DEVELOPMENT OF THE FRUIT BUDS OF THE PEACH IN RELATION TO WINTER INJURY

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L. R. Stanley

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Development of the Fruit Buds of the Peach in Relation to Winter Injury.

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The tenderness of the blossom buds has rather constantly and effectively limited the areas in which commercial peach production is attempted and has thus made peach growing more profitable in the favored regions than it would have been otherwise. Within the favored areas, however, bud tenderness becomes a costly factor all too frequently. In so far as Michigan orchards are concerned, bud killing in winter is far more important than it is during the spring. The saying rather common among peach growers "if the buds reach March 15th, undamaged, a crop is assured," is not far from the truth. Consequently, any study directed toward diminution of bud killing in this state should consider principally winter conditions.

There has been a rather general opinion, based on analogy and observation, that the stage of development attained by peach buds is a factor in winter hardiness; specifically, that the more advanced a bud is, the more tender it is. In the sour cherry, for example, under Wisconsin conditions (26) the buds which are differentiated first and are more advanced in development at the beginning of winter are more tender. Under Missouri conditions (7), advancement of buds during mild

weather in the winter makes them more tender to rather ordinary winter weather.

In Michigan there have beenfrequent observations to the effect that unusually warm weather in October and November develops peach buds to a point which makes them unusually tender during the ensuing winter (5). In Massachusetts (2) abundant sunshine, rather than high temperatures during this period, seems to cause tenderness to winter freezing.

These various reports might be interpreted, though not necessarily, as indicating that the stage of development is the decisive factor in determining hardiness of buds. If these reports are true, then it is a matter of considerable practical importance, because evidence secured in Iowa (21) in connection with apples, and in Wisconsin (25) with sour cherries, indicates that the time of bud differentiation and the development attained before cold weather sets in may be influenced to some degree by cultural practices.

The study reported in this paper was aimed to determine: (1) whether recognized varietal differences in bud hardiness of the peach are related to differences in the stage of development at a given time, and (2) whether shoots of different types of vigor show differences in the stage of development of the blossom buds. To establish these points it was necessary first to determine what might be termed normal progress in

bud development.

REVIEW OF LITERATURE.

Duhamel du Monceau (13) in 1758, reported that flowers with calyx, petals, stamens and pistil can be distinguished in the peach bud in February. In breaking the tips of the anthers in February he observed that juice and grains of dust issued from the interior of the anther. The seed could not be seen.

Geleznoff (15) working at Moscow during the winter of 1847-1848, made some very careful observations on the winter rest period of blossom buds of the elm and other hardy perennials. As reported by Askenasy, he supposes from the results of his experiments, that the standstill in the development of buds during the winter is only apparent. All buds which he studied made progress during January, February and March. The cold decreased very rapidly towards spring and thawing weather occurred frequently; yet Geleznoff did not believe that progress occurs only during the latter period, since he observed a progress in the formation of the buds in the 47 days from December 23 to February 8. During this period the temperature never rose above freezing. He observed new formations, as of pollen in the larch and integument in the elm, during the uninterrupted freezing period.

Askenasy (1) working in the western part of

Germany, reported in 1877 that the development of the blossom buds of the sweet cherry divides itself into two periods separated by a period of rest or very slight growth. The two periods fall in different years; the rest period extends from the end of October to the beginning of February, or approximately three and a half months. From his results, he concluded that it was clear that the blossom buds of the cherry undergo, between the end of October and the end of January, a change in their nature which is to be recognized, not in an increase in weight or size of the parts, but only in changed reactions to higher temperatures. It is easy to suppose that this change is of a chemical nature. One can, for example, suppose that during this time in the growth-capable parts of the bud, a material similar to diastase is formed, which spreads out into the other tissues of the stem and there brings into solution the starches and other reserve materials which are stored in certain cell complexes, especially in the pith rays of the wood. It may be possible that in these cells themselves, without influence on the part of the buds, a chemical change takes place.

Goff (16) apparently conducted the earliest investigations in the United States on fruit bud development and some phases of the problem of winter killing of fruit buds and the factors which influence hardiness. Samples of buds were taken weekly from a Bokara peach tree that

had been planted in the spring of 1898. After passing through the severe winter of 1898-1899 with little injury, the tree made very thrifty growth, and the bud samples were taken, beginning on July 5, 1899. The side buds, each destined to become a flower had it been permitted to remain on the tree, showed at this time no evidence of the forthcoming flower. In samples taken on September 14 the crown showed a decided thickening as compared with side buds of the previous samples. This was, undoubtedly, an indication that the flower was soon to appear. Other samples taken a week later showed unquestionable indications of flowers. Three weeks later, on October 4, the flowers appeared much more advanced; the calyx, petals, stamens and pistil were clearly discernible. It appears therefore, that in this variety of peach, the flowers began to form about the middle of September.

Tufts and Morrow (26) have summarized the information obtained from different parts of the country on the time of initial differentiation of peach fruit buds:

Georgia	June 14
California	June 30
Virginia	July 7
Wisconsin	Sept.21

Weaver (27) found in Nebraska that by September 14 two whorls of stamens had been formed in the fruit buds of the peach.

Wiggans (28) during the progress of his work in California, reported differentiation occurring at

approximately the same time in all sections of the state in which his studies were conducted. He found environmental conditions during winter producing no checking influence on fruit bud development of the pear or apricot under California conditions.

Bradford (3) studying fruit bud differentiation of the apple under conditions obtained in Oregon, found that there was a rather uniform stage for all varieties studied as they went into winter condition. There was considerable range in the time of differentiation of buds in different positions on the tree, but all apple blossom buds go into winter in practically the same stage of development.

Bradford (4) later found in Missouri that there was considerable difference in the stage of development of apple buds going into winter, and that there was marked difference in the way these buds developed during the winter. On the basis of his analysis of the Mikesell records from Wauseon, Ohio, he concluded that accumulations of heat in November and December have some influence in the forwarding of Late Crawford peach blossoms toward opening. There is a tendency, though not very strong, towards an association between lower temperatures in October and low summation between November 1 and blossoming in the peach. This may be associated with some effect of the high October temperatures in prolonging, or of the low temperatures in breaking, the rest period in the peach.

Morgan (23) found in New York that the blossom buds of the apple started to develop earlier in the spring than those of the peach, but that the peach rapidly overtook it.

Drinkard (11) reported from Virginia that the peach is more responsive than the apple to higher temperatures during the winter.

Chandler (7) in Missouri found hardiness of peach buds, when in a fully dormant condition, to be greatly increased by continuous low temperature preceding the date at which the temperature goes low enough to kill. Some varieties of peaches have a longer rest period than others and are, therefore, started into growth more slowly by warm periods in winter. Trees making a late vigorous growth (as out back trees do) are later in finishing their resting period and are therefore in less danger from injury by cold following warm periods in December and January. The hardiest buds are those at the base of fairly strong whips.

Lazenby (22) reported, in Ohio, "the most vigorous peach buds are not at the end of the shoot, but on the part first formed or lower half."

In regard to the winter rest period of buds, Howard (19) found all forms of rest to be caused by unfavorable external conditions, and these conditions determine both the time of occurrence and the degree of intensity of the period of rest.

He found the peach to have a resting period of about six weeks (in Missouri), and that when peach buds are killed it is because of their habit of premature growth during warm days in late winter. Every fruit grower knows that there is no danger of growth taking place in early winter because trees are then in the midst of the rest period. Thus it seems that the rest period of the peach is a very important factor in determining the hardiness of the fruit.

Coville (10), commenting on the effect of cold in stimulating subsequent plant growth, says "the period of chilling required for the peach is so short that, in Georgia, unusually warm weather in December sometimes brings the trees into bloom and the crop of fruit is destroyed by the freezes that follow." This occurrence of premature blooming has also been observed in Texas by Brison (6).

Roberts (25) working with sour cherries in Wisconsin found that the primary killing in the buds seems to be confined to those cells which have a large central vacuole and that the vacuolated condition of the cytoplasm of cells in the region affected renders them more susceptible. The appearance of a large central vacuole is taken as evidence of the approach of maturity of the cells. The rate of maturing would be materially affected by the nutritional and growth conditions of the trees. This fact gives promise of success in attempts to reduce the injury through cultural means.

Johnson (20) secured results which suggest a definite relationship between air temperature and the rate of increase in the moisture content of peach fruit buds. There can be little doubt, however, that other conditioning influences operative before January 1 determine the manner in which these buds respond to temperature. The rate of increase in the moisture index after January 1 was found to vary, in five different years, as the sum of the effective daily mean temperatures above 43°F.

METHOD OF PROCEDURE.

For the purposes of this study, fruit buds samples were collected in two localities, the Michigan State College orchards at East Lansing, and The Corporation Farm Orchards at South Haven (three miles east of Lake Michigan).

The South Haven section is generally conceded to be one of the best peach growing sections in the state because of its proximity to Lake Michigan and its numerous desirable orchard sites. East Lansing, on the other hand, is in a general farming section that is not favorable to fruit growing, especially peaches. It derives less benefit from the moderating influences of large bodies of water. The college orchard stands on a site which gives practically no protection from low temperatures during winter or early spring.

In fact, because of low winter temperatures, good crops of peaches have been secured in only four of the past eight years.

Samples were taken from bearing trees in moderate vigor, previously handled according to the usual orchard practice in Michigan which consists of cultivation and cover cropping.

Buds were taken from the same trees at each collection, and as far as possible, they were taken from the south side of the trees. Two classes or types of buds were preserved:

(1) buds on spurs of 2 inches or less in length.

(2) buds on vigorous growth over 12 inches in length.

To secure a comprehensive picture of the cycle of bud development, samples were taken at intervals of two weeks from July 30 to April 15, except that monthly collections were made during mid-winter.

This schedule was followed closely in the collection of material at South Haven. The sampling at East Lansing was more or less irregular, to fit unusual weather periods, but comprehensive enough to give a fair comparison. The buds used in this work were collected at South Haven during 1926 and 1927, while at East Lansing the samples represented a range of seven years from 1922 to 1928. This gave a basis for comparing bud development during different years when weather conditions varied.

HANDLING OF BUD SAMPLES.

After the buds were removed from the tree, the scales were cut away on two sides of the bud to facilitate the entrance of the killing fluid and later to aid in subsequent infiltration. The cutting away of the bud scales was done in the orchard and the buds were placed immediately in Bilson's killing fluid. The buds were infiltrated with colloidin, sectioned with a sliding microtome to a thickness of 25-40 microns, and stained with Delafield's Haematoxylin. This stain, as reported by Roberts (25), does not stain dead tissue and in buds that had been slightly injured by low temperatures it was possible to differentiate between dead and living tissue. The dead cells could be distinguished by their brown color, while the live tissue took the purple stain of the haematoxylin.

VARIETIES OF PEACHES STUDIED.

Hill's Chili, a variety once popular because of its winter hardiness, was selected for study as offering rather extreme contrast with those varieties that are more tender in bud. Elberta was selected because of its commercial importance and the fact that under Michigan conditions it is rather tender in bud. Other varieties were used for comparison with the hardy Hill's Chili and tender Elberta. The list of varieties from which bud

samples were taken and their classification on the basis of hardiness as suggested by Chandler (8), Hedrick (18), Johnston (21) and others follows:

Very Hardy	Hardy	Tender
Hill's Chili	Kalamazoo	Elberta
Gold Drop	South Haven	Late Crawford
	Fitzgerald	J. H. Hale

With the help of a micro-projector drawings were made, all on the same scale so that bud advancement and increase in size could be accurately compared. Use of a Micro-Tessar lens enlarged the field sufficiently to include groups of three collateral buds where that was deemed necessary to the proper interpretation of the results. Microphotographs were taken of several bud sections to show more detail than could be shown with a micro-projector drawing.

PRESENTATION OF RESULTS.

Differentiation of Fruit Buds of the Peach.

Sections of prospective blossom buds of the Hill's Chili, Elberta and South Haven varieties, from material gathered July 30, August 15 and August 30, 1926, at East Lansing and South Haven, showed no evidence of blossom bud differentiation. This is illustrated by Plates 1(A,B), Plate IV(A,B,C), Plate VII(A,B,C), Plate X(A), and Plate XXII(A,D). Samples gathered on September 15, however, show a relatively advanced stage of differentiation, with

singular uniformity among varieties, between different locations, and between buds taken from spurs and vigorous wood. This early stage of differentiation is illustrated by Plates 1 (c), IV (d), VII (d), X(B), and XXII (B,E).

Fruit Bud Advancement During the Autumn.

From September 15 to December 18 the buds advanced rapidly, as shown by comparison of Plates 1 (E,F), II (A), VII (E,F), VIII (A,B,C), X (C,D,E,F), XI (A,B), XXII (C,F), XXIII (B,D). This development is extremely rapid during the latter part of September and October and slower during November and early December. There is a striking uniformity in the rate of advancement in buds of Hill's Chili, Elberta, South Haven and J. H. Hale, and there seems to be little, if any, difference in the stage of development attained by fruit buds on spur and vigorous wood growth during this period.

Under conditions prevailing in Michigan during the fall of 1926, all fruit buds of the peach varieties studied went into winter in practically the same stage of development. Consequently, any varietal differences in hardiness as shown by resistance to winter cold, could not be attributed to unequal fruit bud development previous to December 15.

Early Winter Development and the Rest Period.

Between November 15, 1926, and January 1, 1927, buds changed but little except for a slight increase in size; this increase seems to have continued also during the

latter part of December. (See Plates II (A), V (C), VIII (C), XI (B), and XXVI (B,C,D). This point cannot be asserted positively in the absence of exact measurements on a large number of buds; nevertheless, it was rather consistent in the material examined. The period between mid November and the first of January is the one of least activity in bud development during the entire progression from differentiation to blossoming and it would correspond closely to the rest period as defined physiologically.

At just what time the rest period begins and closes, it is impossible to state, but during the years under consideration in this study, it is probable that the sub zero temperatures occurring during the latter part of November and early December were instrumental in breaking the rest period. Evidence of this was obtained in examination of bud sections taken in January which showed some development over those of December 18.

Late Winter and Spring Development.

Between January 15 and April 15, bud advancement was naturally slow at first, becoming more rapid in late March. This is represented by Plates II (C,D,E,F), III (A), V (E,F), VI (A,B,C), VIII (D,E,F), IX (A,B), XI (D,E,F), XII (A,B,C), XXII (I), XXIII (E) and XXIV (D). During February and March there was rapid development of the pollen. In February the microspores were differentiated from the pollen mother cells and in March the tetrad stage

was prominent.

By late March or early in April the pollen grains were practically mature. No significant difference in the rate of bud advancement could be detected in buds of different varieties, or from buds taken from either spur or vigorous wood growth. Plate XXXIV (A) shows a longitudinal section through an anther of Elberta bud collected on April 15. This drawing was made with a higher magnification than that used for the other plate drawings. In several sections from material gathered on February 28, ovules could be clearly distinguished. They had not appeared in material gathered before this date. (See Plate V (F).

Comparison of the Rate of Fruit Bud Development in Different Varieties of Peaches.

Plates XIII (A,B,C,D,E,F), and XIV (A,B,C,D,E,F) present a comparative study of the rate of advancement in spur fruit buds of the Hill's Chili and Elberta varieties. Plates XV, XVI and XVII show a similar comparison of fruit buds from vigorous growth of the same varieties. Study of these plates again reveals the uniformity in development of the fruit buds of these two varieties on the same dates throughout the entire period of bud formation. Plate XVIII gives a comparison of the stage of development attained by Elberta spur buds on approximately the same dates at both South Haven and East Lansing. There is no apparent difference in the stage of advancement on the same dates for this variety. Plate XIX presents a

comparison of Elberta spur buds on approximately the same dates, but from samples taken in different years. There is, apparently, a close correspondence between bud development attained on given dates during 1923, 1926 and 1928.

It is of interest to note that microphotographs of peach buds made by Munn (~~25~~ 14) in 1912 when he was studying the relation of cover cropping to fruit bud development show practically the same stage of advancement as those for equivalent dates in the years covered by this present study. Munn's bud samples were taken from the Barden Orchard near South Haven.

Plate XX (A,B) indicates that Gold Drop fruit buds had attained the same stage of development on December 9, 1925, as buds of the same variety on December 16, 1926. Plate XX (C,D,E) is a comparison of Elberta spur buds on slightly different dates in December for the years 1922, 1923 and 1926. There is very little difference in the gross development of these buds. Fruit buds of five varieties, Late Crawford, Fitzgerald, Kalamazoo, Elberta and Gold Drop had reached practically the same stage of development on December 16, 1926, in the college orchard at East Lansing. These buds are shown on Plate XXI (A,B,C,D,E). These comparative studies seem to indicate that fruit buds of several varieties of peaches, produced on different types of wood growth, advance rather uniformly in Michigan under climatic conditions comparable to those of 1926 and 1927.

Winter Injury to Fruit Buds of the Peach.

Samples gathered on and after December 18, 1926, contained specimens showing various degrees of injury from low temperatures. On the morning of December 18 the minimum temperature at South Haven was -10°F. On two occasions in January, temperatures below zero occurred; -7°F. marked a cold wave on January 15 and 16, and -9°F. a similar cold wave on January 26 and 27. Several buds showed injury in the meristematic tissue and pith at the tip of the woody cylinder and in the peduncle below the floral parts, which were themselves uninjured. As observed under the microscope the xylem was discolored in these specimens, sometimes well down the cylinder or up into the blossom. Whether this was direct injury or merely due to diffusion from the injured area cannot be affirmed. This type of injury is apparently the same as that described by Chandler (9) for the peach in New York, and involves essentially the same region of the bud as that noted by Roberts (25) for the sour cherry in Wisconsin. Many buds thus injured by cold temperature, doubtless, ultimately produce peaches, as in the case reported by Chandler, though one injured as much as that shown by Plate XXXI (C) would probably develop no further.

Comparison of Figures B and C in Plate XXXI shows either (1) if the killing were recent, which is improbable, the less advanced of the two buds was affected, or (2) if the killing occurred on December 18, which is probable, the buds had developed in size between mid December and

mid February. The same inference may be drawn from Figure (A) of the same plate which shows the killing of one blossom at a node while the other survived. The injury below the floral parts seems to be the first stage of injury, and a slightly lower temperature brings about killing of the floral parts as well. This is illustrated by the specimens gathered at East Lansing on December 24, 1926, which had been exposed to -14°F. or four degrees lower than the minimum temperature recorded at South Haven. Though injured specimens were not numerous enough in the material examined to warrant definite conclusions, their appearance suggests that the tender point may shift from the base of the bud to the blossom itself during the course of the winter; in other words, the blossom may become more tender. However, this point is far from being established by this study.

Plate XXXI (A) shows a node of three collateral buds taken from vigorous wood growth on February 28. The bud on the left side of the figure is dead while that on the right is alive. The dead bud was killed probably on December 18. The size of the dead bud is assumed to be a fair measure of the size of the bud at the time of killing. If that be true, there is conclusive evidence that there was bud advancement between the date of killing and February 28 when the sample was collected.

The results here presented would seem to indicate that supposed differences in bud advancement offer no clues as to the susceptibility of peach buds to winter injury and killing by low temperatures. It is more probable, as suggested by Chandler (8) and Askenasy (1) that the difference in hardiness between buds of different varieties, buds on the same tree or buds of the same collateral, may lie in the chemical composition of the buds or in the density of cell sap in parts of the bud which are most susceptible.

Plates XXXII (A,B), and XXXIII (A) show other instances of killed buds compared with live buds taken on the same or approximately the same dates. There was some bud killing on January 15, 1927, at both South Haven and East Lansing, when the temperature dropped to -7°F. and -10°F., respectively. This fact was indicated in the sectioned material by the larger size of the killed buds when compared with buds killed in mid-December.

TEMPERATURE RECORDS.

For the purposes of this study, temperature records were secured for both South Haven and East Lansing. These records were furnished by the United States Westher Bureau station at East Lansing. Table 1 gives the minimum, maximum, and monthly mean temperatures at South Haven from May 1, 1926 to May 1, 1927. Table II presents similar data for East Lansing. Table III shows the daily maximum temperatures

Table 1.- Table of Temperatures at South Haven (1926-1927)

Day	September		October		November		December		January		February		March		April	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
1	61	80	57	61	35	48	21	42	12	28	21	42	17	30	21	43
2	65	77	58	69	32	39	13	27	24	37	27	44	17	36	28	49
3	52	78	55	80	30	42	23	40	30	38	33	41	23	36	30	46
4	62	74	65	79	32	43	12	37	32	37	24	38	20	41	32	54
5	67	74	52	68	35	48	16	28	28	36	31	35	30	48	39	55
6	58	75	45	53	39	54	9	22	24	30	33	39	35	43	39	58
7	52	72	42	58	35	60	11	32	19	34	28	39	31	48	27	46
8	60	69	35	65	39	60	28	38	20	30	30	41	35	40	30	46
9	54	60	48	72	32	53	26	36	21	28	24	33	30	50	32	62
10	46	70	56	66	22	34	29	35	12	31	20	29	28	59	32	58
11	48	70	50	66	18	34	23	36	12	28	20	37	35	64	27	62
12	55	60	50	62	18	40	27	38	14	27	24	35	45	59	37	57
13	43	69	41	60	36	46	20	49	19	28	25	32	40	58	35	54
14	45	69	43	59	40	62	11	22	9	21	24	31	38	43	30	60
15	59	68	35	58	45	64	4	14	-7	10	30	41	39	59	46	64
16	60	67	47	59	35	47	9	18	-2	18	36	49	45	70	48	63
17	57	75	32	50	32	37	5	22	16	35	35	39	38	65	51	77
18	58	77	45	59	30	44	-10	18	19	32	15	36	34	58	59	72
19	65	77	34	49	26	35	7	31	19	33	15	35	35	50	48	76
20	50	64	37	45	26	35	28	41	21	31	18	31	27	41	43	50
21	46	76	38	51	28	34	30	38	23	35	25	42	31	35	35	46
22	60	75	44	52	21	36	28	38	15	33	34	48	23	41	31	39
23	53	68	40	51	22	37	28	36	12	28	33	45	28	44	28	41
24	52	68	37	46	23	41	25	38	21	34	32	42	28	44	32	41
25	45	61	31	39	22	45	18	36	16	34	28	37	29	46	33	51
26	39	46	34	42	31	57	19	31	-9	27	25	30	32	46	43	51
27	40	48	29	49	21	32	18	32	-8	25	25	31	29	33	43	54
28	41	54	43	57	21	49	22	32	22	36	27	36	21	41	31	61
29	50	56	37	55	30	48	18	30	31	40	--	--	23	48	41	58
30	48	64	36	48	27	38	13	34	29	41	--	--	35	52	38	51
31	--	--	26	41	--	--	26	37	22	31	--	--	29	50	--	--
Mean	53.0	68.2	42.6	57.1	29.4	44.7	18.0	32.5	16.6	30.8	26.5	37.8	30.6	47.6	36.1	54.8

Table 2.- Temperatures at East Lansing (1926-1927)

	September		October		November		December		January		February		March		April	
Day	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
1	57	79	56	73	30	43	9	41	14	24	22	40	14	26	31	35
2	55	72	55	76	28	35	9	26	24	33	25	41	13	36	26	47
3	51	72	54	79	29	40	26	37	26	34	30	43	15	36	28	50
4	61	81	60	83	31	39	10	31	31	36	20	30	16	44	33	54
5	64	79	50	68	33	47	9	21	23	33	27	32	31	44	40	57
6	56	70	37	56	36	58	6	25	20	25	32	37	29	38	30	61
7	50	81	36	55	33	55	11	34	16	27	30	43	28	39	28	46
8	59	73	30	63	41	56	10	34	14	28	31	43	26	43	26	46
9	44	67	46	67	25	46	10	30	16	25	21	31	24	46	31	58
10	41	73	52	64	18	29	26	36	14	29	17	32	28	53	30	53
11	47	75	43	61	13	31	20	33	14	28	18	39	39	62	23	59
12	51	66	47	67	22	43	25	37	17	29	19	33	48	59	37	62
13	43	66	42	61	37	56	18	46	14	28	19	26	40	59	31	50
14	45	71	36	60	44	62	12	18	-2	18	22	30	38	46	28	58
15	60	81	32	58	43	62	5	12	-12	8	29	38	39	59	37	56
16	57	72	34	59	34	43	8	17	-6	17	36	56	38	70	50	62
17	56	72	28	47	34	41	-10	18	16	30	23	41	37	57	49	80
18	57	81	34	60	28	44	-14	17	19	28	9	23	37	61	54	76
19	60	83	30	44	26	34	8	33	25	34	11	30	30	44	54	80
20	48	73	35	44	25	31	33	38	26	32	17	22	29	32	40	58
21	45	78	38	49	25	30	29	35	29	35	17	36	30	36	32	43
22	55	70	37	55	19	33	29	35	12	33	26	49	24	41	28	42
23	53	72	35	50	27	38	30	36	12	23	32	50	28	43	26	43
24	51	71	33	43	23	38	21	39	11	35	28	51	29	47	27	43
25	32	54	30	39	23	51	18	25	2	31	23	33	29	50	30	54
26	29	55	25	45	27	53	20	36	-10	5	20	28	33	40	43	53
27	41	52	28	50	19	27	18	31	-7	26	25	32	31	35	39	57
28	41	57	43	60	22	47	25	29	26	36	22	34	28	43	32	64
29	45	58	35	57	31	43	18	25	32	42	--	--	24	47	38	48
30	49	67	31	47	30	41	17	34	25	38	--	--	34	57	34	60
31	--	--	25	39	--	--	19	33	21	25	--	--	29	50		
Mean	50.1	70.7	38.6	57.4	28.5	43.2	14.9	30.4	14.9	22.4	22.4	36.5	29.5	46.5	34.5	55.2

Table 3.- Daily Maximum Temperatures Above 43°F. 1927.

Day	January		February		March		April	
	S. Haven	E.Lansing	S. Haven	E.Lansing	S.Haven	E.Lansing	S.Haven	E.Lansing
1								
2							6	4
3							3	7
4						1	11	11
5					5	1	12	14
6							15	18
7					5		3	3
8							3	3
9					7	3	19	15
10					16	10	15	10
11					21	19	19	16
12					16	16	14	19
13					15	16	11	7
14						3	17	15
15					16	16	21	13
16			6	13	27	27		
17					22	14		
18					15	18		
19					7	1		
20								
21								
22			5	6				
23			2	7	1			
24				8	1	4		
25					3	7		
26								
27								
28								
29					5	4		
30					9	14		
31					7	7		
Totals	None	None	13°	34°	198°	181°	169°	155°

DISCUSSION.

This investigation has shown that buds of peach varieties generally reputed hardy under Michigan conditions are in the same state of advancement at any given time in autumn, and during the coldest part of the winter, when bud killing is most frequent in this state, as the buds of varieties shown by experience to be tender.

No difference has been found in advancement at a given time during this same period as between buds on vigorous shoots and those on spurs.

No attempt was made to determine the degree of vacuolization suggested by Roberts (25) as a factor in winter killing of buds. It is conceivable that differences of this kind could occur, with bud advancement as determined by size of floral parts, etc., identical. Explanation of varietal differences must lie rather in the physiology than in the grosser anatomy of the bud. Certainly, degree of advancement is not a criterion of varietal differences in hardiness during the period when bud killing is most common in Michigan; the degree of advancement apparently is not correlated with differences in hardiness of buds occupying different positions on the tree.

Under Michigan conditions, rest period differences seem of questionable importance. There is little or no

indication that buds withstand freezing better in mid-December than they do in January. Since freezing is a recognized means of breaking the rest period, this period should end in early winter. In fact, experimental work by Dutton (12) indicates that the rest period ends by the latter part of December in Michigan. That buds do not ordinarily advance more rapidly during January and February is due to the general absence of high temperatures. The development reported here from November 15, 1926 to February 15, 1927, at South Haven, was made with temperature accumulations (on the day-degree maximum above 43°F. basis) of 31 in November, 6 in December, 0 in January, and 1 in February.

There have been reports (5) of changes in relative varietal hardiness in early spring, Elberta becoming more hardy with reference to many other varieties, or, more accurately, it loses hardiness less rapidly. This fact leads to the inference that spring development of peach buds in Michigan may be independent alike of stage of advancement and of rest period influences. Bud killing in the spring is, however, of less practical importance because it is less common in this state.

The study here reported, then, affords no indication that ordinary cultural practices affect the stage of development of peach buds. It does not prove that

hardiness may not be affected. Counts of dead buds on shoots and spurs of varying degrees of vigor are not altogether consistent. Data reported by Gardner, Marshall and Hootman (14) are rather inconclusive inasmuch as trees which were pruned in the previous winter had higher percentages of bud killing than those which were both pruned and fertilized. It should be stated, however, that trees which were merely pruned had greater average shoot length than the others. If any generalization is to be made, bud injury was greatest on trees making the most vigorous growth.

On the other hand, an unpublished study of growth in an Elberta orchard, made by Bradford at Benzonia, Michigan, showed 51.45 per cent of killed buds on unfertilized trees, and 50.05 per cent on fertilized trees; in other words, there was no difference. Solitary blossom buds on all kinds of growth averaged 60 per cent dead (out of 1310); of 717 single buds coupled with leaf buds (one of each at a node) 46 per cent were dead; and of 1150 blossom buds which occurred in pairs with a leaf bud to each pair, 49 per cent were dead. Stated in another way, the percentages of blossom buds killed on shoots of different lengths were as follows:

1.0- 9.9 cm.	46.53 % dead.
10.0-19.9 "	54.65 % "
20.0-29.9 "	45.78 % "
30.0-39.9 "	47.57 % "
40.0-49.9 "	49.44 % "
50.0-59.9 "	66.95 % "
60.0-69.9 "	47.47 % "

If any difference is indicated by these percentages, it is in favor of somewhat greater hardiness in buds on more vigorous growth. It is quite conceivable that the difference between the results shown by the two studies may be accounted for as varietal differences, or as due to freezing at different periods of the winter.

This study, therefore, should not discourage further investigation of the possibility of influencing bud hardiness by cultural practices. It does show rather definitely that criteria other than the stage of development must be used in appraising these practices, and that cultural practices designed to affect hardiness through influencing the rest period offer little promise under Michigan conditions. Furthermore, since so far as presented to date, these practices hinge upon delqying the beginning of the rest period through prolonged autumnal growth, they are likely to make the tree itself subject to injury from low winter temperature

SUMMARY.

1. Fruit bud differentiation in the several peach varieties studied begins, under Michigan conditions similar to those of 1926, during the first two weeks in September.

2. Fruit buds of the peach develop rapidly during the autumn and go into winter in a relatively advanced stage in which all of the floral parts are well developed.

3. Among the varieties studied, differentiation occurred at approximately the same time in September; development was uniform during the autumn; buds went into winter in practically the same stage of development, and developed uniformly during the winter and early spring until shortly before the blooming period.

4. There is perceptible advancement in peach buds during the winter months, despite the occurrence of few daily maximum temperatures above 43°F., which has been accepted by many investigators as the critical temperature marking the growth response of plants.

5. Winter hardiness of the fruit buds in the peach varieties studied is not, apparently, correlated with grosser development of the buds.

6. When peach buds are injured by low temperatures, the entire bud may not be killed. In early winter stamens and pistils are relatively more hardy than the meristematic and vascular tissue immediately below the pistil.

7. The rest period in fruit buds of the peach, as grown under Michigan conditions, is very short. In the material studied, it apparently began after November 15 and was probably broken by the sub zero temperatures of December 17 and 18, 1926.

8. Because of the short rest period of peach buds in Michigan, no practical importance can be attached to it as influencing orchard practice, other than its possible relation to fall spraying.

9. Differences in latitude, rainfall, temperature and other climatic conditions, though small, between East Lansing and South Haven, seemed to exert no significant influence on fruit bud development in the peach.

10. Cultural practices may yet be found to affect hardiness of peach buds, but the criteria of this effect must be other than the stage of development of the buds.

ACKNOWLEDGMENTS

The writer wishes to make acknowledgment to all those who gave assistance during the progress of this investigation. Particularly is he indebted to Professor F. C. Bradford, under whose guidance the work was conducted, for help and suggestions, translation of literature, and

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Plate I.
Upper left- Hill's Chili spur, Aug. 16,1926 (South Haven)
Upper right- Hill's Chili spur, Aug. 31,1926 (South Haven)
Center left- Hill's Chili spur, Sept. 15,1926 (South Haven)
Center right- Hill's Chili spur, Sept. 30,1926 (South Haven)
Lower left- Hill's Chili spur, Oct. 30,1926 (South Haven)
Lower right- Hill's Chilispur, Nov. 15, 1926 (South Haven)

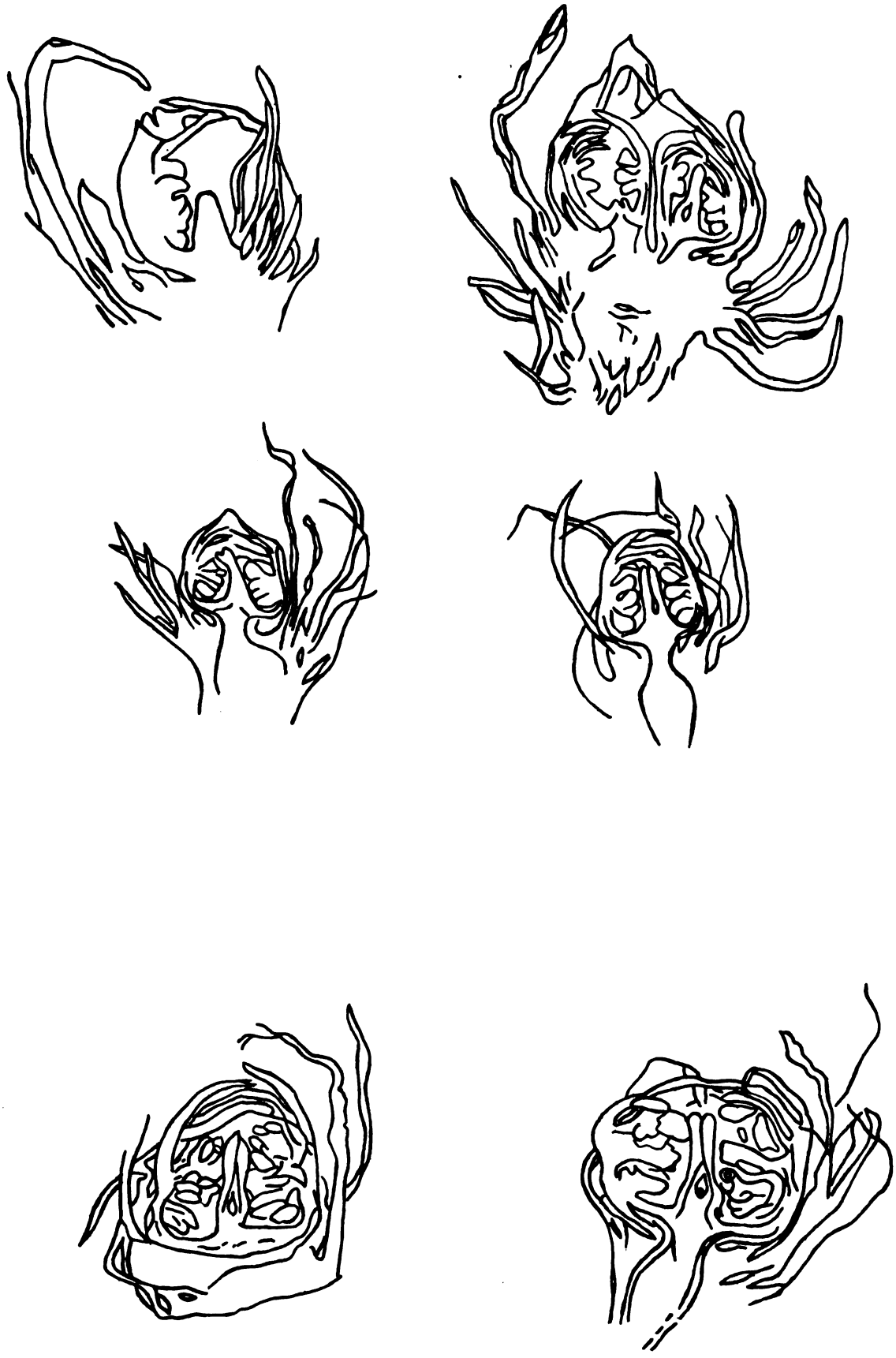
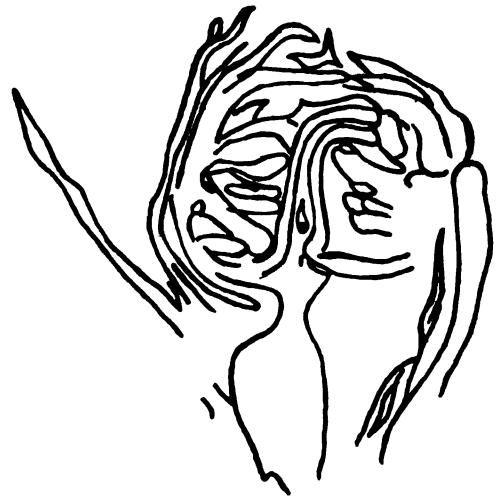


Plate II.
Upper left- Hill's Chili spur, Dec. 18,1926 (South Haven)
Upper right- Hill's Chili spur, Jan. 15,1927 (South Haven)
Center left- Hill's Chili spur, Feb. 15, 1927 (South Haven)
Center right- Hill's Chili spur, Feb. 28,1927 (South Haven)
Lower left- Hill's Chili spur,Mar. 15, 1927 (South Haven)
Lower right- Hill's Chili spur, Mar. 30,1927 (South Haven)

Plate III.
Hill's Chili spur, April 15, 1927.

Plate IV.
Hill's Chili vigorous, July 30,1926 (Upper left) (South Haven)
Upper right- Hill's Chili, Aug. 16,1926 (South Haven)
Center left- Hill's Chili, Aug. 31, 1926 (South Haven)
Center right- Hill's Chili, Sept. 15,1926 (South Haven)
Lower left- Hill's Chili, Sept.30,1926 (South Haven)
Lower right- Hill's Chili, Oct. 30,1926 (South Haven)



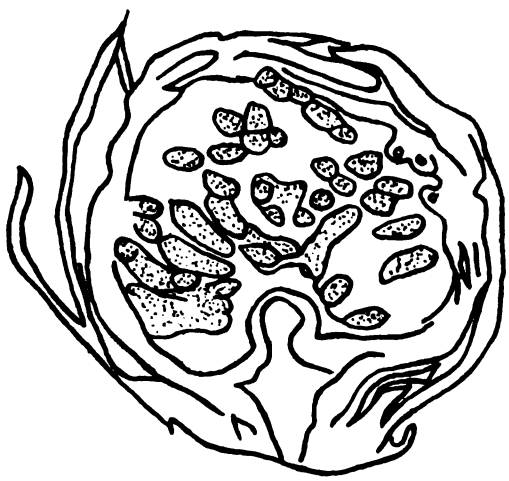
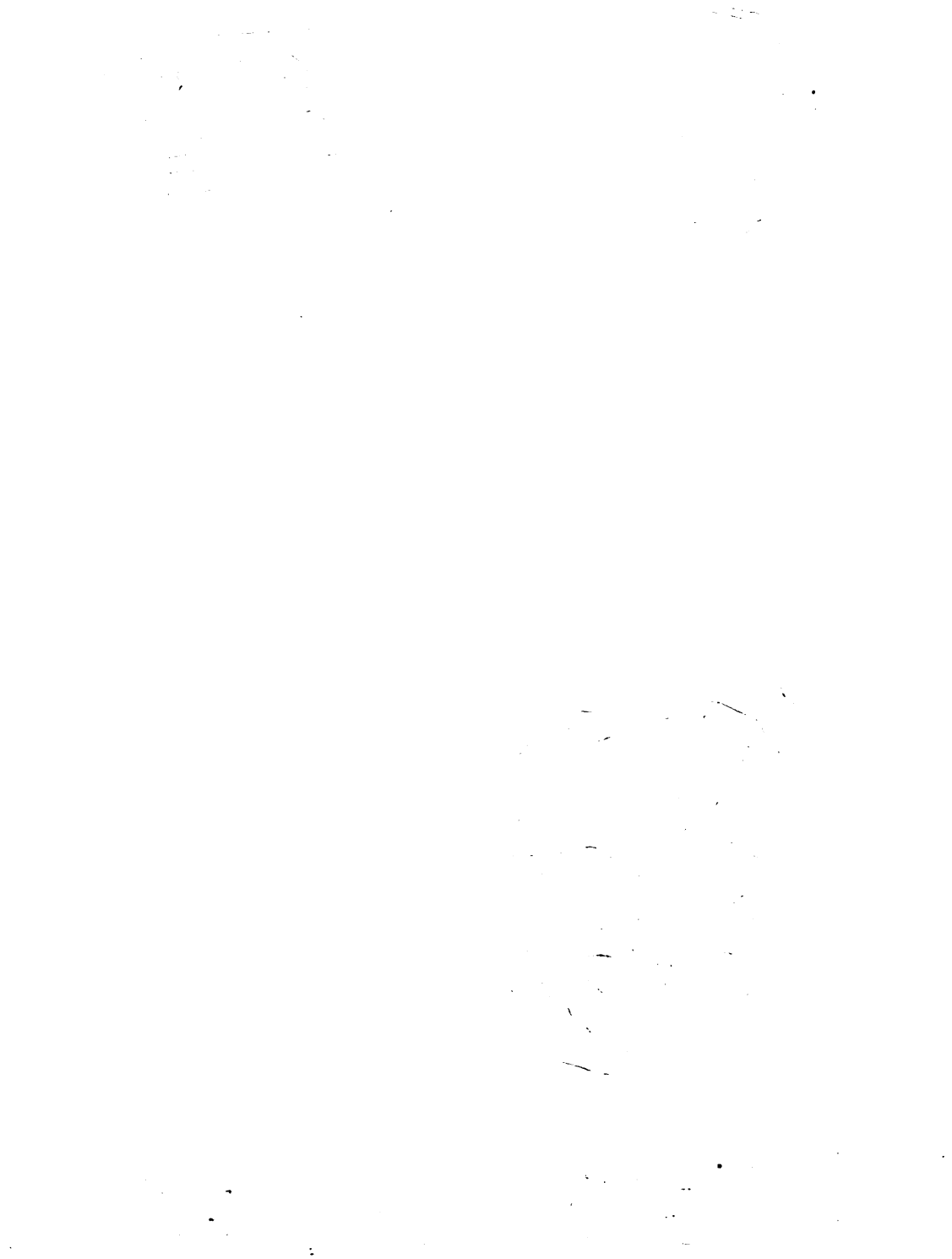


Plate VI.
Upper left- Hill's Chili vigorous, Mar. 15,1927 (South Haven)
Upper right- Hill's Chili vigorous, Mar. 30, 1927 (South Haven)
Lower left- Hill's Chili vigorous, April 15,1927 (South Haven)



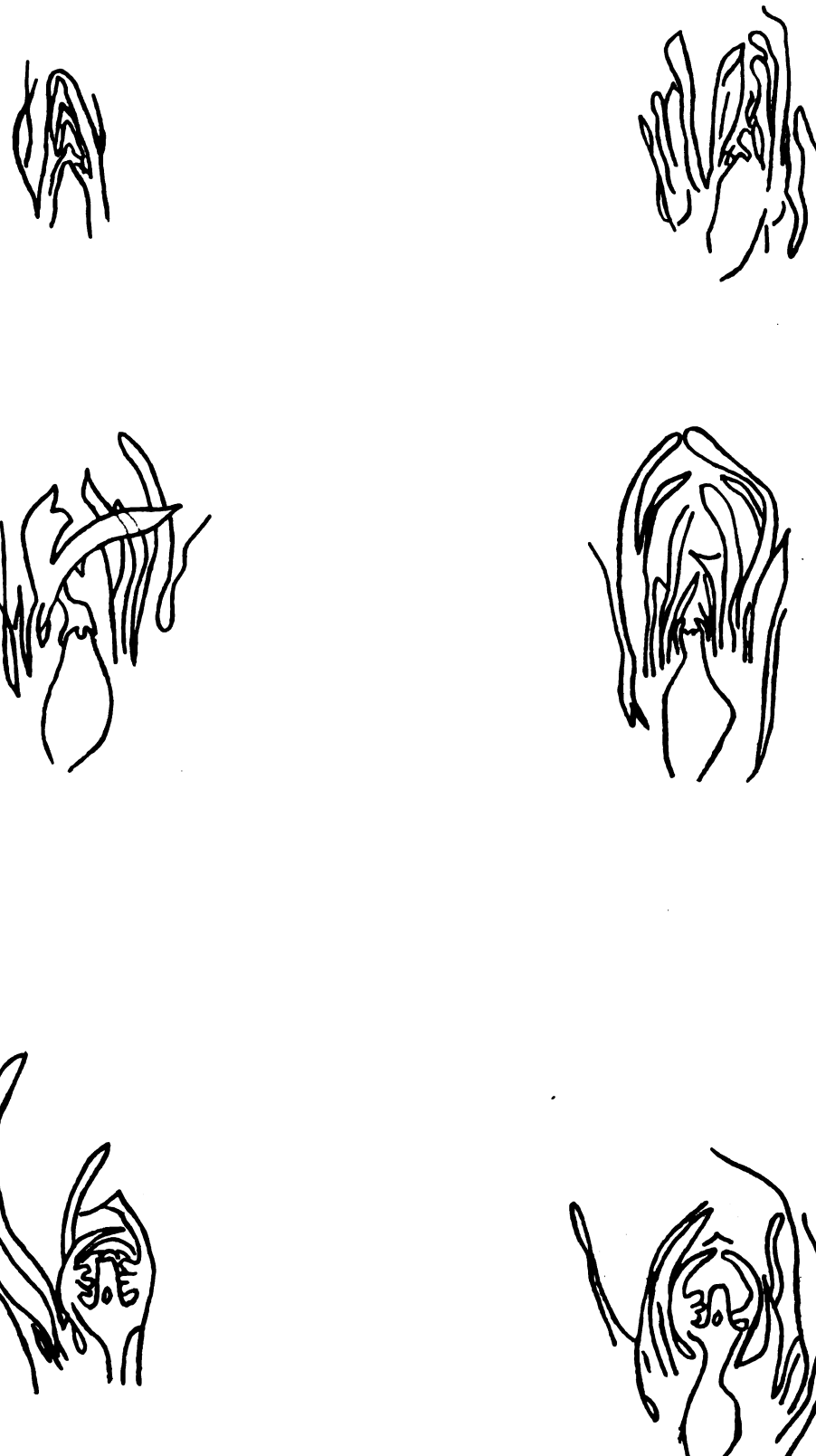


Plate VII.
Upper left- Elberta spur, July 30,1926 (South Haven)
Upper right- Elberta spur, Aug. 16,1926 (South Haven)
Center left- Elberta spur, Aug. 31,1926 (South Haven)
Center right- Elberta spur, Sept. 15,1926 (South Haven)
Lower left- Elberta spur, Sept. 30,1926 (South Haven)
Lower right- Elberta spur, Oct. 15,1926 (South Haven)

Plate VIII.
Upper left- Elberta spur, Oct. 30, 1926 (South Haven)
Upper right- Elberta spur, Nov. 30, 1926 (South Haven)
Center left- Elberta spur, Dec. 18, 1926 (South Haven)
Center right- Elberta spur, Feb. 15,1927 (South Haven)
Lower left- Elberta spur, Feb. 28, 1927 (South Haven)
Lower right- Elberta spur, Mar. 15, 1927 (South Haven)

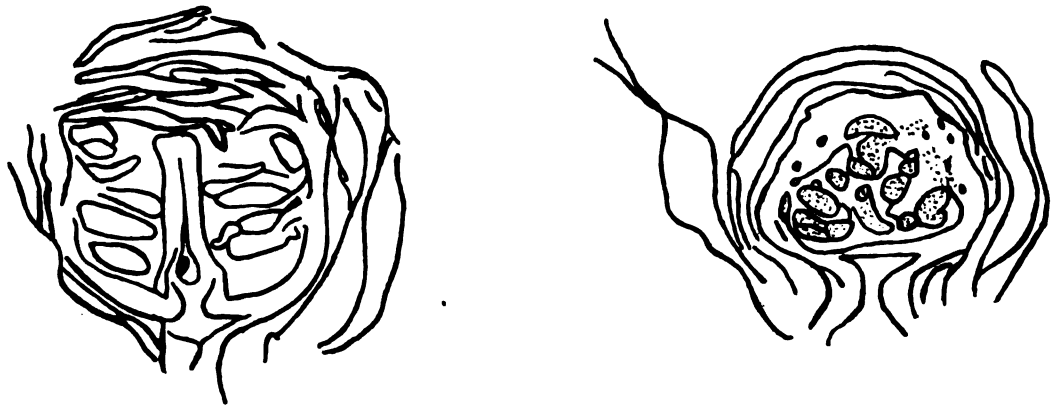
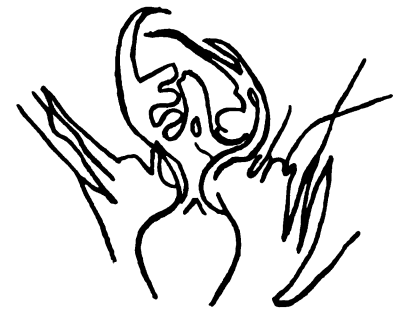


Plate IX.
Upper left- Elberta spur, Mar. 30,1927 (South Haven)
Upper right- Elberta spur, April 15, 1927 (South Haven)

Plate X.
Upper left- Elberta vigorous, July 30,1926 (South Haven)
Upper right- Elberta vigorous, Sept. 15, 1926 (South Haven)
Center left- Elberta vigorous, Sept. 30,1926 (South Haven)
Center right- Elberta vigorous, Oct. 15, 1926 (South Haven)
Lower left- Elberta vigorous, Oct. 30, 1926 (South Haven)
Lower right- Elberta vigorous, Nov. 15, 1926 (South Haven)



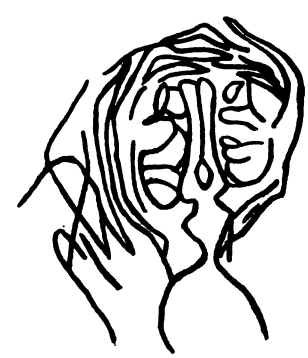


Plate XI.
Upper left- Elberta vigorous, Nov. 30, 1926 (South Haven)
Upper right- Elberta vigorous, Dec. 18,1926 (South Haven)
Center left- Elberta vigorous, Jan. 15, 1927 (South Haven)
Center right- Elberta vigorous, Feb. 15, 1927 (South Haven) Dead
Lower left- Elberta vigorous, Feb. 28, 1927 (South Haven)
Lower right- Elberta vigorous, Feb.28, 1927 (South Haven)

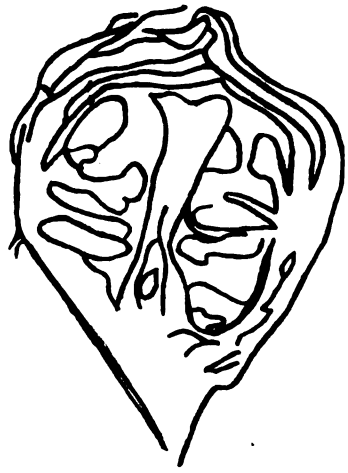


Plate XII.
Upper left- Elberta vigorous, Mar. 15, 1927 (South Haven)
Lower left- Elberta vigorous, Mar. 30, 1927 (South Haven)
Lower right- Elberta vigorous, April 15, 1927 (South Haven)

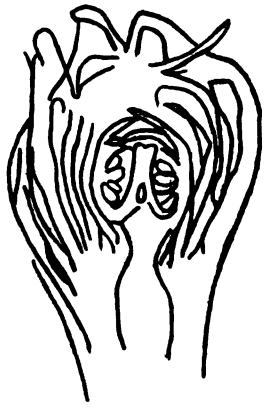


Plate XIII.
Upper left- Hill's Chili spur, Sept. 15, 1926 (South Haven)
Upper right- Elberta spur, Sept. 15, 1926 (South Haven)
Center left- Hill's Chili spur, Oct. 30, 1926 (South Haven)
Center right- Elberta spur, Oct. 30, 1926 (South Haven)
Lower left- Hill's Chili spur, Feb. 15, 1927 (South Haven)
Lower right- Elberta spur, Feb. 15, 1927 (South Haven)

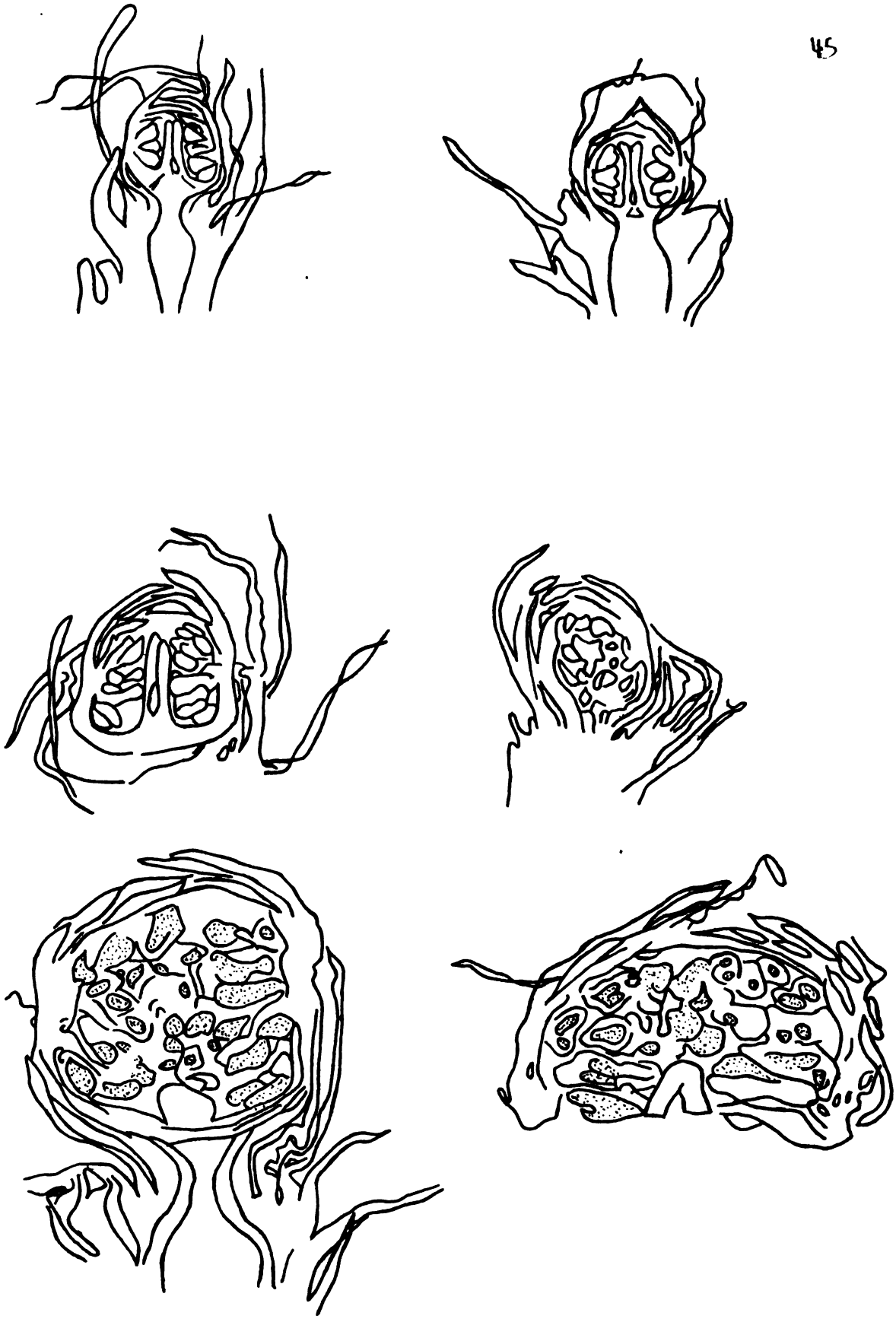
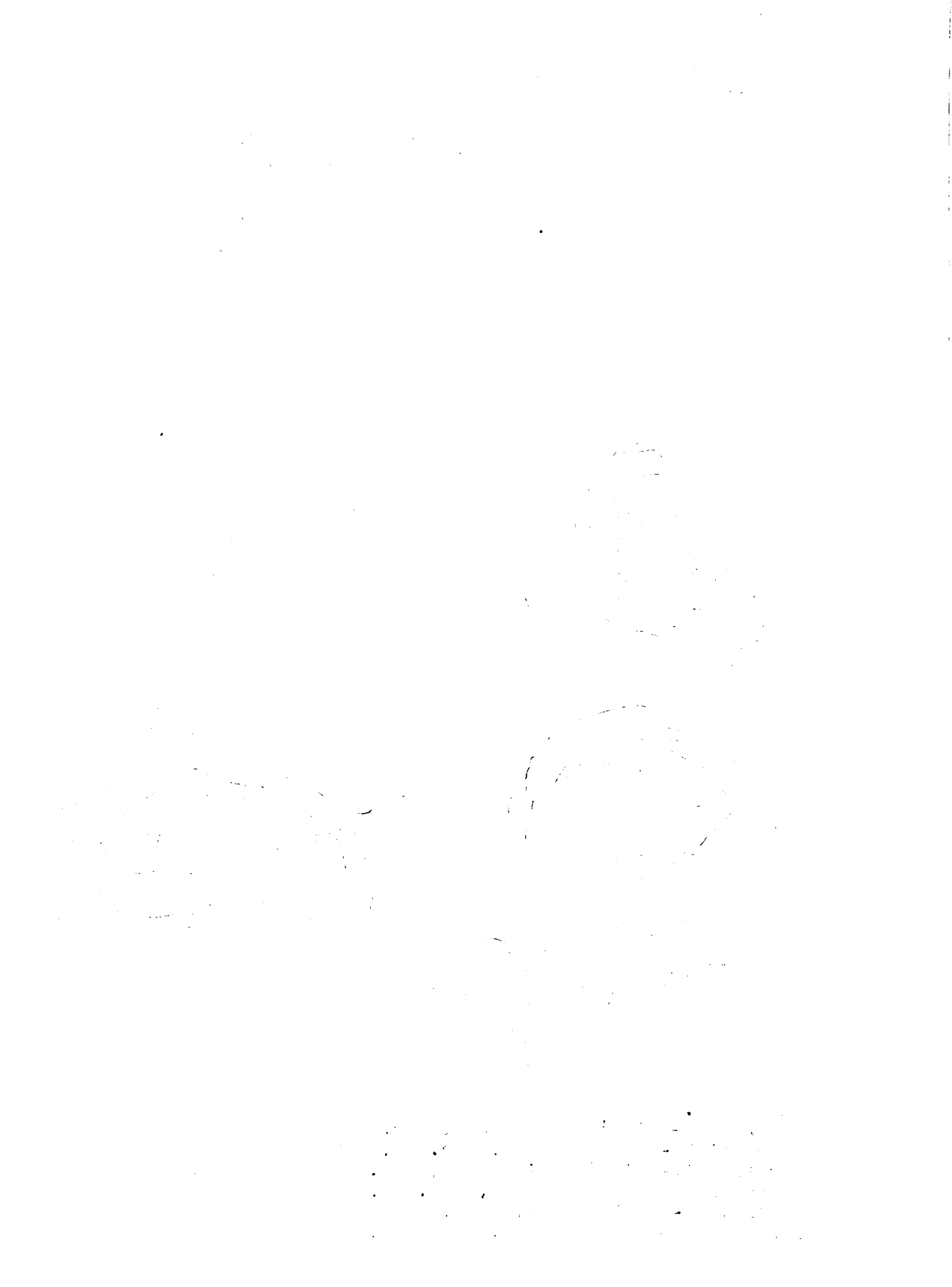


Plate XIV.
Upper left- Hill's Chili spur, Feb. 28, 1927 (South Haven)
Upper right- Elberta spur, Feb. 28, 1927 (South Haven)
Center left- Hill's Chili spur, Mar. 15, 1927 (South Haven)
Center right- Elberta spur, Mar. 15, 1927 (South Haven)
Lower left- Hill's Chili spur, April 15, 1927 (South Haven)
Lower right- Elberta spur, April 15, 1927 (South Haven)



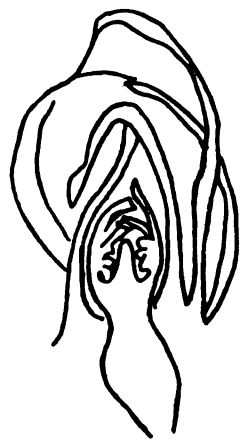


Plate XV.
Upper left- Hill's Chili vigorous, Sept. 15, 1926 (South Haven)
Upper right- HiElbertaili vigorous, Sept. 15, 1926 (South Haven)
Center left- Hill's Chili vigorous, Sept. 30, 1926 (South Haven)
Center right-Elberta vigorous, Sept. 30, 1926 (South Haven)
Lower left- Hill's Chili vigorous, Nov. 30, 1926 (South Haven)
Lower right- Elberta vigorous, Nov. 30, 1926 (South Haven)

Plate XVI.
Upper left- Hill's Chili vigorous, Jan. 15, 1927 (South Haven)
Upper right- Elberta vigorous, Jan. 15, 1927 (South Haven)
Center left- Hill's Chili vigorous, Feb. 28, 1927 (South Haven)
Center right- Elberta vigorous, Feb. 28, 1927 (South Haven)
Lower left- Hill's Chili vigorous, Mar. 30, 1927 (South Haven)
Lower right- Elberta vigorous, Mar. 30, 1927 (South Haven)

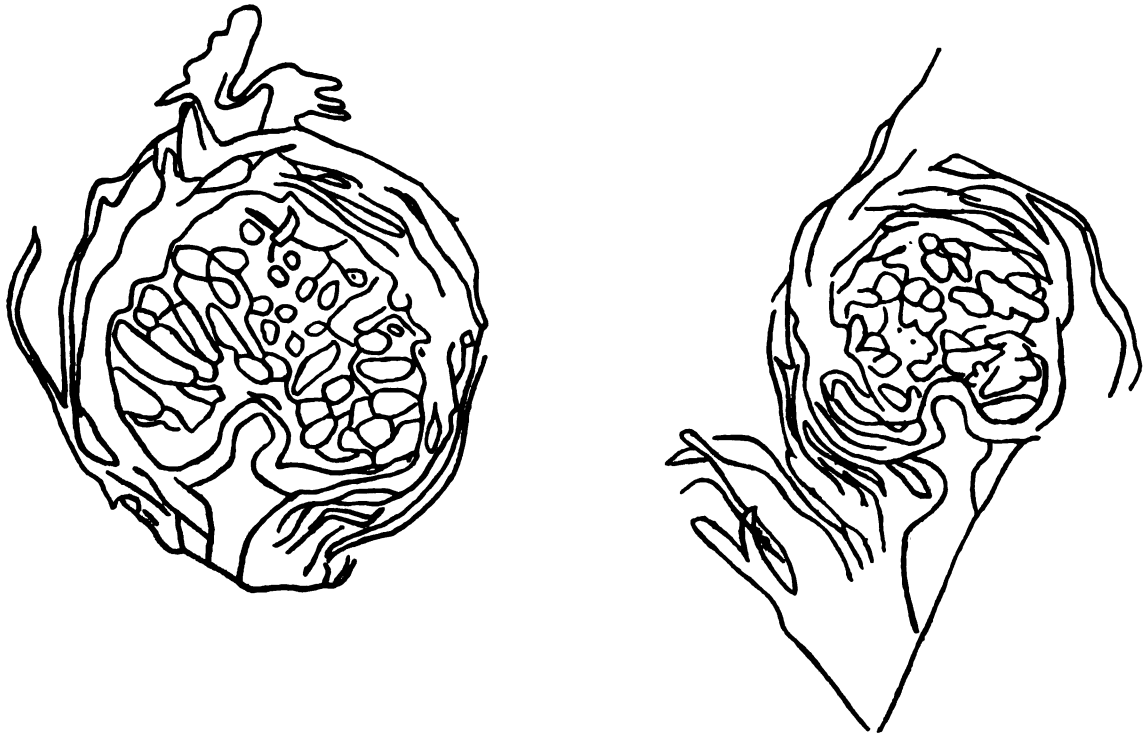


Plate XVII.
Upper left- Hill's Chili vigorous, April 15, 1927 (South Haven)
Upper right- Elberta vigorous, April 15, 1927 (South Haven)

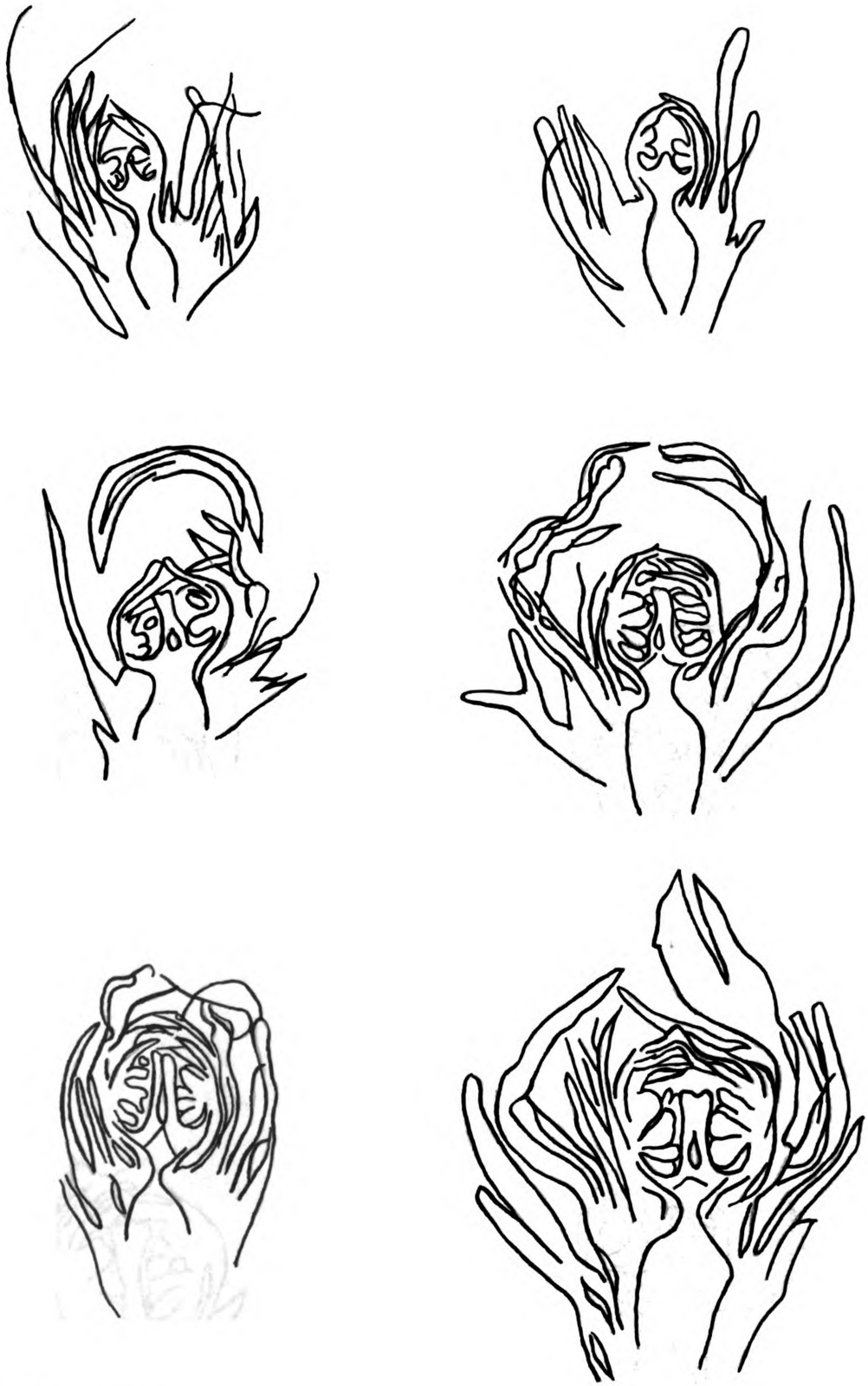


Plate XVIII.
Comparison of Development on the Same Dates at South Haven and East Lansing.
Upper left- Elberta spur, Oct. 15, 1926 (South Haven)
Upper right- Elberta spur, Oct. 15, 1926 (East Lansing)
Center left- Elberta spur, Dec. 18, 1926 (South Haven)
Center right- Elberta spur, Dec. 16, 1926 (East Lansing)
Lower left- Elberta spur, Feb. 15, 1927 (South Haven)
Lower right- Elberta spur, Feb. 24, 1927 (East Lansing)

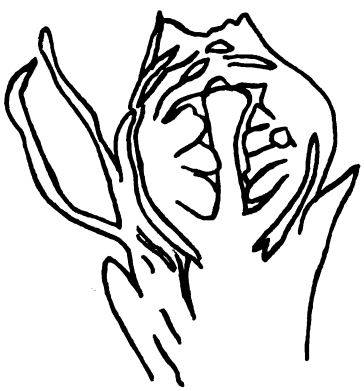


Plate XIX.
Elberta spur buds on Approximately the Same Date in Different Years.
Upper left- Elberta spur, Dec. 16, 1926 (East Lansing)
Center left- Elberta spur, Dec. 24, 1923 (East Lansing)
Center right- Elberta spur, Dec. 24, 1926 (East Lansing)
Lower left- Elberta spur, Feb. 17, 1923 (East Lansing)
Lower right- Elberta spur, Feb. 24, 1928 (East Lansing)

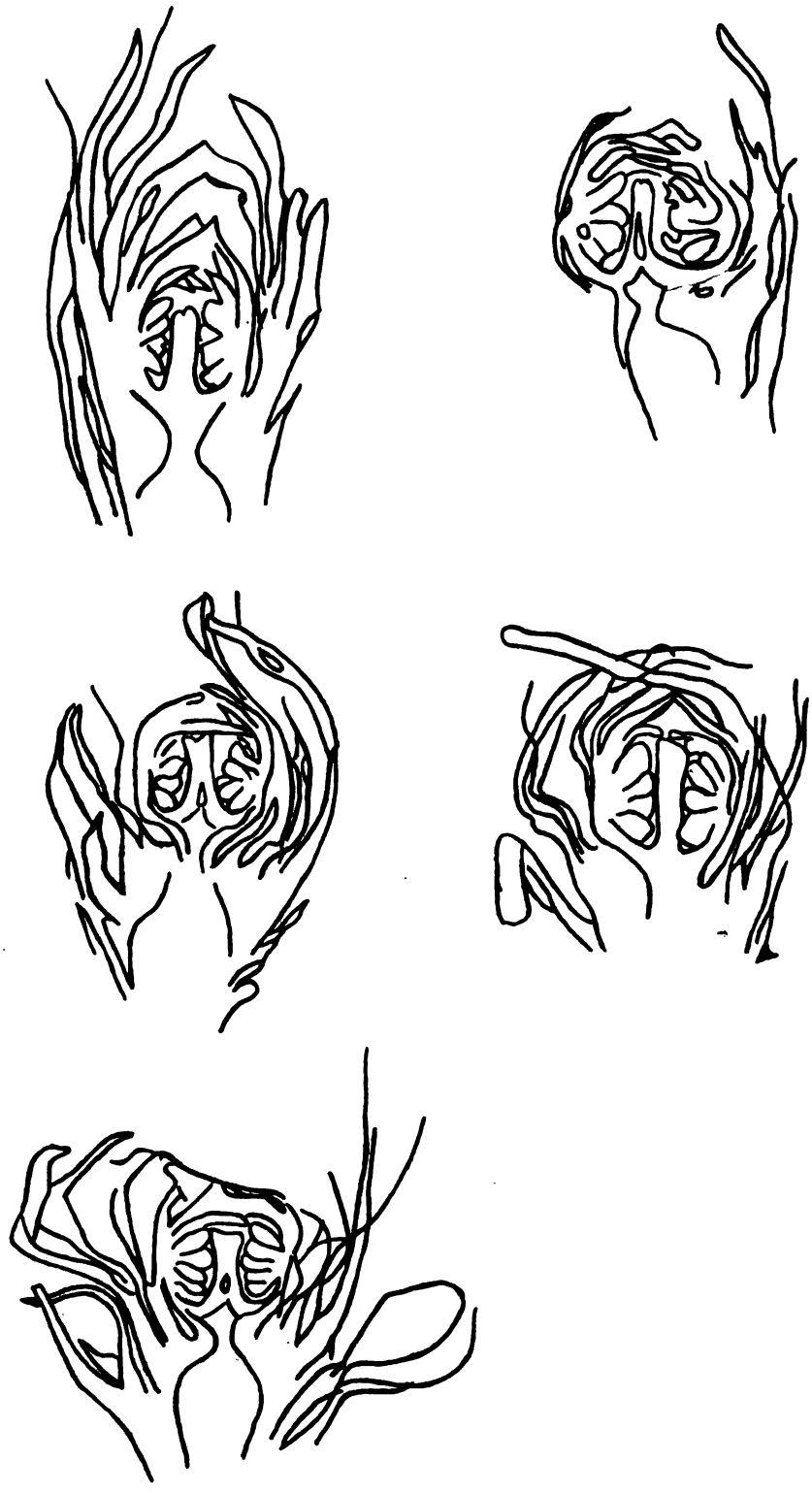


Plate XX.
Varieties at Approximately the Same Date in Different Years.
Upper left- Gold Drop-vigorous, Dec. 9, 1925 (East Lansing)
Upper right- Gold Drop spur, Dec. 16, 1926 (East Lansing)
Center left- Elberta spur, Dec. 2, 1922 (East Lansing)
Center right- Elberta spur, Dec. 24, 1923 (East Lansing)
Lower left- Elberta spur, Dec. 16, 1926 (East Lansing)

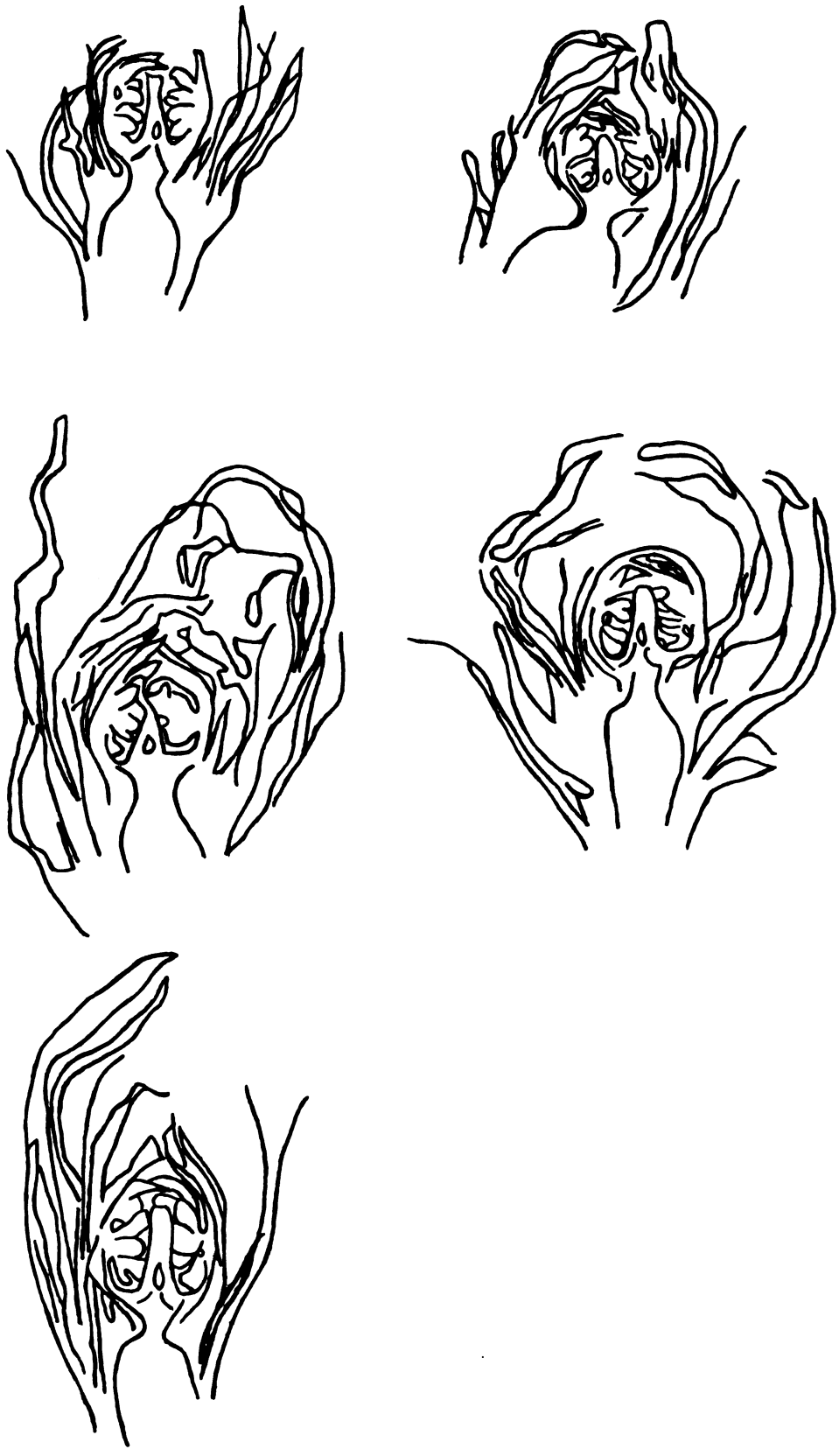


Plate XXI.
Five Varieties on the Same Date.
Upper left- Crawford spur, Dec. 16, 1926 (East Lansing)
Upper right, Fitzgerald spur, Dec. 16, 1926 (East Lansing)
Center left- Kalamazoo spur, Dec. 16, 1926 (East Lansing)
Center right- Elberta spur, Dec. 16, 1926 (East Lansing)
Lower left- Gold Drop spur, Dec. 16, 1926 (East Lansing)

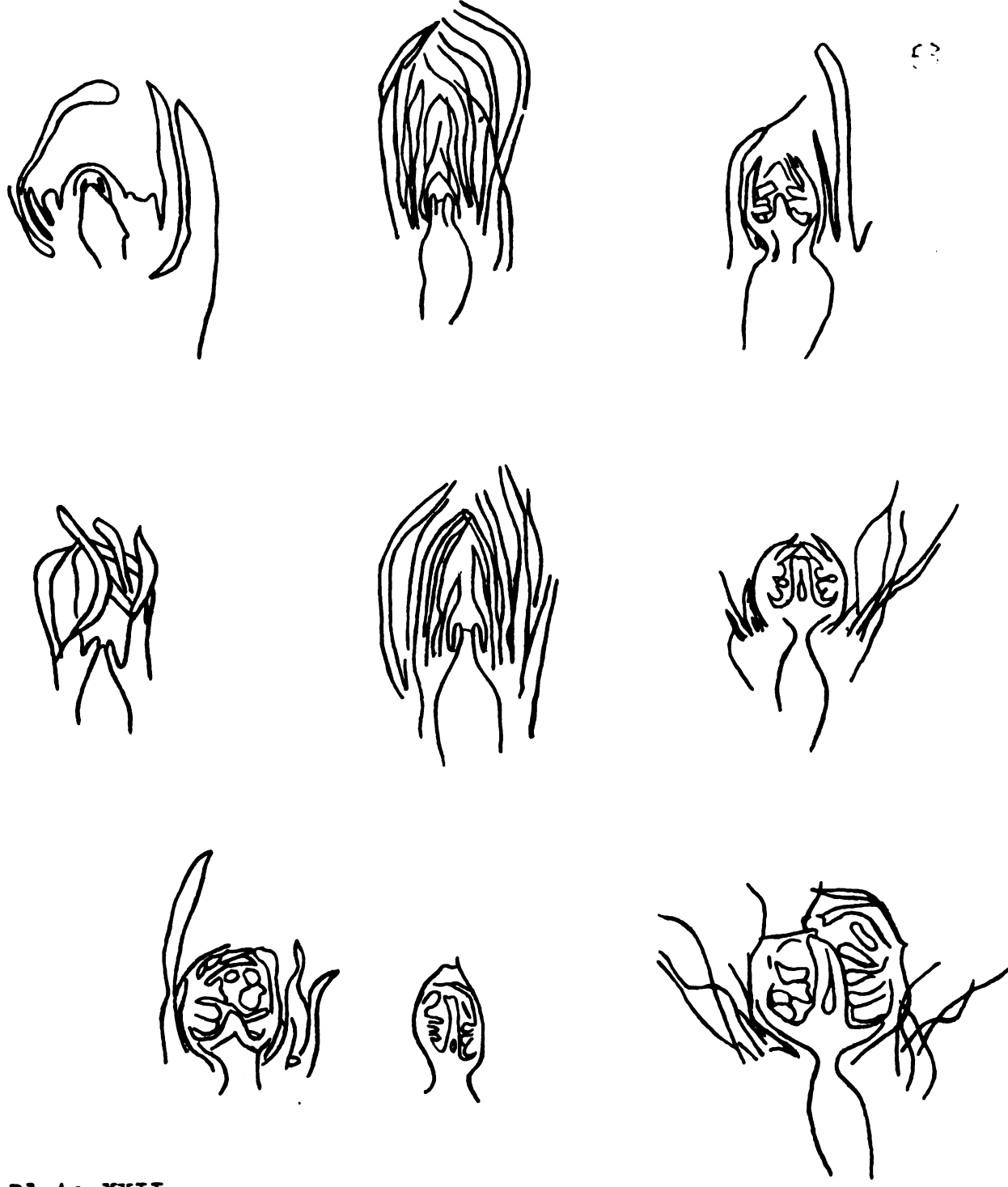


Plate XXII.
Upper left- South Haven vigorous, Aug. 16,1926 (South Haven)
Upper row(center)-South Haven vig.,Sept.15,1926 (South Haven)
Upper right- South Haven vigorous, Sept. 30, 1926 (South Haven)
Center left-South Haven spur, Aug. 16,1926 (South Haven)
Center row(center)-South Haven spur,Sept. 15,1926(South Haven)
Center row(right)- South Haven spur,Nov. 15,1926(South Haven)
Lower left- South Haven spur, Jan. 15, 1927 (South Haven)
Lower row(center) South Haven spur(dead),Mar.15,1927(South Haven)
Lower right- South Haven spur, Mar. 15, 1927 (South Haven)

Plate XXIII.
Upper left- J.H.Male vigorous, Sept. 15,1926 (South Haven)
Upper right- J.H.Male vigorous, Sept. 30, 1926 (South Haven)
Center left- J.H.Male shoot, Sept. 15, 1926 (South Haven)
Lower left- J.H.Male spur, Nov. 15, 1926 (South Haven)
Lower right- J.H.Male spur, Mar. 15, 1927 (South Haven)

Plate XXIV.
Upper left- J.H.Hale vigorous, Sept. 27, 1926 (East Lansing)
Upper right- J.H.Hale vigorous, Nov. 5, 1927 (East Lansing)
Lower left- J.H.Hale vigorous, Nov. 15, 1926 (East Lansing)
Lower right- J.H.Hale vigorous, Feb. 24, 1928 (East Lansing)

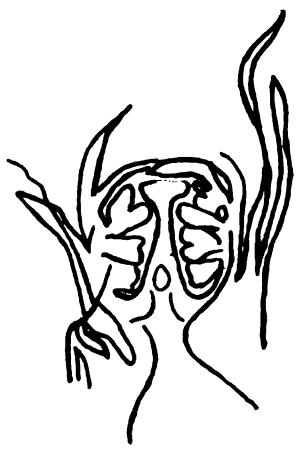


Plate XXV.
Upper left- J.H.Hale spur, Sept. 27, 1926 (East Lansing)
Upper right- J.H.Hale spur, Nov. 4, 1927 (East Lansing)
Lower left- J.H.Hale spur, Jan. 14, 1928 (East Lansing)

Plate XXVI.
Upper left- Fitzgerald spur, Oct. 15, 1926 (East Lansing)
Upper right- Fitzgerald spur, Nov. 5, 1927 (East Lansing)
Lower left- Fitzgerald spur, Nov. 14, 1926 (East Lansing)
Lower right- Fitzgerald spur, Dec. 16, 1926(East Lansing)

Plate XXVII.
Right- Fitzgerald vigorous, Nov. 5, 1927 (East Lansing)
Left- Fitzgerald vigorous, Oct. 15, 1926 (East Lansing)

Plate XXVIII.
Kalamazoo spur, Dec. 16, 1926 (East Lansing)

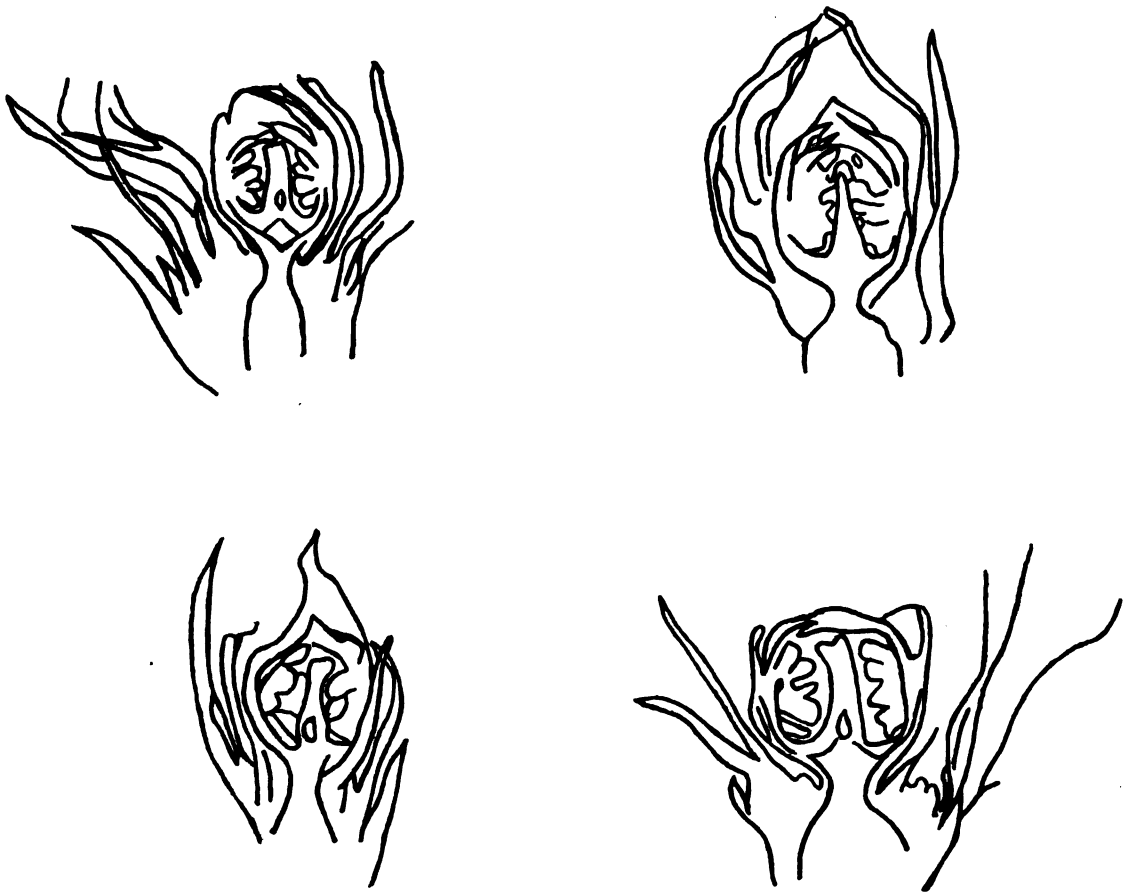


Plate XXIX.
Upper left- Elberta shoot, Nov. 5, 1927 (East Lansing)
Upper right- Elberta shoot, Dec. 2, 1922 (East Lansing)
Lower left- Elberta shoot, Dec. 24, 1923 (East Lansing)
Lower right- Elberta shoot, Jan. 13, 1927 (East Lansing)

Plate XXX.
Upper- Elberta vigorous, Nov. 15, 1927 (East Lansing)
Center- Elberta spur, Dec. 24, 1926 (East Lansing)
Lower- Elberta vigorous, Jan. 13, 1928 (East Lansing)

Plate XXXI.
Upper- Elberta vigorous, Feb. 28, 1927 (South Haven)
The fruit bud on the left of this collateral is dead. The one on the right side is alive.

Lower left- Elberta spur, Feb. 25, 1927 (South Haven)

Lower right- Elberta vigorous (dead), Feb. 15, 1927 (South Haven)
The shaded portion shows dead tissue at the base of the pistil in the vascular area. Other parts of the bud were alive at the time of fixation.

Plate XXXII.
Left- Elberta spur(áliwd), Dec. 16, 1926 (East Lansing)
Right- Elberta spur (dead), Dec. 24, 1926 (East Lansing)

Temperature Range during the period of Killing:
Dec. 17, 1926 **** -10°Fah.
Dec. 18, 1926 **** -14°Fah.
Dec. 20, 1926 **** 38°Fah.

Plate XXXIII.
Hill's Chili vigorous, Feb. 15, 1927 (South Haven)
Dead bud on the left of the collateral. Live bud on the right.

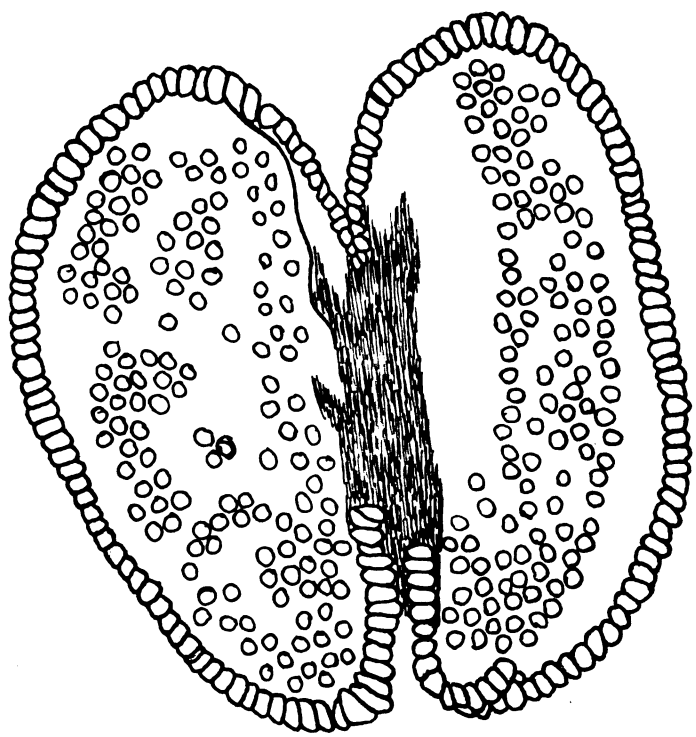


Plate XXXIV.
Longitudinal section through an anther.
Elberta vigorous, April 15, 1927 (South Haven)


Fig. 1

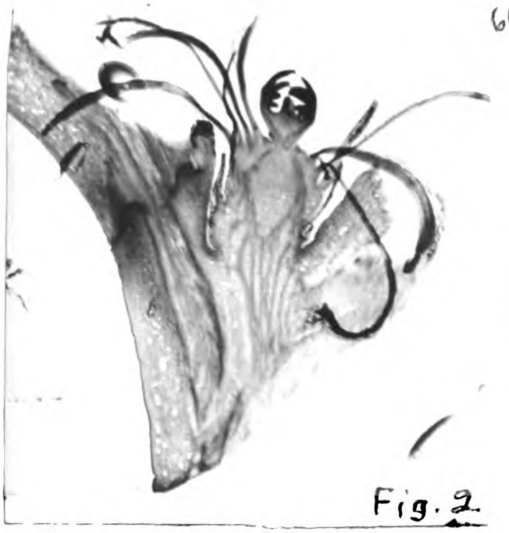


Fig. 2


Fig. 3


Fig. 4


Fig 5


Fig. 6


Fig. 7

Plate XXXV.
Bud development in Elberta peach.
Figure 1. Sept. 15, 1926.
Figure 2. Oct. 15, I926.
Figure 3. Nov. 15, 1926.
Figure 4. Dec. 18, 1926.
Figure 5. Feb. 15, 1927.
Figure 6. Feb. 28, 1927.
Figure 7. Mar. 15, 1927.


Fig. 8


Fig. 9


Fig. 10


Fig. 11


Fig. 12


Fig. 13

Plate XXXVI.
Spur fruit buds of different varieties on approximately the same dates.
Figure 8. Elberta spur bud, Dec. 24,1923.
Figure 9. Crawford spur bud, Dec. 16, 1926.
Figure 10. Kalamazoo spur bud, Dec. 16, 1926.
Figure 11. Fitzgerald spur bud, Dec. 16, 1926.
Figure 12. Elberta spur bud, Dec. 16, 1926.
Figure 13. Gold Drop spur bud, Dec. 16, 1926.


Fig. 14


Fig. 15


Fig. 16


Fig. 17


Fig. 18


Fig. 19


Fig. 20

Plate XXXVII.
Winter injury in fruit buds of the peach.
Figure 14. Hill's Chili bud Jan. 15,1927. Shows injury to vascular tissue below floral parts. (Note double fruit bud.)
Figure 15. Hill's Chili bud Feb. 15,1927. Very slight injury in bascular tissue below pistil.
Figure 16. Hill's Chili bud Feb. 15,1927. Killing very pronounced in the floral parts, and only slight in the vascular tissue.
Figure 17. Elberta spur bud Dec. 16,1926, A live bud.
Figure 18. Elberta spur bud Dec. 24,1926. Entire bud killed, including the peduncle.
Figure 19. South Haven spur bud Jan. 15,1927. A live bud.
Figure 20. South Haven spur bud Jan. 15,1927. A dead bud in which the killing is largely confined to the floral parts, and has affected the vascular tissue only to a slight degree.

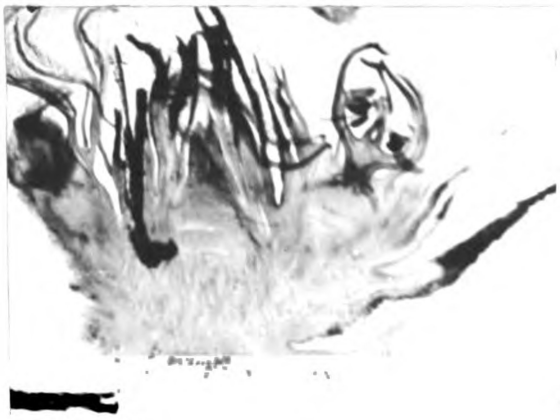


Fig. 21

Fig. 22

Fig. 24

Fig. 23

Fig. 25

Plate XXXVIII.
Showing winter injury to fruit buds, and winter bud development.
Figure21. Elberta bud Dec.18,1926, showing injury to the vascular tissue below the pistil.
Figure 22. Elberta bud Dec.18,1926. A live bud.
Figure 23. Elberta bud Feb. 15,1927. Partly killed bud. Pistils and stamens are alive. Perianth and vascular tissue are killed.
Figure 24. Elberta bud Feb. 15,1927. A live bud.
Figure 25. Elberta bud Feb. 28,1927. One collateral of two fruit buds and one leaf bud, showing a dead fruit bud on the left and a live bud on the right. This illustrates bud advancement during the winter.