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Annual and Biennial Bearing in York Apples

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Annual and Biennial Bearing in York Apples

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Abstract.—In the off year of biennial Yorks spur growth was short, the set was poor, the percentage of blossom buds formed was high and independent of spur growth. The on year, spur growth was longer, a large crop set and few blossom buds formed. There was no correlation between the growth of the individual spur in successive years. In annual Yorks, non-bearing spurs were longer than on alternating trees; about one-third of them formed blossom buds and the percentage of set was very high. There was a correlation coefficient of +0.45 between the growth of individual spurs in successive years. It is concluded that the biennial trees were deficient in carbohydrate the on year and in nitrogen the off year and that these deficiencies acted as limiting factors on spur performance, causing the tree to act as a unit. In annual trees these limiting factors had been removed by nitrate of soda applied the middle of September for four consecutive years, and spur performance was individual. It is suggested that supplementing spring applications of nitrogen the off year by fall applications may be helpful in establishing and maintaining annual bearing.

The horticulturist is so accustomed to regular annual bearing that the tendency to bear crops in alternate years seems by comparison somewhat of an abnormality. Yet for most plants in their native state the sequence of a crop year and one or more years of unproductiveness is rather the rule than the exception. Regularity of bearing has been an important consideration in the selection of varieties, and in consequence varieties with a marked tendency to irregular or alternate bearing have been discarded. A few varieties with other redeeming qualities have persisted as a perennial problem in fruit culture.

The correlation of spur growth and performance pointed out by Roberts[10]* has been a stimulus to the study of production problems and particularly of alternate bearing in apples. Roberts considered blossom formation to be primarily a function of spur length, practically all the spurs in the off year and few or none the on year being of a length associated with blossom bud formation. As a remedy Roberts advocated pruning by small cuts to increase spur growth beyond the blossoming length and so to decrease the percentage of blossom buds formed the off year.

Crow[3] emphasized the shorter spur growth and the earliness of bud differentiation the off year and recommended the heading back of small branches the off year or nitrate of soda applied early in the spring of the off year.

*A list of references will be found on page 16.

Hooker and Bradford[7] found that spur performance in biennially bearing trees might be entirely independent of growth and attributed individual spur performance in such cases to the general nutritive conditions prevalent in the tree as a whole.

Mack[9] likewise found uniformity of spur behavior in alternate bearing trees and considered the nutritive condition of the tree the determining factor. Off-year bearing occurred chiefly on the older wood. Growth the off year was shorter as reported by Crow. Pruning had no effect on bearing habit, but nitrogen favored bearing on terminal growths and young spurs and on successively blooming spurs the off year.

Auchter and Schrader[1] studied annual and biennial bearing in the York. They found no relation between spur length and performance either the on or the off year on alternating trees except that the blossoming spurs that set in the crop year might be those which made greater growth in length or diameter the previous year. In annually bearing trees the longer the spurs, the higher the percentage of blossom bud formation.

Bradford[2] emphasized spur formation as a factor in regular bearing. He found spring applications of nitrogen fertilizers induced annual bearing in biennially bearing Ben Davis and Duchess trees.

These studies have led to a variety of suggestions for the correction of alternate bearing but there seems to be a difference of opinion as to the effectiveness of some of them. A comparison of the data published by the several investigators shows that some of the discrepancies are due to differences in the conditions studied, for alternate bearing in different varieties and even in the same variety is apparently associated with distinct conditions of growth.

HISTORY OF THE EXPERIMENT

The investigation on the alternate bearing habit of apple trees reported in this bulletin was begun in 1920. Through the kindness of Dr. J. C. Jones, a number of 16-year-old York trees at Riverview Orchards, McBaine, Missouri, were placed at the disposal of the Experiment Station. These trees were growing in loess soil, under sod which was necessary to prevent erosion. They had been well cared for and were apparently in good condition. They bore a heavy crop in 1919 and were used in 1920 to study the nutritive conditions characteristic of alternate-bearing trees in their off year. Nitrogen fertilizers were applied to different plots in the spring, summer and fall of 1920 and an unfertilized plot was reserved as a check. During this season samples of spurs and of bark were collected and analyzed. The results of chemical analysis were published in Research Bulletin 50 of this Station.

In the spring of 1921, this orchard suffered from severe late frosts. The trees bloomed profusely, but a large percentage of the flower buds, particularly in the tops of the trees, were killed. However, enough blossoms survived to give a crop averaging approximately five bushels to the tree. This accident interfered with the chemical study of the effects of the previous year's applications of fertilizer and the sampling was discontinued. Nevertheless the fall fertilizer treatment was continued. In 1922 and 1923, it was observed that a number of the trees receiving the fall nitrate treatment bore good crops both years, although the untreated trees in the check plot produced no crop in 1922 and bore an excessively large crop in 1923. In the spring of 1924, a number of treated trees blossomed for the fourth consecutive year while most of the check trees failed to bloom.

In this way, material was available for a comparative study of the conditions characteristic of annual as well as of biennial bearing in the York variety of apple. Spur records were taken from a number of trees in the treated and in the check plots. Records of spur growth and performance were made on spurs in the tops of the trees as well as on spurs that could be reached from the ground.

PERCENTAGE OF BLOOM

The records of each tree were taken separately as the confusion of records from trees alternating in opposite years would simulate regular bearing. The records from the upper and lower branches of each tree were also kept separate as some tendency to alternate within the tree was observed.

In Table 1 the percentages of spurs blossoming on a typical tree from each plot is given. The records extend back to 1916, though the data for the first two years are based on a relatively small number of spurs. The figures show that both trees were markedly biennial before the treatment was begun in 1920 and that the check tree continued to alternate. The treated tree blossomed every year from 1922 on, but the larger part of the bloom was in the upper part of the tree the even years and in the lower part of the tree the odd year. This tree to which a fall application of sodium nitrate was first made in 1920 formed considerably more fruit buds in 1921 than the check tree and produced a heavier bloom in 1922: 15 per cent more on the lower limbs and 36 per cent more on the upper limbs.

TABLE 1.—PERCENTAGES OF SPURS BLOSSOMING ON TWO YORK TREES FROM 1916 TO 1924

Year	Check		Fall nitrate	
	Lower branches	Upper branches	Lower branches	Upper branches
1916	0	....	....	0
1917	100	100	71	86
1918	14	0	14	6
1919	85	50	90	94
1920	9	8	4	7
1921	69	87	83	78
1922	3	10	18	46
1923	97	98	42	19
1924	2	0	36	56

The two trees selected for use in Table 1 are typical of the majority of treated and check trees. However, a few of the treated trees failed to respond to the fall fertilizer treatment and continued to alternate in the same manner as the check trees. A few of the check trees were shown by the spur records to have blossomed very little in 1923 as well as in 1922 and did not come into full bloom until 1924.

The present study is based on the spur measurements of the treated trees that blossomed regularly from 1922 on and of the check trees that continued to alternate in the odd years.

SPUR PERFORMANCE

Tables 2 and 3 show the typical performance of individual spurs on the upper and lower branches of the same trees selected for Table 1.

The records begin with 1918 though some of the spurs included have records extending one or two years farther back. There were not enough older spurs, however, to give a representative picture of the performance of the trees from 1916 on. The alternation of bloom in the check tree and the change from biennial to annual blossoming in the treated tree is seen at a glance.

Although the treated trees blossomed to a greater extent in the upper portion of the trees in 1922 and 1924 and in the lower portion of the trees in 1923, the individual spur records show that the general bearing habit in both parts of the trees were different from the condition revealed in the biennially bearing check trees. In other words the annual performance of the treated trees did not depend solely on biennial bearing in separate parts of the tree. This is indicative of altered conditions throughout the tree which is confirmed by data that will be presented later.

Table 2.—Performance Record of Individual Spurs on a Biennially Bearing York Tree. (The numbers indicate growth in millimeters. F denotes blossoming and L, non-blossoming.)

1918	1919	1920	1921	1922	1923	1924
			Upper Branches			
5	5	10	12F	10	9F	L
11	9F	8	6F	10	8F	L
5	7F	4	6	16F	6F	L
11	6F	4	18F	15	10F	L
7	6	6F	10F	8	9F	L
2	7F	8	9F	10	12F	L
119	7F	21	15F	17	26F	L
4	7	7	8F	4	5F	L
2	8F	12	14F	10	18F	L
6	5	4	9F	18	20F	L
3	9F	20	7	10	10F	L
			Lower Branches			
3	6F	2	3	5	10F	L
10	15F	8	15F	4	10F	L
9	7F	5	10F	30	6F	L
3	9F	20	7	10	10F	L
6F	5F	2	6F	7	7F	L
4	7F	3	2	6	6F	L
3	6F	4	7F	4	7F	L
2	7F	11F	10F	6	10F	L
11	10	7	12F	15	6F	L
8F	4	5	12F	12	10F	L
4	6F	6	6F	10	9F	L

TABLE 3.—PERFORMANCE RECORD OF INDIVIDUAL SPURS ON A YORK TREE TREATED WITH NITRATE OF SODA IN THE AUTUMN. (Growth is shown in millimeters, F denotes blossoming and L, non-blossoming.)

1918	1919	1920	1921	1922	1923	1924
			Upper Branches			
5	10F	8	11F	11	8	F
4	10F	9	17F	10	10	F
4	13F	5	10F	8F	6	F
2	7F	9	18F	14	15	F
21	8F	7	7F	10	11F	L
3	20F	3	10F	7F	3	F
5	10F	20	30	18F	16	L
3	6F	2	6F	3	5F	L
5	6F	7	6F	5	10F	L
2	5	5	10F	10F	5	F
160	14F	15F	6	15F	10	L
7F	6F	3	7F	4	10	L
			Lower Branches			
10	7F	5	8F	10	10F	L
4	7F	5	7F	4	4	L
6F	6	27	32F	8	33F	L
5	8F	5	9F	10	10	F
4	3F	3	7F	4	5F	L
2	4F	3	12F	13	9F	L
2	5F	7	5	7F	10	F
1	5F	20	12F	7F	7	F
8F	10F	5	8F	5	9F	L
2	6F	5	8F	10	5	F
6	10F	8	10	35	40F	L
3	9F	5	2	30F	4	F

SPUR GROWTH

The average growth made by spurs on the treated and check trees is shown in Table 4. Four classes of spurs are distinguished and growth is averaged separately for each class in the upper and lower portions of the tree.

Class 1.—Spurs that blossomed and formed no fruit buds, F.

Class 2.—Spurs that blossomed and formed fruit buds, FB. These spurs blossomed two years in succession, indicating that the flowers fell early enough the year the measurement was taken to allow fruit bud differentiation to occur the same season.

Class 3.—Spurs that did not blossom and formed no fruit buds, L. These spurs were unproductive two years in succession.

Class 4.—Spurs that did not bloom and formed fruit buds, LB.

Wherever there were not enough cases to warrant an average, a blank space has been left in the table. In the alternate bearing trees the great majority of the spurs fall in class 1 the odd years and in class 4 the even years. It will be observed that growth was somewhat greater the year of blossoming, though spurs ordinarily make better growth the non-bearing year as was the case with the treated trees from 1920 on. In both the check and treated trees the spurs in the upper portion of the tree grew somewhat more than the spurs on the lower branches. The most striking difference shown by the treated trees was the greater average growth of the non-blossoming fruit spurs that formed fruit buds after 1920. The nitrate of soda applied in the fall of 1920 and succeding falls evidently increased the growth of non-bearing spurs and the greater fruit bud formation shown in Table 1 was on these longer spurs.

TABLE 4.—GROWTH IN MILLIMETERS OF SPURS ON TREATED AND CHECK YORK TREES. (F— bearing spurs, L— non-blossoming spurs. B denotes flower bud formation.)

	1923	1922	1921	1920	1919	1918
Check Trees						
Upper Branches						
F	14	11	12	12	8	3
FB	....	14	10	9	....	....
L	9	9	9	8	9	9
LB	....	11	8	8	6	5
Lower Branches						
F	12	6	12	8	8	8
FB	....	....	8	11	10	6
L	5	8	6	5	5	9
LB	6	11	7	7	6	7
Treated Trees						
Upper Branches						
F	14	11	9	13	9	....
FB	9	9	12	....	14	7
L	9	7	9	8	10	4
LB	20	17	19	7	13	4
Lower Branches						
F	12	14	9	7	8	7
FB	6	6	9	--	--	8
L	9	7	7	6	7	7
LB	16	21	19	8	4	6

BLOSSOM BUD FORMATION

This fact is shown more clearly by the data presented in Table 5 which shows the percentages of non-bearing spurs that formed flower buds for spur lengths ranging from one to thirty millimeters. The check trees show high percentages, between 87 and 100, for practically all spur

TABLE 5.—PERCENTAGE OF NON-BEARING SPURS OF VARIOUS LENGTHS THAT FORM FLOWER BUDS

Length of spur in mm.	Check		Treated
	On years	Off years	Annual bearing
1	----	----	33
2	17	100	41
3	19	87	43
4	21	93	45
5	21	93	47
6	17	94	48
7	13	88	48
8	8	97	48
9	11	100	50
10	10	91	48
11	14	96	50
12	10	100	51
13	18	100	60
14	10	90	53
15	10	100	57
16	6	100	52
17	0	100	64
18	0	100	61
19	----	100	58
20	0	100	62
21	0	100	55
22	10	100	73
23	0	100	86
24	----	100	75
25	----	100	78
26	33	100	78
27	--------	100	100
28	----	50	83
29	----	100	86
30	----	100	67

lengths in off years and consistently low percentage for all classes of spurs in the on years. The data for the on years is based on a much smaller number of spurs than the data for the off years, as relatively few spurs failed to bloom the on year. The highest percentage of blossom bud formation in the on year occurred in spurs 4 and 5 millimeters long, if the average for spurs 26 mm. in length be ignored as the figure is based on but three measurements.

Although there might be some basis for postulating a relationship between spur growth and behavior in the on years, there is obviously no such relationship in the off years.

The spurs on the treated trees, however, show an unmistakable growth-performance relationship. The longer the spur growth, the higher the percentage of flower formation. Since spur growth and performance are so intimately related, it may be assumed that the influences determining blossom bud formation are localized to some extent within the spur[7]. The treatment has apparently removed those influences farther back in the tree that were responsible for the mass behavior of the spurs on the biennially bearing trees.

TABLE 6.—DISTRIBUTION OF NON-BEARING SPURS IN PERCENTAGE OF TOTAL NUMBER

Length of spurs in mm.	Check: On years	Check: Off years	Treated; Annual Bearing
1-5	36.1	21.9	39.1
6-10	40.0	47.4	33.2
11-15	9.7	15.7	11.4
16-20	4.2	7.1	8.7
21-25	1.4	3.7	2.6
26-30	4.2	2.2	2.0
Over 30	3.4	1.9	3.0

Table 6 shows the percentage distribution of the non-bearing spurs in the various length classes. The largest percentage of spurs on the check trees is in the 6-10 mm. class for both the on and the off years. On the treated trees after they came into annual bearing, the largest percentage was in the 1-5 mm. class. There was a higher percentage of long spurs over 30 mm. on the treated trees and on the check trees in the on year than on the check trees in the off year.

The data on the performance and distribution of spurs of various length on the treated and check trees emphasize the wide difference between them in the conditions determining growth and flower formation.

CORRELATION OF GROWTH SUCCESSIVE YEARS

This difference is shown likewise by the correlation of spur growth in successive years. In Table 7 the growth of spurs in 1922 is correlated with the growth of the same spurs in 1923 on both the check and treated trees. For convenience, only spurs that grew less than 25 mm. in both years were used in the construction of the correlation tables. The means for 1922 were somewhat greater than the means for 1923 in both cases, and the means for the check trees were higher than those for the treated trees. This resulted from the elimination of the longer spurs which were

TABLE 7.—CORRELATION OF SPUR GROWTH IN 1922 AND 1923 ON TREATED AND CHECK TREES

	Check		Treated	
	1922	1923	1922	1923
Mean	5.5 mm	5.0	4.53	4.23
Standard deviation	2.05	2.27	2.41	2.17
Correlation coefficient	−0.0215		+0.451	
Probable error	±0.0525		±0.0284	

more numerous on the latter. The standard deviations were almost half of the means. For the check trees, a small negative correlation coefficient was found which is rendered insignificant by the large probable error. There is therefore no correlation between the growth of individual spurs in successive years on these alternate bearing trees. For the treated trees, a correlation coefficient of +0.45 was found with a probable error small in comparison. This indicates a distinct positive relation between the growth of the individual spurs in successive years on the annually bearing trees. This is rather surprising because on the average these spurs grew more the year blossom buds were formed and less the year fruit was borne. A distinct negative correlation might therefore be exepcted. A perfect positive correlation could be obtained only if every spur grew the same amount each successive year. The fact that a positive correlation of 0.45 was found instead of a negative correlation shows that the effect of bearing on the growth of the individual spur is small as compared with the effect of local conditions determining growth. In other words for spurs under 25 mm. in length, the longer spurs tend to remain long and the shorter spurs short in spite of greater growth on the average the year the blossom buds are formed.

The chief significance of these correlation coefficients lies, however, in the difference revealed between the biennially and annually bearing trees. The absence of any correlation between the growth of individual spurs in successive years on the alternating trees shows that spur growth is controlled from without. The positive correlation for spurs on regular bearing trees indicates that the local conditions determining spur growth one year, or possibly the growth of the spur itself, are factors affecting its growth the next year. The spurs on the treated trees show a degree of autonomy of which there is no indication in the check trees.

This raises the question as to what factors limit the growth of spurs in alternate bearing trees of the type under consideration. There is considerable evidence to show that growth is limited the on year by crop production. The low percentage of blossom bud formation is a direct indication of a carbohydrate deficiency. During the off year there can be no question of a carbohydrate deficiency. In fact the enormous percentage of fruit bud formation the off year shows that carbohydrate accumulates in practically all spurs regardless of length. Nevertheless spur growth frequently averages less the off year than the on year, as previously reported by Crow[3] and Mack[9]. Alternate bearing York trees in the off year are characterized by the pale green color of the leaves which is in striking contrast to the deep green of the tree in bearing. Non-bearing trees resemble the condition found by Kraus and Kraybill[8] in tomatoes grown with a very low nitrogen supply, except that the condition is not so extreme as to interfere with fruit bud formation. Chemical analysis of the bark and spurs published in Research Bulletin 47 of this Station shows that York trees in the off year are in fact relatively lower in nitrogen during the early part of the season and much higher in carbohydrate. It seems probable that spur growth the off year is restricted by the available supply of nitrogen and the accompanying excessive accumulation of carbohydrate. In both the on and the off years, spur growth appears to be limited by nutritive conditions prevalent throughout the whole tree, by carbohydrate diverted to the fruit the year of bearing, and the following year by nitrogen, the supply of which has been exhausted by overproduction the previous season.

SET OF FRUIT

If these alternating trees are suffering from a deficiency of nitrogen the off year, an explanation is offered for the low percentage of fruit which sets then. Roberts[10] has shown that the lower the percentage of spurs blossoming the higher the prcentage of set. In the off year, the spurs records show that as many as 15 per cent of the spurs may bloom and according to the rule just mentioned a large percentage of these blossoms should set. As a matter of fact, the production records show that little or no fruit was borne the off years by the trees in question, not enough in any case to warrant picking. Several of the trees having a 10 per cent bloom in 1922 did not set a single apple. This is reflected in the spur records also which show that over 50 per cent of the spurs blossoming in the off year form blossom buds the same season and bloom again the next year.

Table 8 shows the percentages of spurs blossoming on annual and biennial York trees and the approximate percentages of these blooming spurs that set fruit, as estimated by counts on a number of trees. Annual bearing trees show a high percentage of set that corresponds

TABLE 8.—PERCENTAGE OF SET

	Percentage of spurs blossoming	Percentage of blossoming spurs setting
Annual bearing	30-50%	80-95%
Off year	0-15%	0-20%
On year	70-100%	45-55%
On year with spring nitrate	70-100%	55-70%

roughly with the figures given by Roberts. The alternating trees show a low percentage of fruit both the on and the off year, but particularly the off year. Application of nitrate of soda to biennial trees the spring of the bearing year has increased this set 20 to 25 per cent, showing that even here the percentage of set can be increased materially.

SUMMARY

The conditions present in the alternate bearing trees may be summarized as follows: The tree behaves for the most part as a unit, fruit bud formation being determined by the nutritive condition of the tree as a whole. The off year the tree suffers from an insufficiency of nitrogen. Whatever bloom there may be, fails to set. Growth is weak and carbohydrates accumulate in large amounts. Practically all the spurs form fruit buds for the following year irrespective of length. The amount of spur growth has no relation to blossom bud formation. The following year, practically all the spurs blossom and enough nitrogen has been accumulated during the previous season to permit half of the spurs to set fruit. Spur growth is somewhat better but the growth of the previous season has no effect on the growth this season. The tree sets a large crop which depletes the nitrogen reserves of the tree, and prevents carbohydrate accumulation in the spurs that are not bearing. There is therefore little or no fruit bud differentiation.

The conditions found in the treated trees which were bearing annually are as follows: Whatever bloom there is sets. Growth of the non-bearing spurs is good and the longer the spur the higher the percentage of blossom buds formed. The crop is not so large but that carbohydrate can accumulate in many spurs and about a third of all the spurs form fruit buds for the next year. Spur performance is largely individual and good growth one season is followed by good growth the next. There was a tendency for the larger part of the crop to be borne alternately in the upper and lower branches, but the vegetative conditions are essentially the same throughout the tree. The factors which limited spur performance in the biennially bearing trees and caused the tree to behave as a unit have been eliminated.

CONCLUSIONS

Although annual production has many obvious advantages, there may be some question as to whether annual bearing trees yield more or less fruit than biennially bearing trees. The bearing records collected in 1922 and 1923 show that the annually bearing trees bore on the average 15 bushels in 1922 and 14 bushels in 1923 or 29 bushels for the two-year period. The check trees produced no commercial crop in 1922 and 20 bushels in 1923 or 20 bushels for the two year period. Previous experiments[6] have shown that this yield can be increased to 25 bushels by nitrogen fertilizers applied the spring of the bearing year. There is therefore a clear gain of 4 bushels for the annually bearing trees.

How can a biennially overproducing tree be made to bear annual crops? In the experiment reported in this paper a large proportion of the trees receiving applications of nitrate of soda about the middle of September became annually bearing trees. However, it is not felt that the change from alternate to regular bearing can be attributed to the fertilizer treatment alone. The severe spring frosts which reduced the crop in 1921 to about five bushels per tree unquestionably aided materially in effecting the change. This frost was not in itself responsible for the change because the check trees continued to alternate.

The data presented in this paper indicate that these York trees were suffering from an insufficiency of nitrogen in the off year and that an increase in the nitrogen supply was essential to establish regular production. It is interesting to note in this connection that Hartig[4] found an almost complete disappearance of nitrogen from the wood and bark of beech and oak trees the year of seed production. Spring applications of nitrogen will often bring irregularly bearing apple trees into regular bearing. This has been observed at the Missouri Experiment Station and has been reported by Bradford[2] and other investigators. Yorks, however, do not always respond to this treatment, apparently because the application made the spring of the bearing year increases the set and accentuates the overproduction. The application of nitrogen the spring of the off year is beneficial and has been recommended by Crow[3] and others. The results reported in this bulletin suggest that spring applications the off year may be supplemented where necessary by fall applications. Nitrogen applied about the middle of September is absorbed by the roots and stored in the tree over the winter[6]. An application of five pounds per tree applied the fall of the off year was found to have no direct effect on the set of fruit the following spring, but tended to promote carbohydrate accumulation in the non-bearing spurs and to favor blossom bud formation[5]. It will be recalled that the treated trees in this experiment formed considerably more fruit buds in 1921 than did the check trees. Some of this fruit bud formation occurred on spurs that had blossomed that spring, the flowers being killed by the late frosts, but 44 per cent of all the spurs forming flower buds in 1921 were one year old spurs.

The condition of alternate bearing studied in this experiment is probably typical of many orchards, particularly of the York variety, and is almost certain to develop sooner or later where York trees are grown in sod. The growth-performance relationships found in these trees correspond very closely to the relationships reported by Auchter and Schrader[1] for both annual and biennial York trees in Maryland, though the data are presented in a somewhat different manner.

LITERATURE CITED

1. Auchter, E. C. and A. L. Schrader. Fruit spur growth and fruit bud production. Proc. Am. Soc. Hort. Sci. **20**: 127-144. 1923.
2. Bradford, F. C. Nitrogen-carrying fertilizers and the bearing habits of mature apple trees. Mich. Agr. Exp. Sta. Special Bul. 127. 1924.
3. Crow, J. W. Biennial fruit bearing in the apple tree. Proc. Am. Soc. Hort. Sci 17: 52-54. 1920.
4. Hartig, R. Anatomie und Physiologie der Pflanzen. pp. 251-253. Berlin. 1891.
5. Hooker, H. D. Some effects of fall applications of nitrogen to apple trees. Proc. Am. Soc. Hort. Sci. **19**: 241-243. 1922.
6. Hooker, H. D. Certain responses of apple trees to nitrogen applications of different kinds and at different seasons. Mo. Agr. Exp. Sta. Research Bul. 50. 1922.
7. Hooker, H. D. and F. C. Bradford. Localization of the factors determining fruit bud formation. Mo. Agr. Exp. Sta. Research Bul. 47. 1921.
8. Kraus, E. J. and H. R. Kraybill. Vegetation and reproduction with special reference to the tomato. Ore. Agr. Exp. Sta. Bul. 149. 1918.
9. Mack, W. B. The study of bearing habit of apple varieties. Proc. Am. Soc. Hort. Sci. **19**: 163-167. 1922.
10. Roberts, R. H. Off-year bearing in the apple. Wis. Agr. Exp. Sta. Bul. 317. 1920.