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AN EXPERIMENT IN BREEDING APPLES

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*Riverhead, N. Y. †Absent on leave. ‡Connected with the Chautauqua Grape Work.

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AN EXPERIMENT IN BREEDING APPLES.

U. P. HEDRICK AND RICHARD WELLINGTON.

SUMMARY.

1. There have been few efforts to improve apples, nearly all varieties having come from chance seedlings. Under the knowledge and inspiration of recent discoveries in plant-breeding we ought to breed this fruit more advantageously than in the past. This bulletin is a record of an experiment in breeding apples in the light of the new knowledge.

2. Apples are improved only by the introduction of new varieties. These originate chiefly from cross-fertilized seeds. Possibly a few have arisen from self-fertilized seed and it is known that a very few sorts have come from sports or bud-mutations. It is very doubtful if apples can be improved by bud selection and the so-called "pedigreed" stock is probably worth no more than trees grown under general nursery practices.

3. The material for this experiment came from 148 crosses made in 1898 and 1899. Grafted trees of these crosses began to bear in 1904 and the seedlings came in fruiting in 1908. The crosses have been studied from both the grafts and seedlings, the orchards having had the care usually given commercial plantations.

4. The crosses which have fruited, with the number of each, are:

Ben Davis X Esopus	4
Ben Davis X Green Newtown	13
Ben Davis X Jonathan	11
Ben Davis X McIntosh	11
Ben Davis X Mother	20
Esopus X Ben Davis	29
Esopus X Jonathan	2
McIntosh X Lawver	1
Ralls X Northern Spy	9
Rome X Northern Spy	1
Sutton X Northen Spy	5

5. General considerations arising from the experiment are: 1. These crosses strikingly contradict the idea that seedling apples revert to the wild prototype. 2. The stimulus of hybridity is very marked in the vigor of the crosses under consideration. 3. The behavior of some of the crosses strongly suggests that apples may be prepotent in one or more of their characters.

6. The inheritance of a number of characters is discussed; namely, color of skin, color of flesh, shape, size and acidity.

7. In color of skin, the fruits in which yellow predominates over red seem from the data in hand to be in a heterozygous condition for yellow and red. The fruits in which red predominates are either homozygous or heterozygous. The pure yellows are homozygous.

8. The data are not at all conclusive as to color of flesh but suggest very strongly that Ben Davis and McIntosh, crosses of which gave the best opportunity of studying color of flesh, both carry yellow and white, the white being recessive.

9. Establishing the laws of inheritance of size and shape in apples promises to be a most difficult task, since these characters depend upon so many external as well as internal conditions. The data from these crosses favor the supposition that these characters are inherited practically as intermediates.

10. The study of the inheritance of sweetness and sourness is based wholly upon crosses of sub-acid varieties. The fact that sweet apples appear in nearly all of the crosses is significant. The crosses are so few that the exact 3:1 ratio could hardly be expected in all cases, yet the total progeny indicates strongly that crosses of these sub-acid varieties break up in the proportion of three sour apples to one sweet one.

11. The following is a summary of the inheritance of the characters discussed, in the several varieties:

Ben Davis does not carry yellow; in transmitting shape it is less prepotent than either Green Newtown or Jonathan; as a rule its crosses are intermediate in size; sweetness is carried as a recessive.

Esopus probably carries yellow skin color; shape is intermediate in its progeny; the variable size of its progeny indicates that at least one of its recent ancestors was small; sweetness is carried as a recessive.

Green Newtown possibly carries a red unit factor; the distinctive oblique shape of this variety is prepotent in crosses with Ben Davis; the progenitors of Newtown probably bore large fruits; sweetness is recessive.

Jonathan carries only red skin color; it is more prepotent than Ben Davis in the transmission of shape; sweetness is recessive.

Lawver entered into too few individuals for even rough assumptions.

McIntosh seems to carry both red and yellow skin colors; the white flesh of the McIntosh behaved as a recessive to the yellowish-white color of the Ben Davis; in shape as many progeny of Ben Davis crossed with McIntosh resembled one parent as the other and all were intermediate in size; the ratio of two sweet to nine sub-acid apples supports previous statements that sweetness is recessive.

Mother probably does not carry yellow; shape and size seem to be inherited as intermediates; sweetness is inherited in 2:3 instead of 1:3 proportions.

Northern Spy carries red and yellow skin color; shape seems to be transmitted as an intermediate; its gametes carry large and small size; this variety does not carry sweetness.

Ralls probably does not carry yellow; is more prepotent in transmitting shape-determining factors than Northern Spy in the cross with this variety; the variability in size of its crossed progeny is so great as to suggest that among its recent parents were large and small-fruited apples; it seems not to carry sweetness.

Rome entered into but one individual, hence nothing can be said as to the inheritance of its characters.

Sutton probably carries yellow; it is less prepotent as to shape than Northern Spy; its crosses did not give small fruits; it did not carry sweetness.

12. The following is the disposition of the crosses as to propagation: From the eleven Ben Davis X Jonathan crosses, one is marked for propagation, four for further testing and six for discarding. Ben Davis X Mother gave two seedlings worthy of propagation and eighteen for discarding. Ben Davis X Esopus produced four worthless seedlings but the reciprocal cross contributed two worthy of propagation, one for future testing,

twenty-six for discarding. Ben Davis X McIntosh gave two desirable varieties, three for further testing and six for discarding. Ben Davis X Green Newtown gave four desirable varieties from thirteen seedlings. Esopus X Jonathan gave one for further testing, one for discarding and McIntosh X Lawver produced one individual which is still retained for further test. The Northern Spy crosses have done well, for Sutton X Northern Spy gave two worthy of propagation, three worthy of further testing and none for discarding. Ralls X Northern Spy produced one desirable variety, one worthy of further consideration and seven undesirables; and Rome X Northern Spy gave one of no special merit.

13. Varieties named, after counties in the State, described and distributed, are: Clinton, Cortland, Herkimer, Nassau, Onondaga, Oswego, Otsego, Rensselaer, Rockland, Saratoga, Schenectady, Schoharie, Tioga and Westchester.

14. The behavior of the crosses in this experiment gives some indications of how certain characters are transmitted when found in the varieties involved and forms a basis therefore, for breeding work with these varieties, and suggests, at least, how the characters discussed will behave in other varieties that may be used in breeding.

15. The chief difficulties in the application of Mendelian principles to the breeding of apples are likely to be: 1. The determination of the factors by which the various characters are transmitted. 2. Complications arising when a character skips a generation — does not appear in the F_1 generation. 3. It is possible that some characters may be linked together in transmission and that others will repel each other. 4. The bringing together of complementary characters may result in reversions and thus produce unexpected characters. 5. The breeder will not be able to obtain new characters by working with Mendelian characters nor augment those that exist if we possibly except size and vigor. 6. It will be necessary to work with large numbers of plants — difficult with apples. 7. Disappointments will often come from the attempt to work with fluctuating variations. 8. There is likely to be much confusion between "simple Mendelian characters" and "blending characters."

INTRODUCTION.

Apples have been cultivated for many centuries, yet there seem never to have been well-ordered efforts to improve this fruit. Of the three thousand or more varieties which have been described, nearly all, as their histories show, have come from chance seedlings. When one seeks to know what the raw material of our cultivated apples was, and how it has been fashioned into its present shape, he finds little but surmises. It is true that until recently — until the onrush of discoveries made by Mendel and his followers — plant breeding was little more than dallying in the by-ways of biological science; but there seems to have been no time when even what was passing as current coin in plant-breeding was used to any considerable extent in improving the apple or, for that matter, any tree fruit. Not only has there been apathy, but error and laxity are more prominent than truth and exactness in the little work that has been done.

It is not strange that pomologists have been laggards while agriculturists, gardeners and florists have at least been working. For, as all can see, it is much more difficult to put the principles and methods of plant breeding in practice with fruits. Thus, with trees, much more time and money are required to secure results; the harvests have been and must ever be more meagre, for but comparatively few trees can be grown in breeding experiments; individuals have not taken up the work with fruits, because the pecuniary rewards have been small — in most cases nil; until recently there have been no public institutions having plant-breeding to do and these have been forced to work in the fields where the yields are most immediate; plant-breeding has been so changeable that it has been impossible to lay out a piece of work with fruits and complete the task as planned; lastly, such laws of breeding as we have had have been worked out for herbaceous plants and fruit growers have very generally believed that trees do not follow the same laws — a notion that crops out not infrequently in the scientific literature of the past.

We ought now, however, to be able to breed fruits much more advantageously than in the past. Under the ferment of Mendelian ideas a sufficient body of knowledge has been produced to enable plant breeders to shorten and improve their methods. The old feeling of uncertainty is largely gone, the limitations of breeding are better known, and the breeder can now take aim where before he shot at random. While his tasks, in many respects, are much more difficult than those of the farmer, florist and gardener, the breeder of fruits can take cheer in the fact that almost nothing has been done in his field and that he has practically a virgin soil to till.

The discoveries of the past ten years make a foundation for fruit-breeding but not much real building can be done until we have had more experience in handling the material. With the apple, in particular, because of the time it takes to obtain results, a decade at the very least, it is important that workers give to their fellow-workmen the results of experiments as rapidly as precise and accurate information, be it ever so slight, is obtained. It is with the hope of adding a little to the small store of apple-breeding knowledge now in existence that we are reporting at this time on an experiment in crossing apples at the Geneva Station. Though the experiment has been running fourteen years, this is still but a preliminary report.

Before noting the behavior of the crosses to be discussed, it seems necessary to give brief consideration to the origin of varieties of apples.

THE ORIGIN OF VARIETIES OF APPLES.

Apples, as we shall try to show later, are improved only by the introduction of new varieties. That is, there is no evidence to lead one to suppose that varieties are ever changed for better or worse by selection or degeneration as cumulative processes. Strains, or possibly varieties, rarely arise by selecting bud-mutations but no one as yet has demonstrated that by continuous selection new characters can be developed in apples. It, therefore, becomes highly imporant that we know how varieties of apples originate. Fortunately, data are at hand upon which it seems safe to generalize. *The Apples of New York*[1] gives all that can be learned of the histories of 698 standard sorts of this fruit. How have these come into existence?

1 Beach, S. A. *The Apples of New York*. N. Y. Agrl. Ex. Sta. 1905

Data from The Apples of New York.— No case is recorded in this work of a variety known to have come from a self-fertilized seed.

The seed parent is given for 39 varieties, probably accurate data for it would be most natural for a man growing seedling apples to keep a record of the seed parent if he knew it.

The seed and pollen parents of but one of the 698 apples under consideration are certainly known; the one is the Ontario. Parents are named for the Pewaukee and Gideon, but in each case one of the parents was guessed.

Four varieties are said to have come from sports or bud-mutations.

Sorts from seeds sown without knowledge of either parent and from natural seedlings are put down as chance seedlings; of these there are 71.

The origin of 517 of the 698 varieties is unknown. Among these "unknowns" are many of the best commercial and home apples.

A discussion of this data should give some idea of the past and the present status of apple-breeding.

Varieties from self-fertilized seed.— That none of the varieties of apples grown in America, many of which came from Europe, however, are known to have come from self-fertilized seed is a surprising fact. Either the few men who have tried to produce new varieties of apples have not "selfed" seed, or if such seeds have been produced, the resulting trees have been worthless. There are no records of attempts to obtain varieties of this fruit through self-fertilization. Though some of the chance seedlings or some of those of unknown origin may have so originated, it is not likely, for two reasons, that many have. As is well known, the apple is partially self-sterile, the blossoms of most varieties being much more receptive to pollen from other sorts than to their own. As contributory evidence to this preference for cross-pollination, it may be stated here, although the facts will be set forth more fully later in the text, that it seems almost impossible to obtain self-fertilized seed from the crossed trees of which this bulletin is a record.

A second reason for assuming that few varieties of apples come from self-fertilized seed, is that the apple, in common with many plants, loses vigor under self-fertilization and new varieties are not likely to be selected from feeble seedlings. When cross-fertilization is preferred by a plant, it may, generally speaking, be assumed that the offspring of self-fertilized seed will be wanting in vigor, size and fertility. Two experiences with inbred apples at this Station, while the number of trees involved is too small to give the experiments much weight, are suggestive as to the effects of inbreeding apples.

One of these lots of trees consists of four seedlings from Hubbardston self-pollinated, which are and always have been, with the best of care, but weaklings. None of these bore fruit until in their fourteenth season and then two of them matured one apple each. These Hubbardston seedlings are growing in the same block under the same treatment as the crosses to be discussed, which are wonderfully vigorous and productive. The weakness and sterility of the selfed seedlings are so striking that it should be counted as something more than a coincidence. The behavior of these Hubbardstons may be compared with that of the crosses in Table II, page 163. In 1907 several hundred Baldwin apple seeds taken from fruits in an orchard in which no other varieties were growing, were sown at this Station and though there was a fair germination but 27 rather weak plants survive — the others having succumbed to damping-off fungi, droughts and cold. In the many different batches of apple seedlings grown at this Station during the past six years, none have shown such lack of vigor as these selfed Baldwins.

From the fact that offspring of self-fertilized seeds have played so small a part in the origination of varieties, and because of the known consequences of close interbreeding, the use of selfed seed does not promise much in breeding apples.

Varieties from cross-fertilized seeds.—Although the data given show that but one named variety is certainly known to be the result of a cross, yet in spite of lack of exact knowledge it seems certain that nearly all varieties of apples are crosses, because, as has just been stated, apples normally prefer cross-pollination; and selfed seedlings lack vigor and would largely be weeded out through selection. The experiment in hand has to do only with crossed apples and the behavior of these trees, since we have almost no data from the past regarding crossed apples, should be of especial interest to apple growers and breeders.

If it be true that the apple is to be chiefly improved by crossing, apple breeding becomes a comparatively simple though not necessarily an easy matter. The blossoms are readily interpollinated, the seeds grow as readily as those of vegetables or flowers, and there remains but to select the tree of promise and to propagate it. A little manual skill, knowledge of what exists and of what is wanted in varieties of apples, patience and time, with land to grow large numbers of seedlings, added to definite knowledge of the laws of plant breeding, seem to be the requisites for breeding apples by crossing.

Varieties of apples from mutations.— Four varieties in *The Apples of New York,* are said to have come from sports. These are: Olympia, Banks, Collamer and Red Russet.

The evidence regarding these varieties needs to be examined critically. Olympia was sent out as a " sport from the Baldwin," an " improved Baldwin." Four trees in a Baldwin orchard near Olympia, Washington, produced larger and better colored fruits than the neighboring plants. Cions seems to reproduce the large size and high color, and the novelty was called the Olympia. At this Station, the Olympia from cions taken from trees grown from the originals, is the Baldwin. We are led to conclude that the variation in the trees in Washington was due to some unusual environmental condition and that there is no ground for calling it a " sport," a " mutation," or a new variety.

Banks is given as a bud-mutation of Gravenstein differing from its parent in being bright red, less ribbed, more regular in shape and a little smaller. This variation appeared on a branch of a Gravenstein tree in the orchard of C. E. Banks, Berwick, Nova Scotia, and is now widely grown about the place of its origin. Gravenstein seems to be productive of red variations, Oberdieck[1], Gaucher[2] and Leroy[3] having described variations similar to Banks in Europe. More recently another one

[1] Oberdieck, Deut. Obst. Sort. 1881.
[2] Gaucher, Pom. Prak. Obst. 1894.
[3] Leroy, Dict. Pom. 1877.

has appeared in Washington quite as distinct as Banks but similar to it.[1]

Collamer is a bud-mutation from Twenty Ounce found in the orchard of J. B. Collamer, Hilton, New York, sometime previous to 1900 in which year its propagation was begun. Collamer differs from Twenty Ounce in bearing fruits more highly colored, less mottled and striped, and more regular in shape. The trees differ only in having twigs in the mutation more deeply tinged with red. Mr. Grant Hitchings of South Onondaga, New York, has another red bud-mutation from Twenty Ounce, but so far no one has grown the Collamer and Hitchings sports under conditions that would warrant making a distinction between them.

Red Russet is a well known bud-mutation of the Baldwin, having appeared on a tree at Hampton Falls, New Hampshire, about 1840. Instances are known in which both smooth and russeted Baldwins are borne on the same tree. It is an interesting fact that the Baldwin, the most largely cultivated apple on this continent and under cultivation for at least 170 years, has given but this one authentic variation and that by a bud-mutation — no permanent selections having been made from the many fluctuating variations.

The study of these 698 varieties gives no evidence of seed-mutations in apples, and it seems to show that bud-mutations have so far played a very small part in bringing into existence varieties of apples. The few varieties known to have come from bud-mutations differ from the sorts from which they sprang in so few particulars — chiefly in color — that it can be but doubtfully said that new varieties so originate. Would it not be better to call them strains or races?

Deviations from the type which can be perpetuated as a new race or variety of apples are exceedingly rare. In this fruit, so far as they have been studied, they represent only modifica-

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1 "In an orchard owned by Van Sent & Wipple on Orcas Island, San Juan County, Washington, are fifty Gravenstein trees which have been bearing about ten years. On one of these, starting from the main trunk and about three feet from the ground, is a limb which from the time the tree commenced to bear, has produced beautiful red apples. We call the apple the Red Gravenstein, because it has the Gravenstein flavor, the Gravenstein shape, the Gravenstein core, and ripens at about the same time. In fact it is a Gravenstein in every way except color." *From a circular sent out by the Vineland Nursery Company, Clarkston, Washington,* 1911.

tions of existing characters. Of course, even so, they may furnish material for improvement, slight though it be. When a variation is found in an apple tree there must always be the question as to whether it is transmissible or merely a fluctuation due to the environment of the plant which will disappear with a change in the environment. We are wholly ignorant of the causes or of the conditions which give rise to mutations, although one may now hear provisional whispers as to how they originate. Their exceeding rarity as compared with the countless number of variations which are not transmitted through heredity, shows that varieties of apples, as of other fruits and most other plants propagated from vegetative parts, are wonderfully stable and practically continuous. This brings us to the subject of improving apples by bud-selection.

IMPROVING APPLES BY BUD-SELECTION.

The idea is current among experiment station workers, nurserymen and fruit growers that the apple, and other fruits as well, can be improved by bud-selection. It is held that the variations in fruit, tree, productiveness, vigor and hardiness to be found in varieties of fruit, can be reproduced by taking cions or buds from the plants possessing the variations. A number of fruit growers and nurserymen are putting this theory in practice and trees are now offered for sale with a "pedigree" to show that they came from known, good ancestry.

A study of the varieties of apples, grapes and plums[1] now grown gives no evidence, whatever, that any sort of these fruits has come into existence by continuous selection; that any variety has been improved, or that any variety has degenerated through the cumulative action of natural or artificial selection. No precise experimental evidence has been offered to prove that varieties of fruit can be changed in the least by continuous bud-selection. The trend of scientific thought is now overwhelmingly against the transmission of acquired characters, as most variations seem to be, and against continuous selection as a process of improving or changing plants grown from seeds, and would, if directed to bud-selection, be much more against this supposed means of improving plants.

1 The histories of the best known varieties of these three fruits, so far as they can be learned, are given in the books on these fruits published by this Station.

The variability to be seen in all varieties of apples is due to changing environment — if we except the rare bud-mutations the causes of which are not known. Environmental changes produce manifold modifications in many of the characters of individual apple trees but there is nothing to show that such changes have any effects on varietal characters. These fluctuating variations appear when individuals of a variety have different environments; with a return to the same environment, they disappear. A Baldwin taken from New York to Virginia produces an apple different from the New York Baldwin; taken to Missouri, the Baldwin is still different; taken to Oregon, it is unlike any of the others. If trees are brought back from these states to New York, they become again New York Baldwins.

This discussion of variations, of necessity brief and primary, cannot be dismissed without calling attention to the great importance of further knowledge as to the origin and behavior of bud-mutations, the "sports" of the orchardist. The discovery of their origin, how to produce them, how to control them, might hasten immeasurably the progress of fruit-breeding. Are they the result of intrinsic or of extrinsic influences? If the former, we can only continue to search for them, taking what Nature chooses to give; but if they can be induced by extrinsic agencies, we might do much with them in improving fruits — in making plants evolve.

AN EXPERIMENT IN CROSSING APPLES.

The foregoing introduction prepares the way for the account of an experiment which now follows by calling attention: 1st. To the fact there has been little effort made so far to improve apples. 2d. That the apple has been, and probably can be, improved only by the introduction of new varieties. 3d. That while there is but little knowledge as to how varieties of apples have originated, yet it is probable that most of them have come from crossing varieties and that, therefore, hybridization is the best means of obtaining new varieties of apples and of improving this fruit.

The first task in discussing the experiment in hand, is to describe the material and the way it has been handled. This is done at some length, with the feeling that in the present state of fruit-breeding we need to know the manual of arms quite as much as the principles of war.

The material.— The material of the following discussion comes from 125 apple crosses growing on the grounds of the Geneva Station. The original number of seedlings was 148 of which 46 grew from crosses made at the Station in 1898 and 102 from crosses made in 1899, the comparatively small number of 23 having fallen by the wayside from seed-pan to fruiting age. The seedlings were grown in the greenhouse from plantings made the first year in March and the second year in February, the seeds having been stratified during the winter. The young trees were transplanted to nursery rows in the open as soon as weather permitted. Of the 125 crosses, but 106 have so far fruited.

Method of crossing.—A description of the method of crossing now in use, much the same when these crosses were made, may be of interest to fruit growers who have never performed the operation. The blossom of the apple, of course, needs no description other than to say it is a hermaphrodite — that is, both male and female organs are found in the same flower. In crossing, young flowers are chosen, on the plant selected as female parent, in which the anthers have not yet opened. The stamens bearing the anthers are removed with a sharp scalpel or small forceps. A few days later the stigma is pollinated with pollen from a flower of the plant selected to be the male parent. Accuracy is safeguarded by taking the pollen from a flower which has been protected by a paper bag. The treated flower is then enclosed in a paper bag to protect it from other pollen until seeds have set. After a week or two the paper bag is removed and one of cheesecloth substituted to remain as protection for the fruit until harvest. The greatest care must be exercised in making different crosses to have fingers and tools sterile, probably best accomplished by the use of alcohol before each operation. The pollinating should be done on a bright, sunny day.

Management of the trees in this experiment.— In the spring of 1901, under the direction of Professor S. A. Beach, then in charge of horticulture at this Station, the crosses were all top-worked in bearing trees in a variety orchard. These grafts began bearing in 1904 and have continued to come into bearing until the present year, all now living having borne some fruit. The grafting of the seedlings on bearing trees to hasten the production of fruit was very unsatisfactory and in breeding tree fruits at Geneva now we do not graft. The objections are several: Some of the grafts do not take, others are blown out, others blight, and insects, plant lice in particular, have a propensity for devouring grafts as the choicest morsels to be found in a tree. The chief objection to this method is, however, that one learns little or nothing in regard to tree characters that is reliable — indispensable data for full knowledge of a cross either for scientific or for practical purposes. Lastly, it is "confusion worse confounded" to work with trees bearing several varieties of fruit because of the disorder in pruning, self-pollinating and harvesting.

Fortunately the seedling trees were left in the nursery rows after grafting wood had been removed. Here the writer found them in 1905, rather stunted from much crowding in the row, but still healthy, vigorous plants. In the spring of 1906 these trees were planted at distances of 8 feet in rows 8 feet apart where they are now standing. The first apples were borne in 1908, a few only of the crosses setting fruit. The plantation came into bearing very slowly and in June, 1910, the trees were all ringed with the result that all but 17 of the trees were fruitful in 1911. The 17 laggards are trees which either bore very heavily the preceding year, or had but a sprinkling of fruit which was blown off by one or another of two gales; or, as in the case of at least three trees, ill health and weakness may be the cause of nonfruiting.

Until 1911 the young trees were plowed and cultivated about as are commercial orchards in western New York. The tops of the trees were so interlaced in 1911 that team work in the orchard was stopped. To take the place of cultivation, a heavy mulch of straw manure was applied this year. The plantation has had the usual treatment for San José scale, apple scab and codling-moth. The pruning has been very light from the start — only crossed and dead branches having been removed in any season.

In this and in other experiments it has been found that ringing in June, taking out a section of bark an inch wide, a foot or thereabouts from the ground, seems to be a satisfactory method of hastening the bearing of apple trees. The operation with these trees brought about the desired result and with no perceptible abnormality in tree or fruit.

Difficulty in securing a second generation.— In this experiment we have to deal, it is to be regretted, with only the first generation of hybrid offspring. This brings us to a difficulty we have had in working with these young trees. The great desirability of having the second generation has been recognized from the start and for several years efforts have been made to get selfed seeds from these crosses,— with the result that we have scarcely a score of their offspring. The maledictions of some demon seem to have been showered upon the selfing of these crosses in the shape of accidents, bad weather and holidays at critical times. But beside these fortuitous obstacles, it seems certain that it is rather more difficult to self blossoms on young, vigorous, floriferous apple trees than it is on older plants. One of the great difficulties in Mendelian work with apples, and other tree fruits, will be to obtain the second generation in sufficiently large numbers to give results than can be relied upon.

The crosses.— The crosses, with the number of each, are:—

Ben Davis X Esopus	4
Ben Davis X Green Newtown	13
Ben Davis X Jonathan	11
Ben Davis X McIntosh	11
Ben Davis X Mother	20
Esopus X Ben Davis	29
Esopus X Jonathan	2
McIntosh X Lawver	1
Ralls X Northern Spy	9
Rome X Northern Spy	1
Sutton X Northern Spy	5

DESCRIPTION OF THE CROSSES.

The following is a tabulated description of the characters studied in these crosses. Unfortunately trees of the parents of the same age as the crosses were not available. The size and shape of the fruits of the parents and of the progeny can be compared in the plates. Those not familiar with the parents, all common varieties, can find full descriptions of them in *The Apples of New York*. Detailed descriptions of the newly named varieties are given on pages 177–184.

The abbreviations used in the table are as follows:

Shape of tree.— d, drooping; s, spreading; u, upright.

Form.— c, conical; o, oblate; ob, oblong; ov, ovate; r, roundish.

Color.— b, blush; c, carmine; d, dark; g, green; l, light; r, red; s, striped; y, yellow.

Flavor.— a, acid; s, sweet; sa, subacid.

TABLE I.—DESCRIPTION OF THE CROSSES IN APPLE BREEDING EXPERIMENT.

Number.	Cross.	Height of tree.	Diameter of trunk.	Shape of tree.	Pounds of fruit in 1911.	Length of apples.	Width of apples.	Shape of apples.	Color of fruit.	Flavor.	Season.	Remarks.
		Feet	*Inches*			*Inches*	*Inches*					
18	Ben Davis × Jonathan.....	10	3.25	u. s.	79	2.06	2.62	o. c.	r. s.	sa.	Dec.–Feb.	Resembles Jonathan in shape, color and flesh characters.
19	Ben Davis × Jonathan.....	10	3.06	u. s.	80	2.25	2.62	o. c.	d. r.	s.	Nov.–Jan.	Resembles Jonathan in shape, size and flesh, but much darker in color.
20	Ben Davis × Jonathan.....	12	3.13	d.	88	2.31	2.75	o. c.	y. b.	sa.	Dec.–Mar.	Fruit resembles Jonathan more than Ben Davis.
21	Ben Davis × Jonathan.....	11	3.62	d.	109	2.56	2.50	ob. c.	d. r. s.	sa.	Dec.–Mar.	Resembles Ben Davis externally and internally, but more highly colored.
22	Ben Davis × Jonathan.....	11	2.94	u. s.	30	2.31	2.62	r. tr.	d. r.	sa.	Nov.–Feb.	Of the Jonathan type, but darker in color and inferior in flavor.
23	Ben Davis × Jonathan.....	10	3.	s.	40	2.31	2.87	o. c.	r. s.	sa.	Dec.–Feb.	In shape like Jonathan, but larger and more conic, with Ben Davis color.
24	Ben Davis × Jonathan.....	10	3.25	u. s.	94	2.	2.50	r. o.	d. r.	sa.	Dec.–Feb.	Of the Jonathan type, though smaller.
25	Ben Davis × Jonathan.....	10	3.13	u. s.	47	2.25	2.62	r. o. c.	d. r.	s.	Dec.–Mar.	Resembles Jonathan but is more conic, much inferior in flavor.
26	Ben Davis × Jonathan.....	9	3.75	s.	70	2.50	2.69	r. ob. c.	y. b. r.	sa.	Jan.–Mar.	Externally like Ben Davis; flesh like Jonathan; inferior in flavor.
27	Ben Davis × Jonathan.....	12	3.87	u.	39	2.31	2.75	r. o. c.	d. r.	sa.	Nov.–Feb.	Of the Jonathan type both externally and internally, but more highly colored.
28	Ben Davis × Jonathan.....	10	3.50	s.	65	2.62	2.75	r. c.	y. b. r. s.	sa.	Dec.–Feb.	Resembles Jonathan externally and internally. Named Rensselaer.
40	Ben Davis × Mother.......	10	3.06	u.	69	2.44	2.94	r. c.	d. r.	sa.	Nov.–Feb.	Resembles Ben Davis in shape; darker than parents in color.
41	Ben Davis × Mother.......	10	2.62	u.	40	2.31	2.69	r. c.	d. r.	s.	Nov.–Jan.	Resembles Mother in all characters excepting cavity and basin which are those of Ben Davis.
42	Ben Davis × Mother.......	7	2.31	s.	21	2.37	2.75	r. o. c.	d. r. s.	s.	Nov.–Jan.	Very similar to Mother.
43	Ben Davis × Mother.......	6	1.69	s. d.	2	2.69	2.75	r. c.	d. r.	sa.	Nov.–Jan.	Like Ben Davis in shape, but resembles Mother in color and flesh characters.

44	Ben Davis ×Mother.......	10	2.94	u. s.	45	2.50	2.56	r. c.	d. r. s.	sa.	Jan.–Apr.	Of the Mother type though more conic; quality very inferior.
45	Ben Davis ×Mother.......	8	2.94	s.	53	1.94	2.25	r. c.	r. s.	sa.	Dec.–Feb.	Resembles Ben Davis in color, shape and flesh, but is smaller.
46	Ben Davis ×Mother.......	10	3.25	u.	20	2.	2.50	r. c.	l. r. c.	s.	Dec.–Feb.	Intermediate between Mother and Ben Davis in shape; color of Mother.
47	Ben Davis ×Mother.......	8	3.19	u. s.	48	2.81	2.87	r. o.	d. r. s.	sa.	Nov.–Jan.	Resembles Mother in color, cavity, stem, flesh and shape.
48	Ben Davis ×Mother.......	9	2.94	s.	31	2.50	2.87	r. o.	d. r. c.	sa.	Nov.–Dec.	Shape, cavity, stem and color are those of Mother; flesh intermediate.
49	Ben Davis ×Mother.......	11	3.75	u.	92	2.37	2.50	r. c.	d. r. c.	s.	Nov.–Jan.	Shape that of Ben Davis; color and flesh that of Mother.
50	Ben Davis ×Mother.......	9	2.37	u. s.	20	2.50	2.87	r. c.	d. r. s.	s.	Dec.–Feb.	Size, shape and color of Ben Davis; cavity of Mother.
51	Ben Davis ×Mother.......	9	2.94	u.	70	2.31	2.62	r. ob. c.	r. s. c.	sa.	Dec.–Mar.	Type of Ben Davis in shape and color, though darker; flesh of Mother.
52	Ben Davis ×Mother.......	8	2.62	s. d.	47	2.75	2.87	r. ob. c.	r. s.	sa.	Nov.–Jan.	Type of Ben Davis externally and internally; more mottled in color.
53	Ben Davis ×Mother.......	8	2.62	s. d.	76	2.50	2.75	r. o. c.	r. s.	a.	Dec.–Mar.	Very similar in shape, color, flesh and flavor to Ben Davis, but smaller.
54	Ben Davis ×Mother.......	8	2.13	u. s.	19	2.25	2.87	o. c.	r. c.	s.	Dec.–Jan.	Of the Mother type except in taste, which is that of Ben Davis.
55	Ben Davis ×Mother.......	11	3.75	u. s.	6	2.06	2.62	o.	l. r.	s.	Jan.–Mar.	Shape of Mother, but cavity, color, flesh and stem all those of Ben Davis.
56	Ben Davis ×Mother.......	12	3.87	u.	64	2.94	3.25	r. c.	l. r. c.	sa.	Nov.–Jan.	Size, shape and flesh resemble Ben Davis. Named Schenectady.
57	Ben Davis ×Mother.......	9	3.13	u. s.	68	2.37	2.62	r. c.	r. s. c.	sa.	Dec.–Feb.	Type of Mother though brighter in color and with flavor of Ben Davis.
58	Ben Davis ×Mother.......	10	2.87	u. s.	33	2.19	2.75	r. o. c.	d. r. c.	s.	Nov.–Jan.	Intermediate between Ben Davis and Mother in shape; like Mother in other characters.
102	Sutton ×Northern Spy.....	12	3.50	u.	3	2.50	3.13	r. o. c.	y. d. b.	sa.	Dec.–Mar.	Like Spy in size, shape, flesh and flavor, but yellow in color.
103	Sutton ×Northern Spy.....	12	3.37	u.	1	2.62	3.	o. c.	d. r. s.	sa.	Dec.–Feb.	Like Spy in shape and color, but not flavor; red.
104	Sutton ×Northern Spy.....	10	3.31	u. s.	20	2.56	3.	r. o. c.	d. r.	sa.	Dec.–Mar.	Shape and size of Sutton; ribbed like Spy and flesh of Spy.
105	Sutton ×Northern Spy.....	11	3.37	u. s.	24	2.62	3.31	r. c.	d. r. s.	sa.	Dec.–Apr.	Resembles Spy in shape, flesh, flavor and size, but brighter in color. Named Oswego.
101	Rome ×Northern Spy.....	10	3.50	u. s.	91	2.31	2.94	r. o.	y. b.	sa.	Jan.–May	Resembles Rome in shape; flesh of Spy; unlike either in color.
92	Ralls ×Northern Spy......	11	3.19	u. s.	40	2.	2.56	o. c.	l. r.	sa.	Nov.–Feb.	Resembles Ralls more nearly than Spy in all characters.

TABLE I.—DESCRIPTION OF THE CROSSES IN APPLE BREEDING EXPERIMENT — *Continued.*

Number.	Cross.	Height of tree.	Diameter of trunk.	Shape of tree.	Pounds of fruit in 1911.	Length of apples.	Width of apples.	Shape of apples.	Color of fruit.	Flavor.	Season.	Remarks.
		Feet	*Inches*			*Inches*	*Inches*					
93	Ralls × Northern Spy......	10	2.75	u. s.	14	2.13	2.75	o.	d. r.	sa.	Dec.–Apr.	Resembles Ralls in all characters excepting shape, which is more like Spy.
94	Ralls × Northern Spy......	12	4.	u. s.	29	2.75	3.	r. ob. c.	d. r. s.	sa.	Nov.–Mar.	Of Northern Spy type, shape, color, flesh and flavor; named Schoharie.
95	Ralls × Northern Spy......	11	3.25	u. s.	21	2.31	2.62	o. c.	d. r.	sa.	Jan.–Apr.	Fruit resembles Ralls externally and internally.
96	Ralls × Northern Spy......	9	3.	u. s.	49	1.69	2.83	r. c.	y. b.	sa.	Dec.–Mar.	Type of Ralls in all characters.
97	Ralls × Northern Spy......	10	2.87	u. s.	50	2.25	2.56	r. c.	d. r. c.	sa.	Jan.–Apr.	Resembles Ralls but is more conic; ribbed like the Spy.
98	Ralls × Northern Spy......	9	2.06	u. s.	58	1.87	2.25	o. c.	r. s.	sa.	Jan.–Apr.	Resembles Ralls very closely but not as highly colored.
99	Ralls × Northern Spy......	10	3.25	u. s.	29	2.31	2.75	r. o. c.	r. s.	sa.	Dec.–Feb.	Resembles Northern Spy, though less ribbed and brighter in color.
100	Ralls × Northern Spy......	9	2.75	u.	32	1.31	2.50	o. c.	d. r.	sa.	Dec.–Mar.	Type of Ralls except in flavor, which is that of Spy.
1	Ben Davis × Esopus.......	10	3.25	u. s.	41	2.31	2.56	r. c.	d. r.	sa.	Dec.–Feb.	Type of Ben Davis, but duller and less striped in color.
2	Ben Davis × Esopus.......	11	3.06	u. s.	14	2.56	3.13	r. o. c.	d. r. b.	sa.	Dec.–Feb.	Resembles Esopus in shape, but has flesh of Ben Davis; unlike either in color.
3	Ben Davis × Esopus.......	10	3.25	u. s.	85	1.87	2.37	r. o.	y. d. b.	sa.	Dec.–Feb.	Like Esopus in shape, color and flesh characters. Smaller than either parent.
4	Ben Davis × Esopus.......	11	3.19	u. s.	54	2.87	2.87	ob. c.	t. r. e.	sa.	Dec.–Mar.	Resembles Ben Davis in size and shape, but Esopus in color and flesh.
29	Ben Davis × McIntosh.....	10	3.31	u. s.	85	2.25	2.87	o. c.	r. c.	sa	Dec.–Feb.	Like McIntosh in shape, but duller in color and has flesh of Ben Davis.
30	Ben Davis × McIntosh.....	10	3.25	u. s.	36	2.25	2.75	o. c.	r. s.	s.	Nov.–Feb.	Resembles McIntosh externally; Ben Davis internally.
31	Ben Davis × McIntosh.....	10	2.56	s. d.	43	2.50	2.81	r. c.	y. b. r.	sa.	Dec.–Mar.	In all characters more like Ben Davis than McIntosh.

32	Ben Davis × McIntosh.....	10	2.75	u. s.	10	2.	2.37	r. o. c.	d. r. s. c.	sa.	Nov.–Jan.	Resembles McIntosh outwardly and Ben Davis inwardly.
33	Ben Davis × McIntosh.....	12	3.50	u. s.	36	2.81	3.06	ob. c.	y. b.	s.	Oct.–Jan.	Has shape of Ben Davis, but the clear white flesh of McIntosh; yellow.
34	Ben Davis × McIntosh.....	8	2.75	d.	45	2.50	3.13	r. o.	d. r. s. c.	sa.	Nov.–Feb.	Very similar to McIntosh in all characters. Named Cortland.
35	Ben Davis × McIntosh.....	8	2.13	u.	3	2.37	2.75	r. c.	b. d. r.	sa.	Nov.–Jan.	Similar to McIntosh but more conic and flesh yellower. Named Onondaga.
36	Ben Davis × McIntosh.....	9	3.25	u.	67	2.25	2.75	r. o. c.	d. r.	sa.	Nov.–Feb.	Like McIntosh in shape and color, but resembles Ben Davis in cavity, basin and flesh.
37	Ben Davis × McIntosh.....	10	3.31	u. s.	68	2.13	2.31	r. ob. c.	d. r. s.	sa.	Nov.–Feb.	Like Ben Davis in shape and flesh, but has the color of McIntosh. Named Otsego.
38	Ben Davis × McIntosh.....	11	3.19	u. s.	12	2.56	2.87	r. c.	y. b.	sa.	Nov.–Mar.	Type of Ben Davis in shape, size and flesh; unlike either parent in color.
39	Ben Davis × McIntosh.....	10	2.81	u.	43	2.69	2.87	r. ob.	y. b. r.	sa.	Nov.–Jan.	Like Ben Davis in shape, but the McIntosh in flesh and flavor; unlike either in color.
5	Ben Davis × Gr. Newtown..	9	3.31	u. s.	75	2.25	2.94	r. o. c.	y. b. s. c.	sa.	Dec.–Feb.	In shape, size, flesh and flavor like Newtown; color similar to Ben Davis. Named Clinton.
6	Ben Davis × Gr. Newtown..	12	3.25	u.	36	2.06	2.75	o.	d. r.	s.	Nov.–Feb.	In shape like Green Newtown; in color and flesh like Ben Davis.
7	Ben Davis × Gr. Newtown..	12	3.	u. s.	57	2.62	2.87	o. c.	y. b.	sa.	Jan.–Apr.	In outward appearance like Newtown, but flesh like Ben Davis.
8	Ben Davis × Gr. Newtown..	12	3.25	u.	41	2.81	3.	r. c.	d. r.	sa.	Nov.–Jan.	Resembles Ben Davis in size, color, flesh, characters and flavor.
9	Ben Davis × Gr. Newtown..	12	3.50	u.	8	2.56	2.81	r. ob. c.	d. r.	s.	Jan.–Apr.	Resembles Ben Davis, darker in color and is sweet in flavor.
10	Ben Davis × Gr. Newtown..	10	3.	u. s.	23	2.	2.62	o. c.	d. r. s. c.	sa.	Dec.–Apr.	Resembles Newtown in all characters excepting color, which is more like Ben Davis.
11	Ben Davis × Gr. Newtown..	11	3.31	u.	25	2.50	2.87	r. o. c.	y. b.	sa.	Jan.–Apr.	Resembles Newtown outwardly and inwardly.
12	Ben Davis × Gr. Newtown..	10	3.06	u. s.	79	2.25	2.75	r. o.	y. b.	sa.	Jan.–Apr.	Resembles Newtown in all characters excepting flavor.
13	Ben Davis × Gr. Newtown..	11	3.62	u. s.	97	2.62	3.	r. c.	y. b. r.	sa.	Nov.–Jan.	Resembles Ben Davis in color and flesh, otherwise more like Newtown. Named Westchester.
14	Ben Davis × Gr. Newtown..	9	3.13	s.	64	2.56	3.	o. c.	d. r. s. c.	s.	Nov.–Jan	In shape, basin and flesh like Ben Davis; cavity like Newtown, color unlike either.
15	Ben Davis × Gr. Newtown..	12	3.75	u. s.	70	2.56	3.13	r. o. c.	b. r.	sa.	Jan.–Apr.	Resembles Ben Davis, but more oblate, more highly colored, better flavor. Named Saratoga.

TABLE I.—DESCRIPTION OF THE CROSSES IN APPLE BREEDING EXPERIMENT — *Concluded.*

Number.	Cross.	Height of tree.	Diameter of trunk.	Shape of tree.	Pounds of fruit in 1911.	Length of apples.	Width of apples.	Shape of apples.	Color of fruit.	Flavor.	Season.	Remarks.
		Feet	*Inches*			*Inches*	*Inches*					
16	Ben Davis × Gr. Newtown..	10	3.13	u. s.	50	2.25	2.75	r. o.	y. b. s. r.	sa.	Jan.–Mar.	Type of Newtown, but red.
60	Esopus × Ben Davis.......	11	3.19	u. s.	80	2.37	2.75	r. c.	l. r. s. c.	sa.	Dec.–Mar.	In shape, size and color like Esopus, with flesh of Ben Davis.
61	Esopus × Ben Davis.......	11	3.37	u. s.	43	2.31	2.50	ob. c.	d. r. s. c.	s.	Dec.–Mar.	Shape of Ben Davis, but the cavity, color and flesh like Esopus.
62	Esopus × Ben Davis.......	9	2.56	u.	2	1.87	2.56	o.	d. r. s.	sa.	Jan.–Mar.	Resembles Esopus more than Ben Davis in all characters.
63	Esopus × Ben Davis.......	13	3.87	u.	35	2.31	2.87	r. o. c.	d. r.	sa.	Dec.–Feb.	Resembles Esopus in all characters excepting flavor which is more like Ben Davis.
64	Esopus × Ben Davis.......	12	2.75	u.	9	2.50	2.94	r. c.	y. b.	a.	Nov.–Feb.	Like Ben Davis in shape, but Esopus in flesh characters; unlike either in color.
65	Esopus × Ben Davis.......	8	2.75	s. d.	6	2.75	2.25	o. c.	y. l. r.	s.	Nov.–Mar.	Unlike either parent in size, shape or color; flesh like Esopus.
66	Esopus × Ben Davis.......	11	3.25	u.	49	2.50	2.69	r. c.	d. r.	sa.	Dec.–Mar.	Type of Ben Davis, but more highly colored and more like Esopus in flavor.
67	Esopus × Ben Davis.......	10	3.	u. s.	55	2.62	2.75	r. ob. c.	d. r. s.	sa.	Nov.–Jan.	Very much like Ben Davis in all characters.
68	Esopus × Ben Davis.......	12	4.	u. s.	27	2.62	3.25	r. o.	y. b.	sa.	Jan.–Mar.	Much like Ben Davis in all characters, but more oblate.
69	Esopus × Ben Davis.......	....	....	....	1	2.25	2.62	r. o.	l. r. s.	s.	Nov.–Jan.	Resembles Esopus in color, cavity and flesh; like Ben Davis in shape.
70	Esopus × Ben Davis.......	7	2.06	u. s.	4	2.37	2.62	r. o. c.	y. b. l. r.	sa.	Nov.–Jan.	Like Ben Davis in shape, flesh; unlike either parent in color.
71	Esopus × Ben Davis.......	11	3.25	u. s.	69	2.62	2.62	r. c.	d r.	sa.	Dec.–Feb.	Like Ben Davis in all characters.
72	Esopus × Ben Davis.......	11	3.25	u. s.	42	2.87	2.50	r. c.	d. r.	sa.	Dec.–Mar.	Resembles Ben Davis in size and shape, but with color, cavity and flesh characters of Esopus.
73	Esopus × Ben Davis.......	10	3.75	u. s.	67	2.25	3.	o.	d. r.	sa.	Nov.–Jan.	Resembles Esopus in all characters excepting shape, which is intermediate.

74	Esopus × Ben Davis.......	9	1.75	u.	3	1.81	2.06	r. c.	y. b.	sa.	Jan.–Mar.	Resembles Esopus, but less well colored and smaller.
75	Esopus × Ben Davis.......	12	3.	u. s.	14	2.31	2.81	o. c.	r. s. c.	sa.	Dec.–Apr.	Of Ben Davis type externally; Esopus internally.
76	Esopus × Ben Davis.......	11	3.62	u. s.	74	2.06	2.37	a. c.	d. r.	sa.	Nov.–Mar.	Shape of Ben Davis, but smaller; color and flesh of Esopus.
77	Esopus × Ben Davis.......	12	2.62	u. s.	16	1.87	2.25	o. c.	d. r.	sa.	Jan.–Apr.	All characters resemble those of Esopus; smaller.
78	Esopus × Ben Davis.......	11	3.06	u. s.	30	2.06	2.50	ov. c.	b. r.	s.	Dec.–Mar.	Resembles Ben Davis in all characters; stem very long.
79	Esopus × Ben Davis.......	8	2.87	u.	56	2.50	2.87	r. o. c.	d. r.	sa.	Jan.–Apr.	Externally like Esopus; internally like Ben Davis.
80	Esopus × Ben Davis.......	10	3.06	s. d.	35	2.81	2.87	r. c.	d. r.	sa.	Dec.–Feb.	Shape, color and size like Ben Davis, but more conic; flesh and flavor that of Esopus.
81	Esopus × Ben Davis.......	7	2.37	s.	2	2.62	2.87	r. o. c.	y. b.	s.	Dec.–Feb.	All characters more like Esopus; ribbed and irregular.
82	Esopus × Ben Davis.......	10	2.50	u. s.	8	2.25	2.50	r. c.	d. r.	sa.	Dec.–Mar.	Characters like those of Esopus; smaller and darker in color.
83	Esopus × Ben Davis.......	10	2.87	u. s.	37	2.19	2.50	r. c.	y. b. r.	sa.	Dec.–Mar.	Outwardly like Ben Davis; inwardly like Esopus.
84	Esopus × Ben Davis.......	8	2.69	u.	23	2.	2.75	o. c.	d. r.	sa.	Jan.–Apr.	Characters those of Esopus, but smaller.
85	Esopus × Ben Davis.......	10	3.25	s. d.	9	2.62	3.	r. o. c.	d. r.	sa.	Dec.–Feb.	Like Esopus in shape, but in cavity, basin and flesh resembles Ben Davis.
86	Esopus × Ben Davis.......	8	2.50	s. d.	11	2.50	2.75	r. c.	d. r. s.	s.	Nov.–Jan.	In shape like Ben Davis; in color and flesh like Esopus; small and with poor flavor.
87	Esopus × Ben Davis.......	9	3.25	s. d.	6	2.50	2.62	r. c.	d. r.	s.	Nov.–Jan.	Shape, color and flesh like Esopus; basin and calyx resemble Ben Davis.
89	Esopus × Jonathan........	11	3.25	u. s.	18	2.25	2.69	o. c.	d. r.	sa.	Dec.–Mar.	Resembles Esopus in all characters.
90	Esopus × Jonathan........	10	2.62	u. s.	1	1.75	2.25	o.	d. r.	sa.	Dec.–Apr.	Resembles Esopus in all characters; smaller.
91	McIntosh × Lawver.......	10	4.	u. s.	85	2.13	2.81	r. o. c.	y. b. r.	sa.	Nov.–Feb.	Resembles McIntosh in all but color which is like Lawver, but more yellow.
59	Ben Davis × Mother.......	....	....	....	....	....	....	r. o.	d. r. s. c.	sa.	Nov.–Jan.	Resembles Ben Davis in all fruit characters excepting quality. Named Rockland.
106	Sutton × Northern Spy.....	....	....	....	....	2.75	2.13	o. c.	y. b.	sa.	Dec.–Mar.	Resembles Northern Spy except in color, being yellow. Named Tioga.
17	Ben Davis × Gr. Newtown..	...	....	....	....	......	....	r. ob. c.	r. s. c.	sa.	Dec.–Mar.	Resembles Ben Davis externally and internally. Named Herkimer.
88	Esopus × Ben Davis.......	....	....	....	....	....	....	o.	y. b. l. r.	sa.	Dec.–Mar.	Color of Ben Davis, shape of Esopus. Named Nassau.

GENERAL CONSIDERATIONS.

Reversions.—A striking contradiction to the idea handed down from a remote age that seedling apples "throw back" to the wild prototype and are almost always worthless and degenerate fruits, is brought out in these crosses. The belief in "reversion" is so strongly ingrained in the minds of fruit growers that the term "seedling" is usually one of condemnation. Reversion in the sweeping way it was formerly used, is, in the light of present knowledge, a very misleading term. Nothing is more apparent in examining the fruit and trees under consideration than that they have inherited the characters of their immediate parents. This is so markedly true that in the great majority of the offspring, one acquainted with the parents of the several crosses can from tree and fruit tell the two parents. Ben Davis and McIntosh, for example, show in all of the apples into which they entered. Reversions to remote ancestors may occur, so we are now taught, as the bringing together of complementary factors which had become separated from one another. Such reversions were not apparent in these trees. Contrary to "throwing back" to wild apples, these crosses, in tree or fruit, were quite the equal of any similar number of named varieties, a fact to which many fruit growers can attest, who in the summer of 1911 saw and admired the fruit and trees.

Vigor increased by hybridity.— The stimulus of hybridity seems to be very marked in the vigor of these crosses. In spite of over-crowding in the nursery row for two or three years these trees are exceptionally strong in growth. In the same block are a few selfed Hubbardstons which are much weaker in growth. On another part of the farm are selfed Baldwins also averaging much weaker. These may be but coincidences but the facts are set down for what they are worth. A study of the descriptions of the fruits and of the plates will show that in the majority of the crosses the apples average larger than in either parent. The trees, too, are remarkably productive, a fact brought out by the weights of fruit given in the tabular descriptions.

Table II contains data for the comparison of height of tree, diameter of trunk and quantity of fruit in 1912, from these crosses and from four selfed Hubbardstons. The number of trees in some of the progenies is too small to make the data very valuable but yet the figures are interesting and suggestive.

TABLE II.— AVERAGE HEIGHT OF TREE, DIAMETER OF TRUNKS, AND QUANTITY OF FRUIT.

CROSSES.	Number of trees.	Height of trees.	Diameter of trunks.	Quantity of fruit.
		Feet.	*Inches.*	*Pounds.*
Ben Davis × Esopus	4	10.5	3.1	48.5
Ben Davis × Green Newtown	13	10.8	3.2	50.4
Ben Davis × Jonathan	11	10.4	3.3	67.3
Ben Davis × McIntosh	11	9.8	2.9	40.7
Ben Davis × Mother	20	9.1	2.8	43.3
Esopus × Ben Davis	29	10.0	2.9	32.0
Esopus × Jonathan	2	10.5	2.9	9.5
McIntosh × Lawver	1	10.0	4.0	85.0
Ralls × Northern Spy	9	10.1	3.0	35.7
Rome × Northern Spy	1	10.0	3.5	91.0
Sutton × Northern Spy	5	11.2	3.3	12.0
Hubbardston (Selfed)	4	8.2	2.6	.5

Prepotency.— In the past, horticulturists, in common with breeders of other plants, and of animals as well, have designated certain individuals, varieties in the case of fruits, as "prepotent." Prepotency could be ascribed much more naturally to individuals before it was known that characters are quite independent in transmission, although there is still question in some quarters as to whether potency is a property of a unit character or of all the characters in an individual. Thus because of the great number of their named offspring we have commonly thought the Ben Davis, Fameuse, Oldenburg and Blue Pearmain, as examples, to be "prepotent." In the light of present information it is very doubtful if such prepotency exists in the sense of ability to impress all characters on the offspring.

It is generally agreed, though, that prepotency exists as to characters — that is, that there are marked variations in potency. Accepting this as a fact it must be conceded at once that a variety of apples may be prepotent in two or more characters which may be transmitted to the progeny quite independently of each other. If such be the case we should expect the offspring of some crosses of apples to resemble one parent more than the other. It would seem that in Ben Davis crosses, Ben Davis characters most largely crop out. The progeny in crosses with Ben Davis, more often than not, have a Ben Davis aspect. Whether this is due to prepotency in one or more characters or to the fact that most of the characters in Ben Davis are a little off the ordinary — particularly striking — and because of this distinctness dominate in the appearance of the Ben Davis crosses, cannot be said.

We cannot prove from the behavior of these crosses that the varieties of apples involved are prepotent in any of their characters, but such prepotency is strongly suggested. In breeding work with grapes, raspberries and strawberries on the Station grounds, where many times as many crosses and plants have been under observation, we are more certain that varieties are prepotent in some characters. Such, too, is thought to be the case by workers with other plants and it has long been held by breeders of animals that individuals were "prepotent," which, if true, in light of present knowledge, probably means that there was prepotency in one or more characters of the animals. Knowledge regarding prepotency is a great desideratum in apple-breeding. The improvement of this fruit will go on much more rapidly, if we can select varieties for crossing which have the desired characters in greatest potency.

MENDELIAN INHERITANCES IN APPLES.

No study of heredity at the present time is worthy the name unless it take in consideration the laws brought out by Mendel and his followers. By aid of these laws in this experiment we are enabled to focus ideas which otherwise would have been dim, to give value to facts which a few years ago would have been worthless, and to see clues running through the work which without Mendel's discovery would have remained hidden.

It had not been the intention to discuss Mendelian inheritance in these crosses until we could add the testimony of the F_2 generation. That time seems at the very least a decade off and it is thought best to see what, if anything, can be learned from the F_1 progeny. It must be remembered that since apples are propagated by budding or grafting, a variety always possesses its hereditary characters in the same state — a given character is permanently either homozygous or heterozygous. Therefore, the results obtained in these crosses are to be expected whenever the same varieties are crossed. Hence the F_2 generation is not so necessary in breeding apples as with plants grown from seed.

The reader must keep in mind, however, that there may be several explanations of the behavior of characters in the first generation following a cross and that the crucial test of whatever hypotheses are set forth as regards the characters in these hybrid apples is the behavior in the subsequent generations. Attention must be called, too, though scarcely necessary to one having knowledge of even the rudiments of genetics, to several sources of error in this experiment. Thus, the number of hybrid offspring of these crosses is so small that it is not probable that all of the possible combinations of the different kinds of germ cells are to be found even in the crosses having the largest progenies. Again, the work is vitiated somewhat by the fact that the total progenies of the several crosses have not been under observation, 23 out of 148 or about 15 per cent of the total number, having succumbed to the accidents which befall seedling plants, there being, however, no selection by the hand of man. Lastly, we are working with material of unknown parentage.

The characters of the apple chosen for consideration are those most important to apple growers; namely, color of skin, color of flesh, shape, size and acidity.

Color of skin.— The colors of apples may be roughly divided into five classes; yellow, yellow with a light red blush, yellow with one-third to one-half its surface overlaid with red, nearly solid red, and reddish black. The apples in these crosses contain only three colors, yellow, red and the intermediates between these. Whether the distribution of the intensity of color depends upon a complex or a simplex of unit characters, is at present impossible to determine. Unknown factors play too large a part to permit of an easy determination. Thus, we do not know exactly the nature of color; the amount of color in a variety depends largely upon the soil and the method of orchard management; and, we are working with material of unknown parentage. But if we can state roughly how the color is inherited in a few leading varieties, the knowledge should be of value for either identical or other crosses. From a study of all the material, we may hazard the following provisional statements:

First, the fruits in which yellow predominates over red are in a heterozygous condition for yellow and red; second, the fruits in which red predominates are either homozygous or heterozygous; third, the pure yellows are recessive and consequently are homozygous. These conclusions are drawn from the following data.

In the Ben Davis X Jonathan progeny,[1] we have eleven seedlings, all red or nearly red. The yellow portion of these apples is so meager as not to arouse suspicion of a heterozygous condition. The assumption that there is no yellow in Ben Davis or Jonathan is supported by the results in other crosses in which one of these varieties was a parent. If, however, red consists of a complex of unit characters — the very light red being the simple unit character and the dark red a multiple of red unit characters, then, of course, it is impossible to tell from these few individuals whether yellow is or is not a recessive in this cross. For example, red would have to consist of only three unit characters to require sixty-four individuals to give one yellow. It would not be surprising if the red color in apples consists of more than one unit for red, since in other plants color is often composed of more than one unit character. Thus, Nillson-Ehle[2] separated two distinct blacks in his study of the inheritance of black color in the glumes of oats, and three distinct, inheritable reds in a red Swedish wheat. East[3] found two yellow colors in the endosperm of yellow corn, "each behaving when crossed with its absence, as an independent allelomorphic pair." If one yellow in corn gives a light yellow appearance, it is not unreasonable to expect that one red in apples may give a very light red and a complex of red unit factors a dark red. The only method of determining this point is, of course, by segregating the unit factors in future generations.

1 The first name in all cases is the maternal parent and the second the paternal.

2 Nillson-Ehle, H., 1909, "Kreuzungsuntersuchungen an Hafer und Weizen," Lunds Universitets Arsskrigt, N. F.; Afd. 2, Bd. 5, Nr 2, 1–122.

3 East, E. M., 1910, "A Mendelian Interpretation of Variation that is Apparently Continuous", *Am. Nat.* **44**: 65–82.

In the Ben Davis X Mother apples there are seventeen apparently pure reds and three individuals evidently heterozygous for yellow and red. These three heterozygous apples might, however, under different circumstances, as for instance with a longer season and more favorable soil conditions, develop a more intense red, or in accordance with the assumption made, they may contain a red which is less complex in organization than that of their sisters.

The Sutton X Northern Spy progeny furnishes five individuals, three of which are classed as red and two as yellow. This segregation indicates Mendelian splitting, though the numbers are too few to more than suggest that the red is dominant and the yellow recessive. The yellow individuals, however, may not be pure recessives for a light reddish tinge was present on a few specimens of both trees. Does this reddish tinge signify that red individuals will appear in future generations if the variety be selfed, or is the red due to some physiological condition? Certain varieties, as the Yellow Transparent and Early Ripe, do not have this very light blush of red or bronze, but among all of our present crosses, no true yellows have appeared. Although we do not know whether one unit of red is contained in these yellow individuals, we suspect that both Sutton and Northern Spy must carry yellow as a recessive. This view is substantiated by the fact that in the other crosses in which Northern Spy is a participant, heterozygous individuals appear which evidently carry yellow.

The Rome X Northern Spy produced only one seedling and this is classified as an intermediate in color.

Ralls X Northern Spy gave nine seedlings, seven of which are classified as red, and two as heterozygous for red and yellow. It is probable from this cross that Ralls does not carry yellow as a simple unit character, for if it did, yellow individuals should have appeared.

Ben Davis X Esopus gave three red and one heterozygous red, and the reciprocal cross gave the same two classes, but in the proportion of eighteen to eleven. The difference in the ratios for these two crosses is, of course, of no significance, owing to the few individuals in the first. As there was no evidence of a recessive yellow in the eleven individuals of Ben Davis X Jonathan, one can assume that the Esopus in the Ben Davis and Esopus cross, is responsible for the yellow color.

Esopus X Jonathan gave two reds, in which the red was predominant. From so few individuals one can draw no conclusion, yet the findings substantiate the statements made that Jonathan does not carry yellow.

McIntosh is evidently a carrier of yellow, for in the McIntosh X Lawver — the male being the very dark red — one heterozygous individual is produced, and in the Ben Davis X McIntosh seedlings — Ben Davis probably not carrying yellow as has been previously noted — there are eight apparently pure reds and three individuals heterozygous for red and yellow.

Ben Davis X Green Newtown is an interesting cross. The maternal parent is supposedly a pure red and the paternal parent is yellow with a very light red blush. In the segregation of red and yellow, providing the former is dominant to the latter, the ratio expected would be one pure red to one heterozygous red. Eight reds and five yellowish reds or heterozygous individuals are obtained, the expected classes appearing, but not in a 1:1 ratio.

The distribution of skin color, whether in the form of stripes or solid colors, cannot be expressed in Mendelian terms. The solid and blushed individuals appeared as follows: Ralls X Northern Spy one solid, Ben Davis X McIntosh two blushed, Ben Davis X Green Newtown and Sutton X Northern Spy, one blush from each cross. All of the remaining seedlings produced fruit striped and mottled in various degrees.

Color of flesh.— In flesh colors, though a resemblance to either one of the parents or to an intermediate condition is found in all the individuals, the most marked differences are found in the Ben Davis X McIntosh progeny. This would be expected since McIntosh has a very characteristic white flesh. In the eleven Ben Davis X McIntosh apples, six resemble Ben Davis in flesh color, two are intermediate and three are distinctly McIntosh whites. From so few numbers and because of the lack of knowledge of the parents of these varieties, it is hardly possible to give the gametic constitution of color. If, however, one combines the six Ben Davis colors and the two intermediates, it can be assumed that both Ben Davis and McIntosh carry yellow and white, the white being recessive. This assumption would give nine yellows to three whites and there are eight yellowish individuals to three whites. From the general appearance of the McIntosh flesh, one would think it to be homozygous for white. However, it is not impossible to believe that the yellow is present and that the factor necessary for its development is lacking.

Size and shape.— It promises to be a difficult problem to determine inheritance of size and shape in apples. Castle has found size to be an intermediate character in his study of the inheritance of size in rabbits, and East has found parents of different sizes in maize to produce ears of intermediate length and kernels of intermediate size. The intermediates or F_1 generation in the maize produced progeny which varied in size from the small to the large parent, while the F_1 generation of rabbits produced only offspring of intermediate size. It may be suspected, therefore, that fruits likewise produce intermediate individuals. However, if size and shape consist of a complex of unit characters, it will be very difficult to determine whether they are bred as intermediates or not, for to so ascertain would require the production of thousands of individuals to obtain all the possible combinations of a complex of five or six units. Size and shape of fruits depend upon at least length and breadth measurements — not mentioning such unknown factors as nutrition, fertilization of the ovules and the like. With these unknown factors and in consideration of the meager data, we can draw but the roughest conclusions as to the inheritance of these characters.

Ben Davis X Mother gave six individuals which resemble the mother parent, four that are classed as intermediates and ten which bear paternal characteristics as to shape and size. This classification does not signify that the offspring are exactly like either one of the parents but that the majority of the characters are more like one parent than the other, and consequently bear a closer resemblance to the one than to the other. In this cross none of the twenty seedlings were much inferior or much superior to either parent in size. The size and shape of these crosses are shown in Plates I, II and III.

A slightly greater variation occurred in the eleven Ben Davis X Jonathan progeny. Ben Davis X Jonathan gave nine individuals with marked Jonathan characteristics and two with distinct Ben Davis characteristics, as shown in Plates IV and V.

Sutton X Northern Spy produced three individuals of marked paternal shape, one intermediate and one listed as maternal in general appearance. Four of these individuals gave larger fruits than either parent. This increase in size may be due to a heterozygous condition, which would probably stimulate the production of flesh tissue. These apples are shown in Plate VI.

Rome X Northern Spy is represented by only one individual and, this cross, therefore, throws little light on the inheritance of size and shape. This single representative, however, resembles the Rome in shape and even bears the distinct green and wide cavity which is so characteristic of this variety. In size it slightly outclasses either parent. This cross is not illustrated.

The nine offspring of Ralls X Northern Spy produced great variations in size and shape. This is to be expected since the difference in the size of the parents is more marked. The size of these seedlings ranges from fruits smaller than the maternal to larger than the paternal. Five of these seedlings resemble the Ralls in shape, one the Northern Spy and three are intermediates; all are shown in Plates VII and VIII.

In the Ben Davis X Esopus progeny are two individuals resembling Ben Davis, one an intermediate and one Esopus-like in shape, all shown in Plate IX. The reciprocal cross gave seven of Esopus resemblance, eleven of intermediate, ten of Ben Davis and one of unclassifiable shape. This cross gives the widest range of variation in size and shape — a fact which may be accounted for by the greater number of individuals, but not by the difference in size of the parents. Seven of the seedlings produced fruit larger than Ben Davis and four of them bore fruit smaller than the Esopus — the smallest being no larger than the Lady apple. In shape a few individuals produced fruit more elongated that Ben Davis while others bore fruit as oblate as the Lady. Plates X, XI, XII, and XIII, show the size and shape of the Esopus X Ben Davis apples.

Ben Davis X McIntosh gave three intermediates and four each of Ben Davis and McIntosh shapes. It is interesting to note in

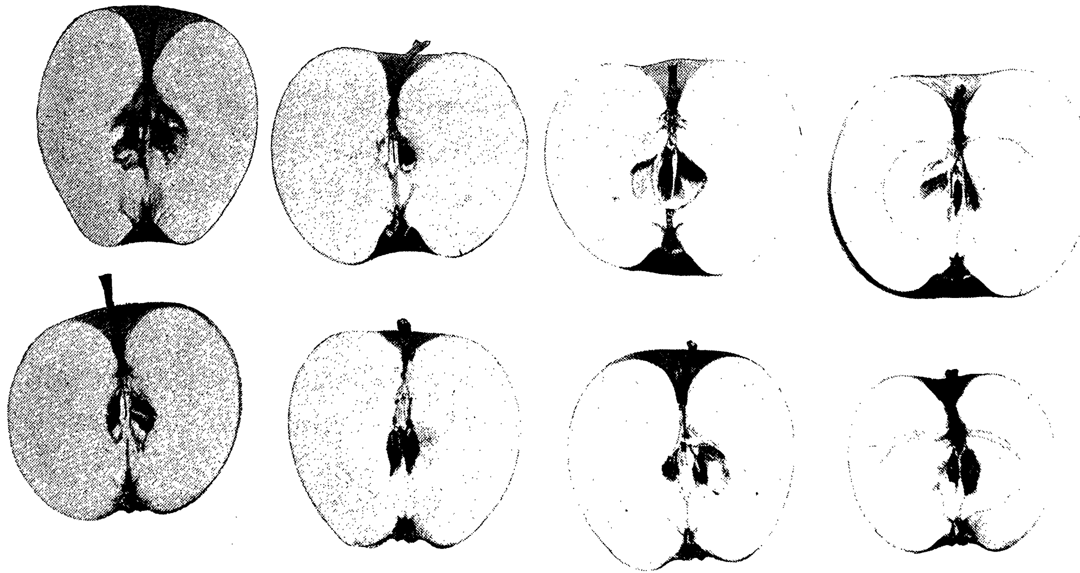

Plate I.— Ben Davis × Mother: Parents and Progeny.

Ben Davis, first figure in upper row; Mother, first in lower row; Rockland, third in upper row.

(Reduced one-half.)

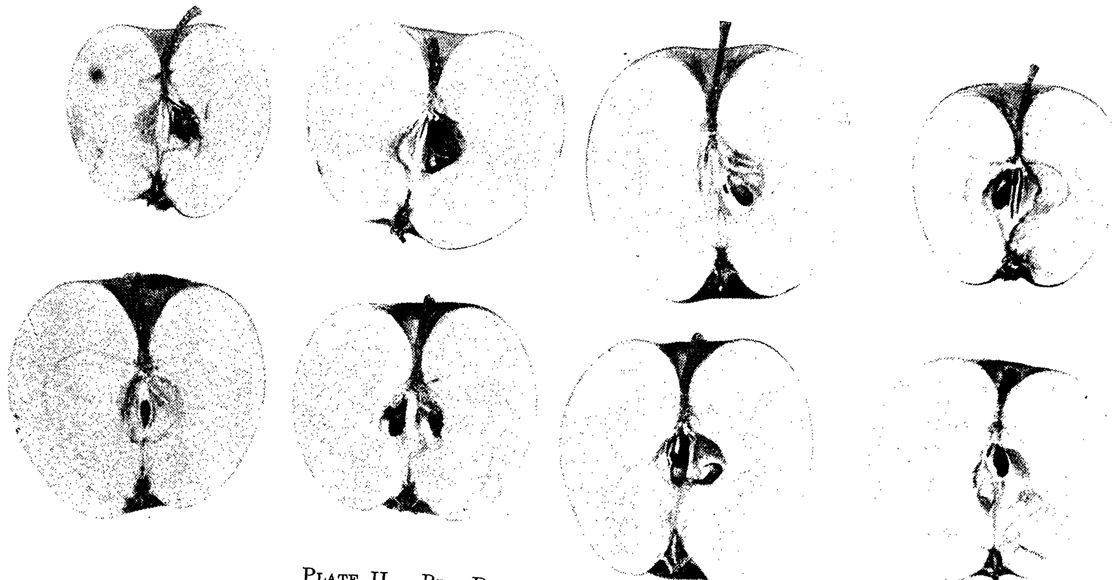

PLATE II.— BEN DAVIS × MOTHER: PROGENY.
(Reduced one-half.)

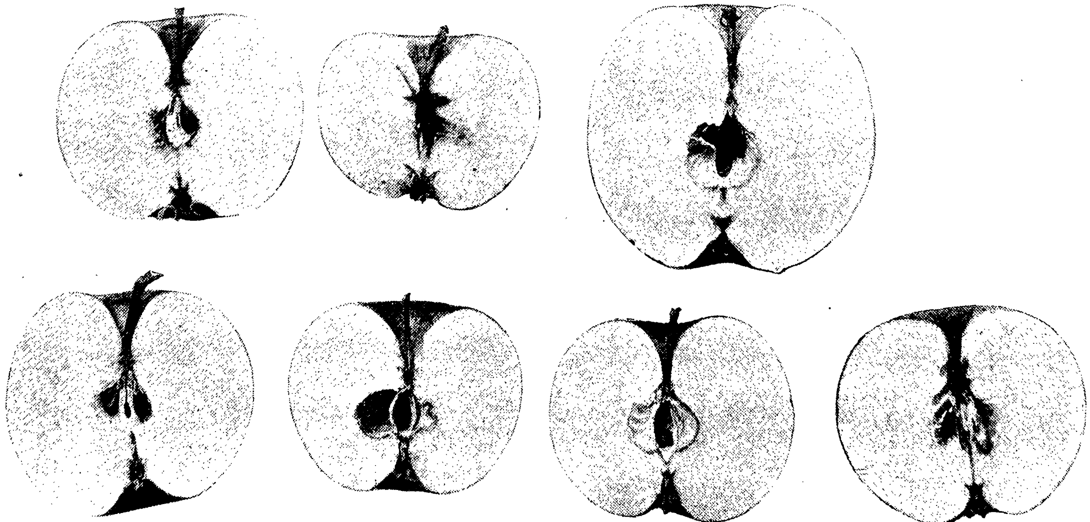

Plate III.— Ben Davis × Mother: Progeny.
Schenectady, last figure in upper row.
(Reduced one-half.)

PLATE IV.— BEN DAVIS × JONATHAN CROSS: PARENTS AND PROGENY.
Ben Davis, first figure in upper row; Jonathan, first in lower row.
(Reduced one-half.)

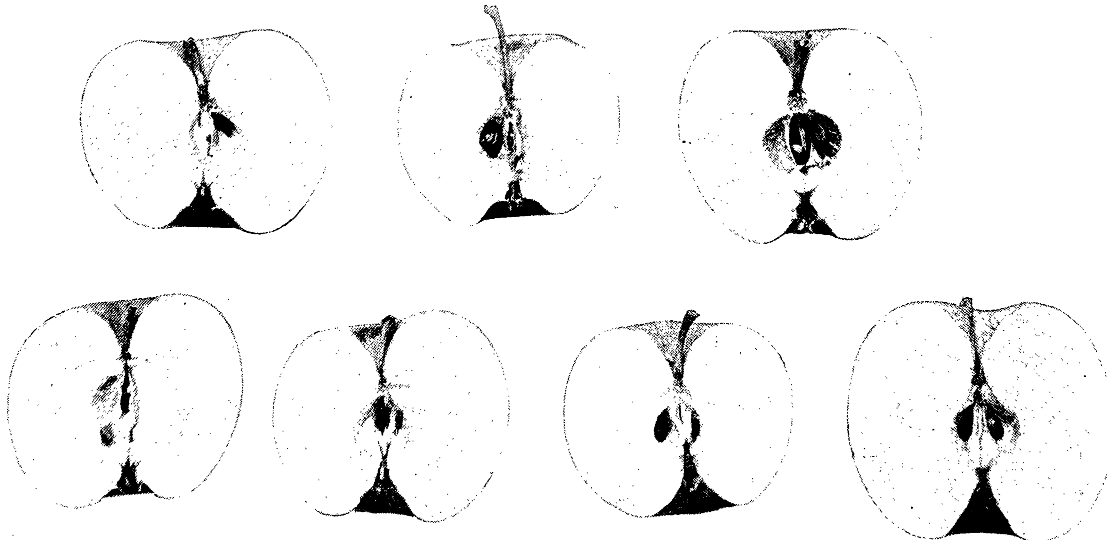

Plate V.— Ben Davis × Jonathan Cross: Progeny.
Rensselaer, third figure in lower row.
(Reduced one-half.)

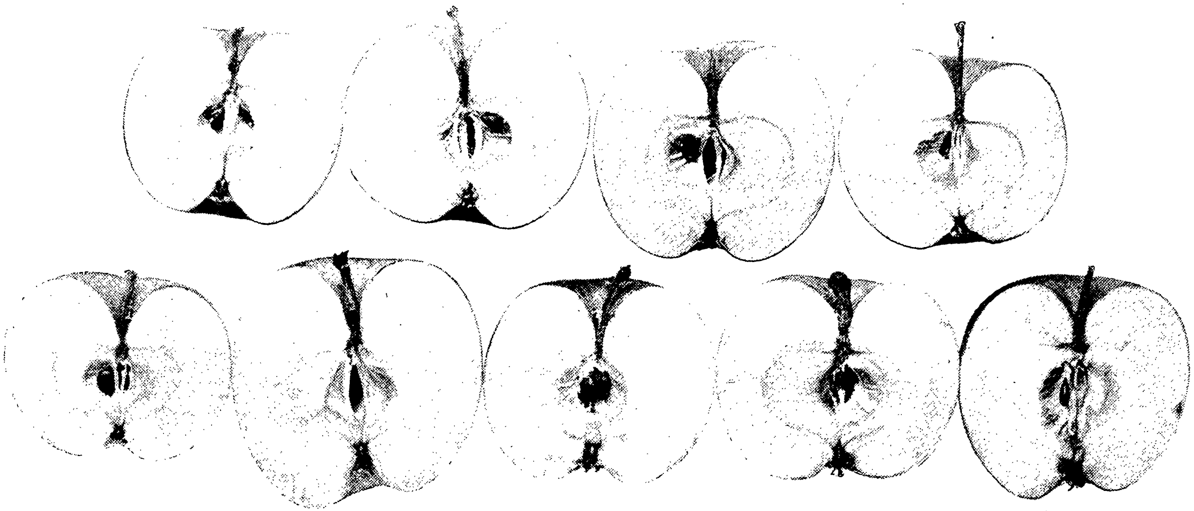

PLATE VI.— SUTTON × NORTHERN SPY CROSS: PARENTS AND PROGENY.

Sutton, first figure in upper row; Northern Spy, first in lower row; Tioga, fourth in lower row; Oswego, second in lower row.

(Reduced one-half.)

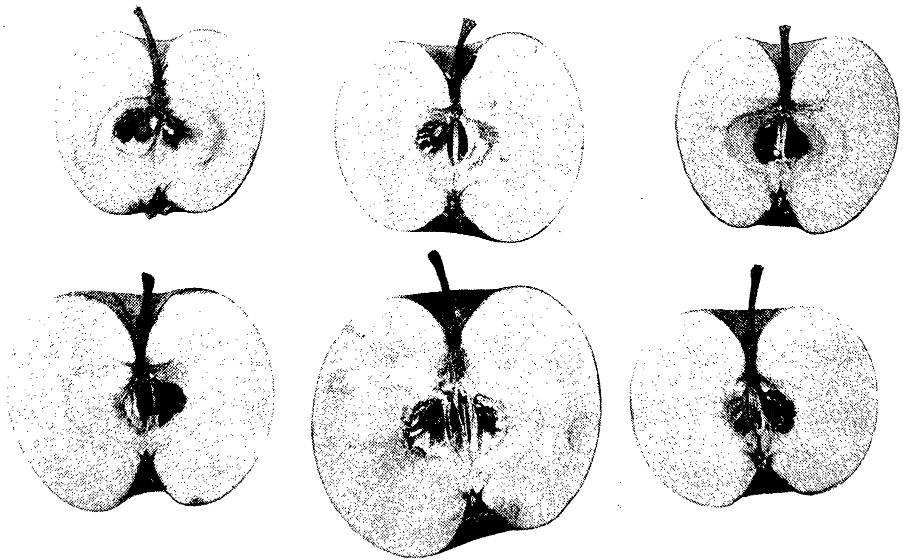

PLATE VII.— RALLS × NORTHERN SPY CROSS: PARENTS AND PROGENY.

Ralls, first figure in upper row; Northern Spy, first in lower row; Schoharie, second in lower row.

(Reduced one-half.)

Plate VIII.— Ralls × Northern Spy Cross: Progeny.

(Reduced one-half.)

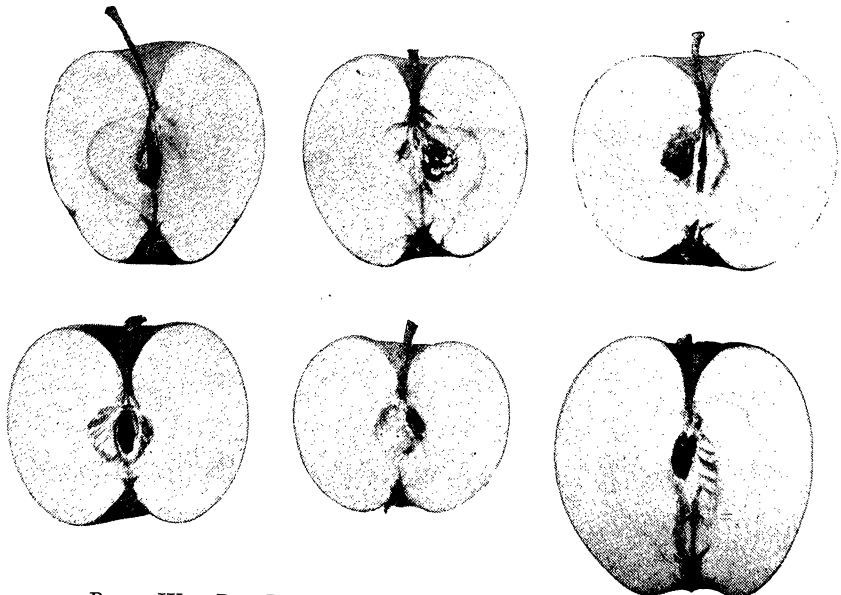

Plate IX.— Ben Davis × Esopus Cross: Parents and Progeny.
Ben Davis, first figure in upper row; Esopus, first in lower row.
(Reduced one-half.)

PLATE X.— ESOPUS × BEN DAVIS CROSS: PARENTS AND PROGENY.

Esopus, first figure in upper row; Ben Davis, first in lower row.

(Reduced one-half.)

Plate XI.— Esopus × Ben Davis Cross: Progeny.

(Reduced one-half.)

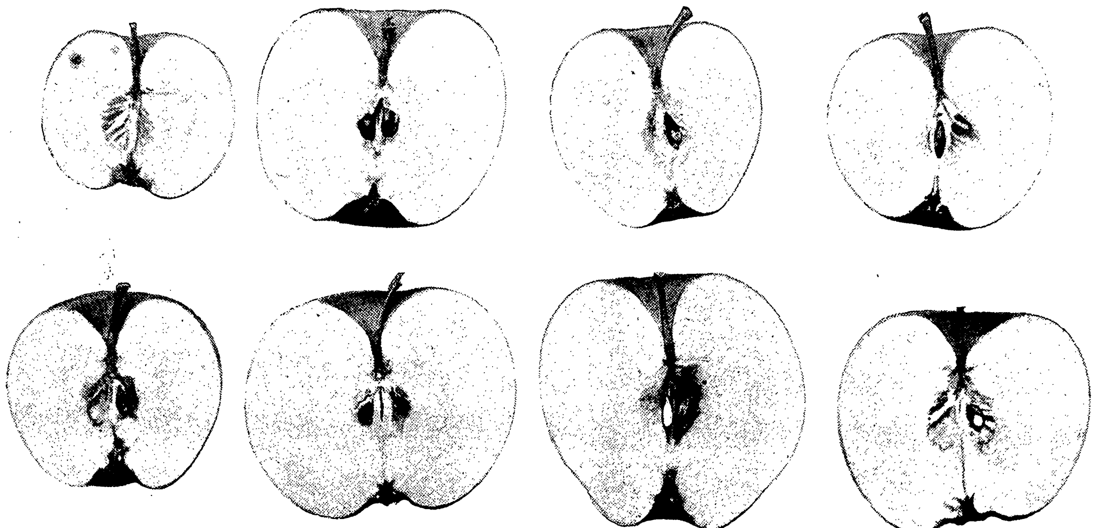

Plate XII.— Esopus × Ben Davis Cross: Progeny.
(Reduced one-half.)

Plate XIII.— Esopus × Ben Davis Cross: Progeny.

Nassau, third figure in lower row.

(Reduced one-half.)

PLATE XIV.— BEN DAVIS × McINTOSH CROSS: PARENTS AND PROGENY.
Ben Davis, first figure in upper row; McIntosh, first in lower row.
(Reduced one-half.)

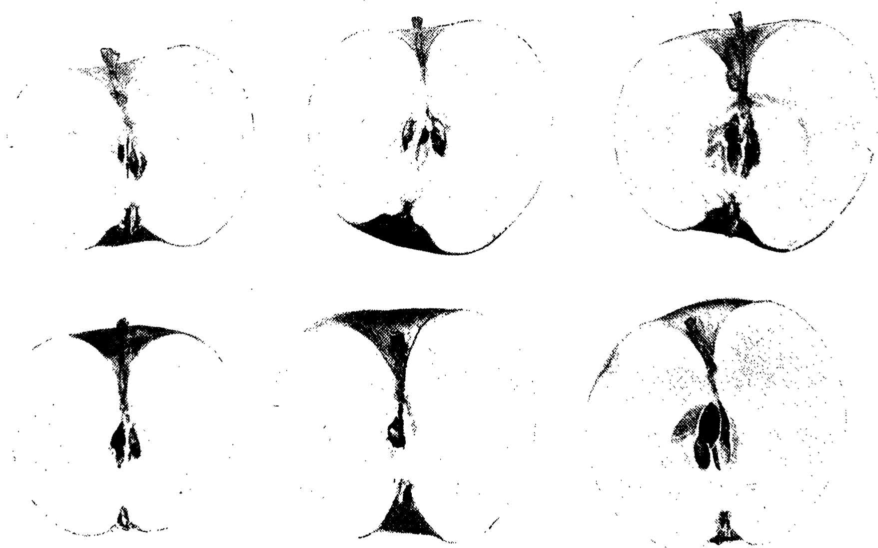

PLATE XV.— BEN DAVIS × MCINTOSH CROSS: PROGENY.

Cortland, first figure in upper row; Onondaga, second in upper row; Otsego, first in lower row.

(Reduced one-half.)

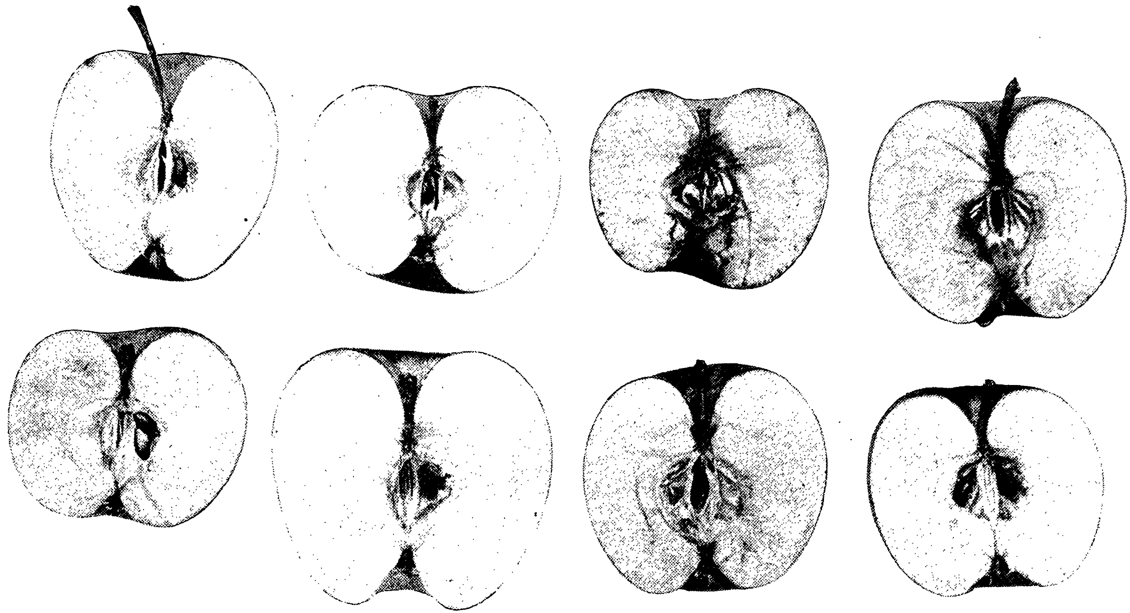

Plate XVI.— Ben Davis × Green Newtown Cross: Parents and Progeny.

Ben Davis, first figure in upper row; Green Newtown, first in lower row; Clinton, second in upper row.

(Reduced one-half.)

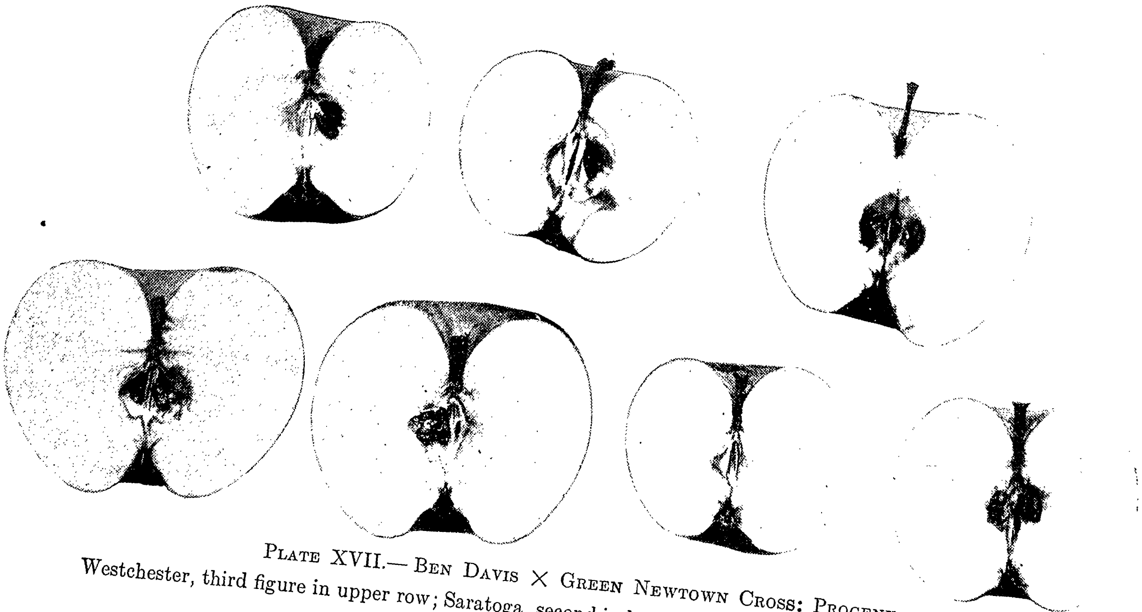

Plate XVII.— Ben Davis × Green Newtown Cross: Progeny.
Westchester, third figure in upper row; Saratoga, second in lower row; Herkimer, fourth in lower row.
(Reduced one-half.)

this cross that the distinctive calyx end of the Ben Davis fruit was markedly impressed on a majority of the offspring. The size of the fruit was not noticeably variable, as only two individuals out of the eleven dropped below the McIntosh in size, and one of these two possessed a remarkably small core and produced only a few seeds — perhaps a sufficient reason for its inferior size. The remaining individuals average as large as the Ben Davis and several surpassed the McIntosh in size. Apples from this cross are shown in Plates XIV and XV.

Ben Davis X Green Newtown produced thirteen individuals. The size of the fruit in one of these seedlings is very large, being one-half as large again as Ben Davis. In fact, half of these seedlings average as large as Ben Davis and none of them fall below the Green Newtown in size as can be seen in Plates XVI and XVII. In shape, six resemble Green Newtown, three Ben Davis and four an intermediate condition.

Acidity.—Acidity and sweetness are relative terms and unnumbered gradations varying from one extreme to the other occur. The separation of subacid from acid apples is difficult, for under more favorable circumstances the acidity may decrease to a marked degree. In this experiment all the parents are subacid varieties, and from an examination of the following data, it will be noted that sweet apples appear in the greater part of the crosses. The numbers in most cases are too few to expect an exact 3:1 ratio, yet the indications strongly favor such an assumption. In the cases where sweet apples did not appear, one must assume that the nonappearance is due either to chance or that all subacid varieties do not carry sweetness as a recessive character. This question can be settled only by further tests. The facts are presented as they appear and conclusions are drawn as far as the limited observations permit.

Ben Davis X Jonathan, both parents being subacid, gave two sweets and nine subacids, while Esopus X Jonathan produced two subacids. In the first cross, one might interpret sweetness or absence of acidity as a recessive to acidity — both parents carrying sweetness. The expected ratio 3:1 is very closely approximated. The second of these crosses throws no light on this assumption for the individuals are too few in number.

Ben Davis X Mother gives eight sweets, eleven subacids and one sour. If the sours and subacid fruits can not be definitely separated, then we have a ratio of 3:2 instead of 3:1 — sweetness being the recessive. Mother, according to this interpretation, must carry sweet as well as Ben Davis.

The four seedlings produced from Sutton X Northern Spy, and the one from Rome X Northern Spy are all subacid. These numbers are too few to hazard an explanation.

Ben Davis X Esopus gave four individuals, all of which are subacid and its reciprocal cross gave a total of seven sweets, twenty-one subacids and one sour. Assuming that the sour individual would have lost its acidity if the season had been more prolonged, we would have practically a 3:1 ratio in this reciprocal cross. The proportions are, however, worthy of note, even though they may be incorrectly interpreted. If the interpretation is correct, Esopus as well as Ben Davis must carry sweetness as a recessive character.

Ben Davis X McIntosh gives two sweets to nine subacids, and Ben Davis X Green Newtown, the same classes but in the proportion of 3 to 10. Both of these crosses are explainable by the 3:1 ratio, and this interpretation must make sweet a recessive in both parents.

Ralls X Northern Spy gave nine subacids and no sweets. In this case, we have two subacids giving no sweets, and therefore, it is doubtful whether one or both varieties carry a recessive sweet. If this be the case, subacid varieties are not necessarily hybrids between sweets and acids. These results are at least valuable from the practical side for it shows that sweet apples can be secured from subacid apples.

Ripening period.— Date of ripening is another character that is undoubtedly inherited, as from all of these crosses of late-ripening apples, only late varieties have been produced — the range of variation not extending on the average much more than a month on either side of the average mean of the parents. It is to be regretted that we have no crosses with parents differing widely in the date of maturity. However, as no early varieties have been obtained from these crosses, it is safe to say that earliness is probably not a recessive character. Season, like size and shape, may be either composed of many factors or it may be inherited as an intermediate condition — a question, of course, still open for experimental evidence.

INHERITANCE IN THE SEVERAL VARIETIES.

The results of the study of Mendelian inheritance in this experiment may be put in more workable shape for the apple-breeder if the discussion of the several characters are summarized under the varieties crossed. At the risk of considerable repetition, such a summary is now given.

Ben Davis.— In the six crosses in which this apple was used, the results indicate that yellow is not carried by Ben Davis — the heterozygous R y progeny being able to obtain their yellow from the other parent in each case. In transmitting shape, Ben Davis was less prepotent than either Jonathan or Green Newtown. In the other cases, the individuals showing preponderance of Ben Davis shape were about equal in number to those showing the shape of the other parent. The term prepotent is here used to mean that either the shape-forming characters of one variety are less heterozygous than those of another, or, that such characters of one parent are dominant over those of the other. The greater the number of heterozygous characters, the greater the number of segregations or splittings that will take place. In size of fruit, the Ben Davis crosses were intermediate as a rule, although the cross with the Green Newtown produced offspring larger than either parent and none smaller. Sweetness appeared as a recessive in all Ben Davis crosses except with Esopus and here the four individuals are too few to permit conclusions.

Esopus.— The crosses between Ben Davis and Esopus are the only ones with sufficient numbers to warrant a postulation as to the gametic constitution of the Esopus color factors. The total individuals obtained are 21 pure reds and 12 individuals heterozygous for red and yellow. As the Ben Davis probably does not carry yellow, the yellow in these heterozygotes must have come from Esopus. Assuming that Ben Davis carries R R and Esopus R y we should expect a ratio of 1 R R to 1 R y. The ratio obtained, 7:4, indicates that red is not carried in such a simplex condition. The fruit shape in the progeny of these crosses is intermediate, while the size is very variable, indicating that one or more of the progenitors of the parents must have borne small fruits. Esopus carries sweetness as a recessive, there being 7 sweet, 25 subacid and 1 acid apple, a close approximation to a 3:1 ratio.

Green Newtown.— The inheritance of fruit characters in this variety are based on thirteen individuals obtained from crosses with Ben Davis. If Ben Davis carries only red and Green Newtown only yellow, all the progeny should have been heterozygous for these colors, but 8 R R and 5 R y apples were obtained. Perhaps the light blush on the Green Newtown signifies the presence of a red unit factor, but this point can be settled only by growing selfed seedlings. As previously noted, the Green Newtown shape is more prepotent than the Ben Davis — the obliqueness of the Newtown, in particular, appearing in the offspring. The fruits of the progeny did not fall below either parent. This fact indicates that the progenitors of the Green Newtown bore large fruits, for if small size is carried as a recessive in Ben Davis, a union of small gametes would probably have taken place even though the numbers are small. Sweetness appeared in a ratio of nearly 3:1, which signifies that this character is carried as a recessive.

Jonathan.— This variety carries only red in its gametes, as in the eleven progeny obtained from a cross with Ben Davis, no evidence of yellow was noted. Jonathan proved to be the more prepotent parent in the transmission of shape, for nine of the eleven seedlings resembled the former. Sweet apples appeared in the proportion of 2:9, which closely approximates a 1:3 ratio, based on sweetness as a recessive to acidness.

Lawver.— No hypotheses can be advanced as to the inheritance of this variety's characters, as only one seedling, obtained from a cross with McIntosh has been described. Its dark red color, however, suggests an absence of yellow.

McIntosh.— Three R y fruits appeared in the eleven Ben Davis X McIntosh seedlings, and one R y in the Lawver cross. If the Ben Davis and Lawver are pure reds then McIntosh must have supplied the yellow in both cases. The white flesh of the McIntosh behaved as a recessive to the yellowish white color of the Ben Davis. In the inheritance of shape and size, McIntosh and Ben Davis were equally prepotent, for, as many progeny resembled one parent as the other and all were intermediate in size. The appearance of two sweets to nine subacid fruits supports the statement that the former character is borne as a recessive in the McIntosh.

Mother.— When crossed with Ben Davis, three heterozygous and seventeen pure reds were produced. If these three individuals are undeveloped reds then Mother does not carry yellow. If, however, Mother carries yellow, its red must be complex in structure. A few more seedlings resembled the Mother in shape than the Ben Davis, but not enough more to warrant the drawing of conclusions. Size was inherited in an intermediate condition and sweetness as a recessive though in the proportion of 2:3, instead of a simple 1:3.

Northern Spy.— This variety crossed with Sutton gave three reds and two yellows tinged with red; crossed with Ralls gave seven pure reds and two heterozygous reds; in the cross with Rome one heterozygous red was the result. The presence of nearly yellow individuals in the first cross signifies either that yellow is carried as a recessive or a simplex red is present in the Northern Spy. Shape in this variety was more prepotent than in Sutton but much less so than in Ralls which impressed its shape on five of the nine seedlings — three being intermediates. The Northern Spy crosses, as a rule, gave large fruits but in the Ralls cross small fruits appeared — the presence of which indicates that both varieties carry small size in their gametes. (See Ralls.) No sweet apples appeared in the Northern Spy crosses which fact indicates that sweetness is not a recessive in this variety. However, if Ralls, Rome and Sutton, with which it was crossed, do not carry sweetness, this character would not appear since it would have been dominated by the acid-producing factor.

Ralls.— If Northern Spy carries yellow, then this variety either does not or its red is complex in composition. This opinion is based on the appearance of seven pure reds and only two heterozygous reds. If both varieties carry yellow, the proportion should be 1 R: 2 R y: 1 Y, that is, one pure yellow should have appeared to three pure and heterozygous reds. As already noted in the Northern Spy discussion, Ralls is more prepotent in the transmission of shape-determining factors. In the Northern Spy and Ralls progeny, we have individuals both larger and smaller than either parent — this variability may be explained by assuming that the progenitors of Ralls and Northern Spy covered variations of similar magnitude. The transmission of acidity in Ralls is discussed under Northern Spy.

Rome.— Little can be said as to the inheritance of the characters of Rome from the one individual grown. Its shape and stem cavity were transmitted to this seedling.

Sutton.— This variety gave three reds and two nearly yellows when crossed with Northern Spy. Thus Sutton as well as the Spy must carry either yellow or a simple red. In the transmission of shape, Northern Spy seems to be sightly prepotent, for it impressed its shape on three fruits to the Sutton's one. Little can be said of the transmission of size except that the Sutton did not give small fruits. The transmission of flavor in Sutton is discussed under Northern Spy.

Conclusion.— The inheritance of skin color, flesh color, size and shape are more or less hypothetical but acidity is undoubtedly inherited as a Mendelian character. Combining crosses, all of which were produced from subacid parents, we get a total of 22 sweet, 82 subacid and 2 acid apples. Fifteen of these are from crosses in which sweetness is not carried by one or both parents, and, therefore, must be eliminated, thus leaving 22 sweets to 69 subacids and acids, numbers which approach very closely the theoretical 1:3 ratio. If the sweet apples contain a higher amount of sugar than the subacid apples, and this assumption is favored, the results are analogous to those obtained by Pearl and Bartlett with crosses of corn[1] where high sucrose content behaved as a recessive to low sucrose.

CONCRETE RESULTS.

All will be interested, it is certain, in knowing how many of the progeny of these crosses seem to the writers to have suffi-

[1] Pearl, R. and Bartlett, J. M., 1911. *Ztschr. Induk. Abstamm. Vereb.* **6**: 27. 1911.

cient value to name or test further. The following are the number: From the eleven Ben Davis X Jonathan crosses, one is marked for propagation, four for further testing and six for discarding. Ben Davis X Mother gave two seedlings worthy of propagation and eighteen for discarding. Ben Davis X Esopus produced four worthless seedlings but the reciprocal cross has contributed two worthy of propagation, one for future testing, twenty-six for discarding. Ben Davis X McIntosh gave two desirable varieties, three for further testing and six for discarding. Ben Davis X Green Newtown gave four desirable varieties from thirteen seedlings. Esopus X Jonathan gave one for further testing, one for discarding, and McIntosh X Lawver has produced one individual which is still retained for further test. The Northern Spy crosses have done well, for Sutton X Northern Spy gave two worthy of propagation, three worthy of further testing and none for discarding. Ralls X Northern Spy produced one desirable variety, one worthy of further consideration and seven undesirables; and Rome X Northern Spy gave one of no special merit.

The data given, even though meager, seem to show that the Ben Davis and the Esopus crosses are of little use in breeding work, and that the McIntosh, Northern Spy and Green Newtown — all varieties of very high quality — might well be used extensively in all work where the object is to obtain varieties of high quality. Few, indeed, of these crosses fell below the average of cultivated varieties in size of fruit, handsome appearance of the apples and in tree characters that make a variety desirable. Fourteen apples worthy of propagation out of 102 crosses so far fruited, gives a most hopeful outlook to apple breeding. These have been more or less distributed to the fruit growers of New York. The following are descriptions of the new varieties:

Clinton. *Ben Davis X Green Newtown.*— Tree vigorous, upright-spreading, open-topped, productive; branches stocky, ash-gray; leaves medium in number, 3⅞ inches long, 1⅞ inches wide, dark green, pubescent, with sharply serrate margins; petiole 1⅝ inches long.

Season, December to February; 2¼ inches by 2 15-16 inches in size, roundish to oblate-conic, often oblique, irregular; cavity acute, of medium depth and width often heavily russeted, compressed; basin of medium depth and width, abrupt, furrowed; calyx partly open, with acute lobes; color greenish-yellow, blushed with dull bronze, splashed with carmine, prevailing effect red; dots large, russet, conspicuous; stem 11-16 inch long, thick; skin tender, smooth, oily, glossy; core axile, large, partly open; core-lines clasping; calyx-tube short, wide, broadly conical; carpels broad-oval, emarginate; seed large, plump, acute, 7 in number; flesh yellowish, firm, crisp, tender, juicy, subacid, aromatic; of good quality.

This apple is very attractive in appearance and of very good quality, resembling Green Newtown in size, shape and quality but of a handsome red color.

Cortland. *Ben Davis X McIntosh.*— Tree of medium vigor, drooping, dense-topped, productive; branches slender; leaves numerous, 4 inches long, 2¼ inches wide, dark green, pubescent, with serrate margins; petiole 1 3-16 inches long.

Season, November to February; 2½ inches by 3⅛ inches in size, roundish-oblate, ribbed, uniform; cavity obtuse, broad, much-russeted, smooth; basin of medium width and depth, obtuse or somewhat abrupt, slightly furrowed; calyx partly open, small, with acuminate, separated lobes broad at the base and medium in length; color greenish-yellow overspread with bright red, darker on the sunny side, splashed and striped with carmine; dots few, small, light gray; stem variable in length, averaging ¾ inch long, slender; skin tough, smooth, waxen, dull, with much bloom; core partly open; core lines clasping; calyx-tube long, conical; carpels obovate, emarginate; seed of medium size, wide, plump, obtuse, numerous; flesh whitish, often with slight tinge of pink, fine-grained, crisp, tender, juicy, subacid, aromatic; of good quality.

In appearance Cortland closely resembles McIntosh in color, shape and flesh characters. It promises to be a valuable commercial apple of the McIntosh type.

Herkimer. *Ben Davis X Green Newtown.* Tree vigorous, upright, slightly spreading, medium productive; branches rather thick; leaves 4 inches long, 2⅜ inches wide, dark green, rather pubescent; with margins inclined to crenate; petiole 1⅚ inches long.

Season, December to March; large, roundish to oblong-conic, irregular; cavity acuminate, deep, broad, marked with russet which often overspreads upon the base, slightly furrowed; basin deep, wide, abrupt, furrowed and corrugated; calyx slightly open, of medium size; color greenish-yellow, partly overspread with red, irregularly splashed and striped with dull carmine; dots large, russet; stem of medium length, thick; flesh yellow, firm, coarse, juicy, brisk subacid; of good quality.

Herkimer resembles Ben Davis both externally and internally more than the Green Newtown but is better in quality. Its good quality, handsome appearance and long-keeping properties, all commend it.

Nassau. *Esopus X Ben Davis.* Tree vigorous, upright spreading, productive; branches somewhat slender; leaves $3\frac{1}{2}$ inches long, $2\frac{1}{16}$ inches wide, dark green, heavily pubescent below, with crenate margins; petiole 1 inch long.

Fruit matures in late October or early November; season, December to March; medium in size, oblate; cavity wide, rather deep; basin wide, shallow, furrowed; color pale yellow, splashed, striped and mottled with bright pinkish-red, blushed on the sunny side; stem medium to long, thick; flesh firm, coarse, juicy, crisp, pleasant subacid, aromatic; good in quality.

Nassau is far better in quality than Ben Davis but is hardly equal to Esopus. The color is more like that of Ben Davis than of Esopus — the contrasting colors of red and yellow being most attractive.

Onondaga. *Ben Davis X McIntosh.*— Tree not very vigorous, upright, dense-topped, productive; branches slender; leaves numerous, 3¾ inches long, 2 1-16 inches wide, medium green, pubescent, with finely serrate margins; petiole 1⅞ inches long.

Season, November to January; 2⅜ inches by 2¾ inches in size, roundish-conic, irregular; cavity obtuse, shallow, greenish-russeted, smooth; basin shallow, obtuse, furrowed; calyx open, large, with long, narrow, acuminate, much separated lobes; color greenish-yellow, almost entirely overspread with dark McIntosh red, darker on the sunny side, splashed and mottled with dark carmine, prevailing effect dark red; dots few, small, grayish or pinkish, obscure; stem ¾ inch long, slender; skin tough, smooth, waxen, dull, with considerable bloom; core abaxile, small, closed; core-lines clasping; calyx-tube short, conical; carpels oval, emarginate, slightly tufted; seed large, plump, acute, 8 in number; flesh tinged with yellow, firm, crisp, tender, juicy, sprightly subacid, aromatic; of good quality.

This apple is very attractive in color and in size and is at least desirable for cooking and would doubtless be relished by most persons as a dessert fruit. It is the general type of McIntosh externally except that it is slightly more conic.

Oswego. *Sutton X Northern Spy.*— Tree vigorous, upright-spreading, dense-topped, productive; branches stocky; leaves numerous, 3¾ inches long, 2 1-16 inches wide, dark green, slightly pubescent, with finely serrate margin; petiole 1 7-16 inches long.

Season, December to April, 2⅝ inches by 3 5-16 inches in size, roundish-conic, ribbed, sides unequal; cavity acute, deep, broad, russeted, often compressed; basin deep, abrupt, smooth; calyx open, large, with broad, acute, separated lobes; color greenish-yellow overspread with dull pinkish red, splashed and striped with darker red, prevailing effect dull red; dots numerous, large, grayish-russet; stem ¾ inch long, thick; skin tough, smooth, dull, covered with bloom; core abaxile, large, open; core lines clasping; calyx-tube long, wide, conical; carpels roundish, slightly emarginate; seed often abnormal being grown together, usually small, wide, short, plump, obtuse, 12 in number; flesh yellowish, firm, crisp, tender, juicy, brisk subacid; very good in quality.

Oswego resembles Northern Spy, though larger, more conical, and brighter in color. The flesh, in color and texture, resembles Spy but the flavor, while equal to that variety, is not that of the Spy.

Otsego. *Ben Davis X McIntosh.*— Tree vigorous, upright-spreading, open-topped, productive; branches stocky; leaves numerous, 3¾ inches long, 2¼ inches wide, medium green, pubescent, with slightly crenate margins; petiole 1⅝ inches long.

Season, November to February; 2⅛ inches by 2 5-16 inches in size, oblong-conic, oblique, not uniform; cavity acute, deep, russeted, compressed; basin shallow, narrow, obtuse, furrowed, compressed; calyx closed, small, with short, narrow, acute lobes; color pale yellow overspread with mottled dark red, splashed and striped with carmine, prevailing effect red; dots numerous, small; stem 11-16 inch long, slender; skin tender, smooth, waxen, covered with bloom; core abaxile, open; core-lines clasping; calyx-tube short, wide, conical; carpels ovate, emarginate; seed of medium size, wide, plump, obtuse, 4 in number; flesh yellow, firm, crisp, tender, medium juicy, mild subacid; good in quality.

This apple is propagated because of its handsome color, good quality, small core and sparsity of seed. The fault that will condemn it if it fails, is small size.

Rensselaer. *Ben Davis X Jonathan.*—Tree vigorous, spreading, productive; branches stocky; leaves numerous, 1⅞ inches wide, 3½ inches long, pubescent, with crenate margins; petiole 1 5-16 inches long.

Season, December to February; 2⅝ inches by 2¾ inches in size, roundish-conic to truncate, uniform; cavity acuminate, deep, greenish-russeted, symmetrical, basin narrow, abrupt, furrowed; calyx small, partly opened, with obtuse lobes; color yellow with a dull red blush, splashed with carmine, prevailing effect red; dots numerous, large, yellowish; stem ⅞ inch long, slender; skin tough, smooth, oily, marked with grayish scarfskin; core axile, of medium size, closed; core-lines clasping; calyx-tube long, wide, conical; carpels ovate, emarginate; seed of medium width, long, plump, acute, eight in number; flesh yellowish, firm, crisp, tender, juicy, subacid, aromatic; of good quality.

While of but medium size, Rensselaer is so attractive in color and of such high flavor as to make it a valuable dessert fruit. It is of the type of Jonathan both externally and internally.

Rockland. *Ben Davis X Mother.*— Tree of medium vigor, somewhat spreading and straggling, productive; branches rather slender; leaves $2\frac{13}{16}$ inches long, 2 inches wide, light green, somewhat pubescent, with serrate margins; petiole $1\frac{1}{16}$ inches long.

Season, November to January; of medium size, roundish-truncate, symmetrical; cavity acuminate, deep, russeted, symmetrical; basin deep, very wide, abrupt, furrowed; calyx partly open, large; color yellow, entirely overspread with dark red, splashed, mottled and obscurely striped with carmine; dots few, small, pinkish-yellow; stem long, thick; skin tough, smooth, dull; core axile, closed; core-lines clasping; calyx-tube short, wide, conical; carpels obovate, emarginate; seed small, short, plump, obtuse, tufted; flesh yellowish, coarse, crisp, tender, juicy, sprightly subacid, aromatic; good to very good in quality.

The fruit of this cross is of the type of Mother. It is most pleasing in appearance, although small, resembling Mother in size, shape, color, texture, flavor and quality. This apple ought to be especially valuable as a dessert fruit.

Saratoga. *Ben Davis X Green Newtown.*— Tree vigorous, upright-spreading, dense-topped, productive; branches stocky; leaves 4 inches long, 2 3-16 inches wide, dark green, pubescent, with sharply serrated margins; petiole 2 inches long.

Season, January to April; 2 9-16 inches by 3⅛ inches in size, roundish-conic to oblate, ribbed, uniform; cavity obtuse, deep, broad, russeted, furrowed; basin deep, wide, abrupt, furrowed; calyx open, large, with short, broad, acute, separated lobes; color greenish-yellow, overspread with bright purplish-red, splashed and mottled with crimson; dots numerous, yellowish; stem ⅝ inch long, thick; skin tender, smooth, very oily; core abaxile, large, open; core-lines clasping; calyx-tube short, wide, conical; carpels ovate, emarginate, tufted; seed wide, plump, acute, tufted, 10 in number; flesh greenish-yellow, firm, coarse, crisp, tender, juicy, subacid, sprightly; of good quality.

This apple is particularly valuable because of its bright color and large size. Its quality is much superior to Ben Davis being nearly or quite as good as Green Newtown. Its season is late.

Schenectady. *Ben Davis X Mother.*— Tree vigorous, upright, dense-topped, productive; branches medium to thick; leaves numerous, 4¼ inches long, 2½ inches wide, dark green, pubescent, with distinctly serrate margins; petiole 1 3-16 inches long.

Season, November to January; 2 15-16 inches by 3¼ inches in size, roundish-conic, sides unequal, ribbed; cavity obtuse, shallow, narrow, russeted, compressed, sometimes lipped; basin narrow, obtuse, furrowed; calyx open, with broad, acute lobes; color greenish-yellow overspread with bright red, mottled and splashed with carmine, prevailing effect red; dots numerous, small, grayish; stem 7/8 inch long, slender; skin tender, smooth, waxen; core abaxile, large, open; core-lines clasping; calyx-tube long, wide, conical; carpels obovate, emarginate; seed wide, plump, acute, 8 in number; flesh yellowish, firm, coarse, crisp, tender, juicy, subacid; of good quality.

This new variety is remarkably attractive, its size, shape and color, all being most pleasing. It is not quite high enough in quality to be called a first-class dessert fruit, but it is much better than Ben Davis and is a splendid apple.

Schoharie. *Ralls X Northern Spy.*— Tree vigorous, upright-spreading, productive; branches stocky; leaves numerous, 4 inches long, 2 1-16 inches wide, dark green, slightly pubescent, with distinctly serrate margins; petiole 1 7/8 inches long.

Season, November to March; 2 3/4 inches by 3 inches in size, roundish-conic, ribbed, irregular; cavity obtuse, shallow, narrow, greenish-russeted, compressed, furrowed; basin narrow, obtuse, furrowed; calyx open, small, with short, broad, acute lobes which are not separated; color greenish-yellow overspread with a mottled and striped dull red, prevailing effect, dull, striped red; dots numerous, small, grayish-russet, obscure; stem 1 3-16 inches long, slender; skin tender, smooth, waxen, core abaxile, large, very open; core-lines clasping; calyx-tube short, wide, broadly conical; carpels broad-ovate, emarginate; seeds small, plump, acute, 15 in number; flesh yellowish, firm, fine-grained, crisp, tender, juicy, pleasant but mild subacid, aromatic; of good quality.

Schoharie is of proper size but somewhat dull in color. Its flavor is such as to make it desirable either as a cooking or as a dessert apple. It is the type of Northern Spy in shape and color; the flesh, too, is that of the Northern Spy, more yellow, but having the same delicious flavor and aroma.

Tioga. *Sutton X Northern Spy.*—Tree very vigorous, upright-spreading, dense, medium productive; branches thick; leaves 3 1/4 inches long, 1 7/8 inches wide, dark green, with considerable pubescence beneath, with serrate margins; petiole 1 1/4 inches long.

Season, December to March; large, oblate-conic, ribbed, symmetrical; cavity acute, of medium depth and width, greenish-russeted, furrowed, often lipped; basin shallow, narrow, obtuse, furrowed, sometimes compressed; calyx closed, with narrow, acute lobes of average length; stem short, thick; skin thin, tender, smooth, covered with heavy bloom; color pale yellow, blushed, mottled and faintly splashed with pinkish-red, prevailing effect yellowish; dots small, numerous, russet, often submerged; core abaxile, large, closed; core-lines clasping; calyx-tube short, wide, conical; carpels ovate, emarginate; seed small, wide, short, plump, obtuse, slightly tufted; flesh yellowish, firm, coarse, crisp, juicy, brisk subacid; of good quality.

A most promising variety because of its handsome appearance and high quality. The fruit is the type of Northern Spy in shape but is unlike either parent in color.

Westchester. *Ben Davis X Green Newtown.*— Tree vigorous, upright-spreading, open-topped, productive; branches stocky; leaves numerous, 3 13-16 inches long, 2 inches wide, dark green, pubescent, with sharply and coarsely serrate margins; petiole 1 7-16 inches long.

Season, November to January; 2⅝ inches by 3 inches in size, roundish-conic, ribbed, oblique; cavity acuminate, deep, broad, russeted, compressed; basin very deep, wide, abrupt, furrowed and corrugated; calyx wide, open, large, with long, narrow, acuminate, separated lobes; color yellow, overspread with dull red, mottled and splashed with darker red; dots numerous, large, grayish, obscure; stem 13-16 inch long, thick; skin tough, smooth, waxen and oily, covered with bloom; core axile, small, closed; core-lines clasping; calyx-tube long, wide, conical; carpels ovate, emarginate; seed wide, acute, 7 in number; flesh yellow, coarse, very tender, juicy, mild subacid, aromatic; good to very good.

Westchester resembles Green Newtown in shape, but has the color of Ben Davis while the quality is even better than that of its justly esteemed paternal parent.

APPLICATION OF RESULTS.

We have laid so much stress upon the Mendelian behavior of several characters of the apples crossed and so much is now heard of Mendel and his work, that the impression may be given that breeding apples consists almost wholly in making Mendelian combinations of characters. Producing new combinations of characters by crossing is but a small part of the work of securing superior varieties of apples. The task of selecting different combinations of unit characters in the progenies of crosses is a tremendous one, requiring knowledge of the many varieties of apples, of all characters of apples and of what ones combined will make a variety superior to existing sorts. It is likely that the greatest part of the work in breeding apples is, or will be when the foundation for breeding is more firmly laid, this selection among the manifold combination of characters that can be made. Following in Mendel's footsteps, we have a quicker route to the desired results in breeding apples, but breeding will still be laborious, slow and disappointing, differing chiefly from that of the past in being now a problem and not of as old, a riddle.

How can Mendelian principles be made most serviceable to breeders of apples? The aim in breeding is to produce varieties with the greatest number of desirable characters and the least number of undesirable ones. Mendel has shown that characters are transmitted as units which segregate in accordance with a definite formula. It remains, then, for the breeder to take certain characters from one parent, others from another, and make as many combinations as possible from which the best can be selected. The first task is to determine how characters are inherited, after which they can be associated or disassociated somewhat as the breeder wishes. The behavior of the crosses in this experiment gives some indications of how certain characters are transmitted when found in the varieties involved and forms a basis, therefore, for breeding work with these varieties, and suggests, at least, how the characters discussed will behave in other varieties that may be crossed.

The application of Mendelian principles to breeding apples, as with other plants, will not be free from puzzling problems. Some of these may be briefly stated.

The determination of the factors by which the various characters are transmitted will prove a very difficult task. If all were simple characters depending upon a single factor, the work would be greatly simplified, but it is likely that we shall find that some of the most important characters of apples depend upon the simultaneous presence of several distinct factors. Thus, in the crosses under study, there are indications that shape, size, and color of fruit, may depend upon the presence or absence of several factors.

Another difficulty is that characters, if recessive, may not appear in the F_1 generation. Now this skipping a generation, when it occurs, will greatly delay and complicate the breeding of plants that are propagated vegetatively, for, if the desired characters do not appear in the F_1 generation propagation cannot proceed at once.

The phenomena of coupling and repulsion, which has been worked out with several plants, though not yet understood, if it appears in apples will tend to complicate breeding processes. That is, some factors seem to be linked together and are so transmitted while others repel one another and refuse to be transmitted together.

Again, the bringing together of complementary factors which somehow in the past breeding of the fruit had become separated, may result in reversions and thus produce unexpected characters.

A breeder may want wholly new characters in apples. These he cannot obtain by making Mendelian combinations.

Existing characters, if we possibly except size and vigor, cannot be augmented by crossing.

To have all of the many characters represented in the offspring it is necessary to work with large numbers of plants — difficult to obtain and time-taking with apples.

It is probable that disappointments will most often come from the attempt to perpetuate variations which are fluctuations dependent upon environment and not upon the constitution of the gametes.

There is likely to be some confusion, for a time at least, until we have more knowledge on the subject, between what are known as "simple Mendelian characters" and "blending characters," or those which may be complex in composition, in which the offspring are seemingly intermediate between the parents.