The Influence of Hormone Spray on the Growth and Pigment Content of Tomato Fruit.

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INTRODUCTION

It is a well known fact that hormone spray increases the fruit set and number of parcenocarpic fruits of tomato. Randhawa[5] reported that fruit set was increased by spraying the flower cluster with β-naphthoxyacetic acid (10 p. p. m.), 2, 4, 5-trichlorophenoxyacetic acid (10 p. p. m.), etc. in greenhouse tomatoes. Singletary[6] observed that early fruit yield was increased by spraying p-chlorophenoxyacetic acid (30 p. p. m.) and β-naphthoxyacetic acid (50 p. p. m.) in the field during the season of low night temperature. Since it was established that hormone spray increases the tomato yield tomato production has become stable all the year round, especially in the case of greenhouse or vinyl tunnel culture, and hormone use on tomato has become common practice. Studies on hormone spray have been carried out with regard mainly to fruit set and fruit yield, but not so much to puberty and colour of fruit. The main purpose of this study was to investigate the development and coloring of fruit after spraying several hormones.

MATERIAL and METHOD

The experiments were carried out from April to September in 1959 at Agricultural Faculty of Shinshu University. Seeds of Aichi tomato were sown in hot bed on April 1, and young plants were transplanted to the field on May 29. Fertilizers applied were N : 28Kg, P : 24Kg and K : 26Kg per 10 a. Hormones used and their concentrations were : para-chlorophenoxyacetic acid (PCPA), 30 p. p. m.; gibberellin, 50 p. p. m.; α-naphthaleneacetic acid (NAA), 50 p. p. m.; 2, 4-dichlorophenoxyacetic acid (2, 4-D), 10 p. p. m. Besides the plots of hormone treatment, a plot with plants that were hand-pollinated and a control plot added. Each plot was replicated twice. Hormones were sprayed on individual flowers on the day of flowering and 2 days after flowering. Measurements were made on the plant height, leaf number, the numbers of flowers and fruits set in each flower cluster, the fruit growth in diameter, the number of seeds contained, the number and weights of harvested fruits, and the pigment contents and carbohydrate contents of fruits. As to the pigment contents, chlorophyll, carotene, lycopene and xanthophyll were analized individually following the previous method.[7] Contents of sugar and starch were measured by Bertrand method, and recorded in percentage to dry matter. Measured values of pigment contents were expressed in mg per 100g fresh weight and extinction coefficient $\log\frac{To}{T}$.

EXPERIMENTAL RESULTS

Aichi tomato used is a heavy fruit type and a middle-late variety. The percentages of fruit set and pigment contents in each hormone sprayed fruit were recorded. Considering that hormones sprayed on each flower cluster might have been translocated into the plant, the growth of plant was also measured in presumption that it was affected by them. The results are shown in Table 1 and 2. Hormone spray was made on June

Table 1. Effect of various hormone treatments on plant growth.

Treatment	18/VI	28/VI	8/VII	18/VII	28/VII
PCPA	26.2	48.5	87.1	113.8	144.3
Gibberellin	26.0	48.3	90.0	115.8	150.4
NAA	25.3	47.0	87.8	115.5	152.2
2,4—D	27.2	49.9	88.1	117.0	151.2
Hand-pollination	23.3	43.5	82.8	112.5	145.3
Control	23.9	45.1	84.5	111.5	136.4

Table 2. Effect of various hormone treatments on leaf number.

Treatment	18/VI	28/VI	8/VII	18/VII	28/VII
PCPA	10.3	14.2	18.8	22.2	25.4
Gibberellin	10.5	14.1	18.9	22.4	25.3
NAA	10.2	14.0	18.8	21.9	25.6
2,4—D	10.4	14.1	18.3	21.3	25.3
Hand-pollination	8.4	13.0	17.5	21.3	24.3
Control	9.8	13.7	17.8	21.4	25.3

15, then, the measurements were started on June 18 and terminated on July 8. The plant height and leaf number among the hormone treated plots did not differ, but comparing with the control, the NAA, 2,4-D and gibberellin sprayed plots showed increases in plant height. It is presumable that hormone spray on each flower influenced the plant growth. The numbers of flowers and fruits and the fruit set coefficient are shown in Table 3. There was no remarkable difference in the number of flowers per flower cluster among plots. However, the plants applied with gibberellin showed the largest number of flowers and the largest percentage of fruit set. On the total of three flower clusters, the fruit set coefficient was higher in the plants applied with PCPA or gibberellin than in the other plots, while the NAA treatment gave the lowest fruit set coefficient of all. Although the fruit set coefficient in the PCPA treatment was almost equal to those of the other plots, the number of flowers was smaller than those in the other plots. The plots with a larger number of flowers tended to have greater fruit set percentage through out the plots. The plants treated with 2,4-D showed the smallest total number of flowers, and the plants treated with PCPA the smallest total number

Table 3. Effect of various hormone treatments on flower and fruit number, and fruit set coefficient.

Treatment	First flower cluster			2nd flower cluster		
	Flower number	Fruits	Fruit set coefficient	Flower numler	Fruits	Fruits set coefficient
PCPA	9.41	4.25	45.2%	7.58	3.80	50.5%
Gibberellin,	10.58	5.66	53.5	9.75	4.00	41.0
NAA	9.75	4.00	41.0	9.66	3.33	34.5
2,4—D	9.58	4.08	42.6	7.66	3.08	40.2
Hand-pollination	9.25	3.91	42.3	9.66	3.66	37.9
Control	12.58	4.91	39.0	8.66	3.75	43.3

Treatment	3rd flower cluster			Total		
	Flower number	Fruits	Fruit set coefficient	Flower number	Fruits	Fruit set coefficient
PCPA	7.58	2.58	34.0%	24.57	10.66	43.4%
Gibberellin	10.50	3.00	29.3	30.83	12.74	41.4
NAA	10.00	2.66	26.6	29.41	9.99	34.0
24-D	7.83	2.08	26.6	25.07	9.24	37.0
Hand-Pollination	7.41	2.16	29.1	26.32	9.73	36.9
Control	8.58	2.41	28.1	29.82	11.07	37.1

Table 4. Effect of various hormone treatments on the growth of fruit. (cm)

Treatment	at flower-ing	2days after flower.	7days after flower.	14days after flower.	21days after flower.	28days after flower.	35days after flower.	42days after flower.
PCPA		0.66	1.36	4.16	6.47	7.86	8.86	9.35
Gibberellin		0.55	0.91	2.69	4.92	6.19	7.48	7.91
NAA		0.57	1.26	4.54	6.99	8.10	9.08	9.51
2,4—D		0.54	1.79	4.80	6.77	8.18	8.99	9.44
Hand-pollination		0.53	0.79	3.05	5.45	6.81	7.65	8.07
Control	0.40	0.59	1.25	3.66	6.35	7.74	7.86	8.96

of fruits. According to the results, the effect of hormone spray on increasing the number of flowers cannot be expected. Table 4 shows the fruit development in diameter. The diameter of ovary on the day of flowering was 0.4 cm. 42 days after flowering, the plants treated with NAA, 2,4-D or PCPA produced fruits of larger size, while the plant treated with gibberellin produced fruits of the smallest. The seed contents of fruits sprayed with hormone are shown in Table 5 and Figure 1. The PCPA and 2,4-D treated plants produced seedless fruits. They might have developed parthenocarpically. While, plants treated with gibberellin and NAA produced seed containing fruits. Although,

Table 5. Effect of various hormone treatments on mean number of seeds contained per fruit.

Treatment	Fruit weight g	Number of seeds
PCPA	530	—
Cibberellin	246	175
〃	462	307
N A A	182	143
〃	410	189
2, 4—D	425	—
Hand-pollination	204	176
〃	500	304
Control	256	191
〃	390	254

Table 6. Effect of various hormone treatments on the number of fruits and weight per plant. (total oi 3 flower clusters)

Treatment	①Number of harvested fruits				Fruit weight g				Individual weight g	Total ② yield g
	Small f.	Middle f.	Large f.	Total	Small f.	Niddle f.	Large f.	Total		
P C P A	0.5	4.8	4.7	10.0	50.4	953.8	1945.7	2949.8	295.0	4183.8
Gibberellin	1.0	5.5	5.3	11.9	115.9	1258.8	2089.0	3463.7	292.7	4370.8
N A A	0.5	5.5	4.3	10.3	52.9	1282.5	1681.2	3016.6	294.3	4109.8
2, 4—D	0.1	5.3	3.5	8.9	11.5	1232.8	1367.4	2611.7	295.7	3360.7
Hand-pollination	0.5	5.1	4.3	9.9	59.8	1123.3	1911.8	3094.9	314.7	3590.3
Control	0.7	5.8	3.7	10.2	64.2	1326.2	1445.6	2836.8	281.3	3571.4

① Small fruit : 0～150g, middle fruit: 150～300g, large fruit: 300g or over
② Total yield till Sep. 17th.

as a rule, the larger the fruits the more seeds they contained, this relation does not hold always. The PCPA treated plants often produced puffy fruits as shown in Figure 1(f). Table 6 shows the number and weight of fruits per plant. The gibberellin treated plants showed a larger and a weight of fruit than the plants in the other plots. The remarkable differences among the mean weight of fruits were not recognized in the treated plots. While, threre was a trend that gibberellin treated fruits were rather smaller than those treated with other hormones, but larger than the control. However, the hand-pollinated fruits were the largest of all. On the total yield, those of the gibberellin, PCPA and NAA treated plants were higher than those of the 2, 4-D treated or hand-pollinated ones. Effects of treatment with various hormones on the chlorophyll content of the fruit are shown in Table 7. Fruits of the 2, 4-D treated plants contained the least chlorophyll and the control fruits the most. In the PCPA and 2, 4-D treated plants chlorophyll mostly dissappeared 46 days after flowering, while in the gibberellin treated and control plants it dissappeared 50 days after flowering. Carotene content of fruits is shown in the Table 8. Change of carotene content in each plot showed an

Table 7. Effect of various hormone treatments on the chlorophyll content of fruit.

Treatment \ Days after flowering	15	25	35	40	46	50	55
P C P A	12.94	8.32	6.86	3.94	1.00	0.0	0
Gibberellin	12.25	7.25	4.82	3.00	1.50	0.25	0
N A A	11.57	7.39	4.19	3.00	0.25	0.0	0
2, 4—D	10.66	6.69	4.13	3.50	0.13	0.0	0
Control	15.25	8.25	5.50	4.19	1.28	0.13	0

Table 8. Effect of various hormone treatments on the carotene content of fruit.

Treatment \ Days after flowering	15	25	35	40	46	50	55
P C P A	0.68	0.31	0.18	0.23	0.76	1.29	1.09
Gibberelin	0.51	0.25	0.12	0.15	0.61	0.91	0.87
N A A	0.71	0.38	0.10	0.13	0.83	1.04	1.03
2, 4—D	0.58	0.18	0.23	0.41	1.04	1.21	1.27
Control	0.73	0.36	0.15	0.25	0.58	0.88	1.07

Table 9. Effect of various hormone treatments on the lycopene content of fruit.

Treatment \ Days after flowering	15	25	35	40	46	50	55
P C P A	0	0	0	0	2.17	20.22	71.00
Gibberellin	0	0	0	0	1.91	15.88	49.75
N A A	0	0	0	0	5.86	19.82	59.50
2, 4—D	0	0	0	0	20.07	33.85	78.75
Control	0	0	0	0	0.46	14.69	74.00

almost identical tendency. The 2, 4–D treated plot contained less carotene in the early stage, but the carotene content increased as the fruits matured. The fruit of the gibberellin treated plants was less the carotene content in all stages. When immature, control fruits showed a higher carotene content, but the rate of increase in the content was small. When they matured the content was less than in fruits of the hormone sprayed plots except the gibberellin treated one. Observation on lycopene content is shown in Table 9. During the 46 days after flowering lycopene appeared in each plot. In the 2, 4–D treated plot it appeared fast, accordingly the content of lycopene was greatest in the 2, 4–D treared plot among the others. In the gibberellin treated and control plots lycopene content was small on the 46th day after flowering, and was smallest in the gibberellin treated plot 55 days after flowering. Xanthophyll content of fruit is shown in Table 10. The xanthophyll content was almost the same throughout the plots, but on the 55th day after flowering the 2, 4–D treated and control plots showed the highest

Table 10. Effect of various hormone treatments on the xanthophyll content of fruit.

Treatment \ Days after flowering	15	25	35	40	46	50	55
P C P A	0.088	0.048	0.046	0.042	0.042	0.104	0.103
Gibberellin	0.062	0.044	0.048	0.032	0.046	0.076	0.073
N A A	0.092	0.056	0.034	0.026	0.050	0.094	0.095
2, 4—D	0.076	0.042	0.042	0.048	0.086	0.096	0.108
Control	0.092	0.052	0.026	0.034	0.036	0.061	0.108

Table 11. Effect of various hormone treatments on the sugar content of fruit.

Treatment \ Days after flowering	15	25	35	40	46	50	55
			Total sugar				
P C P A	17.6	23.0	22.7	26.1	33.7	42.2	39.5
Gibberellin	17.3	27.9	30.0	27.6	31.1	37.8	36.8
N A A	10.8	10.5	20.1	27.9	31.6	33.5	35.4
2, 4—A	7.4	4.7	29.5	28.4	38.1	42.2	39.7
Control	18.1	24.8	26.6	30.0	29.5	37.8	40.0
			Reducing sugar				
P C P A	15.8	21.4	22.4	26.1	31.4	41.4	38.9
Gibberellin	15.8	27.1	29.7	27.6	30.4	35.7	35.7
N A A	9.4	9.4	19.8	27.1	29.7	31.9	34.7
2, 4—D	4.4	2.7	29.0	28.2	36.7	41.3	39.4
Control	16.6	23.5	26.1	29.7	29.2	36.7	38.4
			Non-reducing sugar				
P C P A	1.8	1.6	0.3	0.0	2.3	1.1	0.6
Gibberellin	1.5	0.8	0.3	0.0	0.3	2.1	1.1
N A A	1.4	1.1	0.3	0.8	1.9	1.6	0.8
2, 4—D	3.0	2.0	0.5	0.2	1.4	0.9	0.3
Control	1.5	1.3	0.5	0.6	0.3	1.1	1.6

Table 12. Effect of various hormone treatments on the starch content of fruit.

Treatment \ Days after flowering	15	25	35	40	46	50	55
P C P A	15.8	16.8	12.7	9.1	2.3	2.1	0.0
Gibberellin	14.9	10.5	10.5	6.1	1.9	1.6	1.1
N A A	13.1	11.2	10.3	6.1	2.0	1.4	0.9
2, 4—D	14.7	22.6	7.9	5.8	0.7	1.4	0.7
Control	12.8	10.1	8.7	7.7	3.1	1.4	0.9

xanthophyll contents, while the gibberellin treated plot showed the lowest content.

Sugar content of fruits is shown in Table 11. Total and reducing sugars increased in content as the fruit matured. On the 50th and 55th day after flowering these contents

were the highest. The 2, 4–D and NAA treated plots were lower in the contents until 25 days after flowering, but after this stage these contents reached the level of the other plot and remained the same. Especially the 2, 4–D treated plot contained the largest amount of sugar on the 50th day after flowering. The non–reducing sugar content was small as compared with the reducing sugar content, but slight differences were seen among all plots. Starch content is shown in Table 12. The starch content of fruits decreased as they matured. On the 55th day after flowering, the starch content of each plot became smallest. Especially, no starch found in the PCPA treated plot. It is considered that starch was reduced to sugar as the fruit matured.

DISCUSSION

Generally speaking hormone use is becoming popular gradually in tomato culture and its effect on fruits yield has been recognized in some papers.[1][2] Hormone application is beneficial to the production not only of tomato but of other horticultural crops.[10] Hormone is not only increases the number of flowers and the yield, but also stimulates the whole plant growth. Hormones used in this experiment were PCPA, NAA, gibberellin and 2, 4–D. Many experimental results have been obtained on the effect of spraying these hormones, some of which are conformed to, while some others are against, the result of this experiment. Hormone sprayed on each flower was translocated through the flower and flower stalk to plant, and stimulated the plant growth as shown in Table 1. This translocation resulted in the acceleration of stem elongation, but not in the increase in number of expanded leaves. These results suggest that hormone absorbed acts in cell elongation, while not in differenciation of leaves. The number of flowers was not affected by hormone spray except by gibberellin. It is assumed that this is due to the varietal difference in genetic character of tomato and is difficult to change by hormone spray. In this experiment, the number of flowers does not include flower buds. If flower buds were included, the number of flowers in each flower cluster would be greater than those in Table 3. The number of flowers in the first flower cluster was larger in the control plot with 12. 6, and smaller in the hormone sprayed plots. These hormone sprayed plots showed more flower bud drops, which resulted in smaller number of flowers than in control. The Aichi tomato variety is a heavy fruit type, the weight of a fruit being about 280g or over, and produces many flower buds. The flowering term of the first flower cluster in this variety lasts almost a month. Accordingly, the development of early fertilized fruits prevents flowering of the other buds and increases flower bud drop. Difference in the number of fruits set is not remarkable between the hormone sprayed plots and the control. It is understood that this phenomenon is inherent to the variety of heavy fruit type. Fujii[1] and Fukushima et al[2] reported that the number of fruits set was increased by hormone spray. In this experiment, the cultivation lasted from April to September, when the season is preferable for tomato culture. Accordingly, the fruit growth is normal due to the supply of natural hormone. For these facts, it is presumable that in this experiment hormone spray has little effect. But hormone sprayed fruits except gibberellin treated ones were accelerated in their development as

shown in Table 4. On the other hand, gibberellin checked fruit growth, but increased fruit set and produced the largest yield. Moreover, not only fruit growth was checked but harvest time prolonged. About the increases of early yield by hormone spray, Nyland[4] that spraying 30p. p. m. PCPA increased the tomato yield, and Wedding et al[12] reported that hormone sprayed tomato ripened more rapidly than unsprayed tomato. Tsuchiya[11] also observed that the ripening period was shortened by hormone spray. In this study, the PCPA, NAA and 2, 4-D sprayed plots increased early yield in the first flower cluster, which is the same as the results of the previous workers. Acceleration of fruit ripening by PCPA, NAA and 2, 4-D and fruit growth check by gibberellin may have different mechanisms, but here must be considered Johnson's[3] description that the growth regulator may function either as an auxin-type or anti-auxin hormone or both. Fruit yield was increased by gibberellin spray but those of the PCPA and NAA sprayed plots were less than that of the hand-pollinated plot. Especially in the 2, 4-D sprayed plot it was smallest. Singletary[6] pointed out that when the growing season was favorable for natural fruit set, there was no significant difference among the yields. In the case of this study, the growing season was favorable for tomato culture, and hormone spray may not have affected the tomato yield.

The colour of tomato fruits was not changed by hormone spray, but their pigment contents were influenced. The chlorophyll content in the fruit in the plots sprayed with PCPA, NAA and 2, 4-D was reduced. In these plots, physiological condition of fruit is changed by hormone spray, resulting in the reduction of chlorophyll content. On the other hand, as the result of hormone spray, ripening of fruits was accelerated as compared with control fruits, and chlorophyll contents reduced. As for carotene content the hormone sprayed fruits except those with gibberellin showed higher contents than the control. Carotene content of the plot treated with 2, 4-D was the highest among the plots 46 days after flowering. Lycopene content was increased by hormone spray, especially the appearance of lycopene in the 2, 4-D treated plot is earlier and its content is greater than in the other plots. Wedding et al[12] reported that fruit colour developed by hormone spray was an excellent one. Maturing of fruit was hastened by hormone spray which also increased pigment content. In these fruits the carotene, lycopene and xanthophyll contents were high, while the chlorophyll content rapidly decreased. Gibberellin differed from the other hormones in that it extended the growing season and decreased the pigment content.

Hormone spray had no significant effect on the sugar content of fruits, but the content increased as fruits developed as reported in the previous report.[8][9] Starch contents of fruit decreased as fruits grew. When these carbohydrates and pigments are compared, disappearance of chlorophyll and appearance of lycopene occurred during almost the same period prior to the 46th day after flowering. Sugar content at that time was about 30 percent in dry matter, while starch content was scarce. Accordingly, some conversion may occur from carbohydrates to pigments. It is interesting to notice that this relation is maintained also when hormone sprayed.

SUMMARY

Experiments were carried out to measure the plant growth and the pigment and carbohydrate contents of fruits affected by hormone spray at Shinshu University Agricultural Faculty in 1959. Variety Aichi-tomato was used. Hormone used and their concentrations were para-chlorophenoxyacetic acid, 30 p. p. m.; gibberellin, 50 p. p. m.; naphthaleneacetic acid, 50 p. p. m.; 2. 4-dichlorophenoxyacetic acid, 10 p. p. m. Aqueous solution of hormone was sprayed on each flower from flowering time of the first flower cluster to that of the 3rd flower cluster. The results are as follows.

1. Height of hormone sprayed plant taller than that of the control plant, but there was no difference between the control and the hormone sprayed plants in the number of leaves.

2. The number of flowers and fruits set in each flower cluster in hormone sprayed plots did not increase. However, the gibberellin sprayed plant had the largest and the 2, 4-D sprayed plant the smallest total number of flowers and fruits set. The fruit set coefficient in the PCPA sprayed plot was the heighest of all. Plots sprayed with hormones except gibberellin were accelerated in fruit development more than the control, but the gibberellin sprayed fruits were smaller than those of the control, and its fruit development was checked.

3. The plants in PCPA and 2, 4-D sprayed plots produced seedless fruits as the results of parcenocarpy, but in the gibberellin and NAA sprayed plots produced seed containing fruits. Among the fruits containing seed, the larger the fruits, the more seeds were contained.

4. The fruit yield of the gibberellin sprayed plot was greater than that of control, but among the other hormone sprayed plots there was hardly any difference. The early yield was high in the PCPA and 2, 4-D sprayed plots, but not so high in the gibberellin plot.

5. Chlorophyll content of fruits sprayed with PCPA, NAA and 2, 4-D decreased, but carotene, lycopene and xanthophyll contents increased. In the gibberellin sprayed plot the disappearance of chlorophyll was late, and carotene and xanthophyll contents were less than those in the control.

6. Difference in sugar content of fruits between the hormone sprayed plots and the control was not significant, but both increased the sugar content as the fruit matured. Starch content of the fruit decreased in all plots as the fruit matured.

ACKNOWLEDGEMENTS

The authors express their gratitude to Pro. Tsukamoto, Kyoto University for his guidance, and to Mr. Hayashi and Miss Shimizu for their help during this study. This work was carried out under a grant of scientific reseach provided by the Ministry of Education. The author express their thanks to the Ministry of Education.

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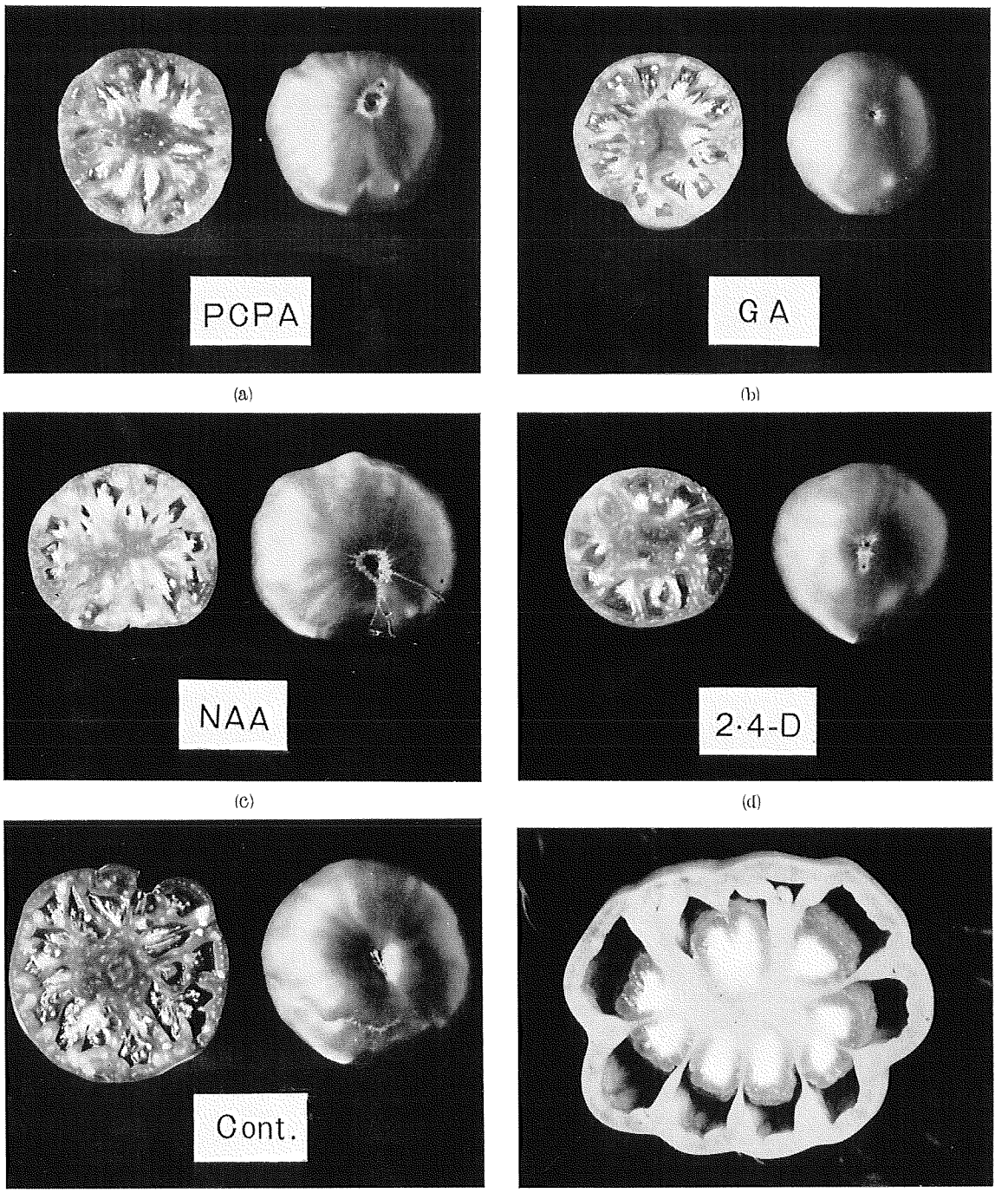

Figure 1. Cross section of the fruits spraying the various hormones.