INHERITANCE OF TREE FORM IN CERTAIN PROGENIES OF CROSS-BRED APPLE SEEDLINGS

By

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INTRODUCTION

Trees of the different apple varieties vary greatly in size, shape, branching habit, and in many other ways. These wide variations are doubtless due to the influence of the ancestral forms. Koch (2) from his study of the wild apple of Asia concluded that our apple varieties have been developed from four or perhaps five wild species. Because of self-sterility and cross-pollination by insects most apple varieties are probably heterozygous.

Since 1900 much careful work has been done in apple breeding. Thus far the emphasis has been placed on size, appearance, texture, flavor, and keeping qualities of the fruit. Little if any direct work has been done on the inheritance of tree shape. This is true of other plants as well. An evaluation of the progeny performances is needed in order to determine the prepotency of the parents. There is a great need at present to know the breeding merits of the many varieties with respect to size, shape, vigor, hardiness, and yield of the tree.

Purpose of this Study

The object of this investigation was to trace parental influences on about 5000 cross-bred apple trees growing in the orchards of the Iowa Agricultural Experiment Station at Ames, Iowa. There were 75 combinations of parent varieties, with 21 varieties used as seed parents and 23 varieties used as pollen parents. The cross-bred seedling trees fell into nine parent-groups, each group having one variety used as male or female parent in each cross.

From a statistical study of measurements devised to indicate form and quality of tree in the parents and progenies under observation, it was hoped to secure fairly reliable information covering the following points:

(1) Characteristic parental tree forms

(2) Form of the cross-bred progenies

(3) Significant differences between the forms of parents and progenies

(4) Inheritance of parental forms in the offspring

(5) Parents showing dominance or prepotency

(6) Range of form variation within each progeny and between different progenies

(7) Range of variation between parent-groups and between progenies with respect to tree form, nursery quality of tree, branching habit, desirability of scaffold branches, tree vigor, and quality of foliage from the orchard standpoint

(8) Determination of parents transmitting the most satisfactory offspring from the viewpoint of tree habit.

REVIEW OF LITERATURE

After a careful search extending over many months no direct references were found on the inheritance of general plant shape. In working with bush and pole bean varieties, Emerson (3) found that, "The intermediate height in F1 and the wide range of variation in F2 from a cross between two pole beans of different heights, are interpreted in accordance with the multiple-factor hypothesis, which postulates that hereditary, quantitative differences are due to two or more non-dominant, independently inherited factors".

The growth habit of apple trees may well be linked with chromosome numbers. The haploid number in the apple is seventeen. Edgecombe at Iowa State College in an unpublished report stated that all the parent varieties in this experiment have the regular diploid number of 34 chromosomes.

It is apparent that high yields, convenience in orchard care, ability to withstand stresses of storm and weight of fruit, have some relation to shape of tree, branching habit, and the nature of scaffold branches. While shape can be greatly modified by pruning, it is best to have a tree that tends to develop into the desired form. Blake (1) states that, "Each variety has its own characteristic type of growth---. Some varieties naturally develop strong and desirable framework without much artificial assistance, while others are irregular or weak in habit, lack spread, or possess other faults".

Concerning the shape and habit of apple seedlings, Lantz and Edgecombe (5) concluded that, "Progenies often differ as much in habit of growth as in height. The habit of growth varies from the strong, straight, stoutly branched type to the slow growing willowy and drooping type. These opposite types and the gradation between them appear in nearly every progeny, but the proportions of each type differ very markedly in the various progenies".

Sax and Gowen (9) in their study of 881 Ben Davis trees as to their productivity concluded that, "Productive and unproductive trees are closely associated with a definite type of habit of growth. The productive trees are large, open, and spreading with short laterals and bear many spurs".

Ruth and Kelly (8) concluded that, "Crotch strength seems to be due more to soundness of the crotch wood than to the crotch angle. Ridging and splitting are to a large extent varietal characteristics. The Willow, which splits down more commonly than any other variety, except possibly the Delicious, is also the variety which forms the heaviest ridges".

Bad crotches that will split and ruin the tree should be avoided. Oskamp (7) concluded that, "Weak unions are especially common in some varieties of apples of which the shoots often grow upright against the trunk or against other branches".

EXPERIMENTAL

Materials

The materials of this investigation were 3,423 cross-bred apple seedlings and 130 trees used as parents. A few of the former are counted twice because they appear in two different parent groups. Thirty-one parent varieties were used in the 75 different crosses which made up the entire group. Two of the parents, Antonovka and Anisim, are of Russian origin. Pewaukee, Patten 1000, and Patten 1003 are hybrids of Russian and American varieties. The remainder, Ames 463, Ames 488, Ames 513, Ashton, Black Annette, Black Oxford, Colorado Orange, Delicious, Grimes, Harrington, Hubbardston, Jonathan, King David, McMahon, Mother, Nelson Sweet, Northern Spy, Northwestern Greening, Opalescent, Patten 1011, Patten 1015, Ramsdell Sweet, Salome, White Pippin, Wealthy, and Yellow Newtown, are of American origin.

The trees were planted 8 1/4 feet by 16 1/2 feet apart in the orchard in 1924 and 1925. They were from ten to fifteen years of age from the seed at the time the study was made. They occupied four plots in a 20-acre tract near Ames. The soil was a glacial clay loam with good surface and sub-surface drainage. With the exception of a side hill on the south, clean cultivation was followed. As the fertility of the land was high no fertilizers were used.

Methods

The measurements of height and spread were taken in the autumn of 1929. All the other measurements were taken in the autumn of 1932. The height was measured to the nearest 3-inch interval from the surface of the soil to the tip of the tallest branch. The spread was measured to the nearest 3-inch interval of the greatest width of branches at right angles to the prevailing wind. The formula for the height-diameter index is $I = (H - 2') / D$, where H is the height of the tree and D is the diameter of its spread. Two feet were subtracted from the height in each case because the trees were headed two feet high. We shall call this ratio the shape index.

A tree with a shape index of 0.51 to 0.80 was defined as a spreading tree. A tree with an index of 0.81 to 1.20 was called a round headed tree. A tree with an index of 1.21 to 1.60 was called upright-spreading; and those with an index of 1.61 or more, upright.

The trees were also graded into four classes with reference to quality of tree. The "very good" trees were those making a vigorous growth, having good orchard habit, and possessing high quality in shape, framework, and branches as contrasted with the "wild type". The "good" trees were those somewhat less vigorous, having a less desirable type of scaffold branches or perhaps too thickly branched, and being a little less desirable than the highest grade. The "fair" trees were still less vigorous and less desirable as to size, shape of top, and quality of branches. The "poor" trees were small and weak or poor as to shape and quality of branches. Some rather vigorous trees, lacking in good scaffold branches and being "leggy" or excessive in "brush" were put into one or the other of the two inferior grades. The two poorest grades, medium and poor, were considered undesirable for orchard planting.

The trees were also graded as to shape into four classes; drooping, spreading, upright-spreading, and upright. These are the shapes generally used in horticultural practice. The angles that the branches made with the trunk and main limbs, the resulting direction of growth, and the general form of the tree were the determining characteristics. These measurements checked closely with the shape index measurements. One difference in the two measurements is that the judgment measurements distinguish between a spreading and a drooping tree while those of the shape index measurements do not. Professor H. L. Lantz and the author agreed on the judgment measurements as they were taken.

As to branching habit, the trees were graded into four classes; thick, medium thick, medium open, and open. The upright growing trees are generally not desirable trees to plant because the branches fail to spread the fruit and foliage sufficiently to permit the entrance of air and sunlight. Then too, the open habit of branching requires very little pruning while that of thick branching requires much.

As to quality of scaffold branches, the trees were graded into four classes; poor, fair, good, and very good. Here the emphasis was placed on the major branches with reference to the angle and strength of the crotch, and the size, sturdiness, and arrangement of the branches.

The trees were graded into four classes with respect to vigor. The vigor measurements were determined by the average amount of terminal growth made during the summer of 1932. A growth of six inches or less was called poor; from six to twelve inches, fair; from twelve to eighteen inches, good; and more than eighteen inches, very good.

The foliage was graded into four classes, poor, fair, good, and very good. The amount and healthfulness of the leaves at the end of the growing season were the bases for these grades. The measurements as to shape of tree, branching habit, quality of scaffold branches, vigor of tree, and quality of foliage are each a little more highly specialized than "grade" of tree which in a general way includes them all.

In treating the data statistically a distribution of the shape indices of the trees in each progeny was first made. From the distribution, the mean and its probable error, the standard deviation, and the coefficient of variability were calculated.

In three of the parent varieties forty trees of each were measured, but in most cases only one, two, or three trees were available for measurement. In eleven of the parent varieties there were no trees available for measurement.

The number of trees in the progenies varied greatly. Results from less than fifteen or twenty trees were not considered trustworthy for anything more than a general trend. Because of this wide variation in the number of trees in a progeny, the distributions in some of the tables are given in percentage instead of number of trees.

Since the data consisted largely of measurements of individuals in progenies, much use was made of progeny tests. Each parent transmits "a sample half" of its inheritance to each of its offspring. Each additional offspring is an independent sample from the same inheritance. A composite picture from a sufficient number of such samples gives a more accurate description of the parental genotype than does the most careful estimate from the parental phenotype.

While each offspring inherits half of its genes from each of its parents, only fifty per cent of its inheritance is thus determined. The other fifty per cent is the result of chance segregation of the parental genes in reduction division. However, these results are true only when heterozygous material is crossed at random and the effects of dominance, nicking, and environment are not considered. Under the simplest genetic conditions where the numbers of genes are large the likeness between an individual and one of its parents is expressed by a correlation of 0.50. The correlation between the individual and the average of its two parents is 0.71.

Progeny tests are especially helpful when only one parent is known as is true in a portion of the cases in this investigation. The most important practical use of these tests is to predict the breeding merit of a parent from the merit of its progeny.

Experimental Data

Thirty-one varieties of apples were used as male or female parents. In some cases reciprocal crosses were made. These progenies were grouped into nine parent-groups. The parent-groups are Delicious, Colorado Orange, Northern Spy, Anisim, Jonathan, Harrington, Antonovka, Grimes, and Northwestern Greening. A parent-group consists of all the progenies having a common parent. The distributions of the shape indices of the nine parent-groups are given in Tables 1a to 9a in the appendix.

Trees of only twenty of the parent varieties were available for measurement. These are grouped with reference to their shape indices in Table 10. According to our definitions there are three spreading, thirteen round, and four upright-spreading trees. There are no upright trees in this list.

Table 10. Parent Varieties with Known Indices Classified as to Shape

Spreading (0.51-0.80)	Index	Round (0.81-1.20)	Index	Upright-spreading (1.21-1.60)	Index
Ashton	0.70	King David	0.81	Grimes	1.24
Opalescent	0.74	Harrington	0.82	Oldenburg	1.26
Jonathan	0.79	Patten 1013	0.82	Wh. Pippin	1.28
		Anisim	0.82	N. Spy	1.39
		Bl. Oxford	0.87		
		N. W. Green.	0.88		
		Col. Orange	0.89		
		Salome	0.99		
		Hubbardston	1.00		
		Sharon	1.10		
		Delicious	1.12		
		Antonovka	1.12		
		Wealthy	1.15		

It will be seen that seven of the fifteen mean shape progeny indices in Table 1a are significantly different from the mean shape index of the common parent. (This calculation is based on the mean difference being equal to three or more times the square root of the sum of the squares of the two probable errors). Also, two progenies in Table 2a; nine, in Table 3a; all, in Table 4a; all but one, in Table 5a; all, in Table 6a; five, in Table 7a; three, in Table 8a; and all but one, in Table 9a have mean shape indices significantly different from their common parents. These results indicate that these differences are not all due to random sampling. The summary of the nine parent-groups, classified into spreading, round, and upright-spreading trees, is given in Table 11.

Table 11. Parents and Progenies Classified as to Shape

Shape of parent		Mean index parent	Mean shape indices of progenies: Spreading 0.51-0.80	Round 0.81-1.20	Upright-spreading 1.21-1.60
Spreading	Jonathan	0.79	0.80	0.87, 0.93, 1.04, 1.05, 1.09, 1.16, 1.19	1.45
Round	Harrington	0.82		1.08, 1.10, 1.11, 1.18, 1.19	1.22
	Anisim	0.82		0.91, 1.03, 1.04, 1.11, 1.11, 1.13	
	N. W. Greening	0.88		1.06, 1.07, 1.11, 1.12, 1.17	1.24, 1.49
	Colorado Orange	0.89		0.93, 0.98, 0.99, 1.10, 1.20	
	Antonovka	1.12		1.04, 1.05, 1.07, 1.07, 1.09, 1.11	1.27, 1.33
	Delicious	1.12		1.03, 1.04, 1.06, 1.10, 1.11, 1.12, 1.12, 1.15, 1.16, 1.18	1.34, 1.35, 1.41, 1.44 1.55
Upright-spreading	Grimes	1.24		0.99, 1.06, 1.17	1.27, 1.30, 1.32, 1.33
	Northern Spy	1.39		1.04, 1.10, 1.14, 1.14, 1.15, 1.19	1.24, 1.30, 1.37, 1.37, 1.44, 1.51

Tables la to 9a show that there are upright trees in over half of the progenies. Table 11 shows that there is but one progeny mean that is spreading in shape and none that is upright. Sixty-seven per cent of the means of the parents and seventy-six per cent of the progeny means fall in the round class. The round parents give eighty-eight per cent of their progeny means round; and twelve per cent, upright-spreading. The upright-spreading parents give forty-seven per cent of their progeny means round; and fifty-three per cent, upright-spreading.

Have the shapes of the parent trees influenced the shapes of their cross-bred seedlings? To get evidence for an answer to this question, the 3,403 cross-bred seedling trees having the shape indices of both parents known were classified and combined in Table 12.

Table 12. Parents and Their Progenies Classified as to Shape of Tree

Shape and indices of parents	No. of trees	Spreading (.51-.80)	Round (.81-1.20)	Upright-spreading (1.21-1.60)	Upright (1.61-)
Spreading (.51-.80) x Round (.81-1.20)	1102	192 (17%)	631 (57%)	271 (25%)	8 (1%)
Round (.81-1.20) x Round (.81-1.20)	1229	173 (14%)	650 (53%)	336 (27%)	70 (6%)
Round (.81-1.20) x Upright-spreading (1.21-1.60	972	4 (6%)	429 (44%)	370 (38%)	119 (12%)
Upright-spreading 1.21-1.60 x Upright-spreading (1.21-1.60)	100		30 (30%)	53 (53%)	17 (17%)

The percentage in each group with reference to shape in Table 12 can be readily compared. The modal percentage of trees in the first row is fifty-seven and falls in the round column. The percentage in the round column gradually decreases downward as the shape of the parent trees becomes more upright. Likewise, in the column under spreading shape, the percentage changes from seventeen at the top of the table to zero at the bottom. In the upright-spreading and upright columns, on the other hand, there is a gradual increase in the percentage numbers from the top to the bottom of the table. The data in Table 12 would seem to indicate that the shapes of the parent trees do have a definite influence on the shape of their cross-bred seedlings.

For further evidence all the crosses, where the shape indices of both parents were known, were collected from Table 1a to 9a and placed in Table 13. The parents and their shape indices are in the first column, the mean progeny shape indices are in the second column, the number of trees in each progeny is in the third column, and the distribution of the progenies is shown at the right. These thirty progenies arranged in the order of mean shape indices of both parents (the mid-parent of Galton) were divided into six equal portions of five progenies each and the number of trees in the four by six cells were changed to percentage. These results gave the data for Table 14.

Table 13. Shape Classification in Parents and Progenies.

Parents and indices	Mean progeny index	No. of trees	Height- (Spreading) .55	.65	.75	(Round) .85	.95	1.05	1.
Anisim .82 x Ashton .70	1.11	10						3	[illegible]
N.W. Greening .88 x Opalescent .74	1.07	12		1	2	2	1	1	[illegible]
Col. Orange .89 x Jonathan .79	.93	29	1	2	7	6	3	4	[illegible]
Anisim .82 x Bl. Oxford .87	1.04	76		4	8	9	17	10	[illegible]
N.W. Greening .88 x Harrington .82	1.11	75		4	6	11	9	6	[illegible]
Jonathan .79 x Salome .99	.80	15	1	4	3	3	2	2	
Anisim .82 x Hubbardston 1.00	1.13	72			5	10	7	10	[illegible]
Antonovka 1.12 x Ashton .70	1.07	55		1	2	6	17	11	[illegible]
Jonathan .79 x Antonovka 1.12	1.09	41			5	7	5	6	[illegible]
Antonovka 1.12 x Jonathan .79	1.05	291		12	23	42	56	41	[illegible]
Delicious 1.12 x Jonathan .79	1.16	17				3	4		[illegible]
Anisim .82 x Delicious 1.12	1.03	270	5	18	40	41	45	30	[illegible]
Delicious 1.12 x Harrington .82	1.18	19			2	2	1	4	[illegible]
Antonovka 1.12 x Bl. Oxford .87	1.07	135	3	2	9	18	30	12	[illegible]
N.W. Greening .88 x Delicious 1.12	1.12	99		4	4	12	19	14	[illegible]
Delicious 1.12 x Salome .99	1.41	12						1	[illegible]
Grimes 1.24 x N.W. Green. .88	1.06	13			2		6	2	
N.W. Greening .88 x Grimes 1.24	1.17	65		1	3	7	10	7	[illegible]
Col. Orange .89 x Grimes 1.24	.99	10	1	1		3	2		[illegible]
N.W. Greening .88 x W. Pippin 1.28	1.49	22						2	[illegible]
N. Spy 1.39 x Jonathan .79	1.19	5					1	1	[illegible]
Harrington .82 x N. Spy 1.39	1.10	64			8	8	11	7	[illegible]
Antonovka 1.12 x Delicious 1.12	1.11	352	3	7	22	34	62	51	[illegible]
N.W. Greening .88 x N. Spy 1.39	1.24	70		1		7	6	7	[illegible]
Antonovka 1.12 x Grimes 1.24	1.27	43		1	1	1	4	4	[illegible]
Gimes 1.24 x Antonovka 1.12	1.33	74			1	2	10	5	[illegible]
Delicious 1.12 x N. Spy 1.39	1.44	16				1		2	[illegible]
N. Spy 1.39 x Delicious 1.12	1.15	264		6	13	35	37	23	[illegible]
Grimes 1.24 x W. Pippin 1.28	1.30	36				2	4	2	[illegible]
N. Spy 1.39 x Wealthy 1.15	1.30	29					4	3	[illegible]
Total		2291		250			1252		

ght- d	diameter indices :Upright-spreading :								Upright						
:1.05	:1.15	:1.25	:1.35	:1.45	:1.55	:1.65	:1.75	:1.85	:1.95	:2.05	:2.15	:2.25	:2.35	:2.45	:2.55
3	3	3													
1	2	1					2								
4	2	2	1	1											
10	9	9	5	3				2							
6	11	11	4	7	1	3	2								
2															
10	13	13	7	2	2	2	1								
11	6	5	2	2	3										
6	5	3	5	3	1	1									
41	52	28	22	8	3	4									
	2	3	1	2	2										
30	24	26	12	9	6	6	4	1			1	1		1	
4	2	1	3	1	1	1		1							
12	22	11	16	6	3	2	1								
14	16	11	5	3	4	2	2	2	1						
1	1	1	2	4	1	1	1								
2				2	1										
7	9	11	4	5	4	1	1		1			1			
	1			1		1									
2	2	2	4	1	3	2	2	2	2						
1	1		1	1											
7	12	6	2	3	4	1	2								
51	57	50	29	16	8	7	1	1	3	1					
7	13	13	9	6	4	3	1								
4	6	8	6	3	3	3	2	1							
5	11	8	11	7	9	7	1	2							
2	1	1	3	1	2	1	3				1				
23	46	37	27	12	9	9	3	3	3		1				
2	3	7	6	5	1	5			1						
3	4	5	4	4	1	1	2		1						
252				661						128					

Table 14. Shape Classification of Inheritance in Cross-bred Apple Trees in Percentage

Number of trees in each of six groups ranked in order of mean shape indices of both parents +	Shape of tree			
	Spreading	Round	Upright-spreading	Upright
202	18	54	24	4
474	11	64	23	2
453	17	53	25	5
209	8	54	29	9
534	8	55	32	5
419	5	47	38	10

+ See Table 13

To determine whether the variations in the column percentages in Tables 12 and 14 are due to random sampling or inheritance, the data in both tables were tested with the Chi-square test (From Fisher's Table, if n = (16-2) = 14, Chi-square must be 29.144 or larger for P to equal 0.01. Chi-square in Table 12 is 251.481. And if n = (24-2) = 22, Chi-square must be 40.289 or larger for P to equal 0.01. Chi-square in Table 14 is 123.108). The values of Chi-square being highly significant in both tables indicate that the shapes of the progeny trees are influenced by the shapes of the parent trees.

To test inheritance in another way, the "mid-parents" in Table 13 were correlated with the means of their progenies. The coefficient of correlation, r, was found to be 0.55 ± 0.09. This is highly significant and is another proof that the tree shape in the progenies is inherited from the parents. Theoretically, the coefficient of correlation should have been 0.71 instead of 0.55. Practically, this value is reduced by the effects of dominance, "nicking", and environmental influences. For still further evidence of inheritance the tree distributions in Table 13 were changed into graphical arrangement to show the mean index shape relation of each parent and progeny. This gave Table 15.

Two facts are noticeable in this new table. First, the mean of the progeny in no case falls below the mean of the lower or more spreading parent. Second, in the upper part of the table the progeny mean falls mainly above the higher or more upright parent; and in the lower part of the table, it tends to fall between the means of the two parents. There is a constant tendency for the mean of the progeny to be above the mean of the two parents when the parents are spreading, and between the two parents when they are upright-spreading. The data in Table 16 furnish further evidence on this question of inheritance.

Table 15. Shape Classification in Parents and Progenies.

Parents and indices					No. of trees	Mean progeny index	Graphical arrangement of progenies: Spreading .55	.65	.75	Round .85	.95	1.05
Anisim	.82	x	Ashton	.70	10	1.11		o		o		
N.W. Greening	.88	x	Opalescent	.74	12	1.07			o	o		o
Col. Orange	.89	x	Jonathan	.79	29	0.93			o	o	o	
Anisim	.82	x	Bl. Oxford	.87	76	1.04				oo		o
N.W. Greening	.88	x	Harrington	.82	75	1.11				oo		
Jonathan	.79	x	Salome	.99	15	0.80			oo		o	
Anisim	.82	x	Hubbard.	1.00	72	1.13				o	o	
Antonovka	1.12	x	Ashton	.70	55	1.07		o				o
Jonathan	.79	x	Antonovka	1.12	41	1.09			o			o
Antonovka	1.12	x	Jonathan	.79	291	1.05			o			o
Delicious	1.12	x	Jonathan	.79	17	1.16			o			
Anisim	.82	x	Delicious	1.12	270	1.03				o		o
Delicious	1.12	x	Harrington	.82	19	1.18				o		
Antonovka	1.12	x	Bl. Oxford	.87	135	1.07				o		o
N.W. Greening	.88	x	Delicious	1.12	99	1.12				o		
Delicious	1.12	x	Salome	.99	12	1.41					o	
Grimes	1.24	x	N.W. Green.	.88	13	1.06				o		o
N.W. Greening	.88	x	Grimes	1.24	65	1.17				o		
Col. Orange	.89	x	Grimes	1.24	10	.99				o	o	
N.W. Greening	.88	x	W. Pippin	1.28	22	1.49				o		
N. Spy	1.39	x	Jonathan	.79	5	1.19			o			
Harrington	.82	x	N. Spy	1.39	64	1.10				o		o
Antonovka	1.12	x	Delicious	1.12	352	1.11						o
N.W. Greening	.88	x	N. Spy	1.39	70	1.24				o		
Antonovka	1.12	x	Grimes	1.24	43	1.27						
Grimes	1.24	x	Antonovka	1.12	74	1.33						
Delicious	1.12	x	N. Spy	1.39	16	1.44						
N. Spy	1.39	x	Delicious	1.12	264	1.15						
Grimes	1.24	x	W. Pippin	1.28	36	1.30						
N. Spy	1.39	x	Wealthy	1.15	29	1.30						
			Total		2291							

Female parent = o
Male parent = o
Progeny mean = o

Parents and Progenies.

No. of trees	Mean progeny index	.55	.65	.75	.85	.95	1.05	1.15	1.25	1.35	1.45	1.55
		Graphical arrangement of parents and progenies										
		Spreading			Round			Upright-spreading				
10	1.11		●		●			○				
12	1.07			●	●		○					
29	0.93			●	●	○						
76	1.04				●●		○					
75	1.11				●●			○				
15	0.80			○●		●						
72	1.13				●	●		○				
55	1.07		●				○	●				
41	1.09			●			○	●				
291	1.05			●			○	●				
17	1.16			●				○●				
270	1.03				●		○	●				
19	1.18				●			○●				
135	1.07				●		○	●				
99	1.12				●			○●				
12	1.41					●		●			○	
13	1.06				●		○		●			
65	1.17				●			○	●			
10	.99				●	○			●			
22	1.49				●				●		○	
5	1.19			●				○		●		
64	1.10				●		○		●			
352	1.11						●	○●				
70	1.24				●				○	●		
43	1.27							●	○●			
74	1.33							●	●	○		
16	1.44							●		●	○	
264	1.15							○●		●		
36	1.30								●○●			
29	1.30							●	○	●		
2291												

Table 16. Parent-Groups Arranged with Reference to Shape Indices of Parents and Progenies

Common parent	Indices of other parents in crosses	Mean progeny indices below common parent	Mean index of common parent	Mean progeny indices above common parent
Jonathan	0.89,0.99,0.99, 1.12,1.12, 1.12,1.12,1.39		0.79	0.80,0.87,0.93, 1.04,1.05,1.09, 1.16,1.19,1.45
Harrington	0.88,1.12,1.39		0.82	1.08,1.10,1.11, 1.18,1.19,1.22
Anisim	0.70,0.81,0.87, 1.00,1.12		0.82	0.91,1.03,1.04, 1.11,1.11,1.13
N.W.Greening	0.74,0.82,1.12, 1.24,1.24,1.28, 1.39		0.88	1.06,1.07,1.11, 1.12,1.17,1.24, 1.49
Col.Orange	0.79,1.24		0.89	0.93,0.98,0.99, 1.10,1.20
Salome	0.79,0.79,1.12, 1.39	0.80,0.87	0.99	1.05,1.37
Antonovka	0.70,0.79,0.79, 0.81,0.87,1.12, 1.24,1.24	1.04,1.05, 1.07,1.07, 1.09,1.11	1.12	1.27,1.33
Delicious	0.79,0.82,0.82, 0.88,0.99,1.12, 1.39,1.39	1.05,1.04, 1.06,1.10, 1.11	1.12 (1.12) (1.12)	1.15,1.16,1.18, 1.34,1.35,1.41, 1.44,1.55
Grimes	0.88,0.88,0.89, 1.12,1.12,1.28	0.99,1.06, 1.17	1.24	1.27,1.30,1.32, 1.33
N. Spy	0.79,0.82,0.88, 0.99,1.12,1.12	1.04,1.10, 1.14,1.14, 1.15, 1.19, 1.24,1.30, 1.37,1.37	1.39	1.44,1.51

The parent-groups are arranged with reference to the shape indices of the common parents in Table 16. The shape index measurements of the second parent are not known in every case. The mean shape indices of the common parents are given in column four. The means of the progenies that are less than the mean of the parent are placed in the column to the left; and the means of the progenies that are more than the mean of the parent, to the right.

The first thirty-three progeny means are higher than the means of their respective parents and are in the column to the right. Of the next thirty-four progeny means, two are equal to the mean of the parent, sixteen are higher, and sixteen are lower. Of the last twelve progeny means, two are higher and ten are lower than the mean of their common parent, Northern Spy.

The mean shape indices of the common parents range from 0.79 to 1.39, or from spreading to upright-spreading. Each of these parents were crossed with varieties having various shape indices as shown in the second column. If partial dominance were not present some of the progeny means of Anisim, North-western Greening, and Colorado Orange parents would be less than the means of their respective parents.

The data in Table 16 indicate that round shape is partially dominant, that the "regression toward the mean of the race" centers at or near the shape index of 1.05, or near the center of the measurements for round shape index.

Table 17. Percentage Distribution of Shape Indices in Trees of Combined Progenies.

Parent-groups	No. of trees	Height-diameter indices										
		Spreading			Round				Upright-spreading			
		.55	.65	.75	.85	.95	1.05	1.15	1.25	1.35	1.45	1.55
Delicious	1511	1	3	7	11	16	11	14	12	9	6	3
Colorado Orange	69	3	4	16	16	17	5	15	3	4	11	
Northern Spy	759		1	4	9	15	10	15	14	10	9	5
Anisim	583	1	5	11	13	17	13	13	12	6	4	2
Jonathan	549		4	10	15	19	12	14	10	7	5	2
Harrington	223		2	7	11	15	11	15	13	9	9	3
Antonovka	1066	1	2	6	11	19	14	17	11	9	4	3
Grimes	288		1	3	6	13	8	14	13	12	10	8
N.W. Greening	356		3	5	10	15	11	15	14	7	7	5

rees of

ices right-spreading 25	1.35	1.45	1.55	Upright 1.65	1.75	1.85	1.95	Mean	Standard deviation	Coefficient of variability
12	9	6	3	3	2	1	1	1.14 ± .01	.30	26.31
3	4	11		4	1			1.03 ± .02	.27	26.21
14	10	9	5	4	2	1	1	1.20 ± .01	.28	23.33
12	6	4	2	2	1			1.05 ± .01	.27	25.71
10	7	5	2	1				1.05 ± .01	.23	21.90
13	9	9	3	2	2			1.13 ± .01	.26	23.01
11	9	4	3	2				1.07 ± .01	.24	21.24
13	12	10	8	7	1	2	1	1.25 ± .01	.28	22.40
14	7	7	5	3	3	1	1	1.16 ± .02	.29	25.00

A second sort of evidence for partial dominance is indicated in the skewness of the progeny distribution curves. The distributions of the combined progenies in each of the parent-groups in Table 17 were tested for skewness with the formula, skewness = (mean - mode) / standard deviation. The results are in the following table:

Parent-group	(Mean-mode) / S.D.	Sign of Skewness
Colorado Orange	(1.03 - 0.95) / 0.27	+ 0.30
Delicious	(1.14 - 0.95) / 0.30	+ 0.63
Northern Spy	(1.20 - 1.05) / 0.28	+ 0.54
Anisim	(1.05 - 0.95) / 0.27	+ 0.37
Jonathan	(1.05 - 0.95) / 0.23	+ 0.44
Harrington	(1.13 - 1.05) / 0.26	+ 0.31
Antonovka	(1.07 - 0.95) / 0.24	+ 0.50
Grimes	(1.25 - 1.15) / 0.28	+ 0.36
R. I. Greening	(1.16 - 1.05) / 0.29	+ 0.38

Positive skewness in all of the above curves of distribution indicates dominance for the low numbers or spreading shape of tree.

A third kind of evidence for dominance is furnished by the three sets of graphs in Plate I. The four graphs in A show the distributions of the largest Antonovka progenies. The nine graphs in B and C give the distributions of the combined progenies in each of the nine parent-groups. The rather extraordinary and interesting thing is the occurrence of a double mode in each of the thirteen curves of distribution. Even more remarkable is that the two modal points fall at 0.95 and 1.15 in each group.

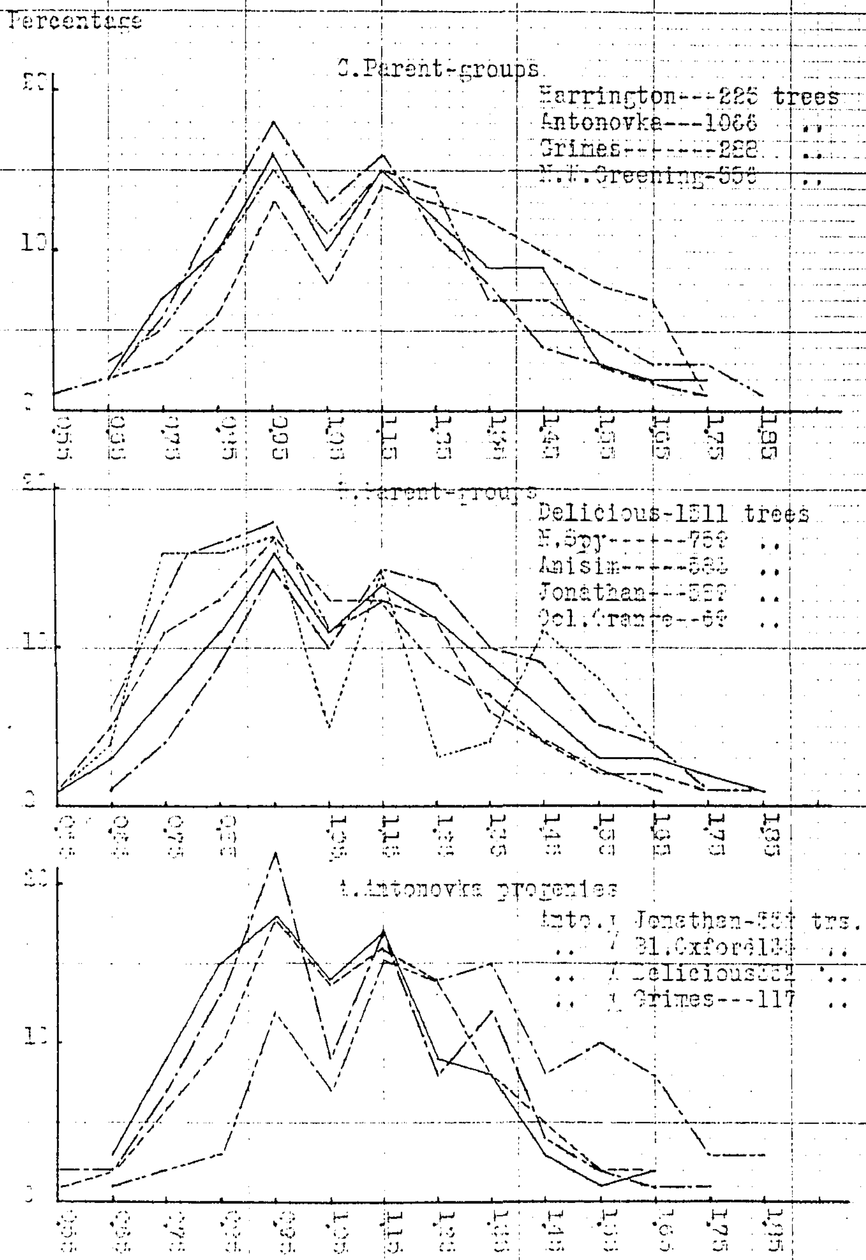

Plate I. Distribution curves of shape indices.

They both fall in the round shape of trees and on either side of the shape index of 1.05. While these apple varieties are heterozygous with respect to tree shape they evidently carry (1) a large number of minor factors for shape as well as (2) a few major dominant ones.

Besides inheritance of 'blending'nature due to many genes and partial dominance due to a few major dominant genes there is doubtless the "combining effect" of several or many dominant genes or "nicking". This is difficult to measure but it may explain cases where an individual tree or the means of a progeny has an unusual shape when compared with the shapes of its parents. The first cross in Table 18 is a good example. The mean index of the mid-parent is 0.76 and the mean index of the progeny is 1.11. Inheritance with partial dominance could hardly give this unusually high shape value. The influence of "nicking" is probably added to these. There are several crosses in Table 18 of this same sort. In most of these cases "nicking" is no doubt giving an added effect to partial dominance in the same direction, toward a more upright shape of tree.

The variability in shape of tree is much greater in the cross-bred progenies than in the varieties. This is best seen in the shape distribution of trees in Tables 1a to 9a. Within varieties the inheritance is identical and the variability is due to differences in environment. The standard deviations range from 0.09 to 0.14. In the cross-bred progenies the variability is due both to environmental causes and differences in inheritance, and the standard deviations range from about 0.18 to 0.40. Varieties generally fall within one tree shape or between two tree shapes. While there are all four tree shapes in a majority of progenies the percentage of each shape varies in each progeny.

There are eight reciprocal crosses scattered through the parent-group. A separate list of these, with the number of trees in each and the mean shape index of each progeny, is given in Table 18.

Table 13. Comparison of Mean Shape of Mid-parent and Progeny

Parentage		Mean index mid-parent	Mean index of progeny	Dif. / P. E. dif.[+]
Anisim	x Ashton	0.76	1.11 ± 0.03	11.00
N.W.Greening	x Opalescent	0.81	1.07 ± 0.10	2.00
Col. Orange	x Jonathan	0.84	0.93 ± 0.03	3.00
Anisim	x Bl.Oxford	0.84	1.04 ± 0.02	9.00
N.W.Greening	x Harrington	0.85	1.11 ± 0.03	12.00
Jonathan	x Salome	0.89	0.80 ± 0.02	4.00
Anisim	x Hubbardston	0.91	1.13 ± 0.02	10.00
Antonovka	x Ashton	0.91	1.07 ± 0.02	10.00
Jonathan	x Antonovka	0.95	1.09 ± 0.03	4.00
Antonovka	x Jonathan	0.95	1.05 ± 0.01	11.00
Delicious	x Jonathan	0.95	1.16 ± 0.04	5.00
Anisim	x Delicious	0.97	1.03 ± 0.01	4.00
Delicious	x Harrington	0.97	1.18 ± 0.04	5.00
Antonovka	x Bl.Oxford	0.99	1.07 ± 0.01	5.00
N.W.Greening	x Delicious	1.00	1.12 ± 0.02	5.00
Delicious	x Salome	1.05	1.41 ± 0.04	9.00
Grimes	x N.W.Greening	1.06	1.06 ± 0.05	0.00
N.W.Greening	x Grimes	1.06	1.17 ± 0.02	5.00
Col. Orange	x Grimes	1.06	0.99 ± 0.10	0.00
N.W.Greening	x White Pippin	1.08	1.49 ± 0.04	10.00
N. Spy	x Jonathan	1.09	1.19 ± 0.05	2.00
Harrington	x N. Spy	1.10	1.10 ± 0.02	0.00
Antonovka	x Delicious	1.12	1.11 ± 0.01	0.00
N.W.Greening	x N. Spy	1.13	1.24 ± 0.02	5.00
Antonovka	x Grimes	1.18	1.27 ± 0.03	3.00
Grimes	x Antonovka	1.18	1.33 ± 0.02	7.00
Delicious	x N. Spy	1.25	1.44 ± 0.05	4.00
N. Spy	x Delicious	1.25	1.15 ± 0.01	7.00
Grimes	x White Pippin	1.26	1.30 ± 0.04	1.00
N. Spy	x Wealthy	1.27	1.30 ± 0.03	1.00

[+] Ratio of mean difference of the shape indices over the square root of the sum of the squares of the two probable errors. $Ed = E_1^2 + E_2^2$

Table 19. Reciprocal Crosses

Parentage	No. of trees	Mean index of progeny	Dif / P.E. dif
Jonathan x Salome	15	0.80 ± 0.02	2.30
Salome x Jonathan	14	0.87 ± 0.02	
Jonathan x Antonovka	41	1.09 ± 0.03	1.30
Antonovka x Jonathan	291	1.05 ± 0.01	
Jonathan x Delicious	128	1.04 ± 0.01	3.00
Delicious x Jonathan	17	1.16 ± 0.04	
N.W.Green x Grimes	65	1.17 ± 0.02	2.00
Grimes x N.W.Green.	13	1.06 ± 0.05	
Harrington x Ramsdell S.	22	1.19 ± 0.04	0.70
Ramsdell S. x Harrington	34	1.22 ± 0.02	
Pewaukee x N. Spy	108	1.14 ± 0.02	5.70
N. Spy x Pewaukee	32	1.37 ± 0.04	
Delicious x N. Spy	16	1.44 ± 0.05	5.80
N. Spy x Delicious	264	1.15 ± 0.01	
Antonovka x Grimes	43	1.27 ± 0.03	1.10
Grimes x Antonovka	74	1.33 ± 0.02	

Reciprocal crosses in plants generally give results that are quite similar. However, the means are significantly different in the third, sixth, and seventh reciprocals in Table 19. The mean differences in these three cases might be due to the small number of trees in one of each pair of crosses or it might be due to some peculiarity of the cytoplasm. or to sex differences in gametic fertility.

Prepotency of the Parents with Respect to Shape

The principle underlying the progeny test is that the resemblance between parent and offspring rests on the number of identical genes that are common to both. The breeding qualities of the parent are best judged by its offspring and these are measured by the progeny test. Because apple varieties are propagated by vegetative reproduction, apple breeders seldom have the paired measurements necessary to get a correlation coefficient. This difficulty is overcome by using a prepotency formula or equation instead. The following adapted from those used by animal breeders is well suited to apple breeding work:

A parent's prepotency = the mean of the progeny ± one-half the difference between the other parent's measure and the mean of the progeny. If the mean of the progeny is less than the other parent's measure the last term is subtracted from the first; otherwise, it is added. If there are two or more progenies the average of the several results gives the prepotency of the parent. The following is the method used in determining the prepotency of the Antonovka variety with reference to tree shape:

The shape indices of the other parents, the mean shapes of the progenies, and the prepotency shape index of the common parent

	Ashton	King David	Jonathan	Grimes	Delicious	Black Oxford	Grimes	Jonathan
	0.70	0.81	0.79	1.24	1.12	0.87	1.24	0.79
Mean	1.07	1.04	1.05	1.27	1.11	1.07	1.35	1.09
Prepotency	1.25	1.15	1.18	1.28	1.10	1.17	1.37	1.24

Average prepotency shape index of Antonovka, 1.22

Since reciprocal crosses gave significant differences in some cases they were used as separate progenies. The number of trees in a progeny varied from six to 352, and the number of progenies used in computing the prepotency shape index values varied from two to thirteen. The following are the prepotency values for fourteen of the parents with reference to shape indices:

Parent	Number of trees	Number of progenies	Shape index of par.	Prepotency shape index	Difference
Ashton	65	2	0.70	1.15	0.45
Jonathan	549	9	0.79	0.93	0.14
King David	101	2	0.81	0.98	0.17
Harrington	223	5	0.82	1.14	0.32
Anisim	583	5	0.82	1.08	0.26
Black Oxford	211	2	0.87	1.06	0.19
N.W.Greening	356	6	0.88	1.22	0.34
Col. Orange	69	2	0.89	0.96	0.07
Salome	113	3	0.99	1.16	0.17
Delicious	1011	13	1.12	1.23	0.11
Antonovka	1066	7	1.12	1.20	0.08
Grimes	287	7	1.24	1.28	0.04
White Pippin	68	3	1.28	1.56	0.28
Northern Spy	761	9	1.39	1.36	-0.03

In all but one of the parents the prepotency index for tree shape is higher than the shape index of the parent. The one exception is Northern Spy. The parents that gave pronounced differences in shape indices were Ashton, Northwestern Greening, Harrington, and White Pippin. The differences in case of these four varieties are 0.45, 0.34, 0.32, and 0.28. The progeny test enables the breeder to determine the prepotency of his parents from small progenies of their offspring. These results enable him to better select parents of both sexes for future breeding work.

Inheritance of Quality of Tree

In Tables 1c to 9c (Appendix) are given the distributions of each parent-group and its progenies with reference to (1) the grade of tree, (2) the shape of tree, (3) the habit of growth, and (4) the quality of scaffold branches.

Tree Quality

The four grades of trees for the combined progenies of each parent-group are given in Table 20.

Table 20. Grade or Quality of Tree in Parent-groups

Parent-groups	Progenies combined					
	No. of trees	Percentage very good	Percent-age good	Percent-age fair	Percent-poor	% g & vg
Delicious	1519	28	27	27	18	55
Colorado Orange	69	13	20	31	36	33
Northern Spy	763	29	27	26	18	56
Anisim	584	27	33	22	18	60
Jonathan	552	37	23	26	14	60
Harrington	226	16	38	30	16	54
Antonovka	1066	54	25	15	6	79
Grimes	288	38	27	23	12	65
N.W. Greening	361	31	31	22	16	62

The percentages of good and very good trees, trees of superior quality and suitable for orchard planting, are given in the column on the right. The parent-groups that give the greatest number of suitable trees for planting are Antonovka and Grimes. Those that give the least number are Colorado Orange and Delicious.

The wide variation within as well as between parent-groups is shown graphically in Plate II. Each horizontal line one unit in length represents a progeny and its percentage of good and very good trees is shown on the vertical axis. The lowest of the Antonovka progenies is higher than the highest of the Colorado Orange progenies. The lowest of the Delicious progenies has eighteen per cent of good and very good trees and the highest of the Delicious progenies has eighty-two per cent, or over four times as many trees suitable for orchard planting. The progenies that give the highest percentages of suitable trees in quality are seen to be scattered through the parent-groups. The ten best and the ten poorest progenies as to quality of trees are given in Table 18.

Table 21. Cross-bred Apple Progenies Arranged with Reference to Tree Quality

Parentage of best progenies in rank order			Percentage good and very good trees	Parentage of Poorest progenies in rank order			Percentage good and very good trees
Anisim	x	Ashton	100	Delicious	x	Northern Spy	38
Grimes	x	N.W. Green.	92	McMahon	x	Northern Spy	37
Antonovka	x	Ashton	91	Nelson Sw.	x	Grimes	35
Antonovka	x	Grimes	86	Delicious	x	Jonathan	35
Antonovka	x	Delicious	82	Col.Orange	x	Ames 463	33
Antonovka	x	King David	81	Delicious	x	Harrington	32
Grimes	x	Antonovka	80	Salome	x	Jonathan	28
Antonovka	x	Black Oxford	75	Harrington	x	Ramsdell S.	19
N.W.Green	x	Northern Spy	74	Bl.Annette	x	Delicious	18
Patten 1003	x	Delicious	74	Col.Orange	x	Yel.Newtown	0

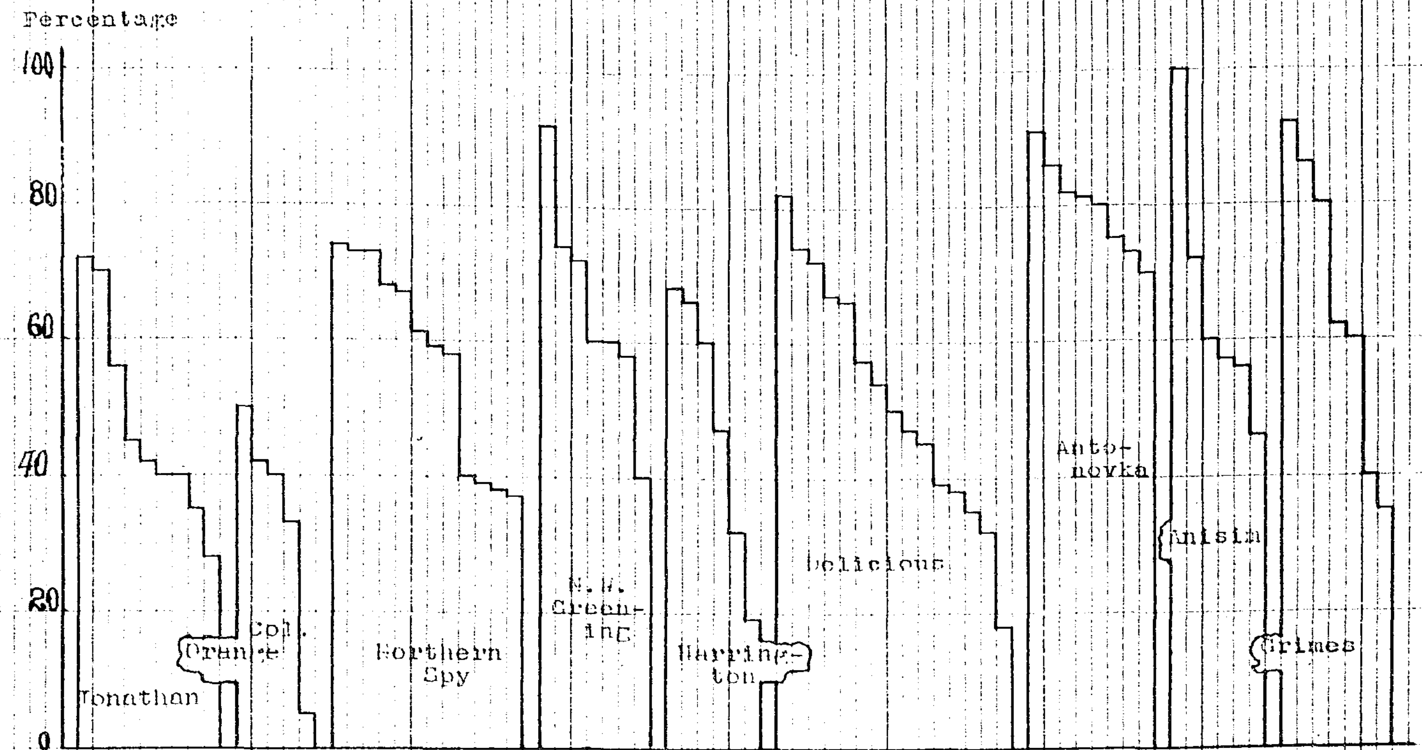

Plate 11. Comparison of parent-groups and progenies with reference to the total percentage of trees grading good and very good in quality.

Prepotency of the Parents with Respect to Quality of Tree

The prepotency indices of the parent varieties for quality of tree were determined by the progeny test. The same formula as given under shape index of tree was used. The number of trees in a progeny varied from 6 to 352, and the number of progenies for computing each prepotency index from two to thirteen. The following are the prepotency values of twenty apple varieties with reference to grade of tree:

Parent	Number of progenies	Number of trees	Grade of tree	Prepotency index for grade of tree	Difference
Ashton	2	65	3.5	3.7	-0.2
Antonovka	7	1066	3.7	3.1	0.6
Anisim	5	583	3.5	2.8	0.7
Hubbardston	2	111	3.0	2.8	0.2
N.W.Greening	6	356	4.0	2.6	1.4
Patten 1011	2	89	4.0	2.6	1.4
Black Oxford	2	211	3.5	2.5	1.0
Patten 1000	2	44	3.0	2.5	0.5
Grimes	7	287	3.8	2.4	1.4
Pewaukee	3	132	4.0	2.4	1.6
White Pippin	3	68	3.5	2.4	1.1
Northern Spy	9	761	3.5	2.3	1.2
Delicious	13	1511	3.8	2.2	1.6
Salome	3	113	3.6	2.2	1.4
Ramsdell S.	3	93	2.5	2.2	0.3
Jonathan	9	549	3.7	2.1	1.6
Harrington	5	223	2.5	2.0	0.5
Nelson S.	2	57	3.0	1.8	1.2
Col.Orange	2	69	3.6	1.6	2.0
Black Annette	2	223	2.5	1.4	1.1

The prepotency index of Ashton with respect to grade of tree is superior to all the others. It is the only parent variety that has a genotype superior to its phenotype with respect to this trait. Next in the order of superior breeding quality of tree grade are Antonovka, Anisim, Hubbardston, Northwestern Greening, and Patten 1011. The poorest in breeding quality with respect to grade of tree are Black Annette, Colorado Orange, and Nelson Sweet. The differences between the prepotency grade and the grade of the parent trees are very great, ranging from 0.2 in case of Hubbardston to 2.0 in case of Colorado Orange.

Tree Shape

The four shapes of trees for the combined progenies of each parent-group are given in Table 22.

Table 22. Shape of Tree in Parent-groups

Parent-groups	Progenies combined					
	No. of trees	Percentage drooping	Percentage spreading	Percentage upright spreading	Percentage upright	Percentage spreading and upright spreading
Delicious	1519	1	15	42	42	57
Col. Orange	69	14	42	35	9	77
N. Spy	731	0	10	35	55	45
Anisim	584	0	11	45	44	56
Jonathan	551	1	22	49	28	71
Harrington	226	0	13	51	36	64
Antonovka	1066	1	25	45	29	70
Grimes	289	0	14	44	45	58
N.W.Greening	361	0	14	48	38	62

The percentages of spreading and upright-spreading trees combined, the two of the four shapes that are considered suitable for orchard planting, are given in the column to the right. The parent-groups that give the greatest number of suitable trees with reference to shape are Colorado Orange, Jonathan, and Antonovka. Those that give the least number are Northern Spy, Anisim, and Grimes. However, the variation with reference to shape of tree is greater between the progenies of a parent-group than between the parent-groups.

The variation in shape within as well as between parent-groups is shown graphically in Plate III. Each horizontal line one unit in length represents a progeny and its percentage of spreading and upright-spreading trees is shown on the vertical axis. The variation in percentage of suitable trees as to shape for planting is very great in most of the parent-groups. In Grimes the progenies range from 32 to 100 per cent. In Northern Spy from 25 to 80 per cent. The progenies that give the highest percentages of trees suitable in shape for planting are seen to be scattered through the various parent-groups. The ten best and the ten poorest progenies as to desirable shape of tree are given in Table 23.

Table 23. Cross-bred Apple Progenies Arranged with Reference to Desirable Shape of Tree

Parentage of best progenies in rank order	Percentage of spreading and upright spreading trees	Parentage of poorest progenies in rank order	Percentage of spreading and upright spreading trees
Grimes x N.W.Greening	100	Anisim x Hubbardston	43
Col.Orange x Grimes	100	Delicious x Salome	42
Antonovka x Ashton	94	McMahon x N.Spy	35
Harrington x Ames 488	88	Patten 1000 x Delicious	34
Jonathan x Salome	87	Patten 1000 x Jonathan	33
Col.Orange x Yel.Newtown	83	Ames 513 x N. Spy	33
Grimes x Antonovka	80	Antonovka x Grimes	32
N.Spy x Jonathan	80	N.Spy x Delicious	32
Antonovka x Jonathan	75	Salome x N. Spy	25
Patten 1003 x Delicious	75	Delicious x N. Spy	25

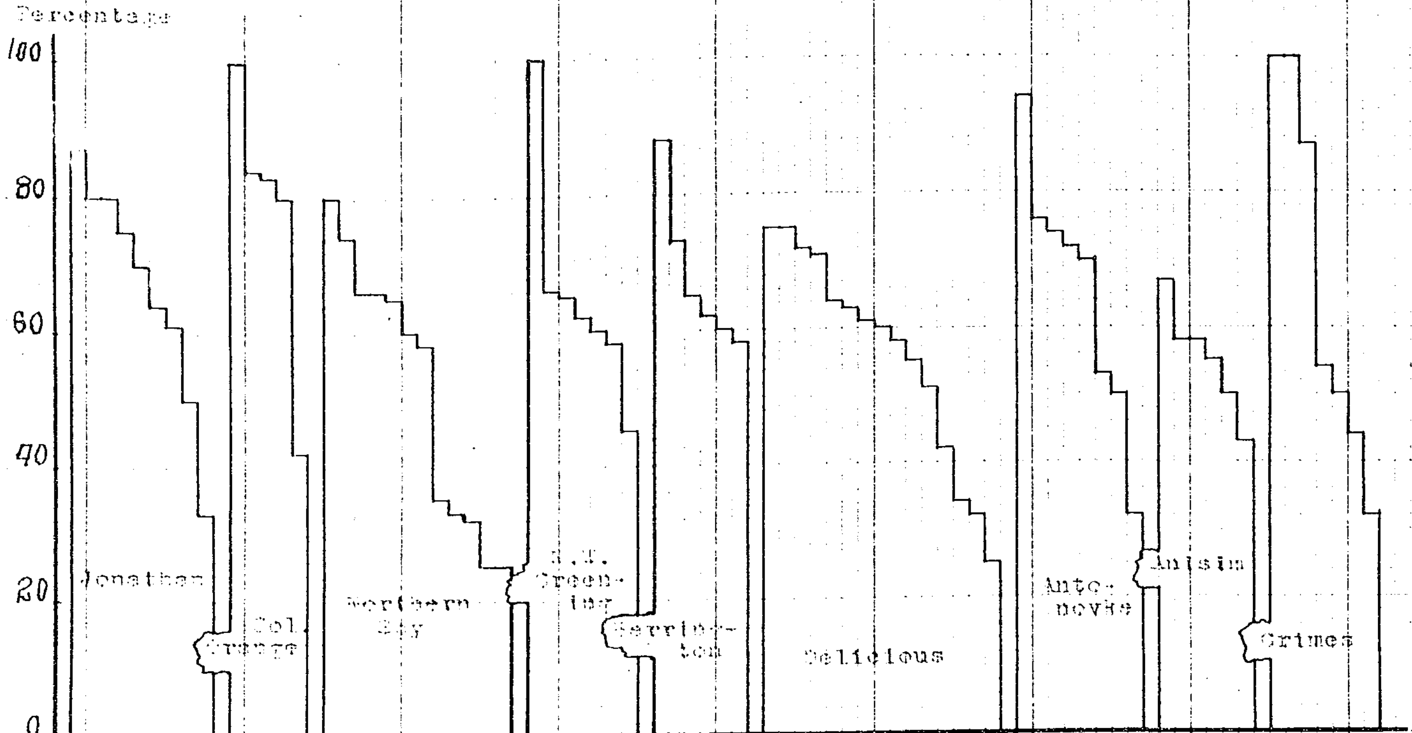

Plate III. Comparison of parent-groups and progenies with reference to the total percentage of spreading and upright-spreading trees.

Branching Habit

The four grades of trees with reference to their branching habit for the combined progenies of each parent-group are given in Table 24.

Table 24. Branching Habit of Tree in Parent-groups

Parent-groups	No. of trees	Percentage open	Percentage medium open	Percentage medium dense	Percentage dense	Percentage open, med.open and med. dense
Delicious	1526	5	30	41	24	76
Col.Orange	69	9	33	36	22	78
Northern Spy	761	4	26	41	29	71
Anisim	591	4	25	40	31	69
Jonathan	552	3	24	45	28	72
Harrington	226	4	29	41	26	74
Antonovka	1067	4	26	40	30	70
Grimes	289	5	24	32	39	61
N.W.Greening	361	4	26	41	29	71

The percentage of open, medium-open, and medium-dense combined, the three of the four grades that are considered suitable for orchard planting, are given in the column to the right. The variation of these combined percentages is rather small, ranging from 61 to 78.

The variation in branching habit within as well as between parent-groups is shown graphically in Plate IV. Each horizontal line one unit in length represents a progeny and its position with reference to the vertical axis gives its combined percentages of open, medium-open, and medium-dense habits of branching. Here again, the variation between progenies is very great. The

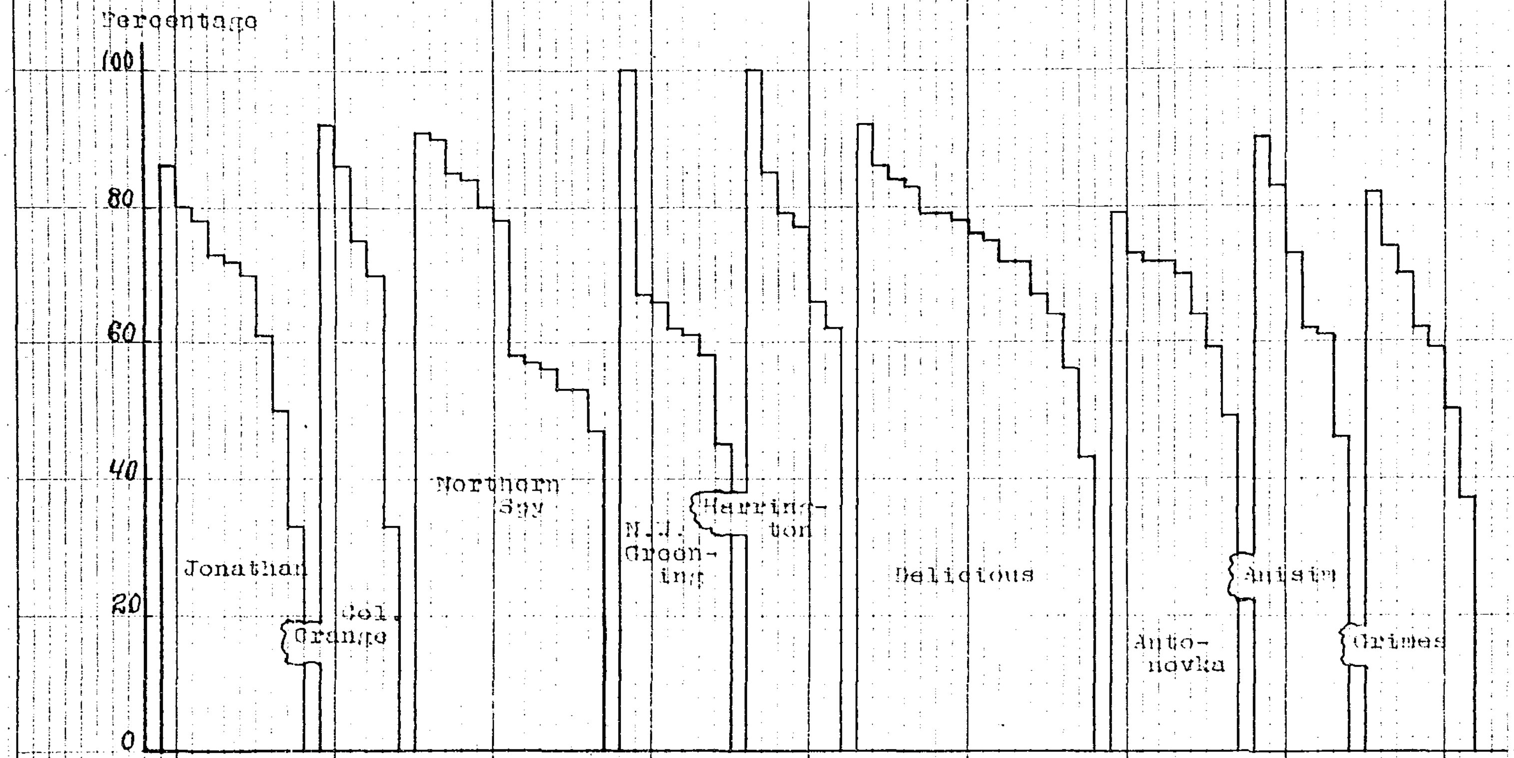

Plate IV. Comparison of parent-groups and progenies with reference to the total percentage of medium thick, medium open, and open trees as to branching habit.

progenies of Jonathan vary in percentage from 33 to 86; Colorado Orange, from 35 to 92; Northern Spy, from 47 to 91; and Northwestern Greening, from 45 to 100. The ten best progenies with reference to branching habit are found in seven of the parent-groups. The ten poorest progenies are found in eight of the parent-groups. The ten best and the ten poorest progenies as to branching habit are given in Table 25.

Table 25. Cross-bred Apple Progenies Arranged with Reference to Desirable Branching Habit

Parentage of best progenies in rank order		Percentage of open, med.-open and med.-dense trees	Percentage of poorest progenies in rank order		Percentage of open, med.-open, and med.-dense trees
Harrington	x Ames 488	100	McMahon	x N.Spy	53
Patten 1015	x Delicious	92	Pewaukee	x N.Spy	53
Col.Orange	x Yel.Newtown	92	Grimes	x White Pippin	50
Patten 1011	x N.Spy	91	Antonovka	x King David	49
Anisim	x Ashton	90	Salome	x N.Spy	47
N.Spy	x Wealthy	90	Anisim	x Hubbardston	46
Patten 1011	x Delicious	86	Patten 1000	x Delicious	43
Col.Orange	x Jonathan	86	Nelson Sw.	x Grimes	37
Harrington	x N.Spy	85	Col.Orange	x Mother	33
N.Spy	x Delicious	84	Patten 1000	x Jonathan	33

Scaffold Branches

The four grades of trees with reference to their scaffold branches for the combined progenies of each parent-group are given in Table 26.

Table 26. Scaffold Branches of Tree in Parent-groups

Parent-groups	No. of trees	Percentage poor	Percentage fair	Percentage good	Percentage very good	Percentage good and very good
Delicious	1522	19	40	33	8	41
Col. Orange	69	17	45	33	5	38
Northern Spy	770	18	36	36	10	46
Anisim	587	12	41	38	9	47
Jonathan	552	17	26	47	16	63
Harrington	225	14	30	46	10	56
Antonovka	1067	6	29	48	17	65
Grimes	289	9	38	37	16	53
N.W. Greening	361	17	40	36	7	43

The percentage of good and very good trees combined, the only two grades that are considered suitable for orchard planting, are given in the column to the right. The three parent-groups having the highest ranking are Antonovka, Jonathan, and Harrington. The three having the lowest ranking are Colorado Orange, Delicious, and Northwestern Greening. The percentage range varies from 38 to 65.

The variation in the quality of scaffold branches within as well as between parent-groups is shown graphically in Plate V. Each horizontal line one unit in length represents a progeny and its position with reference to the vertical axis gives its combined percentages of trees having good and very good scaffold branches. Only the two better grades of the four with reference to scaffold branches are considered suitable for orchard planting. The progenies of Jonathan vary in percentage from zero to 80; Colorado Orange, from 16 to 45; Northern Spy, from zero to 72; and Northwestern Greening, from 25 to 100. Again, there is a wide variation in the progenies.

The twelve best progenies with reference to the quality of scaffold branches are found in eight of the parent-groups. The ten poorest progenies are found in six of the parent-groups. The ten best and the ten poorest progenies as to quality of scaffold branches are given in Table 27.

Table 27. Cross-bred Apple Progenies Arranged with Reference to Desirable Scaffold Branches

Parentage of best progenies in rank order		Percentage good and very good scaffold branches	Parentage of poorest progenies in rank order		Percentage good and very good scaffold branches
Grimes	x N.W.Greening	100	Salome	x Jonathan	28
Antonovka	x King David	81	Patten 1005	x Delicious	26
Antonovka	x Jonathan	80	N.Spy	x Delicious	25
Patten 1000	x Delicious	80	N.W.Greening	x Delicious	23
Anisim	x Hubbardston	79	Patten 1015	x Delicious	19
Patten 1000	x Jonathan	79	Col.Orange	x Mother	16
Antonovka	x Ashton	72	McMahon	x N.Spy	16
Patten 1011	x Delicious	72	Bl.Annette	x Delicious	11
Harrington	x N. Spy	72	King David	x Anisim	8
Pewaukee	x N.Spy	72	N.Spy	x Jonathan	0

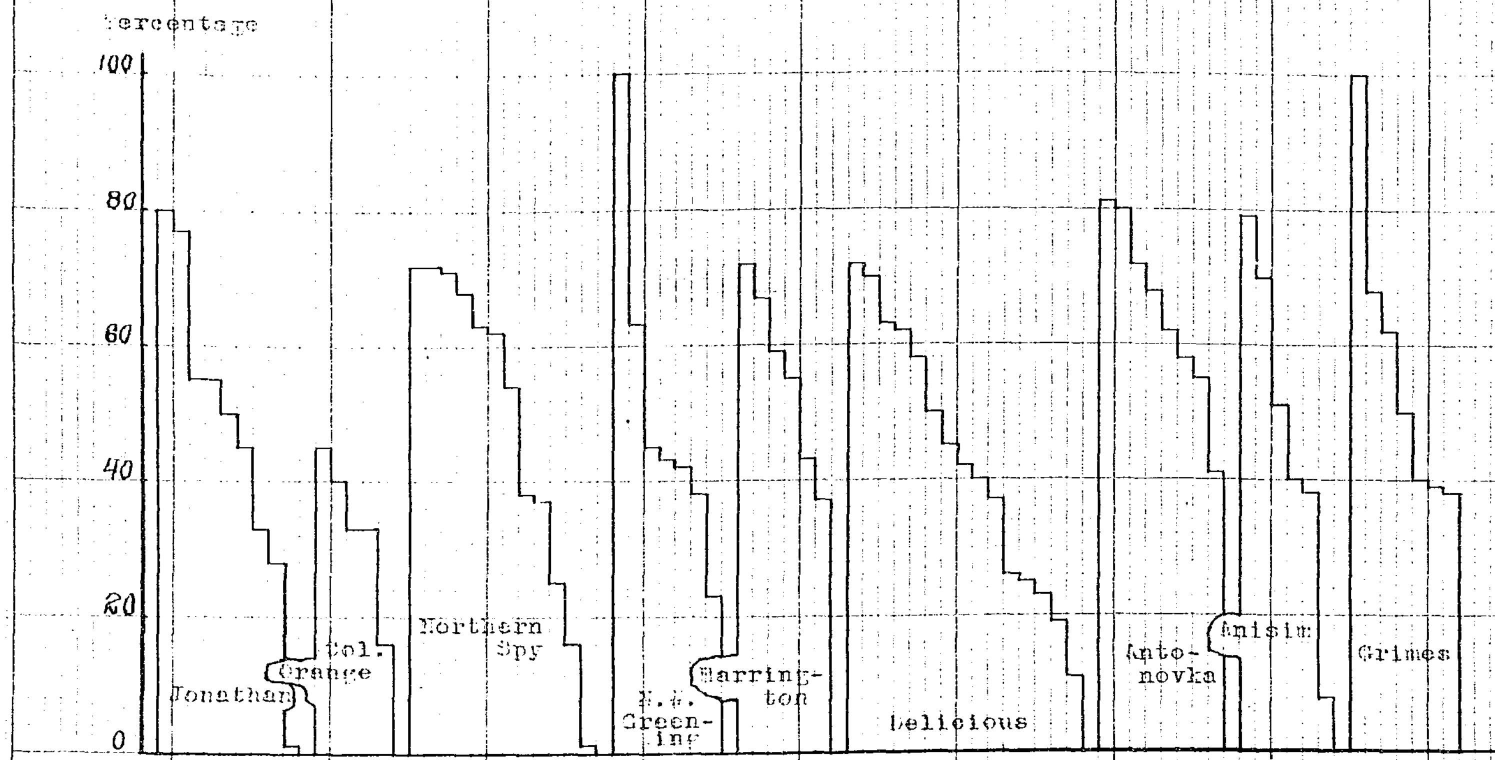

Plate V. Comparison of parent-groups and progenies with reference to the total percentage of trees having good and very good scaffold branches.

Evaluation of Measurements

The apple breeder is desirous of knowing how many and what measurements to make to evaluate the trees in a progeny and to compare the grade of trees in different progenies. With this question of measurements in mind the means of six different measurements for each of fifty-five progenies were computed and placed in Table 28. A multiple correlation was calculated from these measurements, using grade of tree for the dependent variable and shape index, branching habit, quality of scaffold branches, vigor of tree, and quality of foliage for the independent variables.

The simple correlation coefficients and the betas were determined, and from these R, the multiple correlation coefficient, and the regression equation were determined. These values are as follows:

Index A	Habit B	Branches C	Vigor D	Foliage E	Grade X
	rAB=-0.076	rAC= 0.118	rAD= 0.371	rAE= 0.246	rAX= 0.131
		rBC=-0.118	rBD=-0.096	rBE=-0.006	rBX=-0.029
			rCD= 0.611	rCE= 0.472	rCX= 0.607
				rDE= 0.785	rDX= 0.749
					rEX= 0.706
βXA=-0.126	βXB=0.032	βXC=0.223	βXD=0.455	βXE=0.291	
t= 1.356	t=0.371	t=2.053	t=2.691	t=2.109	

R = 0.81

From Fisher's Table the least significant value for the simple coefficients of correlation with fifty-three degrees of freedom is 0.266, while 0.345 is highly significant. The least significant value for R with forty-nine degrees of freedom is 0.444, while 0.508 is highly significant. The least significant value for the betas with forty-nine degrees of freedom is t = 2.009, while t = 2.680 is highly significant.

The above results that are significant are βXC and βXE, while rAD, rCD, rCE, rCX, rDE, rDX, rEX, R, and βXD are highly significant.

The simple correlation coefficients indicate that shape index is significantly correlated with but one of the other five variables, vigor of tree. Apical growth dominance in vertical shoots and upright growing trees is very noticable but as yet there is no general agreement as to the cause. Branching habit is not correlated with any of the other variables. On the other hand, the simple correlation coefficients between branches, vigor, foliage, and grade of tree are each highly significant. This means that a high quality of foliage would produce a vigorous tree growth which would result in strong scaffold branches.

The highly significant value of R indicates that the multiple correlation coefficient and regression are characteristic of an association among the variables and are not to be attributed to random sampling. For estimating tree grade the following approximate weights can be attached to the five independent variables:

Variable	Symbol	Standard regression coefficient	Percentage of weight
Index	A	-0.1257	11
Habit	B	0.0319	4
Branches	C	0.2230	20
Vigor	D	0.4350	39
Foliage	E	0.2910	26
Total		1.1066	100

The standard regression coefficient of grade on index being non-significant, may be only a peculiarity of the sample. The standard regression coefficient of grade on branching habit is positive, small, and non-significant. A poor branching habit is often due to an excessive growth of wood that causes many small branches to develop and grow. Branching habit is not significantly correlated with any of the other variables. It is not confined to certain progenies, the percentage of trees with poor branching habit being quite constant in all the progenies.

The three other betas, or standard regression coefficients of grade on branches, grade on vigor, and grade on foliage, are highly significant. The conclusions are that grade of tree is associated mainly with scaffold branches, vigor of tree, and quality of foliage, and that vigor is the most important of these three in estimating grade. The regression equation is:

$$\bar{X} = -0.3717A + 0.0446B + 0.2606C + 0.3804D + 0.2777E + 0.6569$$

The values of the several variables in each progeny were substituted in the regression equation and the estimated mean grade of tree was computed for each. Grade of tree can now be predicted for further breeding work with any of these crosses. Also, the grade of tree for other crosses of standard varieties of apple trees could be determined by substituting the values of the five independent measurements in the regression equation and solving for $\overline{X}$.

The "estimated grade" subtracted from "grade" gave the "error of estimate" for each progeny. For the fifty-five errors of estimate the standard deviation is 0.29. Two-thirds, or 67 per cent, of the errors of estimate are expected to fall between +0.29 and -0.29. Of the fifty-five cases, thirty-nine, or 71 per cent, fell within this range. This result indicates that the measurements of grade were very accurately made and that an experienced pomologist can determine with confidence the tree quality from a single judgment measurement, grade of tree.

The greater number of positive errors of estimate at the top of the table and of negative errors of estimate at the bottom indicate that experienced workers may slightly over estimate the better trees and slightly under estimate the poorer trees.

The progenies in Table 28 are arranged with reference to grade of tree. The parents transmitting the most satisfactory traits with reference to high grade of tree are found at the head of the list; the least satisfactory, at the bottom. The parents of both the best and poorest progenies are seen to be scattered rather widely in the table. Definite combinations of parents rather than certain parent-groups give the greatest percentage of highly desirable trees with reference to grade.

Table 28. Tree Grades Estimated Singly and from Five Variables and the Errors of Estimate

Parentage		No. of trees	Shape index A	Habit B	Branches C	Vigor D	Foliage E	Grade X	Estimated grade $\bar{X}$	Error of estimate $X - \bar{X}$
Anisim	x Ashton	10	1.1	2.0	2.7	3.3	2.7	3.8	3.0	0.8
Antonovka	x Ashton	55	1.1	2.4	2.8	3.7	3.3	3.6	3.4	0.2
Grimes	x N.W.Greening	13	1.1	2.1	3.8	3.5	3.2	3.5	3.6	-0.1
Antonovka	x Grimes	43	1.3	2.0	2.9	3.4	3.3	3.4	3.2	0.2
Antonovka	x Delicious	352	1.1	2.1	2.6	3.3	3.4	3.3	3.2	0.1
Antonovka	x King David	75	1.0	1.7	3.3	3.3	3.4	3.3	3.4	-0.1
Grimes	x Antonovka	74	1.3	1.9	2.7	3.4	3.1	3.2	3.1	0.1
Patten 1003	x Delicious	27	1.1	2.1	2.0	3.0	2.8	3.2	2.8	0.4
Antonovka	x Jonathan	291	1.0	2.0	3.0	3.2	3.1	3.1	3.2	-0.1
Pewaukee	x N.Spy	108	1.1	1.8	2.8	3.0	3.1	3.1	3.1	0
N.W.Greening	x N.Spy	70	1.2	1.7	2.6	3.1	2.9	3.1	2.9	0.2
Patten 1011	x Delicious	52	1.1	2.4	2.8	3.2	3.0	3.1	3.1	0
Jonathan	x Antonovka	41	1.1	2.0	2.5	2.5	2.5	3.1	2.6	0.5
Antonovka	x Bl.Oxford	135	1.1	2.1	2.3	3.3	3.2	3.1	3.1	0
Anisim	x Hubbardston	72	1.1	1.6	2.9	3.2	2.8	3.0	3.1	-0.1
Salome	x N.Spy	72	1.4	1.6	3.1	3.7	3.1	3.0	3.3	-0.3
Patten 1000	x Delicious	35	1.5	1.5	3.1	3.6	2.7	3.0	3.1	-0.1
N.W.Greening	x Wh.Pippin	22	1.5	1.9	2.4	2.8	2.3	3.0	2.5	0.5
Ames 513	x N.Spy	21	1.5	1.6	2.3	3.0	3.4	3.0	2.9	0.1
N.W. Greening	x Grimes	65	1.2	2.2	2.3	2.7	2.2	2.8	2.5	0.3
Harrington	x N.Spy	64	1.1	2.3	2.9	2.8	2.4	2.8	2.8	0
Grimes	x Wh.Pippin	36	1.3	1.9	1.9	2.6	2.1	2.8	2.5	0.3
Patten 1011	x N.Spy	46	1.1	2.6	2.6	2.9	3.0	2.8	3.0	-0.2
Harrington	x Ames 488	9	1.1	2.7	2.7	2.9	2.1	2.8	2.4	0.4
Delicious	x Salome	12	1.4	2.2	2.7	3.2	3.1	2.8	3.0	-0.2
Patten 1000	x Jonathan	9	1.4	1.6	3.0	3.3	2.9	2.8	3.0	-0.2
Anisim	x Bl.Oxford	76	1.0	2.0	2.6	2.4	2.1	2.7	2.6	0.1
N.Spy	x Pewaukee	32	1.4	2.2	2.2	2.4	3.0	2.7	2.6	0.1
Col.Orange	x Jonathan	29	0.9	2.5	2.3	2.1	2.1	2.7	2.4	0.3
N.Spy	x Wealthy	29	1.3	2.5	2.2	3.1	3.2	2.7	2.9	-0.2

Ames 513 x N.Spy	21	1.5	1.6	2.3	3.0	3.4	3.0	2.9	0.1
N.W. Greening x Grimes	65	1.2	2.2	2.5	2.7	2.2	2.8	2.5	0.3
Harrington x N.Spy	64	1.1	2.3	2.9	2.8	2.4	2.8	2.8	0
Grimes x Wh.Pippin	36	1.3	1.9	1.9	2.6	2.1	2.8	2.5	0.3
Patten 1011 x N.Spy	46	1.1	2.6	2.6	2.9	3.0	2.8	3.0	-0.2
Harrington x Ames 488	9	1.1	2.7	2.7	2.0	2.1	2.8	2.4	0.4
Delicious x Salome	12	1.4	2.2	2.7	3.2	3.1	2.8	3.0	-0.2
Patten 1000 x Jonathan	9	1.4	1.6	3.0	3.3	2.9	2.8	3.0	-0.2
Anisim x Bl.Oxford	76	1.0	2.0	2.6	2.4	2.1	2.7	2.6	0.1
N.Spy x Pewaukee	32	1.4	2.2	2.2	2.4	3.0	2.7	2.6	0.1
Col.Orange x Jonathan	29	0.9	2.5	2.3	2.1	2.1	2.7	2.4	0.3
N.Spy x Wealthy	29	1.3	2.5	2.2	3.1	3.2	2.7	2.9	-0.2
N.W.Greening x Opalescent	12	1.1	2.4	2.2	3.1	2.7	2.7	2.9	-0.2
Pewaukee x Delicious	71	1.1	2.1	2.4	2.9	2.3	2.6	2.7	-0.1
Anisim x Delicious	270	1.0	2.2	2.3	2.5	2.3	2.6	2.6	0
Anisim x Bl.Annette	129	1.1	1.9	2.3	2.2	1.7	2.6	2.2	0.4
N.W.Greening x Harrington	75	1.1	2.0	2.3	2.2	2.0	2.6	2.3	0.3
N.Spy x Jonathan	5	1.2	2.2	1.8	2.4	2.6	2.6	2.4	0.2
Patten 1015 x Delicious	59	1.3	2.5	1.9	2.6	3.1	2.5	2.6	-0.1
Ramsdell S. x Harrington	34	1.2	1.8	2.5	2.1	2.0	2.5	2.3	0.2
N.W.Greening x Delicious	99	1.1	2.3	2.0	2.1	2.1	2.5	2.3	0.2
Jonathan x Delicious	128	1.0	2.1	2.4	2.5	2.2	2.4	2.6	-0.2
Delicious x Jonathan	17	1.2	2.4	2.5	2.8	2.5	2.4	2.7	-0.3
McMahon x N.Spy	32	1.0	1.7	1.8	2.3	2.4	2.4	2.4	0
Delicious x N.Spy	16	1.4	1.7	2.7	2.8	2.5	2.4	2.3	0.1
N.Spy x Delicious	264	1.1	2.3	2.0	2.1	2.5	2.3	2.4	-0.1
Jonathan x Salome	15	0.8	1.2	2.1	2.4	2.1	2.3	2.5	-0.3
Delicious x Harrington	19	1.2	2.2	2.2	2.5	2.1	2.3	2.4	-0.1
Col.Orange x Mother	6	1.1	1.3	2.0	2.5	2.3	2.3	2.4	-0.1
Nelson S. x Grimes	47	1.3	1.5	2.3	2.4	2.2	2.2	2.4	-0.2
King David x Anisim	26	0.9	1.7	2.3	1.8	2.3	2.2	2.5	-0.3
Salome x Jonathan	14	0.9	1.6	2.2	2.1	2.4	2.0	2.4	-0.4
Harrington x Ramsdell S.	22	1.2	2.2	2.4	1.9	1.6	2.0	2.1	-0.1
Col.Orange x Ames 463	12	1.0	2.1	2.1	1.8	2.1	2.0	2.2	-0.2
Col.Orange x Grimes	10	1.0	2.2	2.6	1.5	2.2	2.0	2.2	-0.2
Bl.Annette x Delicious	94	1.3	2.0	1.6	2.0	1.6	1.7	1.9	-0.2
Col.Orange x Y.Newtown	12	1.2	2.6	2.2	2.7	2.0	1.4	2.5	-1.1

CONCLUSIONS

1. The tree shapes in a cross-bred apple progeny vary much more than the tree shapes in a parent variety. The shapes in most progenies vary from spreading through round to upright.

2. Fifty-two of the seventy-five mean progeny shape indices differ significantly from the mean shape indices of their common parents. Also, the highly significant values from the Chisquare test indicate that the shapes of cross-bred apple seedlings are not due to random sampling but are due to inheritance.

3. Three sets of evidence indicate (1) a large number of minor factors for shape and (2) a few major dominant genes. The former give the rather typical curves of shape index distribution and the latter a positive skewness and generally double modes to the distribution curve. The partial dominance centers at the shape index of 1.05, or round headed tree shape.

4. Highly significant mean differences between the shape indices of parents and the mean shape indices of their progenies are probably due in part to "nicking". This combining effect, or complementary action of several or many dominant genes, is difficult to measure. Anisim x Ashton, and Northwestern Greening x Harrington, and a few other crosses in Table 17b are examples.

5. Variations with reference to (1) grade of tree, (2) shape of tree, (3) branching habit, and (4) scaffold branches

differ widely within as well as between progenies. Tables 20 to 27 and Plates II to VI show these differences. Seven progenies of Antonovka gave seventy-nine per cent of good and very good trees, while five progenies of Colorado Orange gave but thirty-three per cent. Also, fifty-five seedling trees of Antonovka x Ashton gave ninety-one per cent good and very good trees, while ninety-four trees of Black Annette x Delicious gave but eighteen per cent.

6. A multiple correlation study with shape, habit, branches, vigor, and foliage as independent variables and grade as the dependent variable showed that:

(a) The multiple correlation coefficient, R = 0.81, being highly significant, the association among the variables is not attributed to random sampling.

(b) The first two betas, grade on shape index and grade on habit, are not correlated with grade.

(c) The last three betas, grade on branches, grade on vigor, and grade on foliage, give highly significant values and show particularly that vigor is the most important of the three in estimating grade.

(d) The standard deviations of the errors of estimate falling within their expected range, indicate that the measurements of grade were accurately made.

7. The progeny tests indicate that in thirteen of the fourteen parents tested the prepotency index for shape is higher

than the shape index of the parent. The parents giving the most pronounced differences are Northwestern Greening, Harrington, and Anisim and their differences are 0.34, 0.32, and 0.26. Also, the progeny tests indicate that the Ashton variety has a higher prepotency index for grade of tree than any of the other nineteen varieties tested. Next to Ashton in tree rank are Antonovka, Anisim, and Hubbardston, the prepotency values for the four varieties being 3.7, 3.1, 2.8, and 2.8. To expect high grade in seedling trees one must cross parents both of which are prepotent for high grade of tree.

LITERATURE CITED

1. Blake, M. A. Pruning young and bearing apple trees. N.J. Agr. Exp. Sta. Ext. Bull. 60. 1927.

2. Crandall, C. S. Apple breeding in the University of Illinois. Ill. Agr. Exp. Sta. Bull. 275. 1926.

3. Emerson, R. A. The inheritance of sizes and shapes in plants. Amer. Nat. 44: 739-746. 1910.

4. Fisher, R. A. Statistical methods for research workers. Oliver and Boyd, London. 1932.

5. Lantz, H. L. and Edgecomb, S. W. Apple breeding: Some significant differences in the vigor and grade of cross-bred apple seedlings. Proc. Amer. Soc. Hort. Sci. 27: 289-295. 1930.

6. Lush, J. L. The number of daughters to prove a sire. Jour. Dairy Sci. 14: 209-220. 1931.

7. Oskamp, J. The young apple orchard. N.Y. (Cornell) Agr. Exp. Sta. Ext. Bull. 233. 1932.

8. Ruth, W. A. and Kelley, V. W. A study of the framework of the apple tree and its relation to longevity. Ill. Agr. Exp. Sta. Bull. 376. 1932.

9. Sax, K. and Gowen, J. W. The relation of tree type to productivity. Me. Agr. Exp. Sta. Bull. 305. 1922.

10. Warren, D. C. The progeny test in poultry breeding. Kan. Agr. Exp. Sta. Cir. 168. 1932.

APPENDIX

Table 1a. Distribution of Shape Indi

Parentage	No. of trees	Height-diameter indi											
		.51-.60	.61-.70	.71-.80	.81-.90	.91-1.00	1.01-1.10	1.11-1.20	1.21-1.30	1.31-1.40	1.41-1.50	1.51-1.60	1.61-1.70
		Spreading				Round			Upright spreading				
Delicious (parent)	40				1	7	9	16	4	1	1	1	
Delicious x Harrington	19			2	2	1	4	2	1	3	1	1	1
" x Jonathan	17				5	4		2	5	1	2	2	
" x N. Spy	16				1	0	2	1	1	3	1	2	1
" x Salome	12						1	1	1	3	4	1	1
Antonooka x Delicious	352	3	7	22	34	62	51	57	50	29	16	8	7
Anisim x "	270	5	18	40	41	45	30	24	28	12	9	6	6
Bl. [illegible]notte x "	94		1	3	1	8	7	15	16	9	11	2	6
Jonathan x "	126		4	15	17	29	11	16	16	9	8	1	
No. Spy x "	264		6	13	35	37	23	46	37	27	12	9	9
N.W Greening x "	99		4	4	12	19	14	16	11	5	3	4	2
Patten 1000 x "	35				1	2	1	4	2	5	2	2	5
Patten 1003 x "	27		1	4	2	8	2	3	3	1	1	1	
Patten 1011 x "	52		1	4	6	10	8	7	7	4	2		1
Patten 1015 x "	59				2	6	4	8	4	15	7	1	4
Pewaukee x "	70	1		2	9	12	9	13	10	6	5	1	

…pe Indices in Trees of Delicious Progenies

…er indices											Mean	Standard deviation	Coefficient of variability
1.51-1.60	1.61-1.70	1.71-1.80	1.81-1.90	1.91-2.00	2.01-2.10	2.11-2.20	2.21-2.30	2.31-2.40	2.41-2.50	2.51-2.60			
				Upright									
											1.12 ± 0.01	0.14	12.53
1	1		1								1.18 ± 0.04	0.28	23.73
2											1.16 ± 0.04	0.24	20.65
2	1	3	0	0	0	1					1.44 ± 0.05	0.32	22.22
1	1	1									1.41 ± 0.04	0.19	13.47
3	7	1	1	3	1						1.11 ± 0.01	0.25	22.29
5	6	4	1			1	1		1		1.03 ± 0.01	0.30	29.12
2	6	4	4	2		1	2	1	1		1.35 ± 0.02	0.36	26.67
1			1	1							1.04 ± 0.01	0.23	21.82
9	9	3	3	3		1					1.15 ± 0.01	0.28	24.35
1	2	2	2	1							1.12 ± 0.02	0.28	25.00
2	5	1	3	3	1	0	2	0		1	1.55 ± 0.04	0.40	25.81
					1						1.06 ± 0.04	0.31	29.81
	1	1		1							1.10 ± 0.02	0.26	23.64
	4	3		5							1.34 ± 0.03	0.29	21.64
		1			1						1.12 ± 0.02	0.24	21.43

Table 2a. Frequency Distribution of Shap

Parentage	No. of trees	.51-.60	.61-.70	.71-.80	.81-.90	.91-1.00	1.01-1.10	1.11-1.20	1.21-1.30	1.31-1.40	1.41-1.50	1.51-1.60	1.61-1.70	1.71-1.80
		Height-diameter indices												
		Spreading			Round					Upright spreading				
Colorado Orange (parent)	2				1	1								
Col. Orange x Ames 463	12			3	2	4		1			2			
" " x Grimes	10	1	1		3	2		1			1		1	
" " x Jonathan	29	1	2	7	6	3	4	2	2	1	1			
" " x Yel. Newton	12			1	2	3		1			2		2	1
" " x Mother	6				1	1	1	1	1	1				

ibution of Shape Indices in Colorado Orange Progenies

meter indi		ces												
[illegible]	1.51-1.60	1.61-1.70	1.71-1.80	1.81-1.90	1.91-2.00	2.01-2.10	2.11-2.20	2.21-2.30	2.31-2.40	2.41-2.50	2.51-2.60	Mean	Standard deviation	Coefficient of variability
nt ing			Upright											
												0.89		
2												0.98 ± 0.07	0.23	23.47
1		1										0.99 ± 0.10	0.32	32.32
1												0.93 ± 0.03	0.22	23.76
2		2	1									1.20 ± 0.10	0.35	29.17
												1.10 ± 0.07	0.17	15.45

Table 3a. Distribution of Shape Indi

Parentage	No. of trees	Height-diameter indi												
		.51-.60	.61-.70	.71-.80	.81-.90	.91-1.00	1.01-1.10	1.11-1.20	1.21-1.30	1.31-1.40	1.41-1.50	1.51-1.60	1.61-1.70	
		Spreading			Round				Upright spreading					
Northern Spy (parent)	1									1				
Northern Spy x Delicious	264		6	13	35	37	23	46	37	27	12	9	9	[illegible]
" " x Jonathan	5					1	1	1		1	1			
" " x Pewaukee	32					3	4	3	4	5	4	2	3	[illegible]
" " x Wealthy	29					4	3	4	5	4	4	1	1	[illegible]
Ames 513 x Northern Spy	21						2	1	1	3	4	3	5	
Delicious x " "	16				1		2	1	1	3	1	2	1	[illegible]
Harrington x " "	64			8	8	11	7	12	6	2	3	4	1	[illegible]
McMahon x " "	32		2	3	4	6	6	3	2	4	1	1		
Patten 1011 x " "	46			1	1	16	3	7	9	3	4	1		[illegible]
N.W. Greening x" "	72		1		7	6	7	13	13	9	6	4	3	[illegible]
Salome x " "	72				1	4	5	9	11	10	12	5	8	[illegible]
Pewaukee x " "	108		2	4	10	20	15	15	13	8	12	7	2	

pe Indices in Trees of Northern Spy Progenies

er indices													
1.51-1.60	1.61-1.70	1.71-1.80	1.81-1.90	1.91-2.00	2.01-2.10	2.11-2.20	2.21-2.30	2.31-2.40	2.41-2.50	2.51-2.60	Mean	Standard deviation	Coefficient of variability
				Upright									
											1.39		
[illegible]	9	3	3	3		1					1.15 ± 0.01	0.28	24.35
											1.19 ± 0.05	0.18	15.13
2	3	1	2					1			1.37 ± 0.04	0.31	22.63
1	1	2		1							1.30 ± 0.03	0.25	19.23
[illegible]	5					1		1			1.51 ± 0.05	0.30	19.87
2	1	3				1					1.44 ± 0.05	0.32	22.22
4	1	2									1.10 ± 0.02	0.26	23.64
1											1.04 ± 0.03	0.23	22.12
1		1									1.14 ± 0.02	0.21	18.42
4	3	1									1.24 ± 0.02	0.23	18.55
5	8	3	3	1							1.37 ± 0.02	0.25	18.25
7	2										1.14 ± 0.02	0.24	21.00

Table 4a. Distribution of Shape Indi

Parentage	No. of trees	Height-diameter indices												
		.51-.60	.61-.70	.71-.80	.81-.90	.91-1.00	1.01-1.10	1.11-1.20	1.21-1.30	1.31-1.40	1.41-1.50	1.51-1.60	1.61-1.70	1.71-1.80
		Spreading			Round				Upright spreading					
Anisim (parent)	1				1									
Anisim x Ashton	10			1			3	3	3					
" x Bl. Annette	129		2	5	13	24	20	26	16	12	7	2	1	1
" x Delicious	270	5	18	40	41	45	30	24	26	12	9	6	6	4
" x Bl. Oxford	76		4	8	9	17	10	9	9	5	3			
" x Hubbardston	72			5	10	7	10	13	13	7	2	2	2	1
King David x Anisim	26	1	4	5	3	6	2	2	1	1		1		

Shape Indices in Trees of Anisim Progenies

...er indices											Mean	Standard deviation	Coefficient of variability
1.51-1.60	1.61-1.70	1.71-1.80	1.81-1.90	1.91-2.00	2.01-2.10	2.11-2.20	2.21-2.30	2.31-2.40	2.41-2.50	2.51-2.60			
				Upright									
											0.82		
											1.11 ± 0.03	0.14	12.61
3	1	1									1.11 ± 0.01	0.21	18.99
5	6	4	1			1	1		1		1.03 ± 0.01	0.30	29.12
			2								1.04 ± 0.02	0.24	23.06
2	2	1									1.13 ± 0.02	0.23	20.35
1											0.91 ± 0.05	0.23	25.27

Table 5a. Distribution of Shape Indic

Parentage	No. of trees	Height-diameter indices .51-.60	.61-.70	.71-.80	.81-.90	.91-1.00	1.01-1.10	1.11-1.20	1.21-1.30	1.31-1.40	1.41-1.50	1.51-1.60	1.61-1.70	1.71-1.80
		Spreading				Round			Upright spreading					
Jonathan (parent)	40		4	22	9	3	2							
Jonathan x Antonooka	41			5	7	5	6	5	3	5	3	1	1	
" x Delicious	128		4	15	17	29	11	16	16	9	8	1		
" x Salome	15	1	4	3	3	2	2							
Antonooka x Jonathan	291		12	23	42	56	41	52	28	22	8	3	4	
Col. Orange x "	29	1	2	7	6	3	4	2	2	1	1			
Delicious x "	17				3	4		2	3	1	2	2		
Patten 1000 x "	9								3	1	1	3		
Salome x "	14		1	4	3	4	1	1						
N. Spy x "	5					1	1	1		1	1			

ape Indices in Trees of Jonathan Progenies

indices 1.51-1.60	1.61-1.70	1.71-1.80	1.81-1.90	1.91-2.00	2.01-2.10	2.11-2.20	2.21-2.30	2.31-2.40	2.41-2.50	2.51-2.60	Mean	Standard deviation	Coefficient of variability
Upright													
											0.79 ± 0.01	0.09	11.86
	1										1.09 ± 0.03	0.24	22.38
			1	1							1.04 ± 0.01	0.23	21.82
											0.80 ± 0.02	0.12	15.00
	4										1.05 ± 0.01	0.21	20.46
											0.93 ± 0.03	0.22	23.76
											1.16 ± 0.04	0.24	20.65
			1								1.45 ± 0.04	0.19	13.10
											0.87 ± 0.02	0.13	14.94
											1.19 ± 0.05	0.18	15.13

Table 6a. Distribution of Shape Indices

Parentage	No. of trees	.51-.60	.61-.70	.71-.80	.81-.90	.91-1.00	1.01-1.10	1.11-1.20	1.21-1.30	1.31-1.40	1.41-1.50	1.51-1.60	1.61-1.70	1.71-1.80
		Height-diameter indices												
		Spreading				Round			Upright spreading					
Harrington (parent)	2			1	1									
Harrington x Ames 488	9				1	2	2	2	1	1				
" x N. Spy	64			8	8	11	7	12	6	2	3	4	1	2
" x Ramsdell Sweet	22	1			1	4	3	1	2	5	4			1
Delicious x Harrington	19			2	2	1	4	2	1	3	1	1	1	
N.Y. Greening x "	75		4	6	11	9	6	11	11	4	7	1	3	2
Ramsdell Sweet x "	34				1	6	2	6	7	5	5	1		1

pe Indices in Trees of Harrington Progenies

r indices 1.51-1.60	1.61-1.70	1.71-1.80	1.81-1.90	1.91-2.00	2.01-2.10	2.11-2.20	2.21-2.30	2.31-2.40	2.41-2.50	2.51-2.60	Mean	Standard deviation	Coefficient of variability
				Upright									
											.82		
											1.08 ± 0.03	0.15	13.89
4	1	2									1.10 ± 0.02	0.26	23.64
		1									1.19 ± 0.04	0.26	22.09
1	1		1								1.18 ± 0.04	0.28	23.73
1	3	2									1.11 ± 0.02	0.28	25.22
1		1									1.22 ± 0.02	0.20	16.39

Table 7a. Distribution of Shape Indice

Parentage	No. of trees	.51-.60	.61-.70	.71-.80	.81-.90	.91-1.00	1.01-1.10	1.11-1.20	1.21-1.30	1.31-1.40	1.41-1.50	1.51-1.60	1.61-1.70	1.71-1.80
		Height-diameter indice												
		Spreading			Round				Upright spreading					
Antonooka (parent)	2					1		1						
Antonooka x Ashton	55		1	2	6	17	11	6	5	2	2	3		
" x Bl. Oxford	135	3	2	9	18	30	12	22	11	16	6	3	2	1
" x Delicious	352	3	7	22	34	62	51	57	50	29	16	8	7	1
" x Grimes	43		1	1	1	4	4	6	8	6	3	3	3	2
" x Jonathan	291		12	23	42	56	41	52	28	22	8	3	4	
" x King David	75	1	3	3	7	15	17	18	7	2	1			1
Grime x Antonooka	74			1	2	10	5	11	8	11	7	9	7	1
Jonathan x "	41			5	7	5	6	5	3	5	3	1	1	

Shape Indices in Trees of Antonooka Progenies

...tor indices													
1.51-1.60	1.61-1.70	1.71-1.80	1.81-1.90	1.91-2.00	2.01-2.10	2.11-2.20	2.21-2.30	2.31-2.40	2.41-2.50	2.51-2.60	Mean	Standard deviation	Coefficient of variability
...t ...ng		Upright											
											1.12	0	
3											1.07 ± 0.02	0.20	18.95
3	2	1									1.07 ± 0.01	0.24	22.33
8	7	1	1	3	1						1.11 ± 0.01	0.25	22.29
3	3	2	1								1.27 ± 0.03	0.27	21.29
3	4										1.05 ± 0.01	0.21	20.46
		1									1.04 ± 0.01	0.19	18.23
9	7	1	2								1.33 ± 0.02	0.26	19.
1	1										1.09 ± 0.03	0.24	

Table 8a. Distribution of Shape In

Parentage	No. of trees	.51-.60	.61-.70	.71-.80	.81-.90	.91-1.00	1.01-1.10	1.11-1.20	1.21-1.30	1.31-1.40	1.41-1.50	1.51-1.60	1.61-1.70	1.71-1.80
		Height-diameter indice												
		Spreading			Round				Upright spreading					
Grimes	40						4	10	13	10	2	1		
Grimes x Antonooka	74			1	2	10	5	11	8	11	7	9	7	
" x N. W. Greening	13			2		6	2				2	1		
" x W. Pippin	36				2	4	2	3	7	6	5	1	5	
Antonooka x Grimes	43		1	1	1	4	4	6	8	6	3	3	3	
Col. Orange x "	10	1	1		3	2		1			1		1	
Nelson Sweet x "	47			1	1	2	3	11	3	8	8	5	2	
N. W. Greening x Grimes	65		1	3	7	10	7	9	11	4	5	4	1	

Shape Indices in Trees of Grimes Progenies

r indices											Mean	Standard deviation	Coefficient of variability
1.51-1.60	1.61-1.70	1.71-1.80	1.81-1.90	1.91-2.00	2.01-2.10	2.11-2.20	2.21-2.30	2.31-2.40	2.41-2.50	2.51-2.60			
s		Upright											
1											1.24 ± 0.01	0.12	9.36
9	7	1	2								1.33 ± 0.02	0.26	19.47
1											1.06 ± 0.05	0.25	23.63
1	5			1							1.30 ± 0.04	0.24	18.46
3	3	3	1								1.27 ± 0.03	0.27	21.29
	1										0.99 ± 0.10	0.32	32.32
5	2		2	1							1.32 ± 0.04	0.25	19.00
4	1	1		1			1				1.17 ± 0.02	0.29	24.80

Table 9a. Distribution of Shape Indices i

Parentage	No. of trees	Height-diameter indi ce												
		.51-.60	.61-.70	.71-.80	.81-.90	.91-1.00	1.01-1.10	1.11-1.20	1.21-1.30	1.31-1.40	1.41-1.50	1.51-1.60	1.61-1.70	1.71-1.80
		Spreading				Round				Upright spreading				
N.W. Greening (parent)	2			1	1									
" " x Delicious	99		4	4	12	19	14	16	11	5	3	4	2	2
" " x Grimes	65		1	3	7	10	7	9	11	4	5	4	1	1
" " x Harrington	75		4	6	11	9	6	11	11	4	7	1	3	2
" " x N. Spy	70		1		7	6	7	13	13	9	6	4	3	1
" " x Opalescent	12		1	2	2	1	1	2	1					2
" " x [illegible] Pippin	22						2	2	2	4	1	3	2	2
Grimes x N. W. Greening	13			2		6	2				2	1		

Indices in Trees of Northwestern Greening Progenies

ter indices													
1.51-1.60	1.61-1.70	1.71-1.80	1.81-1.90	1.91-2.00	2.01-2.10	2.11-2.20	2.21-2.30	2.31-2.40	2.41-2.50	2.51-2.60	Mean	Standard deviation	Coefficient of variability
											0.88		
4	2	2	2	1							1.12 ± 0.02	0.28	25.00
4	1	1		1			1				1.17 ± 0.02	0.29	24.80
1	3	2									1.11 ± 0.03	0.28	25.22
4	3	1									1.24 ± 0.03	0.23	18.55
		2									1.07 ± 0.10	0.35	32.71
3	2	2	2	2							1.49 ± 0.04	0.28	18.59
1											1.06 ± 0.05	0.25	23.63

Table 15. Distribution of Height-diameter Indices in Trees of Delicious Progenies in Respect to Tree Shape

Parentage	No. of trees	[illegible] index	Height-diameter indices: Percentage spreading .51-.90	Percentage round .91-1.20	Percentage upright spreading 1.21-1.60	Percentage upright 1.61-	Mean index of progeny
Delicious (parent)	40	1.17					
Delicious x Harrington	19	.87	11	47	31	11	1.16
Delicious x Jonathan	17	.70		47	53		1.16
" x N. Spy	16	1.30		25	44	31	1.44
" x Malone	12	.90		17	67	16	1.41
Antonovka x Delicious	358	1.10	9	58	29	4	1.11
Anisim x "	207	.83	34	52	10	4	1.05
Bl. Annette x "	94		4	33	41	22	1.30
Jonathan x "	138	.79	15	57	26	2	1.04
N. Spy x "	264	1.30	7	54	32	7	1.13
R. I. Greening x "	90	.88	6	62	25	7	1.12
Patten 1,000 x "	35			23	31	46	1.55
Patten 1,005 x "	37		10	56	29	5	1.06
Patten 1,011 x "	52		10	60	24	6	1.10
Patten 1,015 x "	59			34	46	20	1.32
Hewahtee x "	76		4	62	31	3	1.12

Table 2b. Distribution of Height-diameter Indices in Trees of Colorado Orange Progenies in Respect to Tree Shape

Parentage	No. of trees	Parent index	Height-diameter indices: Percentage spreading .51-.80	Percentage round .81-1.20	Percentage upright spreading 1.21-1.60	Percentage upright 1.61-	Mean index of progeny
Colorado Orange (parent)	2	.89					
" " x Ames 465	12		25	58	17		.98
" " x Grimes	10	1.24	20	60	10	10	.99
" " x Jonathan	29	.79	34	52	14		.93
" " x Yel. Newton	12		8	50	17	25	1.20
" " x Mother	6			67	33		1.18

Table 5b. Distribution of height-diameter indices in Trees of Northern Spy Progenies in Respect to Tree Shape

Parentage	No. of trees	Parent index	Height-diameter indices: Percentage spreading .51-.80	Percentage round .81-1.20	Percentage upright spreading 1.21-1.60	Percentage upright 1.61-	Mean index of progeny
Northern Spy (parent)	1	1.39					
Northern Spy x Delicious	264	1.12	7	54	32	7	1.15
" " x Jonathan	5	.79		60	40		1.19
" " x Pewaukee	32			31	47	22	1.37
" " x Wealthy	29	1.15		38	48	14	1.30
Ames 513 x N. Spy	23			22	48	30	1.51
Delicious x "	16	1.12		25	44	31	1.44
Harrington x "	64	.82	13	59	23	5	1.10
McMahon x "	32		16	59	25		1.04
Patten 1011 x "	46		2	59	37	2	1.14
N. W. Greening x "	70	.88	1	47	46	6	1.24
Salome x "	72	.99		26	53	21	1.37
Pewaukee x "	108		5	56	37	2	1.14

Table 4b. Distribution of Height-diameter Indices in Trees of Anisim Progenies in Respect to Tree Shape

Parentage	No. of trees	Parent index	Height-diameter Indices: Percentage spreading .51-.80	Percentage round .81-1.20	Percentage upright spreading 1.21-1.60	Percentage upright 1.61-	Mean Index of progeny
Anisim (parent)	1	.82					
Anisim x Ashton	10	.76	10	60	30		1.11
" x Black Annette	189		5	64	29	2	1.11
" x Delicious	276	1.18	23	52	20	5	1.03
" x Black Oxford	76	.87	16	59	22	3	1.04
" x Hubbardston	72	1.00	7	56	33	4	1.13
King David x Anisim	86	.81	32	56	12		.91

Table 5b. Distribution of Height-diameter Indices in Trees of Jonathan Progenies in Respect to Tree Shape

Parentage	No. of trees	Parent index	Height-diameter Indices: Percentage spreading .51-.80	Percentage round .81-1.20	Percentage upright 1.21-1.60	Percentage upright 1.61-	Mean Index of progeny
Jonathan (parent)	40	.79					
Jonathan x Antonovka	41	1.12	12	51	29	8	1.09
" x Delicious	161	1.15	13	59	27	1	1.04
" x Melba	15	.90	53	47			.86
Antonovka x Jonathan	201	1.12	12	66	21	1	1.05
Col. Orange x "	39	.89	34	52	14		.93
Delicious x "	17	1.14		53	47		1.16
Patten 1000 x "	9				89	11	1.45
Melba x "	14	.90	34	66			.87
N. Spy x "	5	1.39		60	40		1.15

Table 6b. Distribution of Height-diameter Indices in Trees of Harrington Progenies in Respect to Tree Shape

Parentage	No. of trees	Parent index	Height-diameter indices: Percentage spreading .51-.80	Percentage round .81-1.20	Percentage upright spreading 1.21-1.60	Percentage upright 1.61-	Mean index of progeny
Harrington (parent)	2	.82					
Harrington x Ames 488	9			78	22		1.08
" x N. Spy	64	1.39	13	59	23	5	1.10
" x Ramsdell S.	22		4	41	51	4	1.19
Delicious x Harrington	19	1.12	11	47	31	11	1.18
N.W.Greening x "	75	.88	13	49	31	7	1.11
Ramsdell S. x "	34			44	53	3	1.22

Table 7b. Distribution of Height-diameter Indices in Trees of Antonooka Progenies in Respect to Tree Shape

Parentage	No. of trees	Parent index	Height-diameter indices: Percentage spreading .51-.80	Percentage round .81-1.20	Percentage upright spreading 1.21-1.60	Percentage upright 1.61-	Mean index of progeny
Antonooka (parent)	2	1.12		100			
Antonooka x Ashton	55	.70	5	73	22		1.07
" x Black Oxford	135	.87	10	61	27	2	1.07
" x Delicious	352	1.12	9	58	29	4	1.11
" x Grimes	43	1.24	5	35	46	14	1.27
" x Jonathan	291	.79	12	66	21	1	1.05
" x King David	75	.81	9	77	13	1	1.04
Grimes x Antonooka	74	1.24	1	38	47	14	1.33
Jonathan x "	41	.79	12	56	29	3	1.09

Table 8b. Distribution of Height-diameter Indices in Trees of Grimes Progenies in Respect to Tree Shape

Parentage	No. of trees	Parent index	Height-diameter indices: Percentage spreading .51-.80	Percentage round .81-1.20	Percentage upright spreading 1.21-1.60	Percentage upright 1.61-	Mean index of progeny
Grimes (parent)	40	1.24					
Grimes x Antonooka	74	1.12	1	38	47	14	1.33
" x N.W. Greening	13	.88	15	62	23		1.06
" x White Pippin	36	1.28		30	53	17	1.30
Antonooka x Grimes	43	1.12	5	35	46	14	1.27
Col. Orange x "	10		20	60	10	10	.99
Nelson Sweet x "	47		2	36	51	11	1.32
N.W. Greening x "	65	.88	6	51	37	6	1.17

Table 9b. Distribution of Height-diameter Indices in Trees of Northwestern Greening Progenies in Respect to Tree Shape

Parentage	No. of trees	Parent index	Height-diameter indices: Percentage spreading .51-.80	Percentage round .81-1.20	Percentage upright spreading 1.21-1.60	Percentage upright 1.61-	Mean index of progeny
N. W. Greening (parent)	2	.88					
" " x Delicious	99	1.12	8	62	23	7	
" " x Grimes	65	1.24	6	51	37	6	
" " x Harrington	75	.82	13	49	31	7	
" " x N. Spy	70	1.39	1	47	46	6	
" " x Opalescent	12	.74	25	50	8	17	
" " x W. Pippin	22	1.28		18	45	37	
Grimes x N.W. Greening	13	1.24	15	62	23		

Table 1c. Grade, Shape, Habit, and Branching of Trees in Delicious Progenies

Parentage	No. of trees	Percentage grade of tree				Percentage shape of tree				Percentage habit of tree				Percentage branching of tree			
		Very good	Good	Fair	Poor	Drooping	Spreading	Upright spreading	Upright	Open	Medium open	Medium thick	Thick	Very good	Good	Fair	Poor
Delicious (parent)	40	100						100			100				10		
Delicious x Herrington	19	16	16	47	21	0	21	37	42	10	16	53	21	11	26	37	26
" x Jonathan	17	21	14	51	14	0	7	57	36	7	58	7	25	7	43	43	7
" x N. Spy	16	13	25	56	6	0	0	25	75	0	12	44	44	12	50	38	0
" x Salome	13	25	42	25	8	0	0	42	58	0	42	33	25	8	58	26	8
Antonooka x Delicious	353	57	25	12	6	1	27	45	27	5	30	37	28	12	46	35	7
Anisim x "	270	22	35	27	16	1	11	44	44	7	32	44	17	7	33	43	17
Bl. Annette x "	94	0	18	34	48	1	4	59	36	2	25	40	33	0	11	42	47
Jonathan x "	128	17	28	33	22	0	19	42	39	1	25	52	22	12	33	35	20
N. Spy x "	264	16	23	35	26	0	7	25	68	7	29	48	16	1	24	46	29
N.W. Greening x "	99	26	24	26	24	1	9	51	39	5	38	36	21	0	23	53	24
Patten 1000 x "	35	40	26	31	3	0	3	31	66	0	12	31	57	29	51	17	3
Patten 1003 x "	27	52	22	18	8	0	15	60	25	8	30	26	36	0	26	44	30
Patten 1011 x "	52	38	34	22	6	6	25	46	23	4	47	35	14	25	47	12	16
Patten 1015 x "	59	15	32	36	17	2	12	39	47	39	47	6	8	0	19	51	30
Pewaukee x "	71	27	27	25	21	1	18	57	24	4	21	51	24	11	31	47	11

Table 2c. Grade, Shape, Habit, and branching of Trees in Colorado Orange Progenies

Parentage	No. of trees	Percentage grade of tree				Percentage shape of tree				Percentage habit of tree				Percentage branching of tree			
		Very good	Good	Fair	Poor	Drooping	Spreading	Upright spreading	Upright	Open	Medium open	Medium thick	Thick	Very good	Good	Fair	Poor
Colorado Orange (parent	2		100				100					100		100			
" " x Ames 463	12	0	33	25	42	42	42	0	16	8	17	50	25	0	33	42	25
" " x Grimes	10	40	0	0	60	0	50	50	0	10	30	30	30	30	10	50	10
" " x Jonathan	29	14	28	41	17	17	45	35	3	10	41	35	14	0	45	38	17
" x Yel. Newton	12	0	0	42	58	0	17	66	17	8	50	34	8	0	33	50	17
" x Mother	6	16	34	16	34	0	68	16	16	0	0	33	67	0	16	68	16

Table 3c. Grade, Shape, Habit, and Branching of Trees in Northern Spy Progenies

Parentage	No. of trees	Percentage grade of tree: Very Good	Good	Fair	Poor	Percentage shape of tree: Drooping	Spreading	Upright spreading	Upright	Percentage habit of tree: Open	Medium open	Medium thick	Thick	Percentage branching of tree: Very Good	Good	Fair	Poor
Northern Spy (parent)	1		1.0						100			100			100		
N. Spy x Delicious	264	16	23	35	26	0	7	25	68	7	29	48	16	1	24	46	29
" x Jonathan	5	20	20	60	0	0	20	60	20	0	40	40	20	0	0	80	20
" x Pewaukee	32	28	31	19	22	0	13	53	34	3	31	44	22	0	37	41	22
" x Wealthy	29	30	28	21	21	0	3	62	35	10	38	42	10	37	31	30	22
Ames 513 x N. Spy	21	48	19	23	10	0	5	28	67	0	5	52	43	5	33	52	10
Delicious x "	16	13	25	56	6	0	0	25	75	0	12	44	44	12	50	38	0
Harrington x "	65	21	47	21	11	0	10	50	40	5	40	40	15	17	55	26	2
McMahon x "	32	22	15	41	22	3	6	29	62	0	12	41	47	0	16	53	31
Patten 1611 x "	46	41	20	15	24	0	26	48	26	4	58	29	9	15	39	37	9
N. W. Greening x "	72	52	22	12	14	0	14	44	42	1	11	46	42	5	58	27	10
Salome x "	71	30	43	22	5	0	0	25	75	0	17	30	53	44	27	28	1
Pewaukee x "	108	43	30	18	9	0	15	51	34	2	19	39	47	17	55	20	8

Table 4c. Grade, shape, habit, and branching of trees in Anisim progenies

Parentage	No. of trees	Percentage grade of tree				Percentage shape of tree				Percentage habit of tree				Percentage branching of tree			
		Very good	Good	Fair	Poor	Drooping	Spreading	Upright spreading	Upright	Open	Medium open	Medium thick	Thick	Very good	Good	Fair	Poor
Anisim (parent)	1	100						100				100		100			
Anisim x Anton	10	80	20	0	0	0	0	50	50	0	10	80	10	0	70	30	0
" x Bl. Annette	139	26	30	24	20	0	9	49	42	1	23	42	34	2	36	53	9
" x Delicious	270	22	33	27	18	1	11	44	44	7	32	44	17	7	33	45	17
" x Bl. Oxford	77	31	29	22	18	0	22	43	35	6	24	35	35	18	33	44	5
" x Hubbardston	73	39	33	15	13	0	6	37	57	1	11	34	54	14	65	17	4
King David x Anisim	26	15	31	15	39	0	8	50	42	15	23	35	27	0	8	54	38

Table 5c. Grade, Shape, Habit, and Branching of Trees in Jonathan Progenies

Parentage	No. of trees	Percentage grade of tree				Percentage shape of tree				Percentage habit of tree				Percentage branching of tree			
		Very good	Good	Fair	Poor	Drooping	Spreading	Upright spreading	Upright	Open	Medium open	Medium thick	Thick	Very good	Good	Fair	Poor
Jonathan (parent)	3		100				100					100			100		
Jonathan x Antonooka	41	49	21	20	10	0	15	55	30	0	29	44	27	8	47	30	15
" x Delicious	133	17	28	33	22	0	19	42	39	1	25	52	22	12	33	35	20
" x Salome	15	13	27	40	20	0	27	60	13	7	7	47	39	0	33	47	20
Antonooka x Jonathan	292	50	23	18	9	1	24	51	24	3	22	45	30	22	58	16	4
Col. Orange x Jonathan	29	14	28	41	17	17	45	35	3	10	41	35	14	0	45	38	17
Delicious x "	14	21	14	51	14	0	7	57	36	7	58	7	28	7	43	43	7
Patten 1000 x "	9	45	11	22	22	0	0	33	67	11	0	22	67	33	44	11	11
Salome x "	14	7	21	36	36	0	0	50	50	0	7	43	50	14	14	50	22
N. Spy x "	5	20	20	60	0	0	20	60	20	0	40	40	20	0	0	80	20

Table 6c. Grade, Shape, Habit, and Branching of Trees in Harrington Progenies

Parentage	No. of trees	Percentage grade of tree				Percentage shape of tree				Percentage habit of tree				Percentage branching of tree			
		Very good	Good	Fair	Poor	Drooping	Spreading	Upright spreading	Upright	Open	Medium open	Medium thick	Thick	Very good	Good	Fair	Poor
Harrington	2			100			100					100				100	
Harrington x Ames 488	9	33	33	11	23	0	44	44	12	0	67	33	0	22	45	11	22
" x N. Spy	65	21	47	21	11	0	10	40	40	5	40	40	15	17	55	26	2
" x Ramsdell Sweet	22	5	14	54	27	0	18	55	27	0	41	36	23	5	50	26	18
Delicious x Harrington	19	16	16	47	21	0	21	37	42	11	10	53	21	11	26	37	26
R.I. Greening x "	77	13	46	25	16	0	9	53	38	0	21	39	34	4	39	37	20
Ramsdell Sweet x "	34	18	29	38	15	0	6	59	35	0	18	44	38	6	53	23	18

Table 7c. Grade, Shape, Habit, and Branching of Trees in Antonooka Progenies

Parentage	No. of trees	Percentage grade of tree				Percentage shape of tree				Percentage habit of tree				Percentage branching of tree			
		Very good	Good	Fair	Poor	Drooping	Spreading	Upright spreading	Upright	Open	Medium open	Medium thick	Thick	Very good	Good	Fair	Poor
Antonooka (parent)	2	100						100			100			100			
Antonooka x Ashton	54	72	19	7	2	0	46	48	6	11	41	20	28	9	63	28	0
" x Bl. Oxford	135	46	29	18	7	3	35	39	23	6	21	52	21	5	36	45	14
" x Delicious	353	57	25	12	6	1	27	45	27	5	30	37	28	12	46	35	7
" x Grimes	43	60	26	12	2	0	2	30	68	0	32	32	36	21	47	30	2
" x Jonathan	292	50	23	18	9	1	24	51	24	3	22	45	30	22	58	16	4
" x King David	75	53	28	16	3	0	9	44	47	1	13	35	51	49	32	19	0
Grimes x Antonooka	74	51	29	16	4	0	15	35	50	5	24	30	41	11	51	34	4
Jonathan x "	41	49	21	20	10	0	15	55	30	0	29	44	27	8	47	30	15

Table 8c. Grade, Shape, Habit, and Branching of Trees in Grimes Progenies

Parentage	No. of trees	Percentage grade of tree				Percentage shape of tree				Percentage habit of tree				Percentage branching of tree			
		Very Good	Good	Fair	Poor	Drooping	Spreading	Upright spreading	Upright	Open	Medium open	Medium thick	Thick	Very Good	Good	Fair	Poor
Grimes (parent)	3	100						100				100		100			
Grimes x Antonooka	74	51	29	16	4	0	15	35	50	5	24	30	41	11	51	34	4
" x N.W. Greening	13	53	39	8	0	0	23	77	0	8	32	22	38	85	15	0	0
" x W. Pippin	38	31	31	25	13	0	0	44	56	9	28	18	50	22	28	33	17
Antonooka x Grimes	43	60	26	12	2	0	2	30	68	0	32	32	36	21	47	30	2
Col. Orange x "	10	40	0	0	60	0	50	50	0	10	30	30	30	30	10	50	10
Nelson Sweet x "	47	10	25	44	21	0	8	46	46	2	12	23	63	4	35	49	12
N.W. Greening x "	65	31	29	26	14	0	24	43	33	5	25	52	18	7	31	48	14

Table 9c. Grade, Shape, Habit, and Branching of Trees in N. W. Greening Progenies

Parentage	No. of trees	Percentage grade of tree				Percentage shape of tree				Percentage habit of tree				Percentage branching of tree			
		Very good	Good	Fair	Poor	Drooping	Spreading	Upright spreading	Upright	Open	Medium open	Medium thick	Thick	Very good	Good	Fair	Poor
N. W. Greening (parent)	2	100						100			100					100	
" " x Delicious	99	26	24	26	24	1	9	51	39	5	38	36	21	0	23	53	24
" " x Grimes	65	31	29	26	14	0	24	43	33	5	25	52	18	7	31	48	14
" " x Harrington	77	12	48	25	15	0	9	53	38	6	21	39	34	4	39	37	20
" " x N. Spy	72	52	22	12	14	0	14	44	42	1	11	46	42	5	58	27	10
" " x Opalescent	12	41	17	17	25	0	33	33	34	8	42	33	17	9	33	25	33
" " x W. Pippin	22	36	36	19	9	0	9	36	55	0	27	32	41	0	45	50	5
Grimes x N.W.Greening	13	53	39	8	0	0	23	77	0	8	32	22	38	85	15	0	0

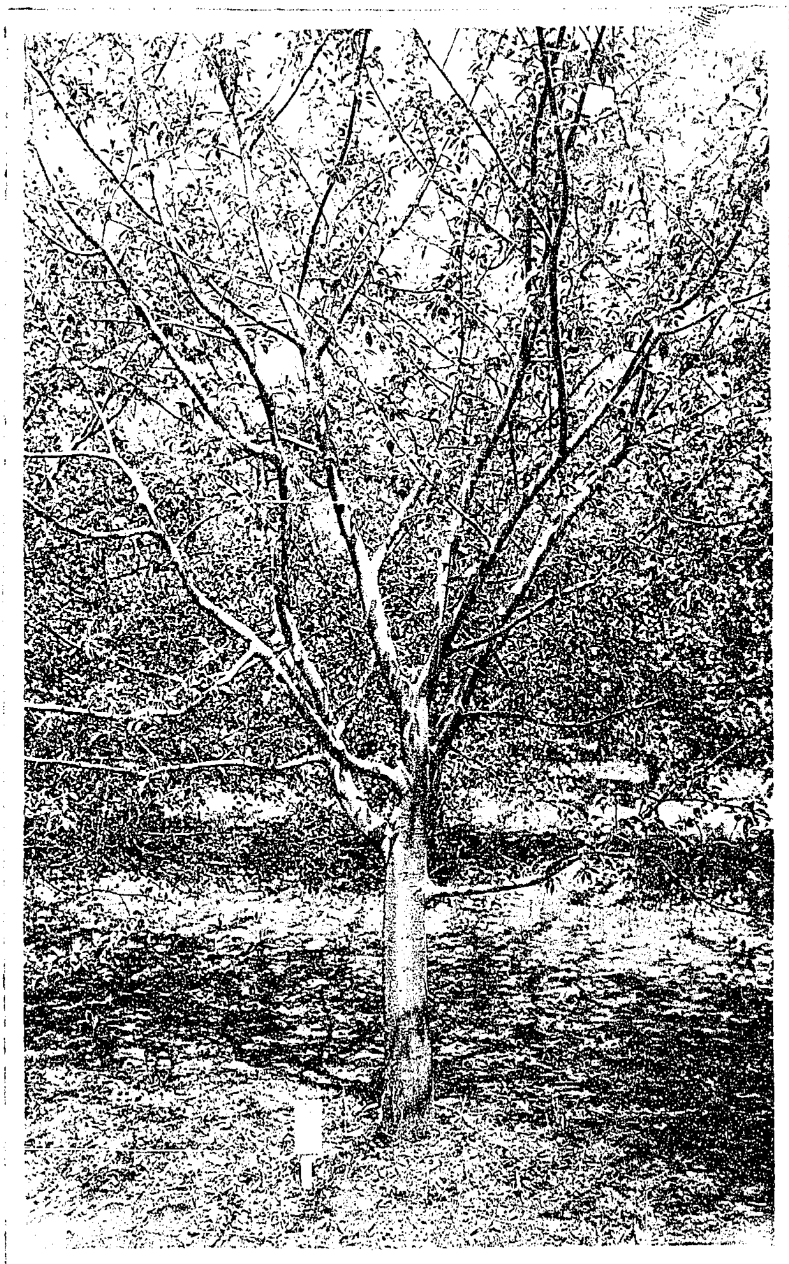

Plate VI. Antonovka X Ashton (40/15034). This progeny rated very high in trees of desirable grade. The tree here shown has an excellent framework and strong scaffold branches.

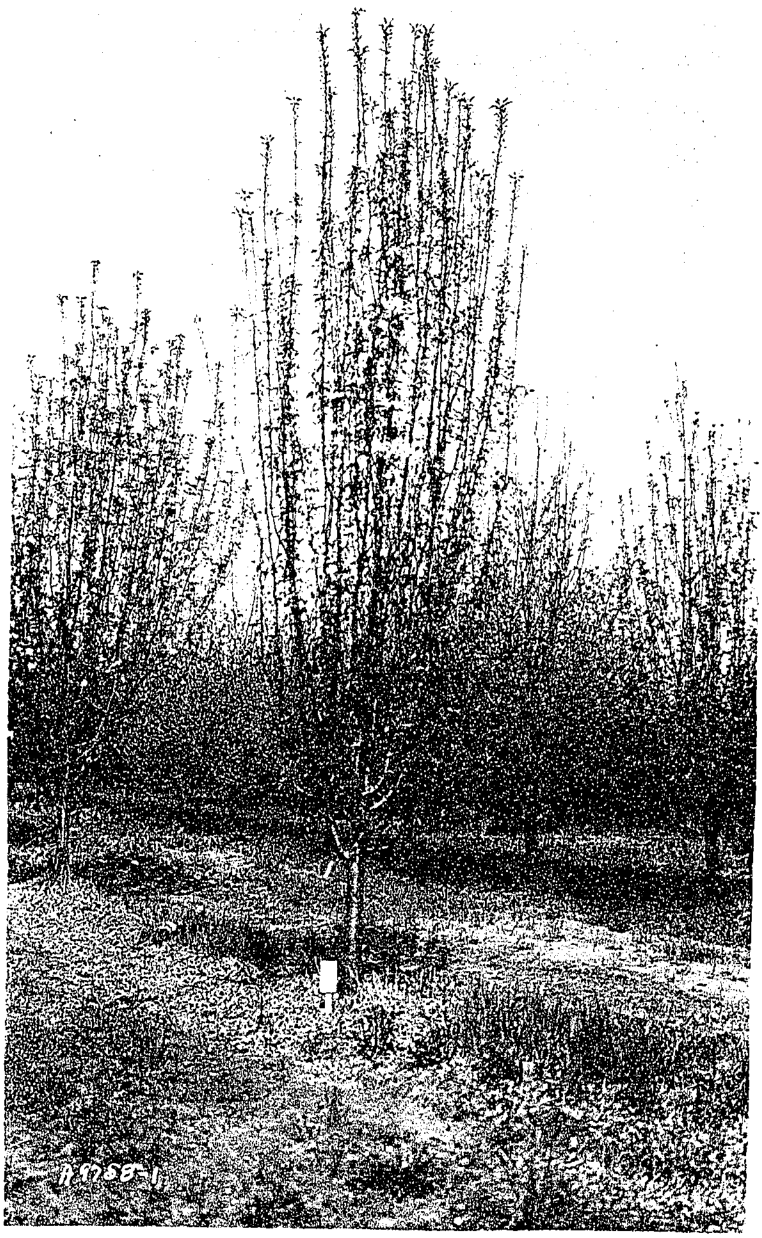

Plate VII. Patten 1000 X Ames 430 (15018).Patten 1000 is Roman Stem unguarded,and Ames 430 is Wealthy X Roman Stem.The progeny here shown is unusual in that nearly all of its trees are extremely upright in shape.

Plate VIII. Right:Patten 1000 × Ames 430 (15018).
Left :Patten 1001 × Grimes (15030).
Progeny at right has upright compact trees in contrast with the upright-spreading type at left.Branching is thick in both progenies.

Plate IX. Right: Harrington X Northern Spy (28/14855).
Left ; Harrington X Northern Spy (29/14855).
The tree to the right is upright, the one to the left is spreading. This progeny like most apple progenies has trees of all four shapes.

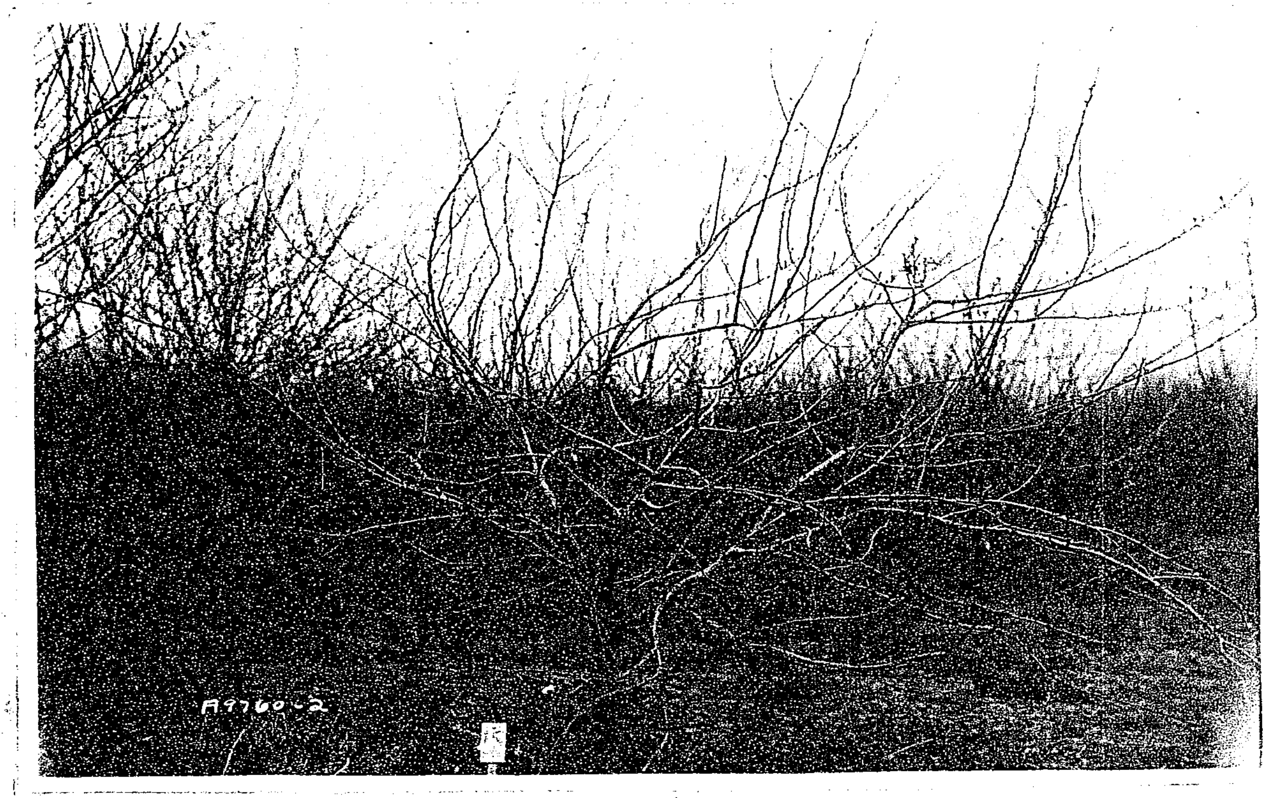

Plate X. Anisim X Delicious(238/14750). A poor tree with slender drooping branches and uncertain direction of growth.

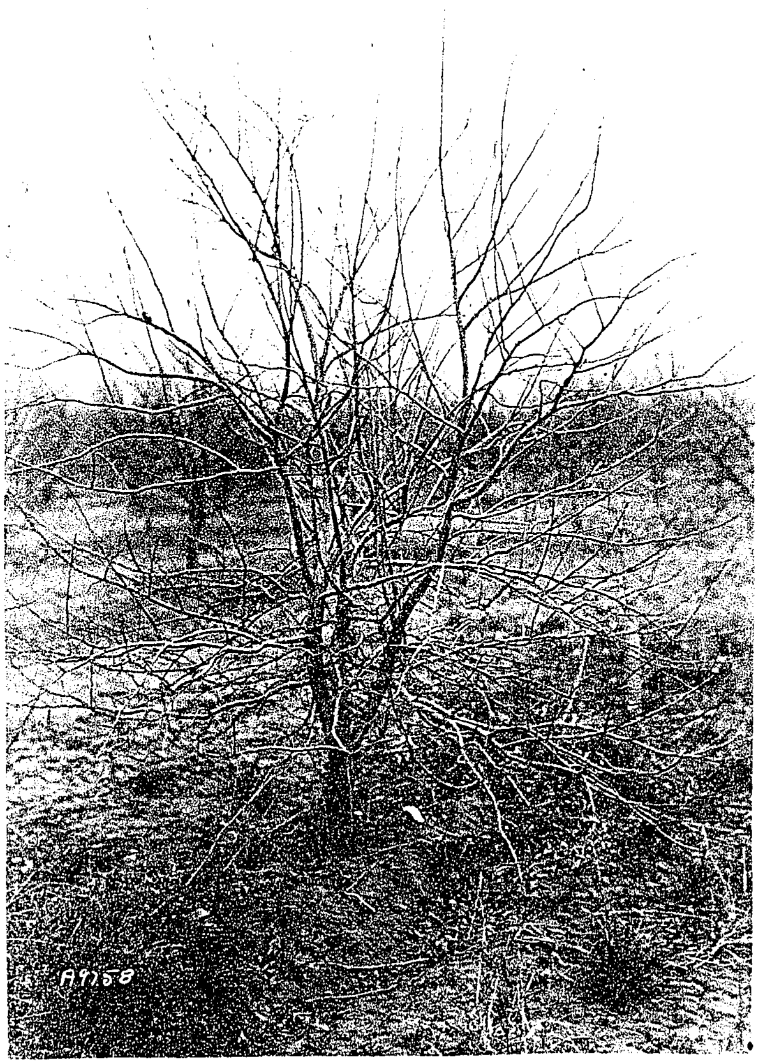

Plate XI. Ames 446 X Macy (15521). A poor type of tree with respect to shape, branching habit, and scaffold branches.

Plate XII. Jonathan X Delicious (20/14850). A very good grade of tree. It is upright-spreading in shape, with very good scaffold branches, and medium open in branching habit.

Plate XIII. Black Annette × Delicious (4/14905).
The trees in this progeny tend to have a thick habit of growth which fills the center with numerous small willowy branches.

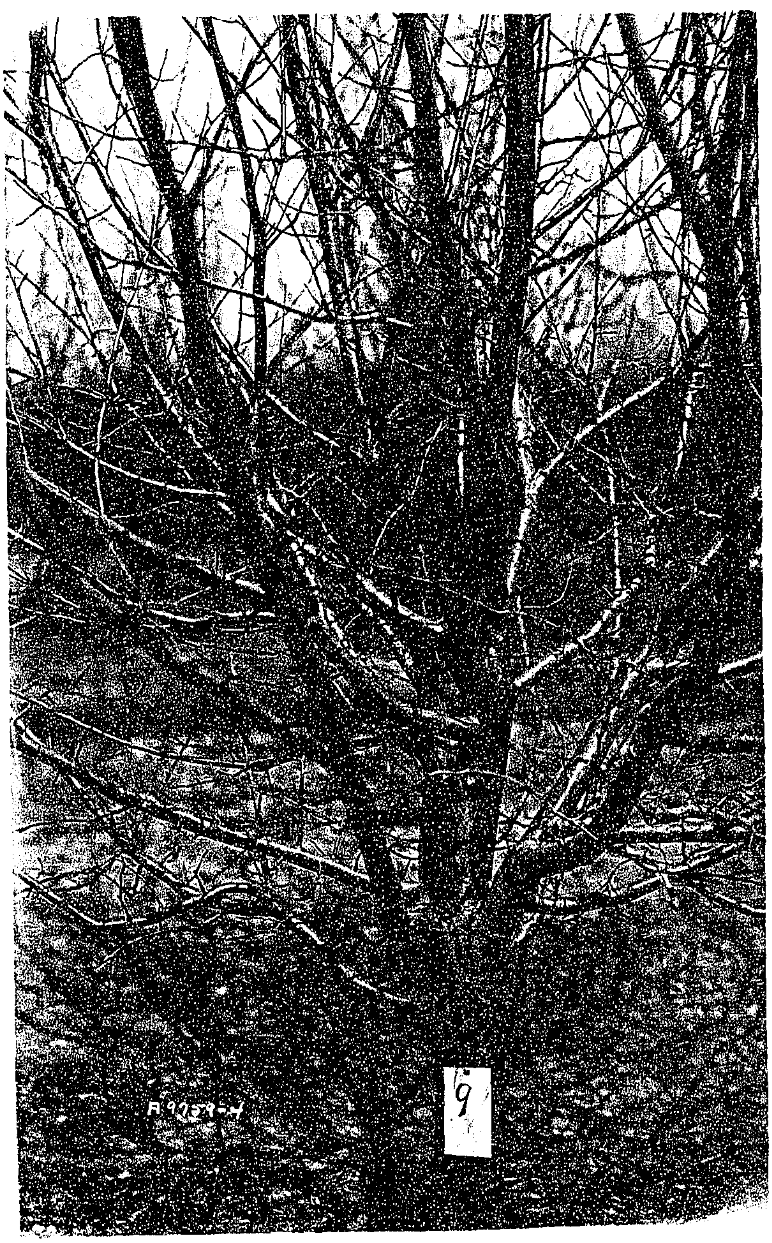

Plate XIV. Salome X Northern Spy (73/14852). A tree of fair grade. The scaffold branches are large but the crotch angles are narrow and undesirable. The central branches are too crowded.