1-1-1927

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H. E. Knowlton

Maxwell J. Dorsey

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Agricultural Experiment Station

College of Agriculture, West Virginia University

N. J. Giddings, Acting Director
Morgantown

A Study of the Hardiness of the Fruit Buds of the Peach

[TECHNICAL]

By

H. E. KNOWLTON and M. J. DORSEY

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 Zoologist

*In cooperation with the U. S. Department of Agriculture, Washington, D. C.

†In charge of the Lakin Sub-station, Lakin, W. Va.

**In cooperation with the State Department of Agriculture, Charleston, W. Va.

‡In charge of the Reymann Memorial Farms, Wardensville, W. Va.

*A Study of the Hardiness of the Fruit Buds of the Peach**

Winter killing of the fruit buds of the peach in West Virginia is a serious limiting factor to an otherwise profitable crop. In some sections a crop failure from this cause alone may occur as often as two or even three times in a five-year period. This problem has been given considerable study in the peach-growing regions of other states, and may be considered as separate and distinct from that of the injury to flowers and young fruits by spring frosts. In this investigation, in West Virginia, attention has been given to the following points: (a) the relative hardiness of the fruit buds of some of the more important varieties, (b) the stages of development in the fruit bud throughout the season, and (c) the influence of culture and fertilizers upon fruit-bud hardiness. These three phases of the subject will be taken up in the order named.

The wood of the varieties under observation in this study was found to be injured less frequently than the fruit buds. During the winter of 1924-25 some wood injury occurred, but as far as observations were made, only young or rapidly growing trees were affected. When winter conditions in this state kill all the fruit buds, there may also be some killing of the wood. It rarely happens in this latitude that the fruit buds prove to be harder than the wood, although an instance of this condition was reported in Ohio by Thayer (1916). The fruit buds, therefore, may be regarded as a more sensitive index to hardiness than the wood.

SOME EFFECTS OF WINTER CONDITIONS IN WEST VIRGINIA

The problem of fruit-bud hardiness with the peach, Japanese plum, and sweet cherry is apparently more important in the latitude of West Virginia than it is farther north. This is because of the mild winters with frequent periods of warm weather. Figure 1 shows daily maximum and minimum temperatures for the winter of 1921-1922. It will be seen in this figure that maximum temperatures were above 50° F. eight times and above 60° three times during December, January, and February. On February 25 the temperature was 75° F. These warm

bells, if they occur toward the end of the rest period in early January and later, start buds into growth. This brings about a marked decrease in their resistance to subsequent low temperatures. In the winter of 1924-1925 almost all fruit buds on the tender and semi-hardy varieties of peach in the Experiment Station Orchard were killed by a sudden drop in temperature to -9° F., following a period of warm weather in late January. In the northern peach sections of New York, Michigan, and Ontario, where warm periods seldom occur during winter, peach buds have withstood temperatures as low as -20° F. without injury. This extreme resistance, however, is only shown at the end of long cold periods.

VARIETAL DIFFERENCES IN THE HARDINESS OF FRUIT BUDS

It is generally recognized by peach growers that the fruit buds of some varieties are hardier than those of others. This condition has been given some study in West Virginia, and in this latitude significant differences were found when a survey was made of some of the more important varieties.

In the spring of 1923 the condition of all of the fruit buds on two hundred nodes, each of some of the more important commercial varieties under test in the Experiment Station variety orchard, was studied. This classification was made at the pink stage, but before the winter-killed fruit buds had fallen. At this time the winter-killed fruit buds could easily be distinguished from those not killed, by differences in size. A study of Table 1 will show interesting differences in the effect of winter temperatures on the different varieties.

While there was considerable killing in all of the varieties, some of them like Reeves, Nectar, and Bilmeyer lost nearly all of their fruit buds from winter killing. The contrast between these and Bellefontaine, Greensboro, or Hiley, in the number of fruit buds or flowers surviving the winter, is noticeable. An interesting feature of the winter-kill in this season was the large number of dead pistils in some varieties. This condition appeared to be peculiar to this season, in view of the fact that only an occasional dead pistil could be found the following season.

Death was apparently due to occurrence of low temperature after considerable growth had taken place. This indicates that the pistil is more susceptible to injury at certain stages of growth than are the other parts of the flower. When only the pistil is killed, bloom occurs in an apparently normal manner, but the flowers drop a few days after opening. Pistil injury was especially noticeable in Carman and Late

TABLE 1.—Fruit Bud Condition on Selected Commercial Varieties of Pea Following the Winter of 1922-1923.

Variety	Total Number of Fruit Buds on 200 Nodes	Percent of Winter-Killed Fruit Buds	Percent of Flowers with Dead Pistils	Percent of Flowers with Live Pistils
Belle.....	301	25.6	8.0	66.4
Bilmeyer.....	118	88.1	5.1	6.8
Burton.....	300	25.0	1.0	74.0
Carman.....	242	6.2	34.7	59.1
Champion.....	151	65.5	4.6	29.9
Crawford Late.....	155	0.0	84.5	15.5
Early Elberta.....	162	52.4	0.6	47.0
Elberta.....	176	47.2	8.5	44.3
Greensboro.....	306	8.2	3.9	87.9
Hiley.....	273	20.5	10.6	68.9
J. H. Hale.....	137	68.6	0.7	30.7
Nectar.....	59	84.7	5.1	10.2
Reeves.....	57	100.0	0.0	0.0
Rochester.....	71	35.2	2.8	62.0
Salwey.....	167	59.3	5.4	35.3

Crawford. It will be seen, then, that at bloom, all the fruit buds produced in the fall can be grouped into three categories as listed in Table 1. It is evident that the crop must be obtained from the flowers with live pistils. A similar classification in other years may show marked difference in the grouping of the buds under the different headings of this table.

The study of the relative hardiness of fruit buds on the terminal growths and on the shorter lateral growths on the interior of the tree discloses some interesting differences. The data on this point are summarized in Table 2.

As before, the buds on 200 nodes were made the basis of comparison. Fruit-bud production was relatively heavy the year that these counts were made, and marked differences were found between varieties. The varieties also varied considerably in the percentages of fruit buds killed. In Belle and Crawford, there was slightly less killing of buds on the inner lateral growths than of those on the outer terminal growths. Elberta, on the other hand, showed considerable more killing on the short lateral growths on the inner part of the tree. Rochester was in the same category, but not so pronounced. It is possible that, if larger numbers of fruit buds of these varieties had been counted, different results would have been obtained.

In making these counts of killed buds, attention was not given to the relative hardiness of buds borne on the basal, median, and terminal parts of the longer outer growths. Observations, however, during the

TABLE 2.—The Relative Hardiness of Fruit Buds Borne on Short and Long Growths During the Season of 1923-1924.

Variety	Trees	Spurs or Laterals Less Than 3½ Inches in Length			Outside Terminal Growths 16 to 20 Inches Long			Percent Fruit Buds Killed on Short Growths	Percent Fruit Buds Killed on Terminals
		Number of Nodes	Number of Flowers Alive	Number of Fruit Buds Winter-Killed	Number of Nodes	Number of Flowers Alive	Number of Fruit Buds Winter-Killed		
Allegheny	1	200	107	51	200	65	106	32	62
	2	200	99	70	200	69	110	41	61
	3	200	168	99	200	93	122	37	57
	4	200	126	102	200	95	73	45	43
Crawford	1	100	24	81	200	14	128	77	90
	2	200	21	163	200	8	166	89	95
	3	200	20	184	200	8	125	90	94
	4	200	29	181	200	19	139	86	88
Berta	1	200	37	142	200	44	31	79	41
	2	200	44	146	200	16	19	77	54
	3	200	35	141	200	17	20	80	54
Rochester	1	200	127	73	200	91	50	37	35
	2	200	110	114	200	118	59	51	33
	3	200	106	97	200	92	51	43	36
	4	200	109	43	200	98	55	28	36

inter of 1924-25 showed that the few buds still alive were either on spurs" or on the base of terminals. Chandler (1908) found that some of the hardiest buds on the tree were borne at the base of the terminal growths. It will be shown later that the buds in this position lag behind the others in development during winter and come to bloom more slowly in the spring.

In the studies of the relative hardiness of some of the more important varieties in the eastern and western parts of the state, the data in Table 3 were obtained. The records cover three years at Morgantown, two at Mason City and at Metz, but only one year at the other locations. Sixteen varieties in all are included in the table. Fruit buds were counted on from 200 to 700 nodes.

The percentages of the fruit buds killed each year at Morgantown and at Metz were relatively large, although one-fourth of the fruit buds, or even fewer, would be ample for a full crop if all were to set fruit. When the percentage of fruit buds killed at Morgantown and at Metz during 1923-24 is compared by varieties with the fruit-bud killing at points east of the mountains, it is evident that there is much

less injury in the eastern counties. This is probably due to the more uniform temperatures that prevail there.

The records of Belle and Elberta in the Smith orchard near Martinsburg may appear exceptional, but the bud killing in this instance was determined from young trees which had grown until relatively late the previous season. There was but little difference between the percent of the fruit-bud killing in the Butts orchard, with young trees, and in the Woods and Fulton orchards, with older trees.⁷ The trees in the Experiment Station and Metz orchards were about seven years old in 1925.

It is interesting to note the bud killing each year in Reeves as compared with some of the other varieties. Blake and Connors (1918) found that varieties like Reeves, Early Crawford, Late Crawford, and Mountain Rose are much more susceptible to fruit-bud injury than Greensboro, Carman, and Belle. Elberta and J. H. Hale have also been injured extensively in the West Virginia Experiment Station orchard. There was a complete loss in a number of varieties in the same orchard in the winter of 1924-25. During the same winter, in the eastern part of the state, the killing of fruit buds appeared to be somewhat variable, some orchards coming through the winter with relatively light injury, while others near by were severely injured. Spring frosts, however, soon after bloom, killed practically all the flowers remaining after the winter killing.

The greater hardiness of the fruit buds of some varieties may have considerable significance when measured by yield. Chandler (1908) says that if only three to ten percent of the fruit buds were to set, there would be enough to produce a full crop of fruit. In 1906 he found that peach trees, with 90 percent of their fruit buds killed, set a good crop of fruit. Blake and Farley (1911) observed that experienced fruit growers are generally satisfied if one-half of the fruit buds survive the winter and early spring. It is evident, however, that with only a small percentage of the fruit buds surviving the winter or early spring low temperatures, a crop will depend very largely upon favorable weather conditions at pollination time.

In stressing the influence of regularity of bearing upon profitable peach growing, Odell (1924) writes regarding a test of twenty-five varieties, in which five to twenty trees of each were planted: "Planted in 1916, these trees bore a fair crop in 1919, and heavy crops in 1920, 1922, and 1924. Such hardy varieties as Carman, Greensboro, and Dayflower bore well in 1923, also doubled the production of other varieties in 1919, making five crops against three and one-half for

most of the others." Differences in the relative hardiness of the fruit buds may, therefore, have a far-reaching influence upon fruit production. Unfortunately, however, when consideration is given to the selection of varieties on the basis of the hardiness of the winter buds other factors must be taken into consideration. The outstanding factor of the peach situation is the dominance of Elberta, which is one of the tenderest varieties as measured by fruit-bud killing. Local conditions and market preference must determine whether it is safe to consider substituting other varieties, wholly or in part, for Elberta.

GROWTH AND DEVELOPMENT OF FRUIT BUDS DURING DORMANT SEASON

All of our deciduous fruit trees normally have an annual period when their tops do not grow perceptibly even if environmental conditions are favorable. This is commonly called the "rest period." It comes on gradually soon after terminal buds are formed in late summer or early fall and continues until some time in winter, the length of the period depending on the kind of fruit. During December in the case of the peach, the rest becomes less profound, and the fruit buds start growing if weather conditions are favorable. This gradual breaking of the rest period of Elberta, Rochester, and Belle for the season of 1921-22 is clearly shown in Table 4.

Branches from three trees of each variety were taken to the greenhouse on the dates stated in the table and placed in water. The time elapsing before blossoms opened on these branches was used as an index of the condition of rest. All the varieties were coming out of the rest period by January 3, and as the season advanced all responded more rapidly to the favorable conditions of the greenhouse. No branches were taken to the greenhouse in the period between December 1 and January 3, consequently, the bloom tests do not show just when the break occurred. In the winter of 1922-23, branches brought in on December 12, bloomed January 9. Hodgson (1924) found that the rest period of the peach ended in California by January 9 to January 26. In Missouri, according to Howard (1910), the peach grew readily as early as January 8. Johnson (1923) reported similar results in Maryland.

Table 4 also shows that Elberta seemed to have a slightly shorter rest period than either Rochester or Belle. This corroborates the observations of Blake (1916), who says that in the winter of 1915-16 there was a good set of fruit buds in one orchard, and that during January "a period of extremely warm weather started the buds to

TABLE 4.—The Break in the Rest Period as Indicated by Date of Bloom of Cut Branches Kept in Water in Greenhouse (1921-1922).

Varieties	Dates Cut Branches Were Taken to Greenhouse	Dates of Bloom	Number Days Before Bloom	Remarks
Elberta.....	Nov. 8			Fruit buds dried up. Leaf buds started by December.
Hochester.....	Nov. 8			Fruit buds dried up. Leaf buds started by December.
Helle.....	Nov. 8			Fruit buds dried up. Leaf buds started by December.
Elberta.....	Dec. 1			Fruit buds dried up.
Hochester.....	Dec. 1			Fruit buds dried up.
Helle.....	Dec. 1			Fruit buds dried up.
Elberta.....	Jan. 3	Jan. 20	17	Center and apical buds opened first.
Hochester.....	Jan. 3	Jan. 20	17	Only a few buds opened, rest dried up.
Helle.....	Jan. 3	Jan. 20	17	Only a few buds opened, rest dried up.
Elberta.....	Jan. 19	Feb. 2	14	All buds opened.
Hochester.....	Jan. 19	Feb. 8	20	All buds opened.
Helle.....	Jan. 19	Feb. 8	20	All buds opened.
Elberta.....	Feb. 9	Feb. 23	14	Winter killed buds on twigs; few opened.
Hochester.....	Feb. 9	Feb. 23	14	Winter killed buds on twigs; few opened.
Helle.....	Feb. 9	Feb. 23	14	Winter killed buds on twigs; few opened.
Elberta.....	Feb. 20	Mar. 2	10	Center and apical buds first.
Hochester.....	Feb. 20	Mar. 2	10	Center and apical buds first.
Helle.....	Feb. 20	Mar. 2	10	Center and apical buds first.
Elberta.....	Mar. 3	Mar. 14	11	Center and apical buds first.
Hochester.....	Mar. 3	Mar. 14-15	12	Center and apical buds first.
Helle.....	Mar. 3	Mar. 14-15	12	Center and apical buds first.
Elberta.....	Mar. 13	Mar. 20	7	Center and apical buds first.
Hochester.....	Mar. 13	Mar. 22	9	Center and apical buds first.
Helle.....	Mar. 13	Mar. 20-21	8	Center and apical buds first.
Elberta.....	Mar. 25	Mar. 29	4	
Hochester.....	Mar. 25	Mar. 29	4	
Helle.....	Mar. 25	Mar. 29	4	

well." He also observed that the same season "gave further evidence that Elberta and other varieties of its group, such as Early Elberta and J. H. Hale, start into growth upon the occurrence of the first warm days of winter and are later injured by cold. On the other hand, varieties like Carman and Greensboro, which respond less quickly to periods of warm weather, escaped with slight loss." Strausbaugh (1921) found in studying three varieties of plums that the one which would withstand the lowest temperature also had the longest and most profound rest period. Pojarkova (1924) found a similar correlation with species of *Ribes*, but not with those of *Acer* and *Berberis*. Strausbaugh also noted that during the rest period the

moisture content of the fruit buds of the semi-hardy plum varieties fluctuated with the temperature. In contrast the moisture content of a hardy variety, Assiniboine, remained fairly constant. Johnson (1923) found that moisture contents of buds of several varieties of peach were negatively correlated with bud hardiness.

Undoubtedly, the extent and the degree of rest influence hardiness by delaying the response of the buds to temperatures that usually bring about growth. As has been shown, warm spells are of frequent occurrence during the winter months in West Virginia, particularly in the territory west of the Alleghenies. The peach, with its rest period soon over, responds to these favorable growing temperatures of mid- and late winter, and then, if the weather becomes very cold later, is injured. On the other hand, the apple, with a long, deep rest period, is not influenced so much by these temperatures. This is probably one of the causes for its remarkable bud hardiness during winter.

POLLEN DEVELOPMENT

Although outwardly no apparent growth takes place during the rest period, development within the fruit bud continues. Flower parts form and enlarge, and by the end of the rest period in January, most of them can be easily distinguished. The time that perceptible cell differentiation began in pollen and ovules following the rest period, and the extent of their development at successive dates during the dormant season, were taken as indices of the changes going on within the fruit bud. Considerable study was given to the differentiation and growth of the fruit buds during the winters of 1921-22 and 1922-23. Fruit buds were collected at intervals from trees of each of the three varieties, Elberta, Rochester, and Belle. Buds were selected separately as follows: (1) from short growths up to $3\frac{1}{2}$ inches in length from the inside of the tree, and (2) from long outside terminal growths, 12 to 24 inches in length, or more. Buds prepared for study from the long branches were further classified into three lots—those from basal, median, and terminal positions on the branch. In the winter of 1922, collections of buds were also made from laterals on the long growths. The material was killed immediately in one percent chromo-acetic acid, imbedded in paraffin, sectioned, and stained in either Haidenhain's or Fleming's Triple stain.

The stages in the development of pollen at the different dates of collection are shown in Tables 5 to 9, inclusive:

TABLE 5.—Stages in Development of Pollen of "Elberta" During Winter of 1921-1922.

DATES SAMPLES WERE TAKEN AND LOCATIONS OF BUDS STUDIED										
	November 8	December 1	January 3	January 19	February 9	February 20	March 3	March 13	March 25	April 4
STAGES IN POLLEN GROWTH	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds
	Long Shoots, Median Buds	Long Shoots, Median Buds	Long Shoots, Median Buds	Long Shoots, Median Buds	Long Shoots, Median Buds	Long Shoots, Median Buds	Long Shoots, Median Buds	Long Shoots, Median Buds	Long Shoots, Median Buds	Long Shoots, Median Buds
	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds
	Short Spur Buds	Short Spur Buds	Short Spur Buds	Short Spur Buds	Short Spur Buds	Short Spur Buds	Short Spur Buds	Short Spur Buds	Short Spur Buds	Short Spur Buds

TABLE 6.—Stages in Development of Pollen of "Elberta" During Winter of 1922-1923.

DATES SAMPLES WERE TAKEN AND LOCATIONS OF BUDS STUDIED								
October 2	November 1	December 12	January 9	February 2	February 20	March 12	March 26	
Long Shoots, Basal Buds Long Shoots, Median Buds Long Shoots, Terminal Buds	Short Spur Buds Long Shoots, Basal Buds Long Shoots, Median Buds Long Shoots, Terminal Buds	Short Spur Buds Long Shoots, Basal Buds Long Shoots, Median Buds Long Shoots, Terminal Buds	Short Spur Buds Long Shoots, Basal Buds Long Shoots, Median Buds Long Shoots, Terminal Buds	Short Spur Buds Long Shoots, Basal Buds Long Shoots, Median Buds Long Shoots, Terminal Buds	Short Spur Buds Long Shoots, Basal Buds Long Shoots, Median Buds Long Shoots, Terminal Buds	Short Spur Buds Long Shoots, Basal Buds Long Shoots, Median Buds Long Shoots, Terminal Buds	Short Spur Buds Long Shoots, Basal Buds Long Shoots, Median Buds Long Shoots, Terminal Buds	Short Spur Buds Long Shoots, Basal Buds Long Shoots, Median Buds Long Shoots, Terminal Buds
1	3 9 1	5 6 1 9 1 8	1 1 5 3 4 3 2	2 1 2 1 4 3 5 2 4 5 2	2 1 7 1 1 1 1 2 1 1 1	1 4 1 8 5	4 2 1 1	1 3
Resting pollen.....								
Mature pollen.....								
Two nuclei, dense cytoplasm.....								
Two nuclei, scant cytoplasm.....								
One nucleus, thick wall.....								
One nucleus, thin wall.....								
Germ pores forming.....								
Microspores liberated.....								
Late tetrads.....								
Early tetrads.....								
Diads.....								
Reduction division.....								
Diakinesis.....								
Open spireme.....								
Synapsis.....								
Pollen mother-cell.....								
Early pollen mother-cell.....								
Archisporial cells.....								
Pre-archisporial cells.....								

TABLE 8.—Stages in Development of Pollen of "Belle" During Winter of 1921-1922.

STAGES IN POLLEN GROWTH	DATES SAMPLES WERE TAKEN AND LOCATIONS OF BUDS STUDIED							
	November 8	December 1	January 3	January 19	February 9	February 20	March 3	March 13
Resting pollen.	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds
Mature pollen.	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds
Two nuclei, dense cytoplasm	Short Spur Buds	Short Spur Buds	Short Spur Buds	Short Spur Buds	Short Spur Buds	Short Spur Buds	Short Spur Buds	Short Spur Buds
Two nuclei, scant cytoplasm.								
One nucleus, thick wall.								
One nucleus, thin wall.								
Germ pore forming.								
Microspores liberated.								
Late tetrads.								
Early tetrads.								
Diads.								
Reduction division.								
Diakinesis.								
Open spireme.								
Synapsis.								
Pollen mother-cell.								
Early pollen mother-cell.								
Archegonial cells.								

DATES SAMPLES WERE TAKEN AND LOCATIONS OF BUDS STUDIED

	October 2	November 1	December 12	January 9	February 2	February 20	March 12	March 26
Resting pollen.....	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds	Long Shoots, Basal Buds
Mature pollen.....	Long Shoots, Median Buds	Long Shoots, Median Buds	Long Shoots, Median Buds	Long Shoots, Median Buds	Long Shoots, Median Buds	Long Shoots, Median Buds	Long Shoots, Median Buds	Long Shoots, Median Buds
Two nuclei, dense cytoplasm.....	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds	Long Shoots, Terminal Buds
Two nuclei, scant cytoplasm.....								
One nucleus, thick wall.....								
One nucleus, thin wall.....								
Germ pores forming.....								
Microspores liberated.....								
Late tetrads.....								
Early tetrads.....								
Diads.....								
Reduction division.....								
Diakinesis.....								
Open Spireme.....								
Synapsis.....								
Pollen mother-cell.....								
Early pollen mother-cell.....								
Archisporial cells.....								
Pre-archisporial cells.....								

STAGES IN POLLEN GROWTH

Resting pollen.....	6	2	2					
Mature pollen.....	5	1	5					3
Two nuclei, dense cytoplasm.....	1	1	4					3
Two nuclei, scant cytoplasm.....	1	1	4					3
One nucleus, thick wall.....	1	1	4					3
One nucleus, thin wall.....	1	1	4					3
Germ pores forming.....	1	1	4					3
Microspores liberated.....	1	1	4					3
Late tetrads.....	1	1	4					3
Early tetrads.....	1	1	4					3
Diads.....	1	1	4					3
Reduction division.....	1	1	4					3
Diakinesis.....	1	1	4					3
Open Spireme.....	1	1	4					3
Synapsis.....	1	1	4					3
Pollen mother-cell.....	1	1	4					3
Early pollen mother-cell.....	1	1	4					3
Archisporial cells.....	1	1	4					3
Pre-archisporial cells.....	1	1	4					3

Since some buds showed quite a range in degree of development of pollen, the most advanced stage, which is the one recorded, was determined for each flower bud. Development of pollen at the different dates was not so advanced as that observed by Drinkard (1909) in Virginia for the variety Luster. He found pollen mother-cells early in November, tetrad formation on December 19, and pollen grains on January 18. Farr (1920) also found a more advanced stage of pollen development, than that recorded in these studies, with a number of varieties growing at different places in West Virginia, Maryland, Virginia, and New Jersey. When pollen growth during the winter of 1921 is compared with growth during the winter of 1922, there are, in general, no marked differences to be observed. If, however, collections had been made on the same dates each year, perhaps some differences would be shown.

All varieties show a great range in pollen development, especially from February until April—(Tables 10 to 11). Thus on February 19, 1922 (Table 10), two out of 30 buds of Elberta show pollen mother-cells in synapsis while four buds have liberated microspores. On January 9, 1923, one Elberta bud had not yet formed archesporial cells (Table 11). Drinkard (1909) found some pollen mother-cells still in the tetrad stage at the end of January, although in most buds pollen grains had been formed. The studies of Farr (1920) also show considerable range in development at the different dates that collections were made. At nearly every collection, Elberta buds showed a wider range in development than did buds of Belle and Rochester. This undoubtedly indicates a greater sensitivity to environmental factors or, in other words, a less profound rest period.

Both Table 10, for the winter of 1921, and Table 11, for the winter of 1922, show Elberta buds to be further advanced by early January than those of Belle or Rochester. Rochester buds seem to develop somewhat more slowly than do buds of Belle. Farr (1920) found that, during January, Elberta and Champion buds were the most advanced, with Belle buds the farthest behind and Carman buds intermediate.

These studies also show the relation that exists between the stage of pollen development, and (a) the position of the bud upon the twig and (b) the length of the twig (Tables 5 to 9). Differences in development in the pollen mother-cells became more pronounced during synapsis, in the early part of January. At this time the pollen from the majority of the terminal and median buds had forged ahead in development. Basal buds apparently did not catch up until the

TABLE 10.—Range in Pollen Development in "Elberta," "Rochester," and "Belle" During Winter of 1921-1922.

DATES SAMPLES WERE TAKEN AND VARIETIES STUDIED									
STAGES IN POLLEN GROWTH									
November 8	December 1	January 3	January 19	February 9	February 20	March 3	March 13	March 25	April 4
Elberta Rochester Belle	Elberta Rochester Belle	Elberta Rochester Belle	Elberta Rochester Belle	Elberta Rochester Belle	Elberta Rochester Belle	Elberta Rochester Belle	Elberta Rochester Belle	Elberta Rochester Belle	Elberta Rochester Belle
32 23 37	28 3 5 14 32 52 2	1 8 53 23 34 28	14 1 17 15 22 10 39 28	4 12 1 4 1 1 5 1 1 1 1 1 2 1 4 2 11 37 14 13	2 4 3 4 13 2 14 1 2 3 4 5 2 10 4 10 1	20 1 12 16 10 8 2 6 3 10 1 2 2 1 1	2 3 26 1 25 1 31 23 1 4 4	18 3 17 6 8 18 5 19 9 1 3	9 5 8 2 2 1 1 1
Resting pollen.....									
Mature pollen.....									
Two nuclei, dense cytoplasm.....									
Two nuclei, scant cytoplasm.....									
One nucleus, thick wall.....									
One nucleus, thin wall.....									
Germ pore forming.....									
Microspores liberated.....									
Late tetrads.....									
Early tetrads.....									
Diads.....									
Reduction division.....									
Diakinesis.....									
Open epireme.....									
Synapsis.....									
Pollen mother-cell.....	28 3 5	2	17 15 22	2 11 37	10				
Early pollen mother-cell.....	14 32 52	34 28	10 39 28	14 13	1				
Archeporial cells.....	2								

Pollen was near maturity. Pollen from most of the buds on the short inside "spurs" maintained a position intermediate between pollen from basal and median buds on the longer growths. Placing the buds from the different positions on the tree according to the average degree of pollen development during January and February, the following order was found: (1) the terminal buds on outside shoots 12 inches or more in length, (2) the median buds from the same shoots, (3) buds from short inside "spurs" up to six inches in length, and (4) basal buds from the long outside shoots. Since fruit-bud initiation is known to begin first on the basal portions of shoots, the rate of development of median and terminal buds must be faster in order that they be further advanced by January. Farr (1920) says, "There is no relation, apparently, between the position of the bud on the twig and its state of development." He noted, however, that double and triple buds are not as far advanced as single buds, and that they generally are found near the proximal end of the twig. Roberts (1922) found that a similar relationship between the degree of development and the number of fruit buds borne at a single node held for the sour cherry. His studies also showed (1917) the "least total development of the blossom buds on the shortest growths, the greatest amount on the medium-length growths, and moderate development on the longest growths." On long terminal growths in the cherry, median buds were most developed, terminal buds least, and basal buds intermediate. The buds most advanced were also the least hardy.

While pollen of basal buds seemed to be at the same stage of development at bloom as pollen of median and terminal buds, the buds themselves were not always at the same stage. In some seasons, particularly early ones, terminal and median buds opened several days before basal buds. This was very noticeable in the early spring of 1917 (See Figure 2).

RELATIVE DEVELOPMENT OF POLLEN AND OVULE

While attention was given primarily to pollen development as an index of growth during the winter months, because of the fact that whole flower buds were sectioned it was possible to determine also from time to time the changes in the ovule. In the flower buds of Berta which were collected on November 8, 1921, there was no growth on the carpel wall to indicate the first stages of ovule formation. At this time pollen from the same flowers was in the archesporial stage. The first outgrowths from the carpel wall were found on January third. By January 19 these occurred much more generally

and were much larger in some ovaries, but, as yet, the start of ovule development had not been made in some pistils. This variation in ovule growth is interesting in view of the stages reached in pollen development. Table 5 shows that pollen growth at this same date (January 19) had advanced considerably since the earlier collection.

In the collections made on February 20, ovule development had gone still farther, but as yet no growing points for the integument had appeared. It was not until March 3 that these were found at a time when the pollen grains from the same flowers had been liberated from the tetrad wall (Table 5). By March 13, both integuments were present in some ovules, but they were not closed sufficiently to form the funiculus. Growth was relatively rapid between March 13 and 23. At the latter date the integuments were nearly closed in some instances, and there was a pronounced growth in the ovule, generally. Megaspore mother-cells were not found in the collections made on April 4, just as the flowers were opening. At this time the pollen grains were in a resting condition. The embryo sac, then, is not formed until after the first flowers open. It will be seen from the foregoing, therefore, that owing to the nature of the growth stages, pollen can be used as an index of winter growth to better advantage than the ovule because of the relatively later formation of the latter.

INFLUENCE OF CULTURE AND FERTILIZATION ON FRUIT BUD HARDINESS

Relatively little attention has been given by investigators to the factors affecting the hardiness of the fruit bud, especially those that can be modified by the grower. The factors affecting wood hardiness have been studied much more extensively. Chandler (1907) as a result of his investigations believes that fruit-bud hardiness can be increased by inducing late growth and a tardiness in both entering and coming out of the rest period. As a result, the buds do not respond so quickly to spells of warm weather in January and February. Late growth can be brought about by pruning, fertilization, or cultivation. He found that thinning the previous crop tended to increase the hardiness of the flower buds. Garcia and Rigney (1914) found greater bud killing in the irrigated alfalfa sod part of a peach orchard than in the cultivated portion. On the other hand, Crane (1924) in peach fertilizer work in West Virginia found markedly greater killing of fruit buds on nitrated trees than on those not receiving it. Late applications of nitrate of soda killed a still higher percentage of fruit buds. The total number of live buds, however, on the nitrated trees

Fig. 2.—Terminal and median buds opening before basal ones.

was greater than on the checks because more buds were produced per shoot.

In view of these somewhat contradictory results further investigations were needed to determine the effect of culture on the extent of the rest period and also upon the internal differentiation and growth of the fruit bud. Kirby (1918) found that on spurs of the Jonathan and Grimes apples, fruit-bud initiation occurs first on trees in sod. He also found that fruit buds from trees in sod continued to be in a more advanced stage of development throughout the dormant season than did those from trees under cultivation.

It would seem, therefore, from the foregoing findings, that there is also a possibility of influencing the rate of fruit-bud development in the peach and thereby its hardiness by different cultural practices. Accordingly, in the spring and summer of 1924, some tests were made in the Variety Orchard on the Experiment Station Farm at Morgantown to determine the effect of applying nitrate of soda, at different times during the growing season, upon the hardiness of the fruit buds the following winter. The trees were eight years old and in good condition, although making a short terminal growth at the time the experiment was started. The pruning and culture were uniform on all trees under test. Again, 200 nodes were used as the basis for comparison, and were taken from one tree under each treatment. The winter of 1924-25 was so severe that fruit buds of only the hardest varieties survived. It is during such conditions, however, that a treatment must be effective, if it is to have commercial value.

The data in Table 12, while not conclusive, are suggestive. The nitrated trees of Rochester and Salwey had noticeably fewer dead fruit buds than the checks. The earlier applications showed the same tendency in Belle, Bilmeyer, and Elberta, while with Champion there seemed to be no difference between the check and nitrated trees. During the winter of 1923-24, Carman and Waddell trees in sod had a noticeably greater percentage of their fruit buds killed than adjoining trees under cultivation. Comparison can be made between the fruit-bud killing in the varieties included in Table 3 with those of Table 12. The earlier applications of nitrate of soda appeared to induce slightly greater hardiness in the fruit buds.

Other seasons with less killing might show greater differences between the treatments than a season like 1924-25, the severity of which was near the limits of temperature endurance for fruit buds of the peach.

TABLE 12.—Effect of Fertilization with Nitrate of Soda on Fruit-Bud Killing (1924-1925) in the Variety Orchard at Morgantown.

Varieties	Times of Application	Amounts Applied in Pounds	Percentages of Buds Alive	Remarks
ex.....	April 23	4	0	Tree in bloom at time of application.
ex.....	July 15	4	less than 1	Occasional live bud on short growths.
ex.....	Check		less than 1	Occasional live bud on short growths.
le.....	April 23	4	2	Occasional live bud on short growths.
le.....	July 15	4	1	Occasional live bud on short growths.
le.....	Check		2	Occasional live bud on short growths.
ampion.....	April 23	4	11	
ampion.....	July 15	4	7	
ampion.....	Check		12	
te Crawford....	April 23-July 15	3	0	
te Crawford....	April 23	4	0	
te Crawford....	Check		0	
arly Elberta....	April 23	4	0	
arly Elberta....	Sept. 10	4	0	
arly Elberta....	Check		0	
meyer.....	April 23	4	2	Occasional live bud on short growths.
meyer.....	July 15	4	less than 1	Occasional live bud on short growths.
meyer.....	Check		less than 1	Occasional live bud on short growths.
berta.....	April 23	4	2	Occasional live bud on short growths.
berta.....	July 15	4	less than 1	Occasional live bud on short growths.
berta.....	Check		less than 1	Occasional live bud on short growths.
eves.....	Apr. 23, July 15			
eves.....	Sept. 10	3	0	
eves.....	Sept. 10	4	0	
eves.....	Check		0	
chester.....	April 23	4	22	Nitrated trees have noticeably more live buds.
chester.....	Sept. 10	4	29	
chester.....	Check		6	
wey.....	Apr. 23, July 15	3	9	
wey.....	Sept. 10	4	4	
wey.....	Check		less than 1	Few alive on short growths.

SUMMARY

The winters of West Virginia are characterized by periods of moderately high temperatures which cause considerable bud growth in the peach. When these high temperature periods are followed by sudden cold spells, especially toward late winter, conditions occur which favor bud killing.

The different peach varieties varied greatly in the hardiness of the fruit buds. Elberta and J. H. Hale were among the tenderest varieties, although not so much so as Reeves, the least hardy of all the varieties under observation. Greensboro was one of the hardest varieties and with some of the others, like Carman and Mayflower, came through the winter of 1924-25 with some live buds.

Fruit-bud killing was not so extensive in the eastern part of the state as in the western part during the winters that this problem was studied. A crop loss may occur either east or west of the mountain from the killing of the fruit buds during the winter.

There was considerable variation in the way in which the different varieties may be affected by winter temperatures. The killing of the flower buds or the killing of the young pistils may eliminate a large proportion of the buds as far as setting is concerned. The killing of pistils, as in Late Crawford, was more extensive in 1921-22 than during any of the other years in which these varieties were studied.

Pollen development increased in rate early in December. Anthesis changes afforded a more sensitive index to growth than blooming test although the latter showed the approximate time of the break in the rest period.

These studies covering two seasons showed that the rest period ends earlier in Elberta than in Belle or Rochester. This condition favors a greater growth response in Elberta during the warmer periods of January and February than in Belle and Rochester. There was much variation in the stages of pollen development found at a given date and likewise a given stage was found for some time later.

There was considerable variation in the degree of development of the fruit buds on different parts of the tree by mid-winter, as measured by degree of pollen differentiation. Generally speaking, buds on the bases of the terminal twigs were latest in development, buds on the middle of the twigs next, and the terminal buds farthest advanced. The fruit buds borne on the short spurs or branches on the interior of the tree were on the average slightly ahead of the basal buds of the outside terminals. The indications are that the buds farthest advanced were the least hardy, although there is seemingly some evidence against this in Table 2.

Ovule development was noticeable at a much later date than that of pollen. The first stages of ovule formation were indicated by growing points on the carpel wall on January 3. Differentiation of integuments was noticed on March 3. Megaspore mother cells were not found in collections made on April 4, just as flowers were opening. The embryo sac, then, is not formed until after the first flowers open.

Nitrate applications were made in an attempt to influence bud hardiness. The results indicated a slight increase in hardiness on tree making but a short terminal growth.

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