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Some Experiments on Polarity of IAA-2-C^{14} Transport in Helianthus annuus seedlings

by

HAYDAR BAĞDA

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Faculté des Sciences de l'Université d'Ankara
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Some Experiments on Polarity of IAA - 2 - C^{14} Transport in Helianthus annuus seedlings

HAYDAR BAĞDA

Botany Depoartment of the Science Faculty of Ankara University

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Radioactive IAA was applied to three weeks old Helianthus annuus seedlings at the very place where they had been grown, i. e. in pots in normal earth outdoors, in the greenhouse, or in the growing chamber.

It was shown by means of autoradiography that IAA has moved both basipetally and acropetally, whatever the applied plant organ may be. It was observed that neither the apical bud nor the leaves by means of transpiration had any first grade effect on IAA translocation. Bi - directional movement was observed even in cut off plant shoots.

INTRODUCTION

Studies on the translocation of auxin in plants are of great importance, because in the growth of plants the centers within the plant where auxin is produced and the directions of movement of the auxins which are produced in these centers play a dominant role in the correlative effects among the corresponding plant organs. There have been made a great deal of investigations on the production, transport, and effects of hormones in plants. In going through the various publications on these studies the general dominance of the point of view, that in the green plant auxin is produced in the apical buds and young expanding leaves of the shoots and is translocated from these centers to those of the elongation region of the stem and that the transport is always toward the physiological base of the tissue, is still striking.

As Mc. Cready (1966) has pointed out, the majority of experiments on polar transportation performed by other scientists were made on segments cut from plant organs, especially on short segments, but "it must be remembered that what is measured is the resultant of several processes occuring in the system, of which transport is only one. Interference with movement may occur at the cut surfaces of the segments where damaged cells are exposed."

On the other hand in earlier studies Bağda (1955), according to the effects of auxin on the buds, not only basipetal but also acropetal auxin translocation has been observed. But these earlier observations were only supported by indirect evidences.

The purpose of the following study is to research auxin translocation in plants in a more direct way.

MATERIALS AND METHODS

The experiments were made on two to three weeks old Helianthus annuus seedlings that were grown in small pots in normal earth. Some of the plants that were used for our experiments were grown in the open air in the garden, some in a greenhouse, and some in a growing chamber of 19 - 21°C temperature, 60 - 70 % humidity and under a fluorescent daylight lamp of 10 000 Lux. The illumination in the growing chamber was arranged in periods of 14 hours of light and 10 hours of darkness.

IAA was applied to the seedlings at the very place where they have been grown. The radioactive IAA that was used in the experiments has been received from the Radiochemical Centre in Amersham, being 3 - Indole (acetic acid - 2 - C^{14}).

The glass tube that was used for IAA application on the seedlings had a diameter of 0.5 cm. In order to render its tip capillary the gss tube was heatened over a glass flame and drawn so that a capillary tip of 0.5 - 1 mm was obtained. One drop that was dropped with this tip contained about $\frac{1 \text{ ml}}{200} = 0.005$ ml.

The epidermis of the cotyledone of the plant on which IAA was to be applied was a little damaged with a razor-blade at a

place far from the midrib and then one drop (about 0.005 ml) of radioactive IAA solution was applied on the injured place.

On the surfaces of cut stems IAA was directly dropped with the same capillary tipped glass tube.

After IAA application we have waited different periods of time. Then the excessive IAA was taken from the leaf or the stem with a blotting paper and the seedlings were immediately cut on earthlevel or if taken out of the pot with its root, the earth was cleaned off the roots and the seedlings were dried.

The seedlings, either cut or with their roots , were put each between a sheet of thin and thick paper in several layers in wood presses with cut holes and tied up firmly. They were immediately put into an electric drying oven of 105°C and left there for 2 - 3 hours.

Thus dried and flattened plants were laid in the darkroom on the chemical side of Kodirex x-ray films. As our films were rather old we let the plants lay on the film for two or in some cases three months. The films were then developed and in this way the translocation of the radio isotopes in the plant could be determined by autoradiography.

Our experiments can be summarized in three groups:

First group experiments.

IAA was applied by means of a capillary glass tube to one of the cotyledones. IAA was left there for various periods, then the plant was cut on earth level and dried immediately in the drying oven and put on the film for autoradiography.

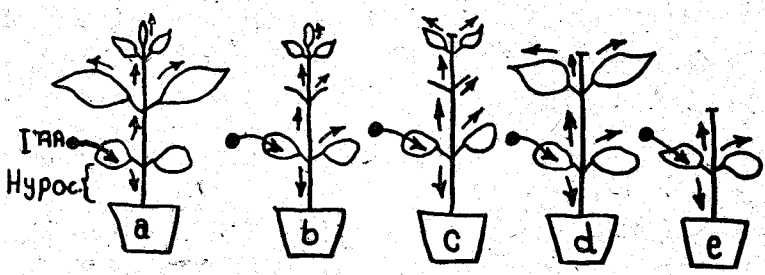

Figure 1. First group experiments

Table 1

First group experiments

Series	a	b	c	d	e	Minutes
Number of Experiment						
1	×	×	×	—	—	30 – 110′
" 2	×	×	—	×	×	120 – 150
" 3	×	—	×	×	×	30 – 40
" 4	×	—	×	×	×	30 – 40
" 5	×	—	×	×	×	30 – 40
" 6	×	×	—	×	×	2,3,4,5,6,7,8,′

As shown in diagrammatic figures the first group experiments were made with five series of plants (a, b, c, d, e).

a- The plants of the series a remained untouched, both before and after IAA application on the cotyledones.

b- Of the plants of the series b only the leaf blades of the first large leaves above the epicotyle were cut off just before IAA application.

c- Of the plants of the series c again the leaf blades of the first large leaves and the apex of the shoot were cut off just before IAA application.

d- At the plants of the series d only the large leaves above the epicotyle were left remaining, the shoot apex and young small leaves above that region were cut off just before IAA application.

e- At the plants of the series e only the epicotyle was left remaining, the shoot was cut off below the first large leave just before IAA application.

The series of plants with which experiments 1, 2, 3, 4, 5, and 6 of the first group were made are signed with the mark x on the diagrammatic figure. The time that IAA was allowed to translocate in the plant is shown in minutes in the last column of the list.

Plate 1: First group experiment d

Experiment 1 was made with three weeks old seedlings of the series a, b, and c grown in the greenhouse in 1965. The used radioactive IAA concentration was 50μg/ml.Consequently one drop of IAA that was applied to the cotyledone was containing $\frac{50\ \mu g}{200} = \frac{1}{4}\ \mu g$ IAA.

The length of the hypocotyle and the epicotyle, as well as the length of the stem until the apical bud of the plants that were used for this experiment are shown in cm in the following list, the time of application is shown in minutes in the last column of the list. So in series a, IAA was applied to the plant for 30 minutes, its hypocotyle being 9.0 cm long, its epicotyle plus length of the apical region until the apical bud being 3.5 cm.

Table 2

Experiment 1

Series	a	b		c		Minutes
Hypocot.	Epicot. + apic. reg.	Hypocot.	Epicot. + apic. reg.	Hypocot.	Epicot. + apic. reg.	
9.0 cm	3.5 cm	7.0 cm	3.5 cm	8.5 cm	5.0	30
7.0	3.0	6.5	5.0	9.0	4.0	40
8.0	4.0	10.0	5.0	8.0	8.0	50
6.5	5.0	7.5	7.5	7.0	7.0	60
8.5	3.5	8.5	3.5	6.5	6.0	70
8.0	5.0	8.5	6.0	10.0	4.0	80
9.0	3.5	7.0	4.5	7.5	4.0	90
9.5	7.0	9.0	6.0	8.0	9.0	100
6.5	5.0	7.0	5.0	8.0	4.0	110

As in this first experiment we did not know the speed of IAA translocation, the applied IAA was remaining with a difference of each 10 minutes from 30 minutes to 110 minutes. But in all the series (a, b, c) IAA was translocated within the plant both basipetally and acropetally even in the short period of 30 minutes. In the b series, although the real leaves over the epicotyle (the blade length being approximately 4 cm) were cut off, IAA was again tranlocated acropetally to the apical bud and until the stalk tips of the cut off leaf blades. This fact shows that transpiration does not play any role in the translocation of applied IAA. In the c series the apical bud being cut off as well as the leaves, we can see that neither the leaves nor the apical bud play a role in the acropetal translocation of IAA.

Experiment 2 was made with 20 days old seedlings that were grown in the greenhouse in May 1965, and was practiced in four series a, b, d, e. In this experiment the series a, b, and d were repeated as control plants, the main subject was concerning type e. Our aim was to find out whether IAA would be translocated until the decapitated epicotyle even if only the epicotyle was existing. The used IAA concentration was 50 μg / ml.

As seen in this experiment, in all series and also in the series e (although here only the epicotyle was existing) IAA has moved acropetally.

Table 3

Experiment 2

Series	a	b		d		e		Minutes
Hypoco.	Epico. + apic. reg.	Hypoco.	Epico. + apic. reg.	Hypoco.	Epico. + apic. reg.	Hypoco.	only Epico.	
7.0 cm	4.0 cm	9.0 cm	7.0 cm	10.0 cm	5.0 cm	12.0 cm	1.0 cm	120′
6.0	4.0	7.5	7.0	9.5	3.0	10.0	1.5	130
7.5	4.0	8.5	3.0	9.0	6.5	7.5	1.5	140
9.0	4.5	9.0	3.0	5.5	7.0	8.5	1.0	150

Table 4

Experiment 3

Series	a	b		d		e		Minutes
Hypoco.	Epico. + apic. reg.	Hypoco.	Epico. + apic. reg.	Hypoco.	Epico. + apic. reg.	Hypoco.	only Epico.	
4.5 cm	2.0 cm	5.0 cm	2.5 cm	3.0 cm	2.5 cm	6.0 cm	1.0 cm	30′
5.5	1.5	5.0	2.0	7.5	1.5	6.0	1.0	”
5.0	2.5	4.0	3.5	5.5	2.5	5.0	2.0	”
6.0	2.5	4.5	2.5	4.0	4.5	7.0	2.5	”
8.0	14.5	11.5	10.0	7.0	11.0	9.5	9.0	40′
7.0	3.5	8.0	3.0	6.0	3.5	6.5	1.0	”
5.5	2.0	5.5	2.5	5.5	2.5	5.5	1.5	”
7.0	9.0	8.5	10.5	6.5	14.5	8.0	3.0	”

Experiment 3 was made with 25 days old seedlings grown outdoors in pots in May/June 1965 and was practiced in four series a, b, d, e. IAA was applied to the plant in the open air. The used IAA concentration was 50μg / ml.

In this experiment IAA was again translocated both basipetally and acropetally, showing that outdoor conditions (especially sunlight) do not inhibit acropetal translocation.

Experiment 4 was made with 16 days old seedlings grown outdoors in pots in June 1965 and was practiced in series a, c, d, e. The used IAA concentration was 50 μg / ml.

In all the plants of these series IAA was again translocated both basipetally and acropetally.

Experiment 5 was made with 26 days old seedlings grown outdoors in pots in July/ August 1965 and was practiced in series a, c, d, e. The used IAA concentration was again 50 μg / ml.

In all the plants of these series IAA has again moved both basipetally and acropetally.

All the plants that were used for the following experiments were grown in pots in the growing chamber under artificial light of 10 000 Lux in 60–70 % relative humidity and a temperature between 17 to 21 °C .

Experiment 6 was made with 21 days old seedlings in December 1965. The aim of this experiment was to prove whether IAA moves at first basipetally and then acropetally or vice versa. The periods of application were kept very short. The used IAA concentration was 80 μg / ml.

The series a, c, d, e were used and in this experiment at the end of each period the plants were taken out of their pots with their roots, rapidly cleaned and dried, then left on the film for a period of two months. As seen in the above table, even in the shortest time of two minutes IAA has been translocated both acropetally and basipetally and has reached the root tips as well as the shoot tips. But it was not possible to determine which direction was the primary one.

Table 5

Experiment 4

Series a		c		d		e		Minutes
Hypoco.	Epico. + apic. reg.	Hypoco.	Epico. + apic. reg.	Hypoco.	Epico. + apic. reg.	Hypoco.	Only Epico.	
7.0 cm	3.0 cm	5.0 cm	4.0 cm	6.0 cm	4.0 cm	8.0 cm	5.0 cm	30′
8.0	5.0	5.0	5.0	8.0	4.0	10.0	2.0	”
9.0	7.0	10.0	6.0	6.0	5.0	9.0	5.5	”
8.0	3.0	6.0	5.0	8.0	6.0	7.0	4.5	”
8.0	4.0	12.0	6.0	9.0	3.0	10.0	7.0	40′
7.0	7.0	11.0	7.0	6.0	4.0	10.0	5.0	”
6.0	6.0	8.0	8.0	7.0	6.0	12.0	5.0	”
4.0	10.0	8.0	4.0	10.0	3.0	8.0	4.0	”

Table 6

Experiment 5

Series a		c		d		e		
Hypoco.	Epico. + apic. reg.	Hypoco.	Epico. + apic. reg.	Hypoco.	Epico. + apic. reg.	Hypoco.	Only Epico.	Minutes
6.0 cm	13.0 cm	9.0 cm	16.0 cm	5.5 cm	20.0 cm	8.0 cm	11.0 cm	30′
8.0	14.5	7.5	16.0	8.5	10.0	9.0	16.0	
6.5	13.5	8.5	13.0	8.0	15.0	5.5	14.0	”
6.0	11.0	7.5	7.0	7.5	11.0	8.0	12.0	”
4.0	16.0	8.0	13.0	7.0	11.5	5.5	9.5	”
9.5	7.5	8.0	9.5	15.5	2.0	7.5	10.0	40′
9.0	12.5	7.0	18.0	6.0	12.0	7.0	13.5	”
7.0	13.0	10.0	12.0	7.5	16.0	9.5	17.0	”
6.0	4.0	10.5	8.0	7.5	4.5	9.0	22.5	”

Table 7

Experiment 6

Series	a	c		d		e		Minutes
Hypoco. + root	Epico. + apic. reg.	Hypoco. + root	Epico. + apic. reg.	Hypoco. + root	Epico. + apic. reg.	Hypoco. + root	Only Epico.	
7.0 cm	4.5 cm	7.0 cm	1.0 cm	6.0 cm	2.5 cm	7.5 cm	3.5 cm	2′
7.5	5.0	6.0	3.5	7.5	3.0	6.1	2.0	”
7.0	3.5	6.0	7.0	7.5	3.0	5.5	3.0	”
4.0	3.0	4.5	5.5	4.0	2.5	5.0	5.0	3′
3.0	4.5	4.0	3.5	3.0	3.0	4.0	1.5	”
2.0	3.5	5.0	4.0	4.0	4.5	5.0	3.5	”
3.5	4.0	5.5	2.5	5.0	3.5	5.0	4.0	”
7.0	5.0	9.0	2.5	8.0	2.0	6.0	3.5	4′
6.5	3.0	6.0	1.0	6.0	2.5	5.0	2.0	”
6.0	2.0	6.0	3.0	7.5	3.5	6.5	3.0	”
4.5	4.5	3.0	4.0	4.0	5.0	4.0	2.0	5′
4.0	2.5	5.0	4.5	4.0	4.0	8.0	4.0	”
3.0	2.5	6.5	4.5	4.0	3.0	6.0	6.0	”
7.0	5.0	8.0	5.0	6.0	3.0	7.0	3.0	6′
7.0	4.0	5.5	1.0	7.0	5.0	6.0	4.0	”
8.0	4.0	7.0	2.5	8.5	4.5	5.0	1.5	”
5.5	3.0	6.0	4.5	6.0	4.0	5.0	7.0	8′
4.5	4.5	3.5	8.0	4.0	3.5	4.0	1.0	”
5.0	4.5	5.5	6.5	3.5	3.0	5.0	4.5	”
4.0	6.0	6.0	5.5	3.0	4.0	4.0	4.0	”

Second group experiments:

In the following experiments IAA was applied to organs after being removed from the plant.

Experiment 7 : The aim of this experiment was to investigate the basipetal and acropetal IAA translocation in removed living organs. From 19 days old Helianthus annuus seedlings that were grown in the growing chamber, only the hypocotyles and the epicotyles were cut off and put vertically on a support in the same room. There were practiced six series a, b, c, d, e, f. In all these series one drop of radioactive IAA of 80 μg / ml concentration was applied with a capillary glass tube.

In the series a and b it was applied on the epicotyle tip, in the series c on the cotyledones, in the series d, e, f the seedling was reversely fixed on the support, in the series d and e IAA was applied on the pyhsiological tip (the basis of the hypocotyle), whereas in the series f it was again applied on the cotyledones.The applied IAA was again left for short periods like 10, 20 and 30 minutes, the remaining of the applied drops was taken away with blotting paper and the plants were dried in 105 °C. The results were again observed by means of two months autoradiography.

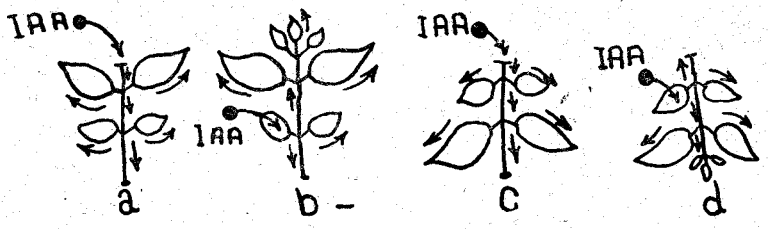

Figure 2: Second group experiments

In all the series it was observed that IAA has been translocated both basipetally and acropetally up to the tips of the removed organs. The fact that this observation could also be made in the series d, e, f is very striking.

Table 8

Experiment 7

Series a		b		c		d		e		f		
Hypo.	Epico.	Hypo.	Epico.	Hypo.	Epico.	Hypo.	Epico.	Hypo.	Epico.	Hypo.	Epico.	Minutes
2.5 cm	2.0 cm	4.5 cm	1.5 cm	5.0 cm	2.0 cm	5.0 cm	1.5 cm	1.5 cm	1.5 cm	3.0 cm	1.0 cm	10′
2.5	1.5	4.0	2.0	5.0	2.5	4.5	2.0	12.0	1.5	3.0	1.0	”
3.0	2.0	4.5	2.0	5.0	2.5	4.5	1.5	1.5	1.0	3.0	1.0	”
2.0	2.0	4.0	2.0	5.0	2.0	5.5	1.5	3.5	1.0	3.0	2.0	”
5.0	2.0	2.5	2.0	3.0	2.0	3.0	1.5	3.5	2.0	4.5	1.5	20′
4.5	2.0	3.0	1.5	3.5	2.0	3.5	2.0	3.0	1.5	4.5	1.0	”
5.0	2.0	2.5	1.5	3.5	1.5	4.0	2.0	3.0	2.0	4.5	1.5	”
4.5	2.5			3.0	2.0	4.0	1.5			5.0	2.5	”
		5.0	2.5	5.0	1.5			5.0	2.0	6.0	3.0	30′
		4.5	3.0	5.5	1.5			4.0	2.5	3.5	2.5	”
		4.5	3.0	5.5	1.0			4.5	2.0	5.5	2.0	”
		4.5	2.5	5.5	1.0			4.5	2.0			”

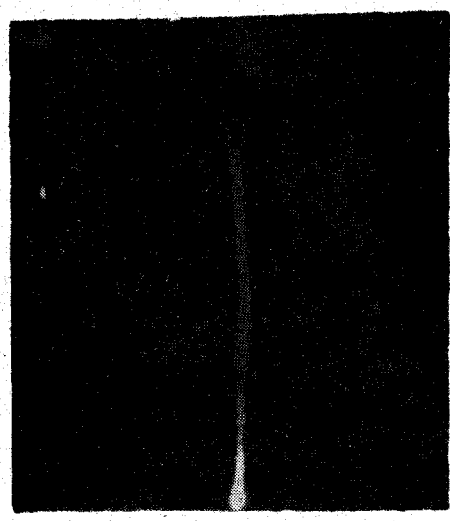

Plate 2 : Second group
experiment a

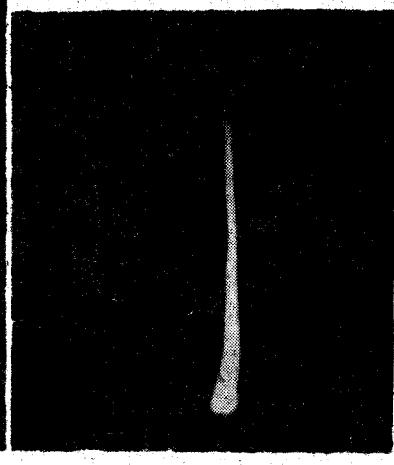

Plate 3 : Second group
experiment d

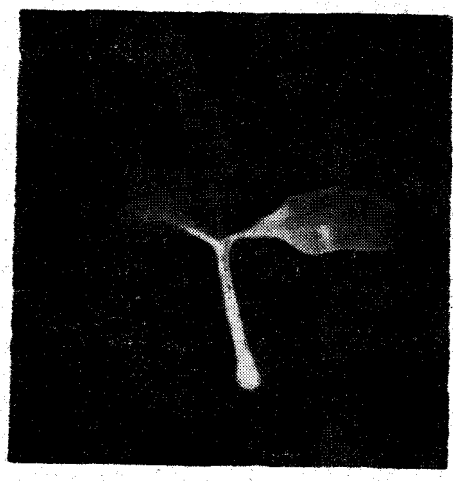

Plate 4 : Second group
experiment e

Experiment 8 was made with 24 days old seedlings that were grown in the same growing chamber in January 1966. They were cut on earth level, only the series a and c were decapitated, and in the same room the series a and b were fixed on a support in normal po-

sition, the series c and d were fixed reversely in vertical position. The peculiarity of this experiment is that in some of the seedlings leaves and apical buds were present. The used IAA concentration was 80 μg / ml.

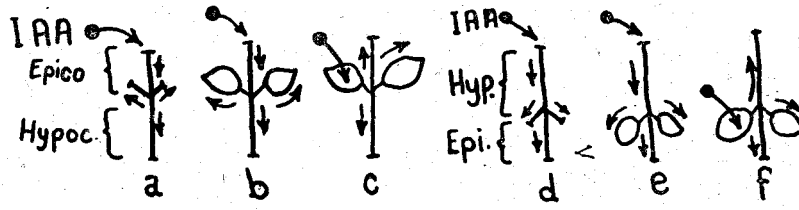

Figure 3: Second group experiments

In all the series IAA has moved both acropetally and basipetally up to the tips of the organs.

Third group experiments:

The peculiarity of this group is that each of the used seedlings had two shoots.

Experiment 9 was made in order to observe the translocation in seedlings each with a pair of shoots. One drop of IAA was applied by means of a capillary glass tube on a leaf of shoot I of 34 days old seedlings that were grown in pots in the growing chamber in December 1965.

The two shoots were obtained by cutting away the apical bud between the cotyledones. The roots of the seedlings in this group were not cut off. The used IAA concentration was 80 μg / ml.

Even after a period of only 10 minutes IAA has moved both acropetally to the apical bud of shoot I and basipetally to the two cotyledones and until the roots, and at the same time it has moved acropetally until the tip of shoot II.

Table 9

Experiment 8

Series	a	b		c		d		
Hypo.	Epico. + apic. reg.	Hypo.	Epico. + apic. reg.	Hypo.	Epico. + apic. reg.	Hypo.	Epico. + apic. reg.	Minutes
5.5 cm.	3.5 cm	5.0 cm	5.0 cm	3.5 cm	3.5 cm	4.0 cm	1.5 cm	20′
5.0	3.0	3.5	3.5	3.0	2.5	3.5	3.0	”
5.5	3.5	4.0	3.5	5.0	3.5	6.0	3.5	”
5.0	3.0	3.5	4.0	8.5	3.0	8.0	2.5	”
6.0	3.0	7.5	3.0	3.5	2.5	3.5	4.0	30′
3.0	4.0	7.0	4.0	3.5	3.0	4.0	4.0	”
4.0	4.0	7.0	3.5	4.0	2.0	3.5	3.0	”
3.0	4.0	8.5	3.0	4.5	3.0	5.0	2.5	”

Table 10

Experiment 9

Hypo. + root	Shoot I	Shoot II	Minutes
8.0 cm	5.0 cm	5.0 cm	10′
6.0	2.0	2.0	”
8.0	3.0	3.3	15′
10.0	2.0	2.0	”
9.0	1.0	1.5	20′
7.5	4.0	4.0	”
10.0	3.0	4.0	30′
6.0	3.0	3.0	”

Experiment 10 was made after having received the results of experiment 9 in the same type on a greater number of plants but under some varied conditions. All the plants in this experiment had again two shoots and their roots were preserved. The shoots in series a and b were equal in length, those in series c and d were difrent in length. In the series a, c, d, IAA was applied to a leaf of one of the shoots, in the series b IAA was applied to one of the cotyledones. The used IAA concentration was 80 μg/ml.

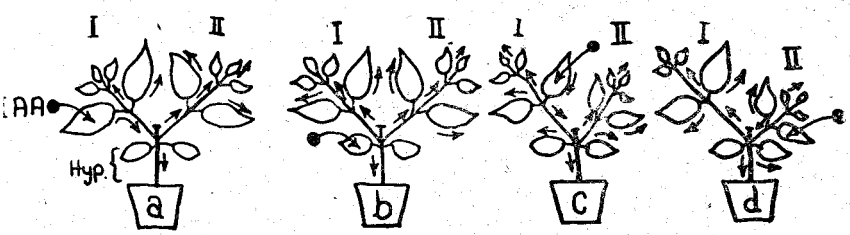

Figure 4: Third group experiments

Wherever IAA was applied in all series even within 10 minutes it was translocated until the roots and the tips. The series of this experiment have shown that IAA was translocated from one shoot to another and has moved both basipetally and acropetally.

Experiment 11: Only shoot II of a 27 days old seedling that was grown in the growing chamber having two shoots was exposed to

Table 11

Experiment 10

Series	a		b			c			d			
Hyp.+ root	Shoot I	Shoot II	Hyp.+ root	Shoot I	Shoot II	Hyp.+ root	Shoot I	Shoot II	Hyp.+ root	Shoot I	Shoot II	Minutes
10.5 cm	4.0 cm	4.0 cm	9.0 cm	4.0 cm	4.0 cm	10.0 cm	3.5 cm	2.5 cm	9.0 cm	5.0 cm	3.5 cm	10′
12.5	5.0	5.0	9.0	3.0	3.0	9.0	5.5	5.5	7.0	3.5	2.0	”
13.0	3.0	3.0	7.0	4.3	4.0	9.0	5.0	4.0	12.0	3.5	1.5	”
10.0	3.0	2.5	7.0	3.0	3.0	6.0	4.0	2.0	9.0	4.0	3.5	20′
11.0	3.0	3.0	9.0	4.0	4.0	9.0	5.0	2.5	9.5	3.0	0.5	”
9.0	2.5	2.5	10.5	2.0	2.0	7.5	2.5	2.0	7.0	4.0	3.0	”
8.5	5.0	4.5	7.0	3.0	3.0	7.5	4.0	2.0	7.0	4.0	2.0	”
5.0	4.0	4.0	5.0	4.0	4.0	8.0	2.0	2.5	6.0	4.0	0.5	”
7.0	3.0	1.0	8.5	4.0	3.5	7.0	5.0	2.0	7.0	4.0	3.0	”
6.0	2.5	2.5	7.5	3.5	3.5	6.5	2.5	1.0	6.0	4.0	2.5	30′
9.0	4.5	4.0	6.0	3.0	3.5	8.5	3.0	2.5	5.5	4.0	3.5	”
6.5	4.0	3.5	7.5	3.0	3.0	10.0	4.0	1.0	10.5	4.0	1.0	”
6.0	3.0	1.0	7.0	3.5	4.0	8.0	3.0	2.0	7.5	4.0	2.0	”
7.0	3.0	4.0	7.0	3.0	1.0	8.0	4.0	2.0	4.0	3.0	1.0	”
6.0	2.0	2.0	6.0	3.5	1.0	8.0	3.0	0.5	5.0	3.0	1.0	”
6.0	4.0	3.0	7.0	2.0	2.0	6.5	5.0	2.0	8.5	4.0	2.0	”
7.0	2.0	2.0	7.0	3.0	1.0	9.0	3.0	2.0	9.0	4.0	2.0	”
10.0	2.0	2.0	8.0	3.0	3.5	8.0	3.5	2.0	6.0	2.0	1.5	”
17.0	5.0	4.0	6.0	3.0	3.0	6.0	3.0	2.0	9.5	3.5	2.0	40′
10.0	2.5	2.5	10.0	1.0	1.0	9.5	3.5	1.0	7.0	2.5	0.5	”
9.5	2.0	2.5	8.0	2.0	2.5	9.0	3.0	1.0	9.0	3.0	1.0	”
8.0	2.5	2.5	5.0	3.0	3.0	6.5	4.0	2.0	7.0	2.5	2.0	”
9.0	3.0	3.0	7.5	4.0	4.0	7.0	5.5	3.0	7.0	4.0	2.5	”
10.0	2.5	2.5	9.0	2.0	2.0	9.5	4.0	3.0	8.0	5.0	2.0	”

a Leitz projection lamp of 150 Watt from a distance of 1 m, whereas on the cotyledone of the part of the plant that was left in the dark one drop of radioactive IAA of 80 μg / ml concentration was applied by means of a capillary glass tube. IAA was left there for 20 to 30 minutes.

Table 12

Experiment 11

Hypo.	Shoot I	Shoot II	Minutes
7.0 cm	4.0 cm	2.0 cm	20′
11.0	4.0	3.0	”
12.0	7.5	5.5	”
8.5	6.0	6.5	30′
7.5	6.0	5.0	”
6.0	4.0	7.0	”

The IAA that was applied to the cotyledone on the dark part of the seedling was translocated to the whole plant within 20 minutes and the illumination on one part of the plant has not inhibited the IAA translocation, especially not the acropetal movement.

DISCUSSION

All of the above experiments that were made with radioactive IAA are supplying clear evidence for basipetal as well as acropetal IAA translocation in plants. This evidence does not agree with the general conception as Leopold (1955, p. 81) has expressed in the following: “The strict downward transport of the growth hormone in plants is a classical instance for polarity in a biological system and affords an excellent opportunity for a study of polarity in general.” On the same page the author pointed out that “a strict polarity of auxin movement apparently does not always exist, for Leopold and Guernsey (1953) have shown that in the Coleus plant the basipetal polarity becomes weaker and weaker as the distance from the vegetative stem apex increases (figure 40). Furthermore in flowering stems there is some acropetal movement even at the stem tip. They have produced some evidence that a substance is formed in the flowering stem apex which permits acropetal transport of auxin.” Although the author is so

giving some hints on acropetal auxin movement he is accepting the general conception of "the strict downward transport". The cause for this point of view seems to be the method with agar diffusion practiced by Went (1928) and their first interpretion of "the polar nature of auxin transport" by means of this method. "Transport from morphological apex to base takes place even against an auxin concentration gradient, that is, even if the bottom block already contains more auxin than the top block". It is the amount of auxin found by means of this method that has caused the conception that auxin moves basipetally.

Again by this method Pilet (1965) has observed that "in Lens stem sections, there is a predominantly basipetal movement of ^{14}C from applied carboxyl labelled IAA (IAA^x)", which shows that even in small sections little acropetal movement may be observed. But it seems uncertain if conclusions on the direction of auxin movement are only supported by observations made on small sections particuliarly of young tissues.

The peculiarity of our earlier studies (Bağda, 1955) which had given some evidence for basipetal as well as acropetal auxin translocation, was in the direct IAA application on the plants and our conclusions were supported by the growth effects of auxin on buds at other regions of the plants.

Our earlier studies had two peculiarities: 1 - The IAA application to intact plant organs (not cut off segments or organs), and 2 - the application of various IAA concentrations. These two peculiarities had helped to show indirectly both basipetal and acropetal translocation, our recent experiments have led to the same results but in a more direct way.

Experiments 1b, 2b, and 3b have shown that the transpiration of the upper leaves does not chiefly affect the acropetal translocation of the auxin which was applied to the base (cotyledone) of the shoot.

Experiments 1c, 4c, 5c and 6c have shown that the apical bud on the shoots cannot have caused the acropetal translocation of the auxin which was applied to the basic parts (cotyledone) of the shoot. Because in these experiments the large leaves that

would cause transpiration, as well as the shoot apexes were cut off, but auxin has again moved upwards.

Although in the d series of experiments 2, 3, 4, 5 and 6 the apical bud and the young apical leaves that are generally accepted as centers of auxin production were cut off, the auxin that was applied on the base was translocated again acropetally as well as basipetally. This result denies the effect of the apical buds and leaves.

The e series of experiments 2, 3, 4, 5 and 6 show that auxin moves again acropetally , even if the organ on which auxin is applied possesses neither its apical bud nor leaves in its apical region, so that only the epicotyle is left.

The various series of experiments 7 and 8 of the second group, that were performed on cut off organs, have showed that it makes no difference for the acropetal and basipetal auxin translocation if the organ is cut off the main plant.

The series d and e of experiment 7 and the series c of experiment 8 have shown that the physiological apex as well as the morphological apex do not play any role in the translocation of auxin that was applied to basic or upper parts of cut off organs. The series d of experiment 7 has clearly shown that even the IAA applied on the physiological apex has moved basipetally although only the hypocotyle (as the physiological apex) and the epicotyle (as the morphological apex) were present. At the same time this experiment showns us that the classical experiments on polarity which were performed by Went with the agar diffusion method have led to some errors.

In experiments 9 and 10 of the third group made on plants with two shoots we have got evidence that the auxin applied on one of the shoots has moved both acropetally and basipetally in the same shoot and passing to the other shoot of course has moved there only acropetally. It was even observed that the IAA that was applied only to one of the cotyledones has again moved acropetally up to the tips of both shoots and at the same time basipetally downwards to the roots.

In experiment 11 the fact that the IAA applied to the cotyledone of the shoot that was left with its cotyledone on the dark side, has moved to the second shoot that was illuminated from the side and was translocated acropetally until its tip, shows that light does not inhibit auxin translocation.

Consequently the above experiments seem to show that IAA translocation in plants is not strictly polar (especially basipetal) but may move basipetally as well as acropetally like other organic compounds. Investigations by Bonnet and Torrey (1965) have also given evidence for the bipolar translocation of artificially applied IAA in root segments, and at the same time for the fact that IAA does not change its characteristics during translocation.

This fact is clearly supported by observations made by Pilet (1965) Page 700: "3 - The IAA^x is practically the only radioactive compound transported through the sections when IAA^x is applied to the apical cut surface. 7 - Labelled IAA (IAA^x) behaves exactly as does unlabelled IAA as far as transport is concerned. 8 - If sections previously contained IAA^x, it is if the absorbed IAA were "pushing" the IAA^x. Likewise, the IAA^x seems to push the IAA previously accumulated in the sections."

There have been made a great deal of investigations on the bi-directional translocation of organic substances in plant organs, especially in shoots and stems, all of which have shown bi-directional translocation in the sieve tubes. Schumacher (1933) has shown that the fluorescin applied on Pelargonium leaves has moved in the sieve tubes of the stem to the lower and upper parts of the place of application and even up to the apical bud. In June and July a predominance of apical movement has been observed. Kursanov (1963) who has made researches on the metabolism and transport of assimilates in sieve tubes has given various evidence for bilateral transport and has particuliarly notified the directions of movement of assimilates in soybeans in different phases of development. (P. 266, Figure 18). Here again the assimilates have been transported both basipetally and acropetally and these bi-directional translocations have become localized in older plants. This fact must always be kept in mind for the bi-

directional translocation in plants of all kinds of assimilates including hormones. An example for the same fact was given by Shumacher as mentioned above.

Increase and decrease in the polarity of auxin during various phases of development like the young, old and flourishing phases of plants has also been demonstrated in various experiments on segments taken from plants by scientists like Jakobs (1950), Leopold and Guernsey (1953), Reiff and Guttenberg (1959), Leopold and Lam (1962). In his recent studies Eschrich (1967) has given clear evidence for the bi-directional translocation in sieve tubes. Different substances (Na H^{14} CO_3, ^{14}C - urea and Kalium - fluorescin) were applied to the lower and upper parts of Vicia faba and it was clearly demonstrated that these substances have moved both basipetally and acropetally within the sieve tubes. This recent study shows again that each of the various substances in the same cell moves bi-directionally.

RESULTANTS

Various experiments with radioactive IAA have demonstrated that IAA is translocated both basipetally and acropetally both in cut off and intact plant organs. This fact is in accordance with the bi-directional translocation observed in sieve tubes. Consequently the strict polarity only in IAA translocation in opposition to all other substances in plants does not seem probable.

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ÖZET

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IAA, bitkilerin hangi organına tatbik edilirse edilsin, hepsinde hem basipetal ve hem de acropetal yayıldığı otoradiografi metodu ile tesbit edilmiştir. Bu yayılışa, ne tepe tomurcuğu ve ne de transpirasyon dolayısiyle yapraklar birinci derecede etki yapmadıkları görülmüştür. Bu bidireksiyonal yayılış, kesilmiş bitki sürgünlerinde de müşahede edilmiştir.

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