SOME EFFECTS OF GIBBERELLIC ACID ON FRUIT PLANTS AND SEED

by

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INTRODUCTION

Gibberellic acid was found to be the main constituent of the fungus, Gibberella fujikuroi (Swada) Wollenw, of rice (13). It possesses growth regulating properties and has been found to cause excessive growth of plants when the temperature and photoperiod are below the optimum for normal growth (10) (13). An excessive dose will cause dwarfing of a plant. Gibberellic acid, in some cases, will replace the cold treatment or after-ripening period for seed (1).

Gibberellic acid does not give the same type of growth as indole-3-actic acid (1). A low concentration of gibberellins will give the same growth-promoting effect as other regulators. It can also stimulate germination of seed whereas other regulators do not (1) (4). Higher concentrations of the acid will increase the dry weight of tissue slightly (5). Gibberellic acid did not enhance the rate of CO_2 fixation per unit of leaf tissue and did not alter the general pathways of short-time metabolism of the newly-fixed $C^{14}O_2$ in the sugars, organic acids, and amino acid products (6).

The objects of this study were: (1) To see if various concentrations of gibberellic acid combined with different after-ripening periods would stimulate peach and apple seed germination; (2) To determine if various concentrations and amounts of gibberellic acid would affect runner and plant formation in strawberries; and (3) To check the effect of varying concentrations of gibberellic acid on the twig growth, size and weight of leaves, and sugar content of the fruit of peach trees.

REVIEW OF LITERATURE

Tukey (12) stated that there is no section of the country that is outstanding in the production of viable peach seed. Viability is not affected by age or condition of the seed. He has also shown that no germination was obtained from some lots of peach seeds while others germinated 100 percent. The normal planting treatment for peach seed is stratification in a moist medium and storage at a temperature of 41° F. for 90 days (14). The average germination for *Prunus persica* is considered to be about 50 percent.

Gibberellic acid, one of the growth regulators, was first discovered by Kurasawa, in the fungus *Gibberella fujikuroi* (Swada) *Wallenw* according to Wittwer and Bukovac (13) and Marth et al. (10). Later Yabuta and Sumiki characterized gibberellin, and the discovery was announced in 1938. The Western hemisphere did not begin active research with this chemical until 1955-56.

Donoho and Walker (4) reported that Elberta peach seed germinated 80 percent in 16 days, after being stratified for 35 days at near freezing temperature and soaked for 24 hours in 100 parts per million solution of gibberellic acid. The controls, soaked in water for 24 hours, germinated only 30 percent, as did the seed treated with 1000 parts per million solution of the acid.

Barton (1) found that as a result of after-ripening *Malus arnoldiana* Sarg. (crab apple) seed for four weeks at 5° C. and treating with gibberellic acid, 90 percent germination of excised embryos was obtained. The strength of gibberellic acid used was not given. Apple seed, Malus pumila, stratified for 75 days in a moist medium at near freezing temperature showed an average germination of 65 percent (14).

The effects on strawberry runner formation of gibberellic acid was not found in the literature. Smith (11) reported that single applications of 100 parts per million of a water solution of gibberellic acid elongated the crowns of strawberries and that higher concentrations did not increase the effect of the acid. It was also noted that 25 parts per million gibberellic acid solution applied to the strawberry plant caused the inflorescences and petioles to elongate. In these tests the potassium salts of gibberellic acid were used.

Donoho and Walker (4) found that gibberellic acid in conjunction with certain physical treatments would break the dormancy of buds of two-year-old peach trees. Trees that had received a portion of the required chilling period showed some shoot growth after being sprayed with an acid solution of 200 parts per million. A solution of 4000 parts per million of the acid sprayed on the trees resulted in 98 percent of the leaf buds growing after 36 days. The trees had received 164 hours of below 45° F. temperature. Weinberger, according to these authors, found the chilling period necessary for activation of vegetative growth in the Elberta peach to be 950 hours with temperatures below 45° F.

Barton and Chandler (2), using the tree peony, showed that 100 micrograms of gibberellic acid in a methanol solution can supplement the cold treatment in breaking epicotyl dormancy. The roots of the peony plants were 20-30 millimeters long. With no cold treatment, the 100 mcg treatments broke epicotyl dormancy in 97 percent of the plants while only 5 percent of the controls grew. There were no differences noted between treated and untreated plants when the roots were 40-50 ml long.

Hacskaylo and Murphey (7) fed a potassium salt solution of gibberellic acid to nine-year-old McKee hybrid poplar trees. One hundred ml of the solution were fed the trees during the months of May, June, and July. These applications did not extend the growing season or have noticeable effect on the leaves. Within two weeks after the September 1 feeding, all of the trees in the 100 and 1000 parts per million series broke lateral and terminal bud dormancy. The solution was introduced into the vascular system at the base of the trees. All growth initiated after September 1 was later killed by low winter temperatures. Lockhart and Bonner (9) broke dormancy in _Camillia japonica_ variety Finlandia with repeated applications of from 4 to 20 mcg or an alcoholic solution of gibberellic acid applied to the terminal bud. Neither day lengths of 8 to 20 hours nor night temperatures of 5° to 18° C. affected the early growth. Wittwer and Bukovac (13) suggested that some long-day plants did not show response to gibberellic acid treatment. Lockhart and Bonner (9) found no significant effects induced by applying the acid on _Pinus coulteri_ or _Pseudotsuga macrocorpa_.

Marth and associates (10) and Gray (5) found applications of gibberellic acid solution after growth has started most effective in influencing growth. The leaves became lighter green in color with some of them being smaller and more spatulate in shape. Also the leaf margins were smoother when compared with untreated leaves. The petiole of the leaf elongated and the dry weight of the new tissue increased with the increase in gibberellic acid concentration.

Bradley and Crane (3) found that the number of cells along the radial diameter of secondary xylem in both vertical and horizontal systems increased when sprayed with gibberellins. The number of cells in the phloem did not increase.

MATERIALS AND METHODS

Seed Germination Study

Seeds of *Prunus persica* (peach) and *Malus pumila* (apple) were used in this study. The peach and apple seed was divided into three lots to be stratified different lengths of time in moist sand at a temperature of 40° F. One lot was unstratified; another lot was stratified 21 days; and the third lot was stratified 46 days. Each of the foregoing lots was then subdivided into five groups to see what effect different rates of gibberellic acid[1] would have on germinative ability of the seed. Four of the groups of seed were soaked for 24 hours in a water solution of gibberellic acid at one of four concentrations. Rates used were 50, 100, 150, and 200 parts per million. Seed of the untreated

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[1] Gibberellic acid was furnished by Velsicol Chemical Corporation, 330 E. Grand Avenue, Chicago, Illinois.

group was soaked 24 hours in water.

The embryos were excised from another lot of peach seed which had been stratified as previously described, and groups of 50 excised embryos each received one of the five treatments as listed above. Each treatment was replicated three times. The seed was then planted in sphagnum moss that had been run through a hammer mill. The shredded moss was soaked in water and placed in wooden greenhouse flats prior to planting. The flats were placed in a greenhouse. The peach seed, both intact and excised, was covered with one-fourth inch of moss. The apple seed was planted in shallow trenches made in the moss, but was not covered. The flats then were covered with a clear polyethylene sheet to prevent excessive evaporation of moisture. One end of the plastic was raised three-fourths of an inch to allow some circulation of air. Counts of the germinated seeds were made twice a week. The temperatures maintained in the greenhouse were night 68° F. and day 80° F. for the duration of the study.

Strawberry Experiment

The strawberry experiments were conducted at the Horticulture farm near Manhattan. Pocahontas, which is a prolific runner and plant producer, and Midland, which is a shy runner and plant producer, were the two varieties selected for the study. The study was conducted to see what effect applications of gibberellic acid would have on runner and daughter plant production. The plants of each variety were set in the spring of 1958, in rows four feet apart, with the plants two feet apart in the row.

Each variety was divided into two plots of 20 plants each.

The plots were broken into treatment lots of five plants each. One plot of plants of each variety was sprayed with 5 ml per plant of the acid solution, of the various concentrations of gibberellic acid. The rates used were 250, 500, and 750 parts per million. Care was taken so as to get all of the acid on the foliar part of the plant. The plants of the other plots were divided as before, however, three applications were made to each plant. The first application consisted of 5 ml of the acid solution; the second, a month later, of 10 ml of solution; and the third, two months after the first, of 10 ml of solution for a total of 25 ml of gibberellic acid solution per plant. The runners and daughter plants each were counted at two-week intervals.

Gibberellic acid was dissolved in methanol and then diluted with water to the desired concentration. The rates of acid used were 250, 500, and 750 parts per million. Gibberellic acid was found to be very slightly soluble in water. A DeVelbiss No. 121 atomizer was used for the application of the acid solution to the plants.

Peach Tree Study

Five peach trees each of three varieties were selected for this study at the Horticulture farm near Manhattan. The varieties and planting dates were: Elberta, which were planted in 1956; Belle of Georgia, which were planted in 1954; and Halehaven, which were set out in 1952. Regular and detailed observations were made after treatment. The shape and coloration of the leaves were noted. The length of internodes of the twigs was observed. Noticeable effects on the rate and duration of growth were recorded. Tests were run to see what effect gibberellic acid had on the total sugars and solids of the fruit.

The powdered gibberellic acid was dissolved in a small amount of methanol and diluted to the desired concentration. The peach trees were divided so that one tree of each variety would receive applications at one of the following rates of 100, 200, 500, and 1000 parts per million. One hundred ml of the acid solution was introduced directly into the xylem of the tree trunks on June 12, July 21, and August 20. An Erlenmeyer flask was fitted with a rubber stopper through which two glass tubes were inserted; one tube served as the solution outlet and the other as an air inlet (Plate I). A rubber hose connected the outlet to the single end of a glass Y tube; two rubber hoses, one each from the branched ends of the Y tube, were connected to large hypodermic needles that were inserted into opposite sides of the tree trunk just above the ground level.

The total sugar content of samples of the fruit of the Belle of Georgia and Halehaven varieties from treated and untreated trees was determined. The procedure suggested by Hassid (8) with modifications was used.

An Esser Planimeter No. 4214 was used to measure the area of leaves as obtained from leaf prints of five leaves from each treatment group. As a further measure of the effects of the gibberellic acid treatments on leaf size, the dry weight of

EXPLANATION OF PLATE I

Apparatus used in feeding gibberellic acid solutions into the vascular tissue of peach tree trunks.

PLATE I

treatment samples of 90 leaves each was obtained by drying in an oven at 105° C.

RESULTS

Seed Germination Studies

Whole Peach Seed. Apparently the gibberellic acid solutions did not readily penetrate the stony endocarp of the peach seeds as shown by Table 1.

Table 1. Effects of various lengths of time of stratification and different rates of gibberellic acid solutions on the germination of peach seeds. Counts were made over a period of 60 days.

Treatment Rate ppm	Average percent germination		
	Stratified 0 days	Stratified 21 days	Stratified 46 days
0	0	0	6.7
50	0	3.0	2.7
100	0	2.7	2.3
150	0	1.3	3.0
200	0	1.0	4.3

Neither the unstratified seed soaked in varying concentrations of gibberellic acid solution for a period of 24 hours nor the unstratified seed not treated with gibberellic acid showed any germination. Seed stratified for 21 days gave only negligible results. None of the untreated seeds germinated, while only an average of 3 percent of the seed treated with 50 parts per million acid solution germinated. The lots of seeds receiving the higher concentrations of acid solution gave progressively lower average percentages of germination with the increase in treatment rates.

About 7 percent of the untreated seeds stratified 46 days, germinated, which was a higher percentage than for any of the gibberellin-treated seed. Seed treated with 50 and 100 parts per million acid solution germinated only slightly less than the seeds receiving the same treatments and stratified 21 days. The seed treated with 150 and 200 parts per million showed slightly more germination than those stratified 21 days which received the same gibberellin treatments.

Excised Peach Seed. Peach seed stratified as in the preceding study were excised and treated with the various acid solutions. All treated embryos showed a higher average percentage of germination than the untreated seeds within each stratification group.

The average germination rate for all unstratified seeds treated with gibberellic acid solution were essentially the same regardless of the treatment concentration, as seen in Table 2. The average percent germination of the unstratified seeds receiving no gibberellin treatments was about one-fourth of the average germination percentage of the treated embryos.

Seed stratified 21 days showed a definite increase in the average percent of germinated embryos when compared to the unstratified seeds regardless of treatment. Treatments of 50, 100, and 150 parts per million acid solution resulted in progressively higher germination percentages. However, embryos treated with a 200 ppm solution germinated at a slightly lower average rate than those treated with the 150 ppm solution.

Table 2. Effects of various lengths of time of stratification and different rates of gibberellic acid solutions on the germination of excised peach embryos.

Treatment Rate ppm	Average percent germination		
	Stratified 0 days	Stratified 21 days	Stratified 46 days
0	4	22	28
50	16	28	50
100	16	34	52
150	16	36	56
200	14	34	62

The untreated excised embryos of seed stratified 46 days had a slightly higher average germination percentage than the untreated embryos stratified 21 days. All embryos treated with gibberellin solutions and stratified 46 days showed a considerably higher average germination rate than those stratified the same length of time but receiving no chemical treatment. It can be seen from Table 2 that the average germination percentages for embryos stratified 46 days were consistently higher than for those stratified 21 days receiving the same chemical treatment.

Apple Seed (*Malus pumila*). Unstratified apple seed treated with 200 ppm gibberellic acid solution germinated an average of 13.1 percent as compared to 5.5 percent for the untreated seeds as shown in Table 3. The acid solution treatments of 50, 100, and 150 ppm resulted in average germination percentages of 7.5, 7.8, and 7.5, respectively.

Seed stratified 21 days all germinated much better than those not stratified. However, for the seeds stratified 21 days, it was found that all gibberellin treatments reduced germination

Table 3. Apple seed stratified different lengths of time and treated with various concentrations of gibberellic acid solutions. These are averages for three replications of 200 seeds each.

Treatment Rate ppm	Average percent germination		
	Stratified 0 days	Stratified 21 days	Stratified 46 days
0	5.5	43.5	29.5
50	7.5	38.5	45.6
100	7.8	41.0	38.5
150	7.5	36.3	24.5
200	13.1	34.8	28.3

when compared to the seeds receiving no chemical treatments. The average germination percentage of the seeds treated with a 100 ppm solution was the highest of all the treated seeds; those seeds treated with 200 parts per million had the lowest germination percentage.

Apple seed stratified 46 days and receiving no chemical treatment had a lower average germination percentage than the untreated seeds stratified for 21 days. Treatment with the 50 and the 100 ppm solutions resulted in an average increase in germination as compared with the untreated seeds. This was not true of those seeds treated at the two highest rates. Those seeds stratified 46 days and soaked in a 50 ppm solution had the highest average germination percentage of any lot in the experiment. Otherwise, all seeds stratified 21 days germinated better than those not stratified or those stratified 46 days. In other studies, apple seed has been reported to germinate an average of 65 percent after stratification for 75 days at temperatures of 40^{o} F. (14).

Strawberry Experiments

Considered over all periods, both varieties, and both rates of application, the level of treatment 0, 250, 500, and 750 ppm acid solution did not significantly affect either the number of runners or the number of plants, as indicated by an analysis of variance. This is shown statistically by the lack of a significant main effect for treatment, and by the absence of interactions involving treatment as shown in Table 4.

Table 4. Analysis of variance comparing the significance for the influence of variety, rate of application, period of application, and treatment level of gibberellic acid on the production of strawberry runners and plants.

	Runners			Plants		
Source of variation	D/F	Ms.	Sig.	D/F	Ms.	Sig.
Variety	1	0.5332	n.s.	1	19.48	
Treatment levels	3	0.3015	n.s.	3	0.9716	n.s.
Period of growth	2	4.969		1	30.96	
Rate of application	1	0.6023		1	0.941	
Variety x treatment	3	0.2656	n.s.	3	0.0905	n.s.
Variety x period	2	0.613	n.s.	1	13.74	***
Variety x rate	1	0.2381	n.s.	1	4.676	*
Treatment x period	6	0.3480	n.s.	3	0.1574	n.s.
Treatment x rate	3	0.0845	n.s.	3	0.6744	n.s.
Period x rate	2	0.6458	*	1	4.964	*
Remainder	23	0.1637		13	0.6160	
Total	47			31		

The varieties did not differ significantly in numbers of runners, but did with respect to numbers of plants. However, the variety difference depends both on the period of study and on the rate by which the treatments were applied. Thus, it is seen that the treatments do have some effect but these effects are not consistently in one direction and therefore, balance out over the whole study. The significant interactions shown in the analysis of variance for runners and plants indicate that such inconsistencies exist.

The only significant interaction for runners revealed by the analysis of variance was between period of application and rate of treatment. In Table 5 it can be seen that between the first and second treatment periods there was a significant difference in number of runners for each rate of application. The number of runners noted at each period was not significantly different as a result of the different rates of application. The average number of runners decreased from the second to the third period on the plant receiving the single application of gibberellic acid. However, on those plants receiving the multiple applications, there was an increase in mean number of runners between the second and the third treatment period although the increase was not significant. The multiple applications produced a significantly greater average number of runners than did the single applications during the third period.

Table 6 shows that the varieties Pocahontas and Midland had about the same average number of daughter plants during the first period, but that the Pocahontas variety produced more plants than Midland during the second period. The Midland variety did not show a significant increase in daughter plants between periods.

Table 5. Mean number of runners of Pocahontas and Midland varieties as influenced by rate and period of an application of gibberellic acid.

Period	Rate of application: 5 ml		Rate of application: 5-10-10 ml
1	1.70	n.s.	1.63
	*		*
2	0.68	n.s.	0.74
	n.s.		n.s.
3	0.34	*	1.02
lsd* = 0.42			

Table 6. Comparison of effects of the strawberry variety and period of application of gibberellic acid on the mean number of plants.

Period	Variety: Pocahontas		Variety: Midland
1	1.60	n.s.	1.35
	*		n.s.
2	4.88	*	2.00
lsd* = 0.85			

Table 7 shows that when averaged over both periods and all treatments, Pocahontas has more advantage in terms of plants produced over Midland when five ml was applied once than when the multiple applications were made. In fact, for the Pocahontas variety, the mean number of daughter plants per week was significantly less as a result of the multiple treatment than from the

Table 7. Mean number of plants as influenced by strawberry variety and rate of application of gibberellic acid.

Rate	Variety: Pocahontas	:	Midland
5 ml	3.86	*	1.54
	*		n.s.
5-10-10 ml	2.61	*	1.81
lsd* = 0.85			

single treatment. All Pocahontas plants produced a significantly larger number of daughter plants than did the Midland plants.

As a sort of a side issue, it was observed that the influence of the two rates of application depended on the period of growth. Table 8 shows that there was not an appreciable difference between rates during the first period, but that there was a definite reduction in growth of daughter plants during the second period.

Table 8. Mean number of Pocahontas and Midland plants as influenced by period and rate of application of gibberellic acid.

Rate	Period: 1	:	2
5 ml	1.32	*	4.08
	n.s.		*
5-10-10 ml	1.62	*	2.80
lsd* = 0.85			

The effect of gibberellic acid solution on daughter plant formation for the Midland variety is contrasted in Plates II and III. Plate IV shows the daughter plants produced by untreated Pocahontas plants while Plate V reflects the effect of multiple application of gibberellic acid on the number of daughter plants. This also bears out the analysis of variance which indicated that the multiple rate of application reduced the number of Pocahontas daughter plants when compared with plants receiving the single treatment.

Peach Tree Studies

The average growth in length of twigs was variable for variety, location, age of tree, and level of gibberellic acid treatment as shown in Table 9. The variety Elberta showed a slight increase in average tip growth over the untreated trees at the 100 ppm treatment level. However, all treatment rates above 100 ppm gave a progressively lower average growth in inches than trees treated at the 100 ppm rate.

The results were different for the second laterals as the twigs of trees receiving 100 ppm gibberellic acid solution made the least growth in length while those receiving 1000 ppm showed the highest average increase.

There was little difference in the average length of the fourth laterals of the trees receiving the various treatment rates. A graphic comparison of growth in length of twigs of the Elberta variety is shown in Plates VI, VII, and VIII. Neither of the other two varieties gave length of twig growth in the same

EXPLANATION OF PLATE II

Untreated Midland strawberry plants.

PLATE II

EXPLANATION OF PLATE III

Midland strawberry plants treated with 5 ml of a 750 ppm of gibberellic acid solution.

PLATE III

EXPLANATION OF PLATE IV

Untreated Pocahontas strawberry plants.

PLATE IV

EXPLANATION OF PLATE V

Pocahontas strawberry plants treated with 25 ml of a 750 ppm gibberellic acid solution.

PLATE V

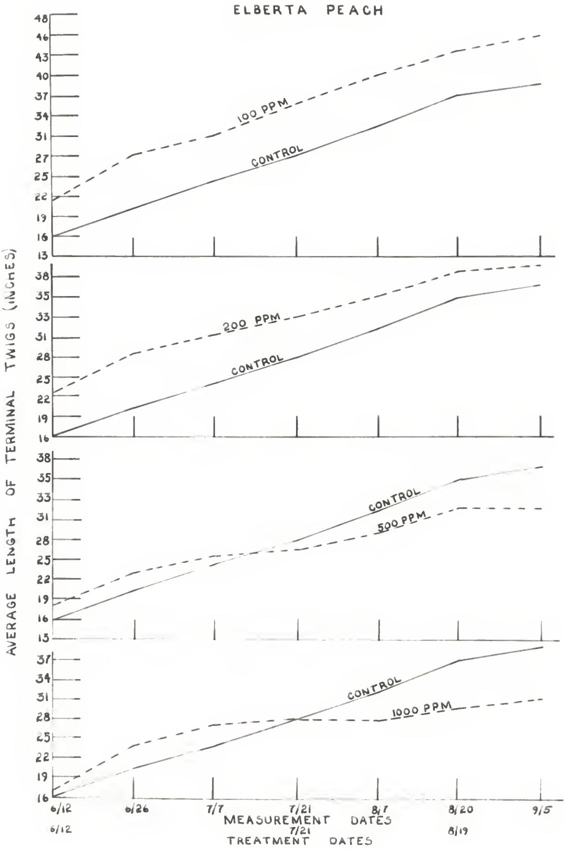
Table 9. The average growth in length of twigs as affected by position on the trees and amount of gibberellic acid solution received. These are average figures for four twigs.

Treatment Rate ppm	Accumulative growth in inches								
	Elberta			Belle of Georgia			Halehaven		
	tips	2nd lateral	4th lateral	tips	2nd lateral	4th lateral	tips	2nd lateral	4th lateral
0	23.0	9.5	6.5	8.2	4.6	6.3	2.4	7.8	8.3
100	24.3	2.0	6.5	29.1	7.4	13.3	2.8	6.1	6.1
200	19.5	6.5	8.0	5.7	4.1	10.9	3.9	5.9	5.8
500	17.3	9.5	7.0	7.8	0	6.5	2.5	2.6	1.3
1000	14.7	13.0	7.0	9.1	7.5	6.7	1.9	1.4	7.1

EXPLANATION OF PLATE VI

Graph showing the effect of various concentrations of gibberellic acid on the length of terminal twigs of Elberta peach trees.

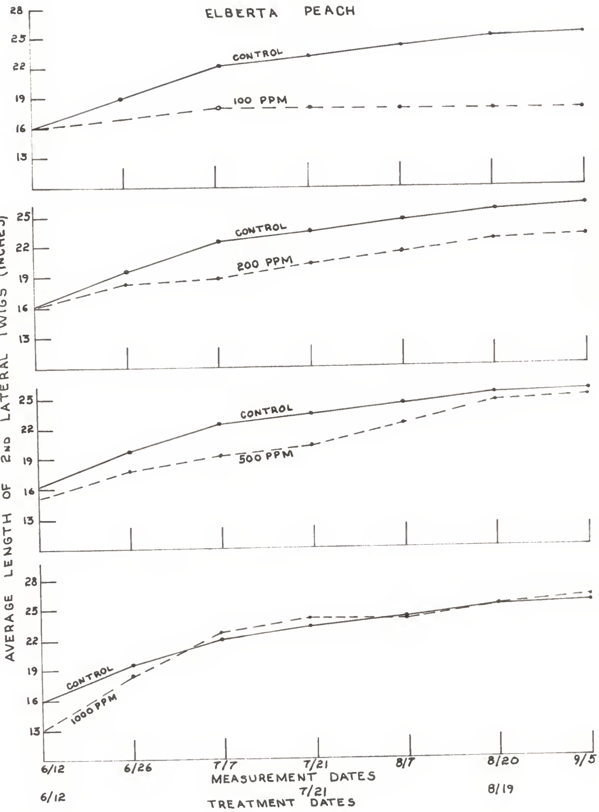
PLATE VI


ELBERTA PEACH
AVERAGE LENGTH OF TERMINAL TWIGS (INCHES)
48
46
43
40
37
34
31
27
25
22
19
16
13
100 PPM
CONTROL
38
35
33
31
28
25
22
19
16
200 PPM
CONTROL
38
35
33
31
28
25
22
19
16
13
CONTROL
500 PPM
37
34
31
28
25
22
19
16
CONTROL
1000 PPM
6/12
6/26
7/7
7/21
8/7
8/20
9/5
MEASUREMENT DATES
6/12
7/21
8/19
TREATMENT DATES

EXPLANATION OF PLATE VII

Graph showing the effect of various concentrations of gibberellic acid on the length of the 2nd lateral twigs of Elberta peach trees.

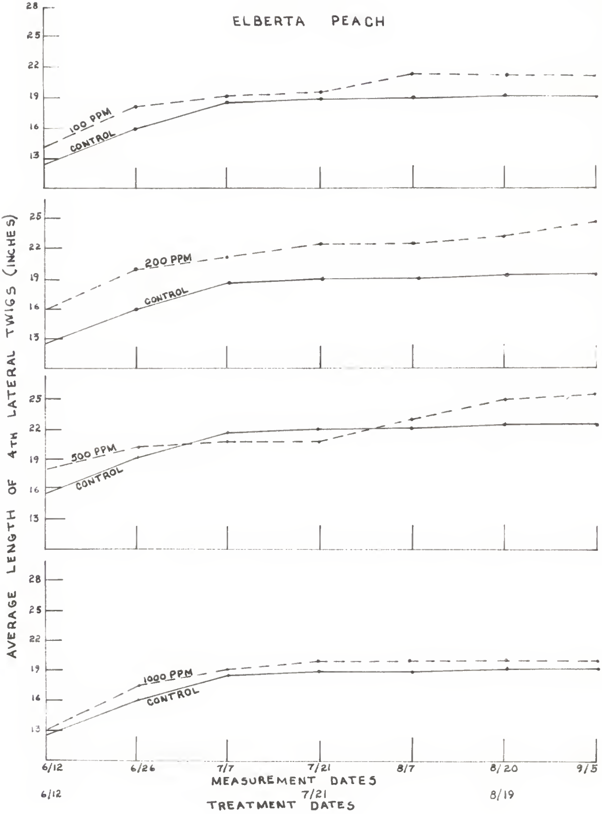
PLATE VII


ELBERTA PEACH
AVERAGE LENGTH OF 2ND LATERAL TWIGS (INCHES)
CONTROL
100 PPM
CONTROL
200 PPM
CONTROL
500 PPM
CONTROL
1000 PPM
28
25
22
19
16
13
6/12
6/26
7/7
7/21
8/7
8/20
9/5
MEASUREMENT DATES
6/12
7/21
8/19
TREATMENT DATES

EXPLANATION OF PLATE VIII

Graph showing the effect of various concentrations of gibberellic acid on the length of the 4th lateral twigs of Elberta peach trees.

PLATE VIII


ELBERTA PEACH
AVERAGE LENGTH OF 4TH LATERAL TWIGS (INCHES)
28
25
22
19
16
13
100 PPM
CONTROL
200 PPM
500 PPM
1000 PPM
6/12
6/26
7/7
7/21
8/7
8/20
9/5
MEASUREMENT DATES
6/12
7/21
8/19
TREATMENT DATES

relation to the acid treatments as the Elberta variety. This is shown in Table 9 when length of growth is compared.

A different response in average growth in twig length at the different treatment levels was found for the Belle of Georgia variety as shown in Table 9. The 100 ppm rate resulted in a decidedly greater average increase in length of terminal twigs than was observed for the untreated trees and for the trees treated at the other levels. The 200 ppm treatment rate resulted in the least terminal growth while twigs of the trees receiving the two higher concentrations were progressively longer. The average length of the terminal twigs of the trees receiving 1000 ppm acid solution was slightly greater than that for the untreated trees.

It was observed that the average length of the second laterals of this variety were exceedingly irregular in response to gibberellin treatments. Average twig growth of trees receiving 100 and 1000 ppm was greater than for the untreated trees; however, the twig growth of trees receiving gibberellic acid at the medium rates was less than for the trees not treated.

The average growth in length of the fourth laterals on Belle of Georgia trees receiving gibberellins at all treatment levels was greater than for the untreated trees, with those receiving 100 and 200 ppm being the greatest.

The terminal twigs of the Halehaven trees showed little variation in average increase in length either on the treated or untreated trees. However, all of the second laterals of the treated trees were shorter than on those not receiving gibberellins. Also a progressively lower average growth in length was noted for each increase in concentration of the gibberellic acid solution. The fourth laterals showed the same pattern of response with the exception of the trees receiving the highest level of gibberellic acid which had a greater average twig length than any Halehaven trees receiving the other acid treatments.

An increase in the length of internodes of Belle of Georgia trees receiving gibberellic acid solution at the rate of 1000 ppm can be seen in Plate IX. This effect also was observed on the Elberta trees. This increase in internode length was not noted on trees treated at the lower treatment rates with gibberellic acid solutions.

The Belle of Georgia trees showed a larger total increase in growth when all treatment rates are added together, than the two other varieties. It can be noted from Table 9 that the vegetative vigor of the peach varieties, as evidenced by the twig growth of the untreated trees, was in descending order: Elberta, Belle of Georgia, and Halehaven. Trees of the first two varieties were much more responsive to the gibberellic acid treatments than were Halehaven trees. Belle of Georgia trees showed a larger total increase in twig growth when all treatment rates were considered than did the other two varieties. The treated Belle of Georgia trees were irregular in their response to the gibberellin treatments.

Various levels of gibberellic acid solution fed into the xylem of the trees did not greatly affect the percent of soluble solids or total sugar content of the fruit of the Halehaven or Belle

EXPLANATION OF PLATE IX

Twig on Belle of Georgia peach tree showing internode elongation. One hundred ml of a 1000 ppm gibberellic acid solution were introduced into the vascular tissue of the trunk.

PLATE IX

of Georgia varieties shown in Table 10. Fruit of the Halehaven variety which received only one application, showed a slight increase in percent solids over fruit from untreated trees. The total sugar content was higher in the fruit of all treated trees than from the untreated trees except for those receiving 1000 ppm of the gibberellic acid solution. Fruit from the Belle of Georgia trees was more variable in respect to both percent soluble solids and total sugar content, but there was no conclusive evidence that the gibberellic acid influenced either.

Table 10. Total sugars and percent soluble solids of the fruit of peaches after treating with gibberellic acid solutions. One treatment of 100 ml.

Treatment Rate ppm	Belle of Georgia[1]		Halehaven	
	gr/100 gr fresh wt.[2]	percent solids	gr/100 gr fresh wt.[2]	percent solids
0	7.8	10.6	5.6	7.6
100	8.2	11.0	6.2	8.4
200	6.6	9.9	6.0	8.3
500	7.0	9.0	6.2	8.1
1000	7.0	10.1	5.6	8.1

[1] These had 200 ml of acid solution before testing.

[2] Grams of total sugar expressed as glucose.

Plates X, XI, and XII show a comparison of the degree of coloring produced in the leaves for the untreated trees and those receiving treatments of 500 ppm and 1000 ppm. This was typical for all trees of similar size and age. The Halehaven variety, which was the oldest and least vigorous, did not develop the lighter leaf color to the same degree as did trees of the other varieties. The pictures were taken before the second treatment

EXPLANATION OF PLATE X

Two-year-old untreated Elberta peach tree.

PLATE X

EXPLANATION OF PLATE XI

Two-year-old Elberta peach tree treated with 100 ml of 500 ppm of gibberellic acid solution.

PLATE XI

EXPLANATION OF PLATE XII

Two-year-old Elberta peach tree treated with gibberellic acid. One hundred ml of a 1000 ppm solution was introduced directly into the trunk.

PLATE XII

was made. After the second treatment the varieties Elberta and Belle of Georgia receiving 1000 ppm, lost many of the green leaves produced before the experiment began and about half of the yellow leaves developed after the first treatment. The Halehaven trees receiving the same treatment did not lose their leaves.

A definite relationship between treatment rates and color of leaves was observed. There was a distinct yellowing of all leaves produced after treatment on the Elberta and Belle of Georgia trees receiving gibberellic acid solutions at the rate of 1000 ppm (Plates IX and XII). The leaves of the Halehaven trees treated at the rate of 1000 ppm also were affected but the degree of "yellowing" was much less than in the other two varieties. Treatment rate of 500 ppm also caused the production of yellow colored leaves in the Elberta and Belle of Georgia varieties. The yellow color was much less intense than in trees treated at the higher rates. The leaves remained yellow until they fell.

The leaves of peach trees treated with gibberellic acid solution showed a variation in width, length, and area between the various levels of treatment, as shown in Table 11, as well as between varieties. This is also brought out by orthogonal comparisons for the foregoing measurements in Plates XIII, XIV, and XV.

Leaves of the Elberta trees treated at the rate of 200 ppm increased in width, length, and area compared to leaves of the untreated trees and of any of the treated trees of this variety.

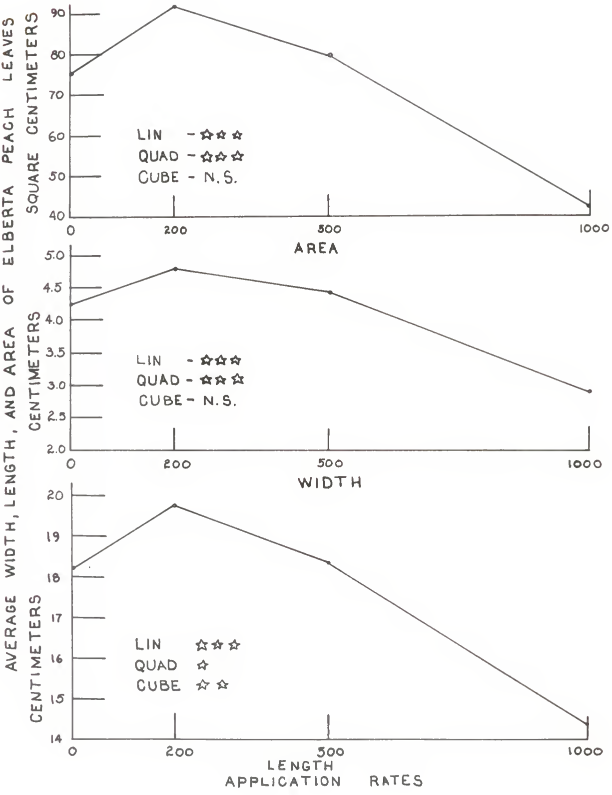
Table 11. The average width, length, and area of representative samples of leaves of different gibberellic acid treatments.

Treatment	Elberta			Belle of Georgia			Halehaven		
Rate ppm	Width cm	Length cm	Area sq cm	Width cm	Length cm	Area sq cm	Width cm	Length cm	Area sq cm
0	4.18	18.18	75.38	4.40	18.48	79.46	4.14	20.16	82.96
200	4.66	19.70	91.70	4.36	19.36	87.76	--	--	--
500	4.38	18.26	79.27	4.28	18.08	78.78	4.54	19.58	86.17
1000	2.96	14.30	42.09	3.92	15.46	64.26	4.52	22.08	94.77

EXPLANATION OF PLATE XIII

An orthogonal comparison of levels of gibberellic acid treatments on leaves of Elberta peach trees.

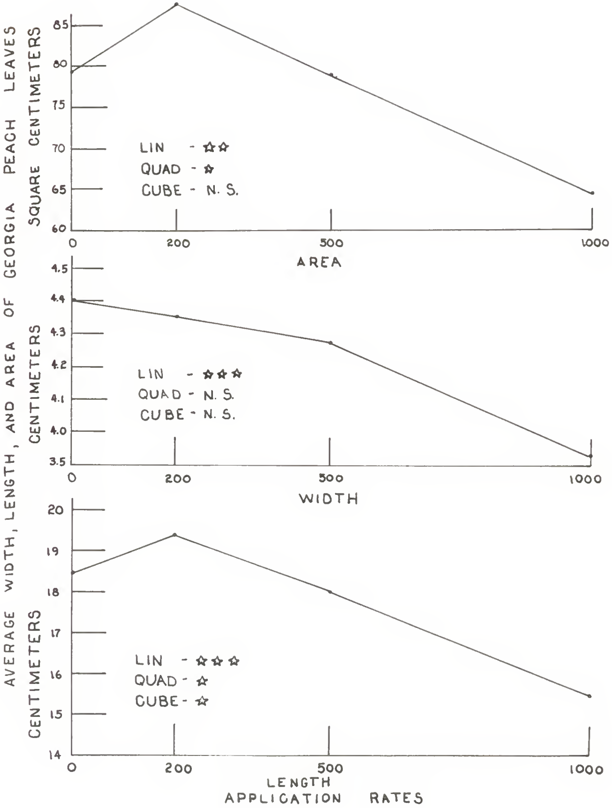
PLATE XIII


AVERAGE WIDTH, LENGTH, AND AREA OF ELBERTA PEACH LEAVES
SQUARE CENTIMETERS
90
80
70
60
50
40
LIN - ☆☆☆
QUAD - ☆☆☆
CUBE - N.S.
0
200
500
1000
AREA
CENTIMETERS
5.0
4.5
4.0
3.5
3.0
2.5
2.0
LIN - ☆☆☆
QUAD - ☆☆☆
CUBE - N.S.
0
200
500
1000
WIDTH
CENTIMETERS
20
19
18
17
16
15
14
LIN ☆☆☆
QUAD ☆
CUBE ☆☆
0
200
500
1000
LENGTH
APPLICATION RATES

EXPLANATION OF PLATE XIV

An orthogonal comparison of levels of gibberellic acid treatments on leaves of Belle of Georgia peach trees.

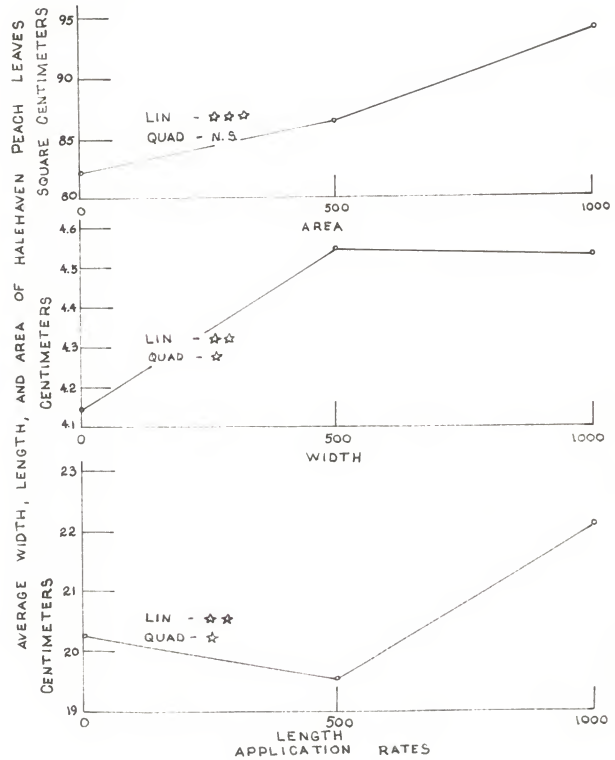
PLATE XIV


AVERAGE WIDTH, LENGTH, AND AREA OF GEORGIA PEACH LEAVES
SQUARE CENTIMETERS
85
80
75
70
65
60
LIN - ✩✩
QUAD - ✩
CUBE - N. S.
0
200
500
1000
AREA
CENTIMETERS
4.5
4.4
4.3
4.2
4.1
4.0
3.5
LIN - ✩✩✩
QUAD - N. S.
CUBE - N. S.
0
200
500
1000
WIDTH
CENTIMETERS
20
19
18
17
16
15
14
LIN - ✩✩✩
QUAD - ✩
CUBE - ✩
0
200
500
1000
LENGTH
APPLICATION RATES

EXPLANATION OF PLATE XV

An orthogonal comparison of levels of gibberellic acid treatments on leaves of Halehaven peach trees.

PLATE XV


AVERAGE WIDTH, LENGTH, AND AREA OF HALEHAVEN PEACH LEAVES
SQUARE CENTIMETERS
95
90
85
80
LIN - ☆☆☆
QUAD - N.S.
0
500
1000
AREA
CENTIMETERS
4.6
4.5
4.4
4.3
4.2
4.1
LIN - ☆☆
QUAD - ☆
0
500
1000
WIDTH
CENTIMETERS
23
22
21
20
19
LIN - ☆☆
QUAD - ☆
0
500
1000
LENGTH
APPLICATION RATES

Trees receiving 500 ppm decreased in all measurements when compared with leaves from the trees treated with 200 ppm; these leaves were slightly larger than those from the untreated trees. Leaves from the trees treated at the rate of 1000 ppm averaged less than one-half the size of those treated with 200 ppm.

Leaves of the Belle of Georgia trees treated at the rate of 200 ppm increased in length and area compared to leaves from the untreated trees or from any of the trees of this variety receiving other treatments. The width decreased with each increase in gibberellic acid concentration. Leaves from trees receiving 500 ppm solution decreased in all measurements when compared with leaves from trees treated with 200 ppm. They were also smaller than the leaves from trees receiving no chemical treatment. All measurements of leaves from trees treated with 1000 ppm rate averaged less than those from the leaves of untreated trees and trees receiving other treatment rates. This decrease in size between leaves of the trees treated at the 1000 ppm rate and the untreated trees percentage-wise was less than for leaves of Elberta trees receiving this treatment.

The area of leaves of the Halehaven variety treated with rates of 500 ppm was greater than for the leaves from the untreated trees although the treated leaves were slightly shorter than the untreated ones. Leaves from the tree treated with 1000 ppm showed an increase in measurements over the leaves from trees treated with 500 ppm except for the width which was slightly less. All measurements of leaves receiving this treatment were larger than for the leaves of the untreated trees. This was considerably different than for the other two varieties whereas stated previously, leaves receiving the 1000 ppm treatment gave considerably smaller measurements than the leaves from untreated trees.

As a further measure of the effect of gibberellic acid solution on growth of peach trees, the dry weight of leaves from treated and untreated trees was compared. Table 12 shows that the 200 ppm treatment increased the weight of the Elberta leaves when compared to the leaves from the untreated trees. Increasing the treatment rate of gibberellic acid to 500 ppm and 1000 ppm caused the leaves to be lighter in weight than those from trees treated with 200 ppm. They were also lighter in weight than the leaves from the untreated trees.

Table 12. The total dry weight in grams of 90 peach leaves taken from treated and untreated trees.

Treatment Rate ppm	Elberta	Belle of Georgia	Halehaven
0	38.52	39.78	31.95
200	39.42	34.56	--
500	32.58	36.18	31.50
1000	13.05	25.58	33.48

In comparing the leaves from the Belle of Georgia variety it was observed that those from the untreated trees were the heaviest. All gibberellic acid solutions reduced the dry weight of treated leaves as compared to the untreated. Leaves from trees treated with rates of 500 ppm were heavier than those from trees receiving 200 ppm. Trees receiving the 1000 ppm rate weighed the least. These weights do not show the same relationship to the level of treatments as was shown between treatment rate and area of the leaves.

Dry weights of the leaves of the Halehaven variety did not show the same general relationship to treatment levels as was found for treatment rate and leaf area. The area of the leaves was increased by the 500 ppm treatment; however, this treatment decreased the dry weight slightly below that of leaves from the untreated trees. The 1000 ppm treatments resulted in an increase in dry weight over leaves of the trees receiving the 500 ppm treatment as well as the leaves from the untreated trees.

DISCUSSION

It was found that soaking peach seed in gibberellic acid solution of various levels did not shorten the needed after-ripening period necessary for germination. When the seeds were not stratified there was no germination regardless of the concentration of acid solution used. Seeds stratified 46 days and treated with various gibberellic acid solutions germinated poorly. This was due, in part, probably to the failure of the solution to penetrate the stony endocarp. Further, the viability of this particular lot of seed was low. Peach seed, on the average, need 75 days stratification (14) at temperatures of 40^{o} F.

Excised embryos of unstratified seed had a low percentage of germination regardless of treatment. After stratification for 46 days and soaking in gibberellic acid solution, there was a decided increase in germination of the embryos when compared with the unstratified seeds. Seeds treated with the 100 and 200 ppm germinated 52 and 62 percent, respectively. This is in reverse order to results as reported by Donoho and Walker (4). These differences may, in part, be due to the lots of seed used.

Gibberellic acid solutions had a varied effect on the germination of apple seed. It was found that the various gibberellic acid treatment of unstratified seed increased germination only slightly as compared with the controls. When seeds were stratified each for the 21- or 46-day periods, it was found that the shorter stratification period gave the highest germination for the untreated seeds. This phenomenon can not be fully explained as the longer stratification period should increase germination. The seed manual (14) states that apple seed, on the average, need 75 days stratification at temperatures of 40° F. for after-ripening. The gibberellic acid solution in some cases had an inhibitory effect on the germination of apple seed as was true with all treated seeds stratified 21 days. The 50 ppm and 100 ppm solutions increased germination in the lots stratified 46 days. Apparently, the gibberellic acid solution stimulated the after-ripening processes necessary for germination. More work is needed on this problem.

Spraying gibberellic acid solutions on the foliage of Pocahontas strawberry plants increased significantly the production of runners and daughter plants as compared with the Midland variety. Repeated applications of gibberellic acid solution, sprayed on Pocahontas plants, decreased significantly the number of daughter plants. Repeated applications of gibberellic acid solution increased the number of Midland daughter plants, but not significantly. The runners of the Midland variety seemed to be determinate in growth. The early runners would terminate with a plant, with few runner plants being formed. The application of gibberellic acid solution seems to break this tendency and the runners become indeterminate in nature with more plants being developed. Multiple applications of gibberellic acid caused a significant reduction of plants produced by the Pocahontas variety. These treatments may have caused the parent plants to become determinate in nature. It would seem that a single application of gibberellic acid solution would be the best for plant production as a result of this experiment.

Several times during the growing season there was excessive soil moisture due to the large amount of rainfall, as shown in Table 13. In addition to being wet, the season was characterized by cool temperatures.

The use of gibberellic acid solution introduced into the xylem of the trunks of peach trees produced varied results. Apparently, the lower concentrations promoted even regular lengthening of the twigs without causing the internodes to lengthen abnormally. The 1000 ppm treatments produced a flush of growth of short duration, causing increased internode length but no increase in overall total growth. When the highest concentration was used, the tips of the twigs formed rosettes within a month; rosette is defined as a short internode bearing a cluster of leaves. Prior to forming rosettes and after the first feeding, the internodes lengthened considerably. This rosetting did not

Table 13. Daily temperature and precipitation for the period June 12 to September 5, 1958 at the Horticulture farm near Manhattan.

Date	Temperature (° F.)		Precipitation	Date	Temperature (° F.)		Precipitation
June	Max.	Min.	(inches)	July	Max.	Min.	(inches)
12	95	67	0	26	88	64	0
13	93	74	0	27	88	65	1.19
14	77	65	1.43	28	88	61	0
15	78	65	0	29	95	63	0
16	82	58	0	30	94	77	0
17	84	59	0	31	88	69	0.43
18	85	59	0.17	Aug.			
19	86	65	0	1	89	69	0
20	78	64	0	2	94	65	0
21	77	56	0.89	3	95	62	0
22	76	59	0	4	94	69	0
23	86	47	0	5	95	69	0
24	71	54	0	6	94	71	0
25	68	51	1.78	7	88	69	0
26	78	45	0	8	90	65	0
27	85	60	0	9	89	65	0
28	88	62	0	10	90	65	0
29	90	66	0	11	96	72	0
30	92	69	0	12	97	69	0
July				13	93	69	0
1	95	74	0	14	97	68	0
2	93	76	0	15	96	77	0
3	89	66	5.58	16	80	68	3.23
4	90	66	0.16	17	88	58	0
5	78	68	0	18	87	59	0
6	84	57	0	19	89	65	0
7	84	61	0	20	89	71	0.39
8	84	59	0	21	80	65	0.51
9	90	65	0	22	76	55	0
10	92	63	0.48	23	78	64	0
11	86	61	1.63	24	77	57	0
12	81	63	0	25	78	48	0.24
13	91	65	0	26	84	59	0
14	96	74	0	27	94	63	0
15	81	61	0.58	28	95	68	0
16	69	63	0.65	29	100	68	0
17	88	64	1.76	30	94	72	0
18	95	69	0	31	83	53	0
19	91	73	0	Sept.			
20	71	64	0	1	95	63	0
21	77	63	0	2	93	67	0
22	83	59	0	3	95	68	0
23	88	66	0	4	79	67	1.39
24	90	67	0.80	5	90	68	0
25	87	64	0				

occur on trees receiving the lower levels of concentrations nor the controls. The rosette type of growth was not broken by applications of the second and third feedings of gibberellic acid solution into the xylem of the trunk.

The sugar content of the fruit from the varieties Belle of Georgia and Halehaven showed no definite trend as a result of the application of gibberellic acid solutions. The percent solids showed even more variation. It may be assumed that gibberellic acid did not have a significant effect on the fruits of the peach trees under the conditions of this experiment.

The leaves of peach trees receiving the lower treatment levels of gibberellic acid solution were increased in size, compared with the untreated leaves. This increase in size was not accompanied by chlorosis or yellowing of the leaves which was characteristic of the leaves of the trees receiving the high treatment rates. It would seem that these trees with larger leaves should be able to manufacture more carbohydrates than smaller untreated leaves. These trees retained their leaves later in the fall, and seemed to be in a healthy condition. Many of the leaves of the trees receiving the high concentration abscissed prematurely; those that remained became inactive early in the fall. This situation did not occur with the Halehaven trees as the higher levels of gibberellic acid solution produced the largest leaves of any variety studied. Since trees of this variety were lowest in vegetative vigor, the explanation for this occurrence is not known.

In comparing the weight of leaves from treated and untreated peach trees it was found that the weight and area of the Elberta leaves were in direct relationship except for the trees receiving the 500 ppm treatment. In leaf area, these leaves were larger than the untreated leaves but weighed less. This was in disagreement with Gray (5) who found that there is a slight increase in dry weight in a number of plant species with an increase in concentration of gibberellic acid used. The total dry weights of the untreated peach varieties varied considerably. The 1000 ppm treatments increased the dry weights of leaves of the Halehaven varieties--the only variety in which this occurred. Possibly some varietal characteristic or physiological factor accounted for the difference in behavior.

SUMMARY

Gibberellic acid solutions did not shorten the after-ripening period necessary for peach seed germination.

Gibberellic acid solutions replaced a portion of the after-ripening necessary for germination of excised peach embryos.

The after-ripening process was stimulated in apple seeds by some gibberellic acid treatments in combination with stratification. In general, the results were highly variable.

A single application of gibberellic acid solution to the foliage of the strawberry plants significantly increased plant production for the Pocahontas variety.

The application of gibberellic acid solutions to Midland strawberry plants caused the plants to change from a determinate

to an indeterminate type of growth.

The lower concentrations of gibberellic acid solutions introduced into the xylem tissue of the trunks, increased the length of terminal twigs of Elberta and Belle of Georgia peach trees. The Halehaven variety did not show the same amount of growth.

The internodes of peach tree twigs were greatly lengthened when high concentrations of gibberellic acid solutions were introduced into the trunks even though the total twig length was not significantly increased.

The sugar content and percent solids were not affected noticeably by introducing gibberellic acid solutions into the trunks of the trees.

The leaf area of Elberta and Belle of Georgia peach trees was increased by treatments with low concentrations of gibberellic acid solutions but was decreased with each successive increase in treatment rates. The leaf area of the Halehaven variety increased with each increase in treatment rate.

The dry weight of leaves of the Elberta peach variety increased with low treatment rates of gibberellic acid but decreased as a result of the high treatment rates. All gibberellin treatments decreased the dry weight of the leaves of Belle of Georgia peach variety. In contrast to the other two varieties, the highest treatment rate increased the dry leaf dry weights compared to the untreated leaves.

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SOME EFFECTS OF GIBBERELLIC ACID ON FRUIT PLANTS AND SEED

by

ENOCH DAWSON KENWORTHY

B. S., Oklahoma Agricultural and
Mechanical College, 1936

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1959

The purpose of this study was to see what effect varying concentrations of gibberellic acid had on the germination of peach and apple seed, runner and plant development of strawberry plants, and vegetative growth of peach trees.

The seeds were stratified for varying lengths of time. The experimental treatments in which peach pits were soaked for 24 hours in various concentrations of gibberellic acid did not replace any of the after-ripening period required for germination. Excised embryos receiving the same after-ripening treatment and soaked in acid solution levels, showed a marked increase in germination.

Apple seed given the same after-ripening treatment as the peach seed did not give any conclusive evidence that the acid treatment would replace part of the after-ripening period.

There was a significant difference in runner formation in strawberry plants receiving the multiple rate of gibberellic acid solution application compared to those plants getting a single application. Daughter plant numbers were reduced for the Pocahontas variety when the multiple applications were made. Plant production increased slightly for the Midland strawberry plants as a result of the multiple treatment rate. It was noted that application of the chemical at the higher rates caused the growth habit of the plants of the Midland variety to be somewhat indeterminate. However, the Pocahontas variety produced significantly more daughter plants than the Midland variety with either rate of application.

Gibberellic acid solutions fed into the xylem at the base of the trunk of peach trees had a distinct effect on growing tips of vigorous trees. Treatment at the rate of 100 ppm increased twig length, leaf area, and dry weight of leaves on young peach trees. Treatment rates of 1000 ppm resulted in rosetting of twigs, reduced growth as indicated in a decrease in twig length, leaf area, and dry weight of leaves. Other effects of high treatment rate applications of gibberellic acid solutions were premature dropping and a severe yellowing of leaves.

There was little effect on total sugars or percent of soluble solids of fruit on trees into which gibberellic acid solutions were introduced.