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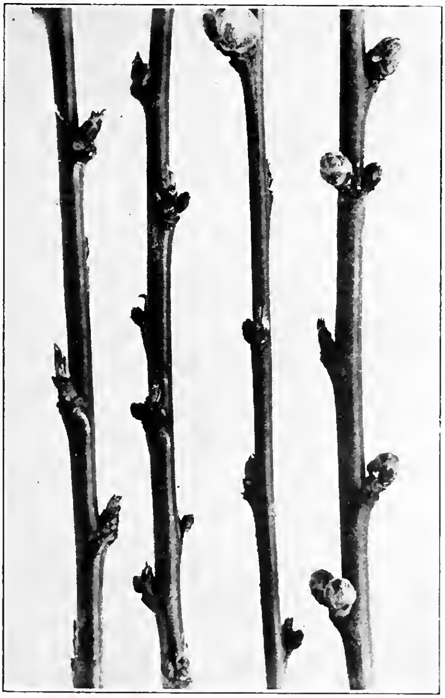
Morgantown

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

[TECHNICAL]



By

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

The wood of the varieties under observation in this study was und to be injured less frequently than the fruit buds. During the nter of 1924-25 some wood injury occurred, but as far as observa-ns were made, only young or rapidly growing trees were affected. hen winter conditions in this state kill all the fruit buds, there may so be some killing of the wood. It rarely happens in this latitude at the fruit buds prove to be hardier than the wood, although an stance of this condition was reported in Ohio by Thayer *(1916)*. The uit buds, therefore, may be regarded as a more sensitive index to rdiness than the wood.

)ME EFFECTS OF WINTER CONDITIONS IN WEST VIRGINIA

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

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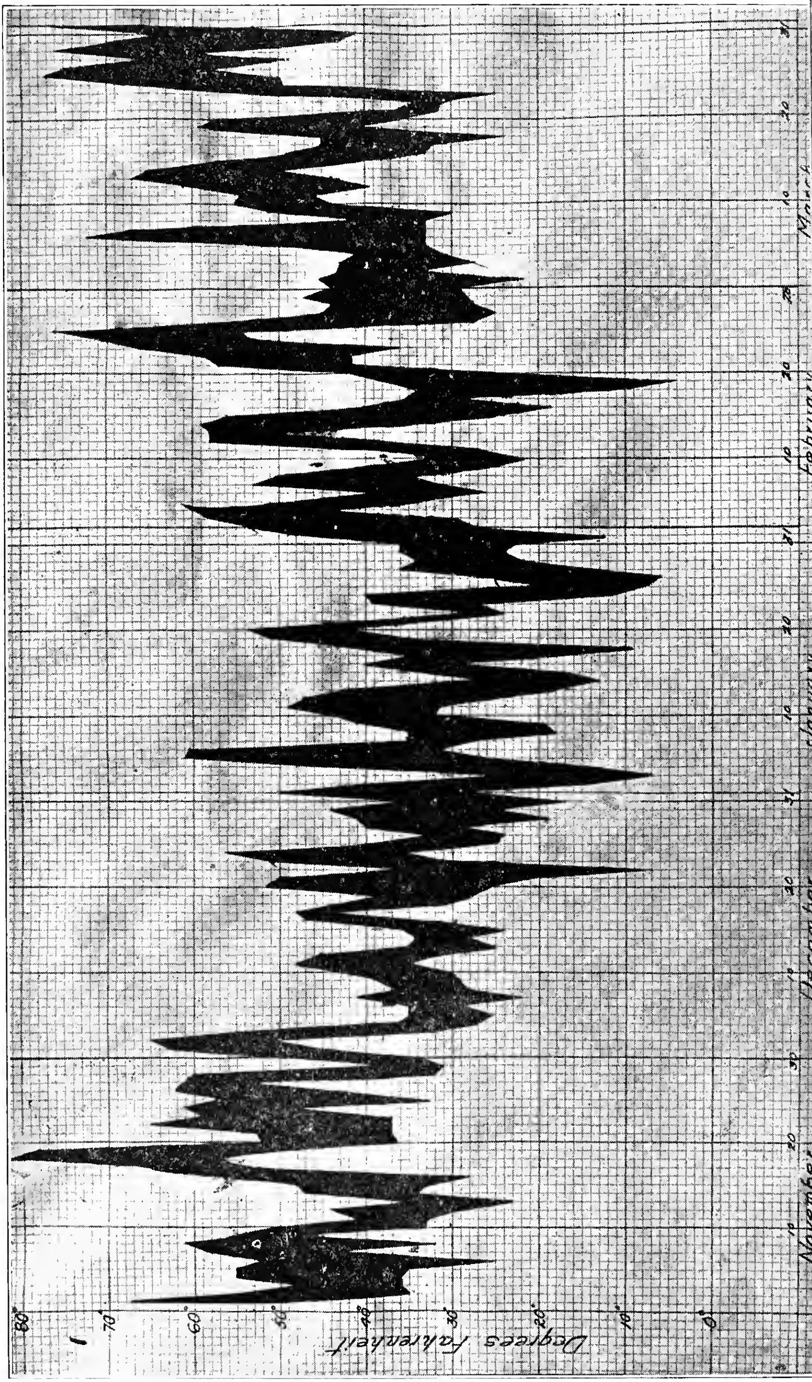
Degrees Fahrenheit
November
December

ells, if they occur toward the end of the rest period in early January nd later, start buds into growth. This brings about a marked de- rease in their resistance to subsequent low temperatures. In the inter of 1924-1925 almost all fruit buds on the tender and semi-hardy rieties of peach in the Experiment Station Orchard were killed by a dden drop in temperature to —9° F., following a period of warm eather in late January. In the northern peach sections of New York, ichigan, and Ontario, where warm periods seldom occur during inter, peach buds have withstood temperatures as low as —20° F. ithout injury. This extreme resistance, however, is only shown at e end of long cold periods.

ARIETAL DIFFERENCES IN THE HARDINESS OF FRUIT BUDS

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

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

While there was considerable killing in all of the varieties, some them like Reeves, Nectar, and Bilmeyer lost nearly all of their fruit ds from winter killing. The contrast between these and Belle, rton, Greensboro, or Hiley, in the number of fruit buds or flowers rviving the winter, is noticeable. An interesting feature of the ling in this season was the large number of dead pistils in some rieties. This conditon appeared to be peculiar to this season, in w of the fact that only an occasional dead pistil could be found the lowing season.

Death was apparently due to occurrence of low temperature after isiderable growth had taken place. This indicates that the pistil more susceptible to injury at certain stages of growth than are the er parts of the flower. When only the pistil is killed, bloom occurs an apparently normal manner, but the flowers drop a few days after ening. 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 pr duced in the fall can be grouped into three categories as listed Table 1. It is evident that the crop must be obtained from the flowe with live pistils. A similar classification in other years may show marked difference in the grouping of the buds under the differe headings of this table.

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

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

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

'ABLE 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		
	1	200	107	51	200	65	106	32	62
	2	200	99	70	200	69	110	41	61
lle	3	200	168	99	200	93	122	37	57
	4	200	126	102	200	95	73	45	43
	1	100	24	81	200	14	128	77	90
.te	2	200	21	163	200	8	166	89	95
Crawford	3	200	20	184	200	8	125	90	94
	4	200	29	181	200	19	139	86	88
	1	200	37	142	200	44	31	79	41
oerta	2	200	44	146	200	16	19	77	54
	3	200	35	141	200	17	20	80	54
	1	200	127	73	200	91	50	37	35
Rochester	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 ome of the hardiest buds on the tree were borne at the base of the rminal growths. It will be shown later that the buds in this posion lag behind the others in development during winter and come nto 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 ata in Table 3 were obtained. The records cover three years at Iorgantown, two at Mason City and at Metz, but only one year at ie other locations. Sixteen varieties in all are included in the table. ruit buds were counted on from 200 to 700 nodes.

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

TABLE 3.—Varietal Differences in Percent of Fruit Buds Killed in Different Locations in West Virginia.

VARIETIES	LOCATIONS AND YEARS												
	Ruttencutter Orchard Mason City		Horticultural Farm Morgantown			Homer Campbell Orchard Metz, Marion County		E. A. Leatherman Orchard Rada, Hampshire County	Cecil Woods Back Creek Orchard Company Berkeley County	M. W. Fulton Orchard Cherry Run, Morgan County	Reed Butts Orchard Morgan County	Ernest McDonald Orchard Inwood, Berkeley County	Smith Orchard Martinsburg, Berkeley County
	1923-24	1924-25	1922-23	1923-24	1924-25	1923-24	1924-25	1915-16	1923-24	1923-24	1923-24	1923-24	1923-24
Belle		52	34	51	95	88	68	70	2	6	5	10	72
Bilyou				48	88			50					
Carman	28	38	40	33	92	44	70	20	2	4	3		
Champion	68	58	68	65	89	46	93	80	6		6	21	
Early Elberta			53	88	100								
Elberta	55	95	56	74	100	81	100	98	5	6	10	12	66
Fox		95		69	99			99					
Hiley			31	77	99			99	10		6		
J. H. Hale			70	91	100			89			84	35	
Krummel					92			60					
Late Crawford	64	95	85	87	100			90					
Mayflower				25	74			50					
Reeves			100	100	100			100	7				
Rochester			38	44	94								
Salwey	29	24	65	46	95	44	86	60		16	10		
Smock		63						70		5			

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

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

It is interesting to note the bud killing each year in Reeves as ompared with some of the other varieties. Blake and Connors *(1918)* ound that varieties like Reeves, Early Crawford, Late Crawford, and Iountain Rose are much more susceptible to fruit-bud injury than reensboro, Carman, and Belle. Elberta and J. H. Hale have also een injured extensively in the West Virginia Experiment Station rchard. There was a complete loss in a number of varieties in the ıme orchard in the winter of 1924-25. During the same winter, in the ıstern part of the state, the killing of fruit buds appeared to be somehat variable, some orchards coming through the winter with relavely light injury, while others near by were severely injured. Spring osts, however, soon after bloom, killed practically all the flowers maining after the winter killing.

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

In stressing the influence of regularity of bearing upon profitable ach growing, Odell *(1924)* writes regarding a test of twenty-five rieties, in which five to twenty trees of each were planted: "Planted 1916, these trees bore a fair crop in 1919, and heavy crops in 1920, 22, and 1924. Such hardy varieties as Carman, Greensboro, and ayflower bore well in 1923, also doubled the production of other rieties in 1919, making five crops against three and one-half for most of the others.'' Differences in the relative hardiness of the frui buds may, therefore, have a far-reaching influence upon fruit produc tion. Unfortunately, however, when consideration is given to th selection of varieties on the basis of the hardiness of the winter bud other factors must be taken into consideration. The outstanding fac of the peach situation is the dominance of Elberta, which is one of th tenderest varieties as measured by fruit-bud killing. Local condition and market preference must determine whether it is safe to conside 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 con ditions are favorable. This is commonly called the ''rest period.'' I 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 frui buds start growing if weather conditions are favorable. This gradua 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
lberta.......	Nov. 8			Fruit buds dried up. Leaf buds started by December.
.ochester.....	Nov. 8			Fruit buds dried up. Leaf buds started by December.
elle.........	Nov. 8			Fruit buds dried up. Leaf buds started by December.
lberta.......	Dec. 1			Fruit buds dried up.
ochester.....	Dec. 1			Fruit buds dried up.
elle.........	Dec. 1			Fruit buds dried up.
lberta.......	Jan. 3	Jan. 20	17	Center and apical buds opened first.
ochester.....	Jan. 3	Jan. 20	17	Only a few buds opened, rest dried up.
elle.........	Jan. 3	Jan. 20	17	Only a few buds opened, rest dried up.
lberta.......	Jan. 19	Feb. 2	14	All buds opened.
ochester.....	Jan. 19	Feb. 8	20	All buds opened.
3elle.........	Jan. 19	Feb. 8	20	All buds opened.
lberta.......	Feb. 9	Feb. 23	14	Winter killed buds on twigs; few opened.
ochester.....	Feb. 9	Feb. 23	14	Winter killed buds on twigs; few opened.
elle.........	Feb. 9	Feb. 23	14	Winter killed buds on twigs; few opened.
lberta.......	Feb. 20	Mar. 2	10	Center and apical buds first.
ochester.....	Feb. 20	Mar. 2	10	Center and apical buds first.
elle.........	Feb. 20	Mar. 2	10	Center and apical buds first.
lberta.......	Mar. 3	Mar. 14	11	Center and apical buds first.
ochester.....	Mar. 3	Mar. 14-15	12	Center and apical buds first.
elle.........	Mar. 3	Mar. 14-15	12	Center and apical buds first.
lberta.......	Mar. 13	Mar. 20	7	Center and apical buds first.
ochester.....	Mar. 13	Mar. 22	9	Center and apical buds first.
elle.........	Mar. 13	Mar. 20-21	8	Center and apical buds first.
lberta.......	Mar. 25	Mar. 29	4	
ochester.....	Mar. 25	Mar. 29	4	
elle.........	Mar. 25	Mar. 29	4	

swell." 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 3½ 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

STAGES IN POLLEN GROWTH	November 8				December 1				January 3				January 19				February 9			
	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
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																1			1	3
Late tetrads																				
Early tetrads																	7		1	4
Diads																	3	1		
Reduction division													2				1	3	1	
Diakenesis																			1	
Open spireme												1	2	2	6	4		2		
Synapsis									2	1	2	3	3	5	7	2		2		
Pollen mother-cell					9	5	9	5	4	15	12	3	3	4	2	1				
Early pollen mother-cell					2	3	6	3												
Archesporial cells	8	9	12	3	2															

STAGES IN POLLEN GROWTH	February 20				March 3				March 13				March 25				April 4			
	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
Resting pollen																	3	2	4	
Mature pollen												2	3	3	7	5			2	
Two nuclei, dense cytoplasm											3		2		3	1			1	
Two nuclei, scant cytoplasm									7	4	10	5			4	1			1	
One nucleus, thick wall	2				6	4	8	2	1											
One nucleus, thin wall	1	1		2			1			1										
Germ pores forming																				
Microspores liberated	1		2		1			1												
Late tetrads			3	1																
Early tetrads	3	6	4					2												
Diads		1																		
Reduction division																				
Diakenesis																				
Open spireme																				
Synapsis																				
Pollen mother-cell																				
Early pollen mother-cell																				
Archesporial cells																				

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

DATES SAMPLES WERE TAKEN AND LOCATIONS OF BUDS STUDIED

STAGES IN POLLEN GROWTH	October 2				November 1				December 12				January 9			
	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
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															1	
Diakenesis															1	
Open spireme															5	3
Synapsis														4	3	2
Pollen mother-cell											5	6				
Early pollen mother-cell										1	9					
Archesporial cells						3			1	8						
Pre-archesporial cells	1		4	2		3	9	1								

STAGES IN POLLEN GROWTH	February 2				February 20				March 12				March 26			
	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
Resting pollen															1	3
Mature pollen											1		4	2	1	
Two nuclei, dense cytoplasm											4	1				
Two nuclei, scant cytoplasm											8		1			
One nucleus, thick wall						2	1	7		5						
One nucleus, thin wall				2				1								
Germ pores forming								1								
Microspores liberated			4	3				1								
Late tetrads			5	2		2	1	1								
Early tetrads		4	5	2			1									
Diads																
Reduction division		2	1													
Diakenesis																
Open spireme																
Synapsis		1														
Pollen mother-cell																
Early pollen mother-cell																
Archesporial cells																
Pre-archesporial cells																

TABLE 7.—Stages in Development of Pollen of "Rochester" 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				March 25				April 4			
	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	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
Resting pollen																																					2		1	2
Mature pollen																																				3		2		
Two nuclei, dense cytoplasm																																	4	2	2					
Two nuclei, scant cytoplasm																														1			7	8	1	3				
One nucleus, thick wall																													12	4	6	9			1					
One nucleus, thin wall																									8			4	1	1	2									
Germ pore forming																									4	1	4	1												
Microspores liberated																									2	1	1	2												
Late tetrads																							1	1		7	3													
Early tetrads																			1				2			2														
Diads																				1			1	1																
Reduction division																			1							1														
Diakenesis																										1														
Open spireme																	1				6	3		1																
Synapsis													3		8	4	6	1	4		1	5	4																	
Pollen mother-cell						2		1	19	17	9	8	12	17	8	2	2	12				1																		
Early pollen mother-cell					6	15	8	3																																
Archesporial cells	8	4	6	5																																				

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

DATES SAMPLES WERE TAKEN AND LOCATIONS OF BUDS STUDIED

STAGES IN POLLEN GROWTH	November 8				December 1				January 3				January 19			
	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
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																
Diakenesis																
Open spireme	3												1			
Synapsis												2	4	1	11	6
Pollen mother-cell					1	2		2	8	1	11	3	11	14	3	
Early pollen mother-cell					16	12	12	12	12	10	5	1				
Archesporial cells	15	9	8	5												

STAGES IN POLLEN GROWTH	February 9				February 20				March 3				March 13				March 25				April 4			
	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
Resting pollen																					2	2	2	2
Mature pollen																	4		7	6	1			
Two nuclei, dense cytoplasm													4		4		6	6	5	1				
Two nuclei, scant cytoplasm													17	4	3	1	3	5	1					
One nucleus, thick wall									11	4	4	9		9	6	8			3					
One nucleus, thin wall									4	3	5	4			3	1								
Germ pore forming									2	6														
Microspores liberated								3			3													
Late tetrads					4		6	7	1															
Early tetrads					4	4	4	2																
Diads				1	1	1	1																	
Reduction division					1	3																		
Diakenesis	1				2	3																		
Open spireme				4	3	1																		
Synapsis	18	7	9	3																				
Pollen mother-cell	5	8																						
Early pollen mother-cell																								
Archesporial cells																								

Stages in Development of Pollen of "Belle" During Winter of 1922-1923.

STAGES IN POLLEN GROWTH	October 2				November 1				December 12				January 9				Feburary 2				February 20				March 12				March 26			
	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
Resting pollen																													6		2	2
Mature pollen																													5	1	5	3
Two nuclei, dense cytoplasm																											3	1	1	1	4	3
Two nuclei, scant cytoplasm																											2		1		1	
One nucleus, thick wall																									6	3	9	5				
One nucleus, thin wall																										1						
Germ pores forming																							2		2							
Microspores liberated																																
Late tetrads																		2	2			2	9	7	1							
Early tetrads																		4	8			4										
Diads																		1	1				2									
Reduction division																		1	5				1									
Diakenesis																		1	5	7		1										
Open Spireme																				1												
Synapsis															5	7				3		3										
Pollen mother-cell												1		5	12	1						1										
Early pollen mother-cell											11	6																				
Archesporial cells					3		5	3	3	8	8																					
Pre-archesporial cells		4	6	3	1		5								1																	

Since some buds showed quite a range in degree of developmen of pollen, the most advanced stage, which is the one recorded, wa determined for each flower bud. Development of pollen at th different dates was not so advanced as that observed by Drinkar *(1909)* in Virginia for the variety Luster. He found pollen mothe cells early in November, tetrad formation on December 19, and polle grains on January 18. Farr *(1920)* also found a more advanced stag of pollen development, than that recorded in these studies, with number of varieties growing at different places in West Virgini Maryland, Virginia, and New Jersey. When pollen growth durin the winter of 1921 is compared with growth during the winter of 192 there are, in general, no marked differences to be observed. If, how ever, collections had been made on the same dates each year, perhap some differences would be shown.

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

Both Table 10, for the winter of 1921, and Table 11, for th winter of 1922, show Elberta buds to be further advanced by ear January than those of Belle or Rochester. Rochester buds seem develop somewhat more slowly than do buds of Belle. Farr *(192* found that, during January, Elberta and Champion buds were t most advanced, with Belle buds the farthest behind and Carman bu intermediate.

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

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

STAGES IN POLLEN GROWTH	DATES SAMPLES WERE TAKEN AND VARIETIES STUDIED																													
	November 8			December 1			January 3			January 19			February 9			February 20			March 3			March 13			March 25			April 4		
	Elberta	Rocehester	Belle	Elbarta	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
Resting pollen																												9	5	8
Mature pollen																						2			18	3	17	2	2	1
Two nuclei, dense cytoplasm																						3		8	6	8	18	1		
Two nuclei, scant cytoplasm																						26	1	25	5	19	9	1		
One nucleus, thick wall																2			20		28	1	31	23		1	3			
One nucleus, thin wall																4			1	12	16	1	4	4						
Germ pore forming																				10	8									
Microspores liberated										1			4			3		3	2	6	3									
Late tetrads																4	2	17		10	1									
Early tetrads													12	1		13	2	14	2	2										
Diads													4	1	1	7	2	3												
Reduction division										2			5	1				4		1										
Diakensis													1		1			5		1										
Open spireme	3						1			14		1	2	1	4	2	10	4												
Synapsis									2	17	15	22	2	11	37		10													
Pollen mother-cell				28	3	5	8	53	23	10	39	28		14	13		1													
Early pollen mother-cell				14	32	52	34		28																					
Archesporial cells	32	23	37	2																										

TABLE 11.—Range in Pollen Development in "Belle" and "Elberta" During Winter of 1922-1923.

STAGES IN POLLEN GROWTH	DATES SAMPLES WERE TAKEN AND VARIETIES STUDIED															
	October 2		November 1		December 12		January 9		February 2		February 20		March 12		March 26	
	Belle	Elberta	Belle	Elberta	Belle	Elberta	Belle	Elberta	Belle	Elberta	Belle	Elberta	Belle	Elberta	Belle	Elberta
Resting pollen															10	6
Mature pollen														1	14	5
Two nuclei, dense cytoplasm													3	5	8	
Two nuclei, scant cytoplasm													3	8	2	1
One nucleus, thick wall												10	23	6		
One nucleus, thin wall										2		1	1			
Germ pore forming											2	1	2			
Microspores liberated										7		1				
Late tetrads									4	7	18	4	1			
Early tetrads									12	11	4	1				
Diads									2		2					
Reduction division								1	6	3	1					
Diakenesis								1	13		1					
Open spireme								9	1							
Synapsis							12	13	3	1	3					
Pollen mother-cell					7	12	18			1	1					
Early pollen mother-cell					17	9										
Archesporial cells			11	3	19	10										
Pre-archesporial cells	13	7	6	13		2		1								

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

While pollen of basal buds seemed to be at the same stage of elopment at bloom as pollen of median and terminal buds, the buds mselves were not always at the same stage. In some seasons, parilarly early ones, terminal and median buds opened several days ore basal buds. This was very noticeable in the early spring of 7 (See Figure 2).

RELATIVE DEVELOPMENT OF POLLEN AND OVULE

While attention was given primarily to pollen development as an ex of growth during the winter months, because of the fact that ole flower buds were sectioned it was possible to determine also m time to time the changes in the ovule. In the flower buds of erta which were collected on November 8, 1921, there was no wth on the carpel wall to indicate the first stages of ovule forma-. At this time pollen from the same flowers was in the archesporial stage. The first outgrowths from the carpel wall were found on uary third. By January 19 these occurred much more generally and were much larger in some ovaries, but, as yet, the start of ovul development had not been made in some pistils. This variation i ovule growth is interesting in view of the stages reached in polle development. Table 5 shows that pollen growth at this same dat (January 19) had advanced considerably since the earlier collections

In the collections made on February 20, ovule development ha 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 time when the pollen grains from the same flowers had been liberate from the tetrad wall (Table 5). By March 13, both integuments wer present in some ovules, but they were not closed sufficiently to forr the funiculus. Growth was relatively rapid between March 13 and 25 At the latter date the integuments were nearly closed in some ir stances, and there was a pronounced growth in the ovule, generally Megaspore mother-cells were not found in the collections made o April 4, just as the flowers were opening. At this time the polle grains were in a resting condition. The embryo sac, then, is no formed until after the first flowers open. It will be seen from th foregoing, therefore, that owing to the nature of the growth stage pollen can be used as an index of winter growth to better advantag than the ovule because of the relatively later formation of the latte

INFLUENCE OF CULTURE AND FERTILIZATION ON FRUIT BUD HARDINESS

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

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 hardiest 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.

'ABLE 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.
lle............	April 23	4	2	Occasional live bud on short growths.
lle............	July 15	4	1	Occasional live bud on short growths.
lle............	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	
rly Elberta.....	April 23	4	0	
rly Elberta.....	Sept. 10	4	0	
rly 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.
)erta..........	April 23	4	2	Occasional live bud on short growths.
)erta..........	July 15	4	less than 1	Occasional live bud on short growths.
)erta..........	Check		less than 1	Occasional live bud on short growths.
eves..........	Apr. 23, July 15 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 oderately high temperatures which cause considerable bud growth the peach. When these high temperature periods are followed by dden cold spells, especially toward late winter, conditions occur hich favor bud killing.

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

Fruit-bud killing was not so extensive in the eastern part of th state as in the western part during the winters that this problem wa 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 differen varieties may be affected by winter temperatures. The killing of th flower buds or the killing of the young pistils may eliminate a larg proportion of the buds as far as setting is concerned. The killing c pistils, as in Late Crawford, was more extensive in 1921-22 than durin any of the other years in which these varieties were studied.

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

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

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

Ovule development was noticeable at a much later date than tha of pollen. The first stages of ovule formation were indicated b growing points on the carpel wall on January 3. Differentiation c integuments was noticed on March 3. Megaspore mother cells wer 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 oper

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

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