; but the difference in the composition of the dry matter is very significant. The low carbohydrate content in abnormal leaves might be due to inhibited photosynthetic activity, higher respiration, or more rapid translocation of the synthesized material.

DISCUSSION

Weaver (16) sprayed 14 day old bean plants with solutions of different concentrations of 2,4-D of which the lowest one will roughly compare to the concentration of 10 p.p.m. He found a decreased rate of growth of the top after the treatment, while the growth of the roots was only slightly increased in kidney bean plants, but significantly increased in soybean plants for a period after the treatment. Although not proved conclusively, there is an indication of increased root growth after the treatment with low concentrated sprays of 2,4-D. Such a development would be brought about if the downward translocation of organic solutes was accelerated. Smith et al. (13) have already suggested that 2,4-D is able to stimulate the activity of the phloem tissue in solute translocation. Low carbohydrate content in some of the leaves of treated plants, as found in this study, would suggest that this effect on translocation is the principal one. However, a decreased chlorophyll content as found after treatment with a solution of 100 p.p.m. of 2,4-D indicates that also an inhibition of the photosynthesis might play a role.

The change in the metabolism brought about by the treatment with 2,4-D seems, on the basis of the present study, to have a secondary effect on the axillary growth

and the time of maturity of the plant. This effect of 2,4-D is not found to have been reported before, although Weaver (16) mentions delayed and decreased pod production. The opposite effect, hastening of maturity, is reported by Wittwer and Murneek (19) who sprayed snap beans in the flowering stage with different growth substances, among which was 2,4-D. This difference in response might be due to difference in age of the plants and tissue involved. In the case of the snap beans the effect seems to be a direct one on the growth of the ovary, while in the present study the effect is an indirect one following stimulated axillary growth.

Any practical significance of delayed maturity is not clearly seen unless it will cause increased yield of the plants. On basis of the greenhouse experiment in the present study there is no evidence that this is the case. The increased axillary growth gave rise to more leaf surface, flowers, and fruit sets. However, many of the fruits did not develop into seed bearing pods and the yield was not increased as compared to untreated plants.

SUMMARY

1. The effect of non-herbicidal sprays of 2,4-dichlorophenoxyacetic acid on red kidney bean grown under greenhouse conditions as well as under field conditions is studied.

2. 10 p.p.m. of the sodium salt of 2,4-dichlorophenoxyacetic acid had no appreciable effect on the percentage of fresh weight of water, ash, Ca, P, Protein and N-free extract of the plants grown in the greenhouse.

3. The treatment decreased for a period the rate of top growth but seemed to increase the root growth, although this result is not conclusive.

4. The treatment was found to stimulate lateral growth of the plants. Evidence is the increased length of lateral branches (fig. 5).

5. The treatment was also found to delay maturity of the plants. The ripening of the pods and the yellowing of the leaves occurred from 10 to 14 days later in the case of treated plants as compared to untreated plants.

6. In the field experiment the treatment with 10 p.p.m. of 2,4-dichlorophenoxeacetic acid did not decrease the rate of top growth to any extent; while treatment with 100 p.p.m. inhibited top growth for a considerable length of time.

7. The treatment with 10 and 100 p.p.m. of 2,4-dichlorophenoxyacetic acid decreased the content of ascorbic acid of the leaves, and the treatment with 100 p.p.m. decreased the content of carotene and chlorophyll.

8. No data are given concerning yield and time of maturity in the field experiment.

9. A proposed action of 2,4-dichlorophenoxyacetic acid upon the translocation of available carbohydrates seems to yield an explanation for the responses to the treatment observed in this study.

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Fig. 1. Plants to the left the day after spraying with a solution of 10 p.p.m. of the Na-salt of 2,4-dichlorophenoxyacetic acid. Plants to the right are untreated.

Fig. 1.

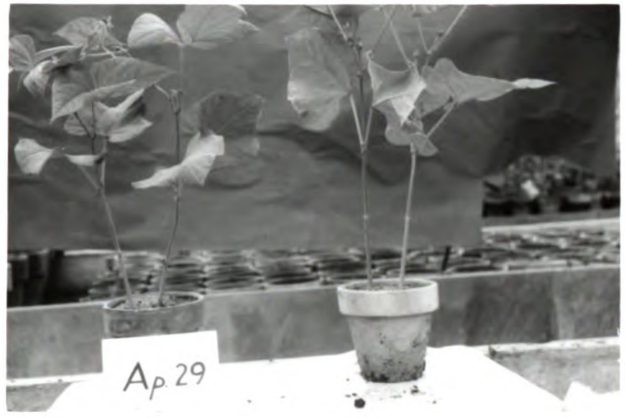

Fig. 2. Plants to the left twelve days after spraying with a solution of 10 p.p.m. of the Na-salt of 2,4-dichlorophenoxyacetic acid. Plants to the right are untreated.

Fig. 2.

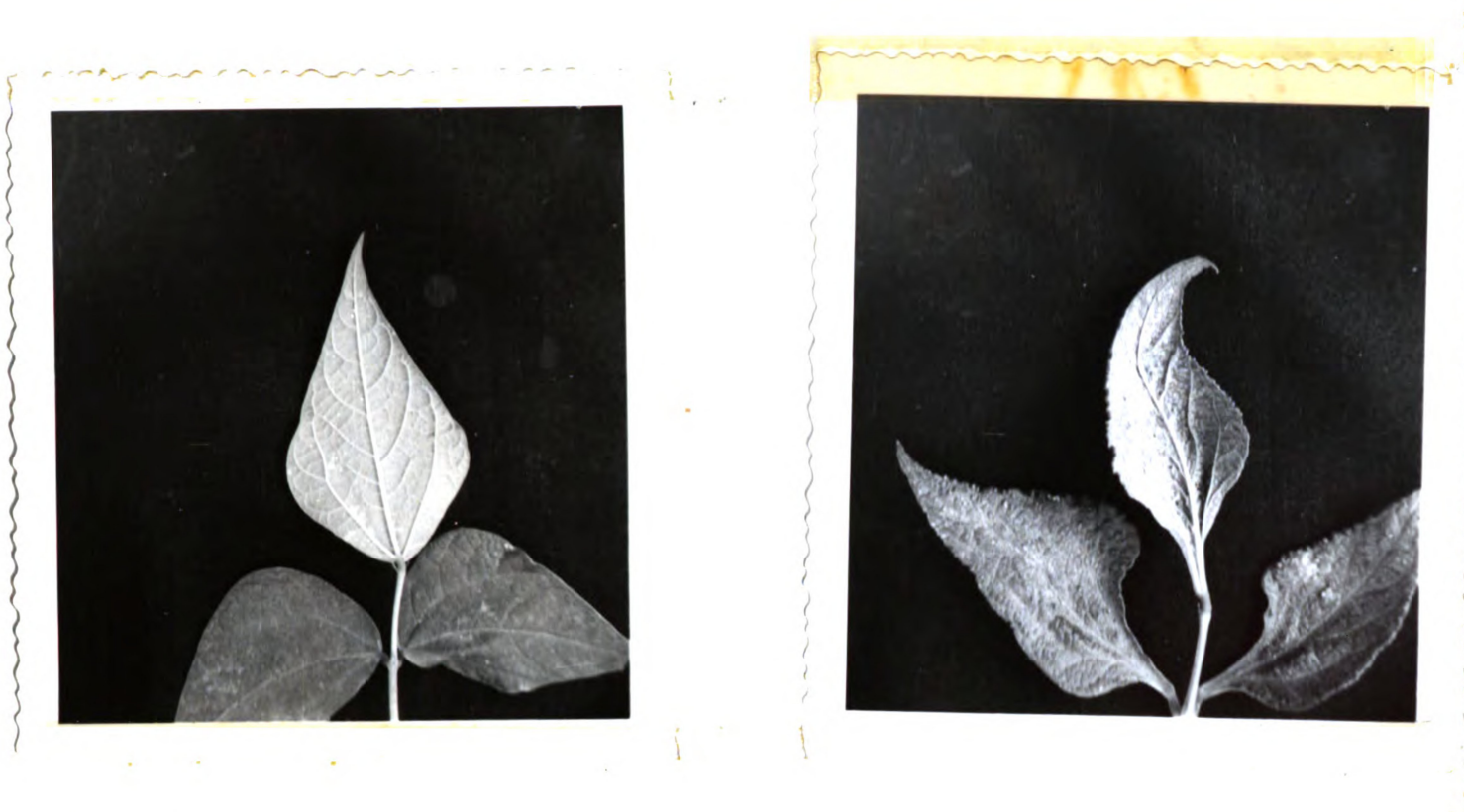

Fig. 3. To the left a normal bean leaf. To the right a leaf showing abnormalities due to treatment of the plant with 2,4-dichlorophenoxya cetic acid.

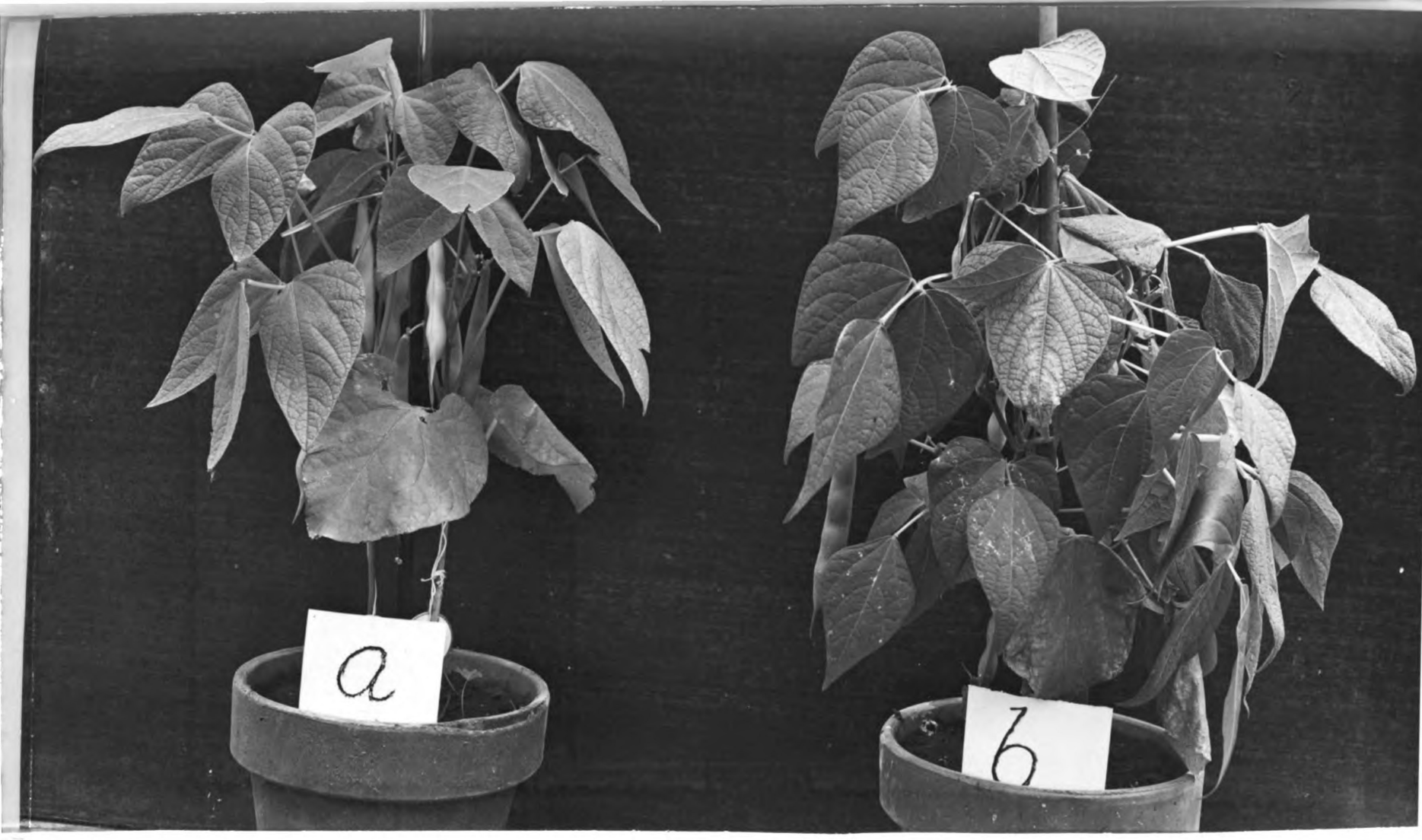

Fig. 4.

Fig. 4. a - untreated plants, b - plants treated with a solution of 10 p.p.m. of the Na-salt of 2,4-dichlorophenoxyacetic acid at the time the first trifoliate leaf was expanding.

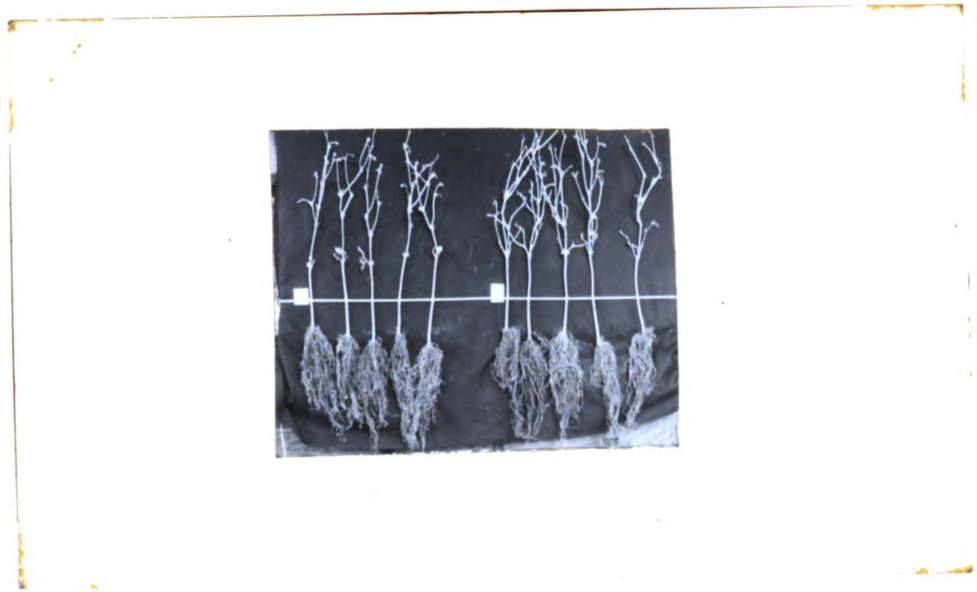

Fig. 5.

Fig. 5. To the left five untreated plants, to the right five plants sprayed with a solution of 10 p.p.m. of the Na-salt of2,4-dichlorophenoxyacetic acid at the time the first trifoliate leaf was expanding. On the above plants all leaves and petioles are removed to show the difference in axillary growth. The white line indicates the point of the cotyledonary node.

Fig. 6. Plants in the field experiment the day after treatment , to the left with a solution of 1 p.p.m., in the middle with a solution of 10 p.p.m., and to the right with a soluiton of 100 p.p.m. of the Na-salt of 2,4-dichlorophenoxyacetic acid.

Fig. 6.

Fig. 7.

Fig. 7. Plants in the field experiment on July 28., a - untreated, b - sprayed with a solution of 1 p.p.m., c - with a solution of 10 p.p.m.; and d - with a solution of 100 p.p.m. of 2,4-dichlorophenoxyacetic acid.