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The Effect of Height of Head on Young Apple Tree Growth and Yield

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Agricultural Experiment Station

College of Agriculture, West Virginia University

N. J. Giddings, Acting Director
Morgantown

The Effect of Height of Head on Young Apple Tree Growth and Yield

(A Preliminary Report)

Stayman Winesap trees in the spring of 1925, showing the comparative
and shape. The tree at the left was headed at one foot and the tree on the
at three feet. Notice the leaning trunks of the high-headed trees.

By

H. L. CRANE

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*The Effect of Height of Head on Young Apple Tree Growth and Yield**

(A Preliminary Report)

An experiment to determine the effect that the height of head of young apple trees has on growth and yield was started in the spring of 1916. For the purpose of this work, two varieties, Rome and Stayman, which are quite distinct in nature and type of growth, were used. One-year-old trees, carefully selected for uniformity of size and vigor, were planted. These trees were of the nursery grade, five to seven feet, and for the most part were approximately seven feet high. The root systems of the individual trees were pruned as nearly alike as possible before planting, removing mainly the broken roots and cutting off the rough, irregular ends.

Five pruning treatments, or heights of heads, were made of each of the two varieties. They were: (1) tops cut back to 1-foot trunk; (2) tops cut back to 2-foot trunk; (3) tops cut back to 3-foot trunk; (4) tops cut back to 4-foot trunk; and (5) tops cut back to 5-foot trunk.

In every case the length of the trunk left after pruning was measured from the point at which the tree was budded, to the apex. An effort to obtain a length of tree trunk of 1, 2, 3, 4, or 5 feet, as the case might be, the trees were set so that the point at which they were budded was just at the surface of the soil.

The experimental work was conducted on a single row of trees through an orchard on the Horticultural farm at Morgantown. The orchard was planted with rows sixteen feet wide, and the trees thirteen feet apart in the rows. Two trees of Rome and four of Stayman were used for each height of head or pruning treatment, making thirty trees in all. The order of planting was two trees of Rome, then four trees of Stayman; this planting being repeated four times until the row was filled. In the spring of 1924, every other tree was removed to give the permanent trees more room. This left only one tree of Rome and two trees of Stayman for each method of treatment. An attempt was made to prune the trees uniformly, this, however, was difficult, due to the wide differences in the types of trees and their responses.

*Submitted for publication, May, 1926.

The methods of training and subsequent pruning were as follows. The trees were trained to the modified central leader form, having two scaffolds of four main branches each. The upper scaffold was approximately three feet from the lower one. The first season, the lower scaffold branches were selected and if they had made more than eight inches growth they were cut back to that length. The central leader was left from twenty to twenty-four inches long. All other branches were removed. Pruning the second season consisted of reducing the number of laterals on each main scaffold branch to two, all other shoots being removed. The central leader was headed back to about four feet from the first scaffold.

In the third and fourth seasons, the second scaffold was formed in the same manner as the first. The subsequent pruning was light and consisted mostly of a mere thinning out of thick places in the trees and the removal of interfering or crossing limbs. No heading back was practiced after the fourth season. In all cases, it was the aim to give all the trees the same type and severity of pruning. This was impossible during the first two or three years in the case of the high-headed trees, because of their tendency to produce branches below the head. These shoots had to be removed in addition to the pruning necessary to train the trees. In this way, the high-headed trees received a little heavier pruning than the low-headed ones, for the first few years. Since that time, there has been practically no difference in pruning trees of different heights of heads.

CARE OF THE ORCHARD

The trees in the experimental plot received cultivation and cover crops each year. The cultivation consisted of five to ten treatments with a light draft harrow, a spike-tooth harrow, or disc, as the nature of the soil warranted. A cover crop consisting of a mixture of vetch and hairy vetch was sowed during August. In the spring, the cover crop was plowed or disced under. An application of about two hundred pounds of 16 per cent superphosphate (acid phosphate) was made at the time of seeding the cover crop. In the spring of 1924, the trees received the only application of nitrogen, which consisted of fifty pounds of nitrate of soda per tree. This was applied when the trees were in bloom. The trees were kept thoroughly sprayed, at all times, to prevent any damage by insect pests or diseases.

METHODS OF OBTAINING DATA

In order to determine the exact amount of growth made each year by the trees of different heights of heads, the total lengths of the new shoots for the previous growing season were measured in the early spring. The trees were then pruned and the length of the one-year-old wood removed was measured. The new growth produced each year was measured for the first six years, after this, the only growth measurement made was the annual increase in trunk diameter.

When the trees in this experiment were planted, the diameters of their trunks were measured with calipers at a point approximately half way between the ground and the place where the heads were to be formed. This point was marked by painting a narrow band half way round the tree. The tree trunks were measured each year with the exception of 1918 and 1919.

To get a record of the fruiting of the trees, the number of blossom clusters was counted, and the yield of fruit was measured in total weight in pounds and in total number of apples produced.

PRESENTATION OF DATA

In presenting the data in this report, the individual, year-by-year tree records are given in two instances, while in all other cases only averages of the trees for each of the various treatments are recorded. In calculating the data for the annual length of shoot growth and the average annual increase in trunk circumference, Student's Method (5), which has been advocated by Love and Brunson (3) as an aid in interpreting similar data, was used. In the tables where this method of calculation was used, the column dealing with odds is important, as it gives a fairly accurate measure of the significance of the differences between treatments. Odds much below 30:1 indicate tendencies only, while greater odds approach absolute certainty, as a limit.

TREE GROWTH

The data presented in this report cover the first nine years after the trees were set, 1916-1924, inclusive, hence they are largely concerned with tree growth up to the age at which fruit production began.

Annual Shoot Growth

Table 1 shows the average total length of annual shoot growth per tree for the first six years. The low-headed trees, with one exception, made much more growth than those which were headed higher. This is true regardless of whether any one year's growth or all of the six

TABLE 1.—Length of Shoot Growth Produced by Individual Trees the First Six Growing Seasons Following Planting.

Varieties	Heights of Heads	Tree Numbers	Lengths of Shoot-Growths in Feet Produced by Seasons						S Y T
			1916	1917	1918	1919	1920	1921	
ROME	1 foot	1		(died)					
		2	5.42	27.25	97.25	209.00	325.00	796.00	1,48
		Average	5.42	27.25	97.25	209.00	325.00	796.00	1,48
	2 feet	7	1.25	19.92	42.00	113.50	252.00	376.00	8
		8	7.00	31.58	53.66	129.00	297.00	345.00	8
		Average	4.12	25.75	47.83	121.25	274.50	360.50	8
	3 feet	13	2.92	12.75	35.58	86.50	207.00	244.00	5
		14	5.92	17.58	38.25	89.75	146.00	366.00	6
		Average	4.42	15.16	36.91	88.12	176.50	305.00	6
	4 feet	19	4.92	17.08	33.58	89.75	147.00	236.00	5
		20	1.42	8.00	20.25	45.50	115.00	179.00	3
		Average	3.27	12.54	26.91	67.62	131.00	207.50	4
STAYMAN	1 foot	25	1.00	8.00	14.83	43.50	84.00	157.00	3
		26	4.92	17.20	22.33	51.75	107.00	163.00	3
		Average	2.96	12.60	18.58	47.62	95.50	160.00	3
	2 feet	3	5.25	29.00	71.92	141.50	200.00	676.00	1,1
		4	6.33	25.66	59.50	162.50	311.00	657.00	1,2
		5	6.50	32.33	87.00	181.50	334.00	662.00	1,3
		6	2.75	16.92	45.66	129.00	262.00	447.00	9
		Average	5.20	25.98	66.02	153.62	276.75	610.50	1,1
	3 feet	9	2.83	23.75	56.66	148.00	303.00	594.00	1,1
		10	3.75	30.83	71.58	169.75	304.00	473.60	1,0
		11	3.75	21.16	44.50	138.75	302.00	391.00	9
		12	4.50	23.08	45.33	131.00	250.00	436.00	8
		Av erage	3.71	24.70	54.51	146.87	289.75	473.65	9
	4 feet	15	4.08	19.75	41.58	93.00	228.00	380.00	7
		16	4.83	17.25	56.16	133.50	275.00	357.00	8
		17	5.08	24.25	49.08	107.25	184.00	367.00	7
		18	4.83	23.50	51.92	106.00	307.00	471.00	9
		Average	4.70	21.19	49.68	109.93	248.50	393.75	8
	5 feet	21	2.16	8.25	20.33	48.25	80.00	164.00	3
		22	0.0	16.25	41.58	86.75	183.00	251.00	3
		23	0.0	3.08	13.42	42.75	95.00	199.00	2
		24	2.83	11.75	22.25	78.25	138.00	258.00	0
		Average	1.25	9.83	24.39	64.00	124.00	218.00	3
	5 feet	27	4.83	27.75	27.16	48.50	113.00	196.00	3
		28		(not same variety)					
		29	13.25	27.00	32.33	86.00	142.00	229.00	3
		30		(not same variety)					
		Average	*9.04	*27.37	29.75	67.25	127.50	212.50	3

*Most of this growth was produced near the ground and had to be removed.

years' growths are considered. During the first growing season the trees headed at one foot made more growth than those headed at two feet, but the amount of shoot growth decreased as the height of head increased. The one exception, as has been noted, was the Stayman trees headed at five feet. These trees made considerably more growth during the first three years after being set in the orchard than those headed at four feet. This was due to the fact that the trees headed at five feet produced a large part of their branches below the head, making it necessary to remove them. This lot of trees was the only one to form any number of branches below the head.

The Rome trees headed at the same height did not respond in the same way. During the third growing season the trees of this variety headed at one foot made about three times as much growth as those headed at five feet. The same ratio existed at the end of the six-year period. As the experiment progressed the difference in growth between the high-headed and the low-headed trees became more pronounced.

Data for total length of annual growth as influenced by the height of head have been calculated, using Student's Method, and are given in Table 2.

TABLE 2.—Comparison of Annual Growths as Influenced by Different Heights of Heads.*

Varieties	Year	Comparative Growths at Different Heights of Heads				
		1 Foot	2 Feet	3 Feet	4 Feet	5 Feet
ROME	1916	1.00	.76	.81	.60	.54
	1917	1.00	.94	.55	.46	.46
	1918	1.00	.49	.38	.27	.19
	1919	1.00	.58	.42	.32	.22
	1920	1.00	.84	.54	.40	.29
	1921	1.00	.45	.38	.26	.20
	Average Odds	1.00	.67 800:1	.51 2499:1	.38 9999:1	.31 9999:1
STAYMAN	1916	1.00	.71	.90	.24	1.74
	1917	1.00	.95	.81	.38	1.05
	1918	1.00	.82	.75	.37	.45
	1919	1.00	.95	.71	.41	.43
	1920	1.00	1.04	.89	.44	.46
	1921	1.00	.77	.64	.35	.35
	Average Odds	1.00	.87 32:1	.78 521:1	.36 9999:1	.74 5:1

*In this table, the average annual length of new growth produced on the trees headed at one foot has been taken as unity, and the growth of the trees of the other treatments has been compared with those headed at one foot.

The annual growth of the trees of various heights of head have been compared with those headed at one foot. In every instance but one, the odds were very significant in favor of the trees headed at one foot. This exception was in the case of the Stayman trees headed five feet. As has already been pointed out the variation was due to the fact that these trees made most of their growth below the head in the first two years.

Severity of Pruning

Experiments have shown that pruning has a dwarfing effect on young trees. It is also true that the more severe the pruning the greater the trees are dwarfed. As the type and amount of pruning necessary to shape and train the trees with different heights of heads must vary to some extent, if any difference existed in pruning, the effect of the height of head might be overcome. In order to eliminate any influence of pruning, the trees were pruned as nearly as possible in the same manner and with the same severity (excepting the pruning necessary to keep branches from the trunks). Careful records were kept of the total length of one-year-old wood removed each year. The data are given in Table 3.

TABLE 3.—Average and Total Lengths of Wood Removed in Pruning Recorded by Varieties, Different Heights of Heads, and Years.

Varieties	Heights of Heads	Average Length of Wood Removed in Feet per Tree by Years					Total Wood Removed
		1917	1918	1919	1920	1921	
ROME	1 foot	15.2	75.6	118.5	152.0	224.0	585.3
	2 feet	17.3	32.2	68.5	153.5	216.0	487.5
	3 feet	6.3	24.7	52.7	99.0	191.5	374.2
	4 feet	8.5	19.9	36.7	71.5	127.0	263.6
	5 feet	10.9	13.2	23.8	56.5	90.0	194.4
STAYMAN	1 foot	14.6	37.6	88.4	126.0	282.3	548.9
	2 feet	15.4	30.7	88.5	146.0	269.0	549.6
	3 feet	14.3	30.7	68.2	124.2	213.7	451.1
	4 feet	5.9	16.8	32.3	56.2	102.5	213.7
	5 feet	24.1	22.6	41.2	58.0	124.0	269.9

From the data in Table 3 and those given in Table 1, the percentages of each year's growth removed by pruning during the first few seasons have been calculated and are given in Table 4.

TABLE 4.—Percentage of Each Year's Growth Removed by Pruning, 1917-1921 Inclusive.

Varieties	Heights of Heads	Percentage of Total Annual Growth Removed by Years					Percentage of Growth Removed 1917-1921
		1917	1918	1919	1920	1921	
ROME	1 foot	55.9	77.7	56.6	46.7	28.1	40.09
	2 feet	67.1	67.3	56.4	55.9	59.9	58.45
	3 feet	41.5	66.9	59.8	56.0	62.7	59.76
	4 feet	67.7	73.9	54.2	54.5	61.2	58.74
	5 feet	86.5	71.0	49.9	59.1	56.2	57.64
STAYMAN	1 foot	56.1	56.9	57.5	45.5	46.2	48.23
	2 feet	62.3	56.3	60.2	50.3	56.7	55.33
	3 feet	67.4	61.7	62.0	50.0	54.2	54.49
	4 feet	60.0	68.8	50.4	45.3	47.0	48.40
	5 feet	88.1	75.9	61.2	45.4	58.3	57.01

In the case of both varieties, the trees headed at one foot had the least amount of wood removed. The trees which were headed higher than one foot, with one exception, received practically the same severity of pruning. This exception was in the case of Stayman headed at four feet, which had about 7 percent less wood removed than did the other trees headed higher than one foot. The striking thing brought out in this table is that the trees headed at five feet required the removal of but little more wood to form the head at that height than was required for those headed at two feet. The Rome trees headed at two feet had approximately 1 percent more wood removed than those headed at five feet, while the Stayman trees headed at five feet required the removal of about 2 percent more wood than those headed at two feet.

The low-headed trees, in their first and second growing seasons, produced fewer and longer shoots than the high-headed trees. During the succeeding years, the growth produced on the main scaffold branches and primary laterals was distributed so much better on the low-headed trees that more wood could be left to advantage. The differences in the amounts of wood removed in pruning the trees of different heights of heads, however, would not account for the great differences obtained in shoot growth.

Weight of Wood Removed by Pruning

During the four-year period, 1922-1925 inclusive, the wood removed by pruning was weighed. These data are given in Table 5.

TABLE 5.—Average and Total Weights of Wood Removed in Pruning, Recorded by Varieties, Different Heights of Heads, and Years.

Varieties	Heights of Heads	Average Weight of Wood Removed per Tree by Years in Pounds				Total for Four Years	Average per Year
		1922	1923	1924	1925		
ROME	1 foot	9.50	12.20	12.40	17.30	51.40	12.85
	2 feet	3.75	3.95	4.70	4.00	16.40	4.10
	3 feet	2.12	2.85	3.25	3.00	11.22	2.80
	4 feet	1.50	1.80	3.50	2.10	8.90	2.22
	5 feet	1.37	2.40	2.65	1.60	8.02	2.00
STAYMAN	1 foot	6.37	7.35	7.76	9.80	31.28	7.82
	2 feet	6.50	7.00	7.12	10.70	31.32	7.83
	3 feet	4.62	7.15	7.05	10.20	29.02	7.25
	4 feet	2.18	2.17	3.77	4.45	12.57	3.14
	5 feet	2.25	3.55	3.65			

*All pruning was done during the spring months each year.

The data presented in Table 5 show that the amount of wood removed was closely proportional to the growth the trees made during the first six growing seasons. The Stayman trees may be divided into two classes as to the severity of the pruning, those headed from one to three feet, and those from four to five feet. The trees headed at three feet were smaller at the time of this report (May, 1926) than those headed at two feet or one foot. Yet, for some unaccountable reason the difference in pruning during the four-year period (1922-25) was not in proportion to tree size, as these higher headed trees were pruned almost as heavily as those headed lower.

The Rome trees headed at one foot had, due to their much larger size, much more wood removed from them than any of the others. These trees were probably better located than any of the others on account of a slight dip in the land, which caused the soil to have a higher moisture content and possibly greater fertility. These differences in pruning and in the soil were not sufficient, however, to influence greatly the growth or size of trees, as was shown by trees of the same varieties which grew in an adjacent row, sixteen feet away and received the same culture.

Increase in Circumference of Tree Trunks

The annual increases in the circumference of the tree trunks were measured from the time the trees were planted. These data are given in Table 6.

The trunks of the high-headed trees were much smaller in circumference than those of the low-headed trees. The circumference of the

TABLE 6.—Comparison of Circumferences of Tree Trunks by Varieties, Heights of Heads, and Years.

Varieties	Heights of Heads	Tree Numbers	Circumferences at Planting in 1916	Circumferences of Tree Trunks in Inches by Years*					
				1916	1919	1920	1921	1922	1923
ROME	1 foot	1		(died)					
		2	1.13	1.26	5.87	8.50	11.25	14.00	16.12
		Average	1.1	1.26	5.87	8.50	11.25	14.00	16.12
	2 feet	7	1.19	1.29	4.50	6.25	8.37	10.12	11.75
		8	1.26	1.63	4.62	6.25	8.00	9.50	10.75
		Average	1.22	1.46	4.56	6.25	8.18	9.81	11.25
	3 feet	13	.91	.97	3.37	4.87	6.25	7.75	9.50
		14	.85	1.04	3.87	5.37	7.00	8.75	10.25
		Average	.88	1.00	3.62	5.12	6.62	8.25	9.87
	4 feet	19	1.00	1.10	3.87	5.50	7.12	8.50	10.25
		20	.85	1.04	3.00	4.50	5.75	7.00	8.50
MAN		Average	.92	1.07	3.43	5.00	6.43	7.75	9.37
	5 feet	25	.88	1.13	3.25	4.02	6.37	7.62	9.50
		26	1.13	1.41	3.50	4.87	6.37	7.75	9.25
		Average	1.00	1.27	3.37	4.74	6.37	7.68	9.37
	1 foot	3	1.57	2.01	6.62	9.00	11.62	13.75	15.75
		4	1.63	1.82	6.62	8.87	11.25	13.25	15.75
		5	1.50	2.01	6.62	9.12	10.62	13.50	15.75
		6	1.44	1.63	5.50	7.87	9.75	11.50	13.25
		Average	1.53	1.87	6.34	8.71	10.81	13.00	14.92
	2 feet	9	1.50	1.63	6.00	8.25	10.87	12.75	15.00
		10	1.60	1.92	6.50	9.00	11.37	13.25	15.50
		11	1.50	1.63	5.50	7.50	9.50	11.12	13.00
		12	1.32	1.41	5.75	8.00	10.12	12.12	14.50
		Average	1.48	1.64	5.93	8.18	10.46	12.31	14.50
	3 feet	15	1.32	1.57	5.25	7.25	9.62	11.50	14.00
		16	1.32	1.44	5.62	7.75	10.12	12.00	14.37
		17	1.16	1.29	4.50	6.25	8.00	9.25	11.00
		18	1.19	1.29	5.50	7.50	9.62	11.50	13.75
		Average	1.24	1.39	5.21	7.18	9.34	11.06	13.28
	4 feet	21	1.19	1.26	3.75	5.25	6.62	8.00	9.75
		22	1.16	1.26	5.00	7.37	9.62	11.37	13.50
		23	1.16	1.19	3.25	5.12	6.75	8.50	10.50
		24	1.32	1.35	4.60	6.25	7.87	9.25	11.00
		Average	1.20	1.26	4.12	5.99	7.71	9.28	11.18
	5 feet	27	1.07	1.38	3.50	5.12	7.25	9.00	11.25
		28		(not same variety)					
		29	1.09	1.35	4.12	5.62	7.25	8.50	10.12
		30		(not same variety)					
		Average	1.08	1.36	3.81	5.37	7.25	8.75	10.68

* measurements were taken at the end of the growing season each year.

Rome Beauty trees in the spring of 1925, showing comparative size and shape. The tree at the left was headed at one foot, the tree in the center at three feet, and the one on the right at five feet.

tree trunks became smaller as the height of the head increased. From Table 6, it may be seen that the Stayman made larger gains in trunk circumference than the Rome, due to the more vigorous growth of his variety.

In Table 7 is given the average yearly increase in trunk circumference as influenced by the height of head of the trees. The total increase in the circumference of the trunk was greatest, on both varieties with the trees headed at one foot. The increase in trunk girth became less as the height of the head increased. When the differences between the trees headed at one foot and those headed higher were compared by Student's method, it was found that, in the case of the Rome, all the trees headed higher than one foot had made significantly smaller increases in trunk circumference than those headed at one foot. With the Stayman, however, significant odds were found only with those trees headed at four feet.

TABLE 7.—Average Increases in Trunk Circumferences Recorded by Varieties, Different Heights of Heads, and Years.

Varieties	Heights of Heads	Average Increases in Trunk Circumferences in Inches Recorded by Growing Seasons						Total Increase for Eight Seasons	Average Increase per Season	Odds In Favor of 1-Foot Head
		1916	*1919	1920	1921	1922	1923			
ROME	1 foot	.13	4.61	2.63	2.75	2.75	2.12	14.99	2.50	
	2 feet	.24	3.10	1.69	2.13	1.63	1.44	10.23	1.70	118:1
	3 feet	.12	2.62	1.50	1.50	1.63	1.52	8.89	1.48	132:1
	4 feet	.15	2.36	1.57	1.43	1.32	1.52	8.35	1.39	112:1
	5 feet	.27	1.10	1.37	1.63	1.01	1.69	7.07	1.17	38:1
STAYMAN	1 foot	.34	4.47	2.37	2.10	2.19	1.92	13.39	2.23	
	2 feet	.16	4.29	2.25	2.28	1.85	2.19	13.02	2.17	3:1
	3 feet	.15	3.82	1.97	2.16	1.72	2.22	12.04	2.00	11:1
	4 feet	.06	2.86	1.87	1.72	1.57	1.90	9.98	1.66	38:1
	5 feet	.28	2.45	1.56	1.88	1.50	1.93	9.60	1.60	19:1

*Includes growth for seasons of 1917 and 1918.

Volume of Top

In an attempt to show more clearly the differences existing in tree shape and bearing surface, the height and spread of the trees were measured in the early spring of 1925. The distance from the ground to the lowest limbs was also measured. The tops of the trees were found to conform more closely to the shape of a sphere than to any other geometrical figure, as the trees had not borne crops sufficiently heavy to spread the tops. To calculate the volume of the tree tops, of which may be considered potential bearing area, the distance from the ground to the lowest limbs was subtracted from the height

of the trees, which gave the diameter of the top in a vertical direction. This was then averaged with the width of the tree, which resulted in what was used as the diameter of the tree or sphere. The volume of the sphere was then calculated in the usual manner ($V=1/6\pi D^3$). These data are given in Table 8.

TABLE 8.—Heights, Widths, and Volumes of Trees as Influenced by Height of Heads; Measurements Made in the Spring of 1925.

Varieties	Heights of Heads	Average Heights in Feet	Average Widths in Feet	Average Distances from Ground to Limbs in Feet	Average Volumes Tops in Cubic Feet
ROME	1 foot	15.0	16.0	2.50	1515.08
	2 feet	12.5	11.0	3.25	543.45
	3 feet	12.5	9.5	4.00	381.70
	4 feet	13.0	8.0	4.75	280.31
	5 feet	13.5	8.0	5.50	268.08
STAYMAN	1 foot	15.50	16.75	1.25	1949.81
	2 feet	15.75	17.00	2.00	1901.11
	3 feet	15.62	17.00	3.12	1680.23
	4 feet	15.25	14.50	4.25	1085.23
	5 feet	(All trees removed at this time)			

The high-headed trees were several years behind the low-headed trees in actual size when the top measurements were taken in 1925. They were less stocky, less vigorous, and much less desirable. The lower the trees had been headed, the larger was the top, as shown by measurements of height and breadth, or total volume. Both varieties responded in the same way. The Stayman, being a more vigorous grower, made larger trees than the Rome, but the response to the height of head was the same.

BLOOM AND YIELD

As has been stated, since this report covers only the first nine years of the life of the trees after they were set in the orchard, it must necessarily deal largely with growth. The trees were still so young at the time this report was prepared that very little could be expected from them in bloom and yield of fruit.

The trees produced their first bloom in the spring of 1920, four years after they were set in the orchard. At this time, the number of blossom clusters was counted on each tree. This was continued for three more years. These data are given in Table 9.

It is interesting to note that the high-headed trees were the first to bloom, and that they continued to bloom more heavily than the low-headed trees. This is especially significant when the great difference in size of the trees is considered.

TABLE 9.—Average Number of Flower Clusters Per Tree Recorded by Varieties, Different Heights of Heads, and Years.

Varieties	Heights of Heads	Average Number of Flower Clusters per Tree by Years				Total 1920-23
		1920	1921	1922	1923	
ROME	1 foot	0	6.5	74.0	105.0	185.5
	2 feet	0	0.5	.5	32.5	33.5
	3 feet	0	2.0	13.5	15.7	31.2
	4 feet	3.0	2.0	1.5	20.0	26.5
	5 feet	3.5	12.0	14.5	164.0	194.0
STAYMAN	1 foot	0	0	.3	20.0	20.3
	2 feet	0	0.2	0	3.4	3.6
	3 feet	0	0	.5	12.5	13.0
	4 feet	0	0	.5	62.5	62.7
	5 feet	9.0	8.3	134.5	330.0	481.8

The only data obtained on yield of fruit were taken for the two crops borne in 1923 and 1924, for which the total weight of fruit was determined as well as the number of individual fruits produced per tree. These data are given in Table 10.

TABLE 10.—Yield in Pounds and Number of Apples per Tree Recorded by Varieties, Different Heights of Heads, and Years.

Varieties	Heights of Heads	Average Yield in Pounds per Tree by Years			Average Number of Apples per Tree by Years			Average Weights of Fruits in Pounds
		1923	1924	Total	1923	1924	Total	
ROME	1 foot	6.0	9.6	15.6	19.0	29.0	48.0	.32
	2 feet	2.2	0	2.2	4.0	0	4.0	.55
	3 feet	5.6	2.5	8.1	15.5	4.0	19.5	.41
	4 feet	0	1.5	1.5	0	3.0	3.0	.50
	5 feet	6.0	11.7	17.7	12.5	24.0	36.5	.48
STAYMAN	1 foot	2.4	3.7	6.1	5.5	9.0	14.5	.42
	2 feet	.9	18.7	19.6	2.0	53.5	55.5	.35
	3 feet	1.1	14.3	15.4	3.7	34.0	37.7	.40
	4 feet	5.3	27.4	32.7	11.0	65.5	76.5	.42
	5 feet	16.8			62.0			

The amount of fruit borne to the date of this report was too small to be of much value in determining the effect of height of head on fruit production. At the end of the first nine-year period, the yield had not been influenced to any appreciable extent by the height of the head. Practically all of the effect of the low heading of trees was that of producing trees of greater size and bearing area. Time alone will tell whether the trees of greater bearing area will produce crops significantly greater than those of the high-headed trees.

DISCUSSION

It is unfortunate that a larger number of trees was not included in this experiment. The data in regard to growth are so consistent, however, that it would seem that the effect of the height of head on the growth and yielding capacity of the trees is fairly clearly defined. This is especially true when it is considered that the results of the experiment substantiate those secured by Wiggans (6), and Howe (2) and the observations of Chandler (1).

Wiggans (6), in reporting on the growth made by similar trees which had been headed at different heights, says that, from the very beginning, the low-headed trees produced shoots which were much longer, and at the same time formed a larger number of branches than did the high-headed trees. Although no counts or measurements were made in the West Virginia experiment, it was observed that the low-headed trees produced more shoots, and also longer and stockier shoots, than the trees headed higher. This was especially true as the trees became older, since the trees headed at five feet grew in a manner similar to trees several years older; that is, the length of growth and the comparative diameter of the shoots were reduced.

Howe (2) used nine different varieties in testing the effect of high and low heads on growth and fruit production. He reported that, at the end of the first ten-year period, the low-headed trees were considerably larger in actual size, and more vigorous and stocky than the high-headed trees, and further that the low-headed trees of each variety bloomed and set fruit about one year earlier than the high-headed trees. Every variety but one yielded more fruit when the trees were headed low. He states that "the results indicate an economic advantage in the practice of low-heading due to increased yields and greater ease in orchard operations, and advances the opinion that, unless considerable care is taken in the formation of high heads, the larger amount of wood that must be removed may impair the vigor of the trees and check their development.

Under the conditions of the West Virginia experiments this opinion could hardly be true, as there was very little difference in the percentages of the total growth removed from the high- and the low-headed trees. Certainly the great difference in size of trees cannot be explained entirely on the basis of the dwarfing effect of pruning. There are apparently several factors operating, which taken together cause the wide variation in tree size.

Chandler (1) thinks that the large amount of pruning necessary to obtain a high head, and the injury which the young high-headed

ees suffer from bending about during early summer are responsible for the rather marked differences in the trees.

Numerous investigations in pruning have shown that the pruning of young trees dwarfs them to a degree dependent on the severity of the pruning. In this experiment, it was not necessary to prune the high-headed trees much more severely than the low-headed ones to form a high head. Certainly, the small difference between the amount of wood removed from the high- and the low-headed trees is too small to account for the differences existing in the size of the trees. It should be pointed out again that the trees in this experiment were planted as one-year old whips and were headed at the desired height at the time of planting. In this way, the main scaffold branches were produced at the height desired with a minimum amount of pruning. Had all the trees been headed at the same height at the time they were planted, and the high heads formed later by removing the lower limbs, more severe pruning would have been necessary. This, in view of the present knowledge of the dwarfing effects of pruning, would probably have caused wider differences in the size of the trees than actually resulted.

As an advantage of low-heading, it is claimed by some investigators that trees so headed do not grow as tall as if they had been headed higher. This claim is not borne out by the results of this experiment, since only a part of the bearing surface of the low-headed trees was wider than that of the trees headed higher. Considering the actual height of the trees, the low-headed ones grew as tall as those headed highest. The striking fact brought out by the data is the uniformity of the height of the trees regardless of the height of head. The greatest difference in the trees with different heights of heads was in the breadth and not in the actual height of the top. The low-headed trees, particularly of the Rome variety, developed much wider tops than those headed higher (See Table 8).

The height of head had no influence on the general type of tree as each variety maintained its usual characteristics. The high-headed trees had a tendency to bend and lean due to the influence of the prevailing winds. This was not so noticeable with the low-headed trees.

In so far as cultivation is concerned, no difference between the high- and the low-headed trees was found, other than that usually experienced with larger trees. The implements used in cultivation were those commonly employed in the average orchard. Other operations such as pruning and spraying were facilitated by the low-headed trees, and, no doubt, when the trees begin to bear heavy crops, harvesting operations will be easier.

CONCLUSIONS

From the data presented it must be concluded that low-headed trees make more shoot growth, and larger gain in trunk diameter than high-headed trees. Low-headed trees, as a result of this greater growth, have a larger bearing area than the high-headed trees. At the end of nine years, there was no appreciable difference in yield of the trees of different heights of heads. The trees were still too young, however, to expect much in fruit production. Judging by top area, it would appear that the low-headed trees will likely outyield the high-headed trees in the near future.

RECOMMENDATIONS TO GROWERS

There are considerable variations in the recommendations of horticulturists, and in the practices of commercial fruit growers, in regard to the height of heading young apple trees. Several important factors are considered in these recommendations and practices, such as ease of spraying, picking, pruning, thinning, prevention of winter injury to the tree trunk, and soil temperature.

The height at which the trees are headed should be determined, in a large measure, by the importance that the grower places on one or more of the foregoing factors. After all, over emphasis may be placed on some factor because of the grower's likes or dislikes.

If there is any difference, in tree growth and capacity to bear large crops, between high- and low-headed trees, the height of head which produces the largest tree in the shortest time should be given first consideration. It should be the aim and desire of the commercial grower to produce a tree as large as possible, which is capable of bearing maximum quantities of high grade fruit, in the least time. It is believed by the writer that this may be best accomplished by heading the trees low, preferably from one foot to two feet from the bud graft.

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