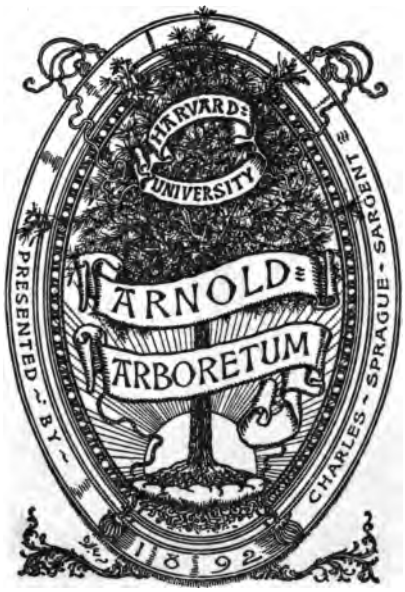

WORK OF THE UNITED STATES DEPARTMENT OF AGRICULTURE ON PLANT HYBRIDISATION

BY

HERBERT J. WEBBER

(*In charge of the Plant-Breeding Laboratory*)

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WORK OF THE UNITED STATES DEPARTMENT OF AGRICULTURE ON PLANT HYBRIDISATION.*

By HERBERT J. WEBBER, in charge of the Plant-breeding Laboratory.

WHILE some work on plant-breeding has been in progress in the United States Department of Agriculture for a number of years, until recently it has been almost wholly in the line of simple selection without the direct application of hybridisation and cross-breeding. The work on hybridisation proper as a means of securing variations and improvements was started only a few years ago, and as yet all the work is in an uncompleted state. Some points of interest have been secured, however, and I shall briefly describe some of these in this paper. The work thus far undertaken has been mainly on Oranges, Grapes, Pineapples, Pears, Apples, Wheat, Corn, and Cotton. It will not be possible to discuss all of the experiments in progress, and features will be selected here and there which it is thought will be of interest to the members of the Conference. The work on Oranges and Pineapples which will be described has been conducted by the writer in conjunction with Mr. Walter T. Swingle, and equal credit should be given him for any factors of importance brought out. Owing to the unfinished condition of the work this paper will largely treat of the improvements which it is desired to secure, with an indication of the progress made.

ORANGE HYBRIDISATION.

The work on the hybridisation of the Orange and other citrous fruits was begun in 1893, but was greatly interrupted by the severe freezes in the winter of 1894 and 1895, and again last winter, February 1899, when a number of the hybrids which would have fruited this year were frozen down. We have secured about 2,000 citrous hybrids which are being grown and tested, but none of these have yet fruited, and the comparisons given below are accordingly based entirely on foliage characters, habits, &c.

A Hardy Orange.—The most important development that we are striving to produce in citrous fruits is a hardy Orange which will withstand the severe frosts that occasionally cause such serious damage in the Orange regions of the United States. This we hope to secure by hybridising the Japanese Trifoliate Orange (*Citrus trifoliata*) with the various varieties of the Common Sweet Orange (*C. aurantium sinensis*). The Trifoliate Orange is a deciduous trifoliolate tree which is perfectly hardy as far north as New York, and is coming to be used extensively as a hedge plant. The fruit is small and bitter, and is generally considered worthless:

* In this paper the term "hybrid" is used, comformable to the *Century Dictionary*, as a generic term to include all organisms arising from a cross of two forms noticeably different, whether the difference be great or slight. Adjectives are sometimes used to indicate the grade of the forms resulting from a cross, such as racial, varietal, or bigeneric hybrids. Where a hybrid of two races or species is crossed with a third race or species a triracial or trispecific hybrid would result. (See discussion on this point in *Year-book*, United States Department of Agriculture, 1897, p. 384.)

it is, however, sometimes used for preserves. It is very late in starting in the spring, the flowers appearing before the foliage, and not even showing till the Common Orange is nearly out of bloom. It is thus regularly about a month later in starting in the spring than the common Orange and other citrous fruits, and is never caught by late frosts. Again in the fall it ripens it fruits early, and becomes dormant a considerable period before the Common Orange. The Common Orange, on the other hand, is an evergreen unifoliolate tree growing more or less during the entire winter unless checked by severe cold. Judging from the results which have been obtained with other plants it seems perfectly possible by crossing and recrossing the Orange with the hardy *trifoliata* to ultimately secure a hybrid combining the fruit characters of the former with the hardiness of the latter.

Many instances are recorded where hybrids have been obtained combining certain characters of the parents, but only a few are known to the writer where increased hardiness has been secured. According to Verlot,* the forms of *Rhododendron arboreum* are rendered hardier by crossing with *R. catawbiense*. Macfarlane has called attention to the hardiness of a hybrid between the hardy *Montbretia Pottsii* and *Tritonia aurea*, which latter is easily injured by cold. He says, referring to the winter of 1891–92: "The corms of the first (*Montbretia*) appear scarcely to have been injured. Those of the hybrid have been largely killed off, at least to the extent of sixty per cent., while *Tritonia*, never hardy in exposed ground, has survived only where it is planted against, and can creep along, the outer side of a hothouse wall."† A second case is also described by Macfarlane where a hybrid between a hardy and a tender species is intermediate in hardness between the two. He says: "*Philesia buxifolia* is a hardy plant, and resists well our winter colds. *Lapageria rosea* requires the temperature of a cold hothouse to flourish, while the bybrid succeeds if kept protected from frosts and the more cutting winds. In the southern counties of Britain it lives and flowers out of doors."† A similar case of increased hardiness secured by hybridisation is cited by Manda: "By crossing *Rosa Wichuraiana* with greenhouse Teas the result is astonishing, as the plants are not only hardy but retain their foliage during the winter. Thus a new race of evergreen Roses has been added to our collection, and promises to be the beginning of a new and useful class."‡

The change desired in the Orange is not so great as one is at first inclined to think. If by infusing a slight portion of the *trifoliata* blood into the Orange we can somehow modify its habits of growth and cause it to remain more dormant through the winter, and later into the spring, we have accomplished our aim, and this, we think, is perfectly possible. The production of Grape hybrids having the resistance to *Phyloxera* of certain of the American species such as *Vitis riparia* and *V. rupestris*,

* Verlot, Jean Baptiste, "Sur la Production et la Fixation des Variétés dans les Plantes d'Ornement," cited in Bailey's *Plant Breeding*, p. 145.

† Macfarlane, Dr. J. M., "A Comparison of the Minute Structure of Plant Hybrids with that of their Parents, and its Bearing on Biological Problems," *Trans. Royal Soc. Edinburgh*, vol. xxxvii. Pt. I. No. 14, p. 258.

‡ Manda, W. A., "Hybrid Wichuraiana Roses," *Gardening*, vol. vi. No. 145, Sept. 15, 1898, p. 9.

and the fine fruits of the European varieties, which it is claimed have been obtained by certain French hybridisers, is an accomplishment of

1 2 3

FIG. 1.—CITROUS HYBRIDS, SHOWING COMPARATIVE VIGOUR.

this nature. On the other hand it seems within the limit of possibility to secure an early ripening strain, possibly deciduous, which will be very much hardier than any of the desirable varieties now known.

The Common Orange and *C. trifoliata* are very distinct in character, and are somewhat difficult to hybridise. In my personal work I find that, even using the utmost care, only about one twentieth of the flowers pollinated seem to be affected by the cross, and only about one per cent. of the flowers cross-pollinated finally mature fruit. There is a further loss in the small percentage of germination, not more than half of the seeds germinating. We have secured quite a number of hybrids, however, where both the Orange and *trifoliata* were used as the seed-bearing parent. Some of these plainly show characteristics of both parents, and are doubtless true hybrids. Out of forty hybrids of the *trifoliata* crossed with pollen of the Sweet Orange, twenty-nine resemble the Trifoliate Orange in habit and foliage characters so far as can be observed, while eleven are clearly intermediate in these characters. These eleven intermediate plants are very similar to each other, and apparently derive certain characters from each parent. The leaves are trifoliolate but are much larger than those of normal *Citrus trifoliata*. The central leaflet has a tendency to enlarge, while the lateral leaflets remain about the normal size or in some cases are reduced in size. (Compare fig. 1, which gives a hybrid (772) between its two parent species, all three being seedlings of the same age.)

The majority of the species of Citrus are polyembryonic, several embryos developing in one seed, and frequently giving several seedlings when germinated. This introduces an interesting complication into citrous hybridising. Strasburger * has shown that the egg cell proper is apparently fecundated in the normal way, and develops into a single embryo, and that the other embryos are developments from certain cells of the nucellus (the mother tissue), near the apex of the embryo sac, which become enlarged and divide, and finally push out into the embryo sac, forming what are termed adventive embryos. When fully developed in the mature seed, these adventive embryos cannot be distinguished from the embryo developed in the normal way from the fecundated egg cell. In many cases a seed from a hybrid fruit has yielded more than one seedling, and in several instances seedlings from the same seed are of totally different character, showing that one has been affected by the hybridisation while the others are like the mother parent. In such cases it seems evident that the intermediate seedling which shows the effect of the male parent is from the embryo, resulting from the development of the fecundated egg cell, while the seedlings resembling the mother parent only, are developed from the adventive embryos, which, as explained above, arise directly from cells of the mother parent without any intervention of the male element.

In the pot shown in fig. 2, No. 2, three seedlings are developing from a single seed of a Tangerine Orange which was crossed by Mr. Swingle with pollen of *trifoliata*. One of the seedlings has trifoliolate leaves, while the other two have unifoliolate leaves like the mother parent. There can be no possible doubt that these three seedlings come from the same seed, as this difference was plainly visible when the seedlings were about an inch high, and fearing that there might be an error I carefully

* Strasburger, Dr. Eduard, "Ueber Polyembryonie," *Jenaische Zeitschr. für Naturwissensch.* XII.

dug up the seed and found them still connected with the cotyledons and all encased in the same seed coat. The same precaution was taken in another similar case, and the fact of the occurrence of such cases, is beyond a question of doubt, whatever be the interpretation. There can be but little doubt that here the trifoliolate seedling comes from the embryo developing from the egg cell proper, and shows the effect of the hybridisation, while the other two seedlings resembling the Tangerine mother plant are from adventive embryos. It should also be noticed that the leaves of the trifoliolate seedling are much larger than those of typical *trifoliata*, as is plainly shown by a comparison with a

1 2 3 4

FIG. 2.—TRUE AND FALSE CITROUS HYBRIDS.

trifoliata seedling shown in fig. 2, No. 1. A similar case, of different parentage, is shown in fig. 2, No. 3. The seed of No. 3 was the result of a cross made by Mr. Swingle of *trifoliata* with pollen of the Sweet Orange. Here the seedling with large leaves is doubtless from the embryo affected by the hybridisation, while that with fewer and smaller leaves resembling true *trifoliata* (in this case the mother parent) is doubtless from an adventive embryo. The reciprocal hybrids of the above, when the Sweet Orange is used as the mother parent and the *trifoliata* as the father parent, several of which have been secured, frequently exhibit the same phenomenon (see fig. 4, No. 1). Similar cases have occurred among our hybrids of Orange and Pomelo, and Orange and Tangerine.

All of the forty hybrids of the Trifoliate Orange crossed with Sweet Orange mentioned above were from a single fruit. In the case of the eleven seedlings which plainly show intermediate characters there can be but little doubt but that they are all from embryos developed from egg cells proper, and thus true hybrids. In the case of the twenty-nine hybrids which show no effect of the male parent it is very doubtful whether they may not be developments from adventive embryos. It seems prob-

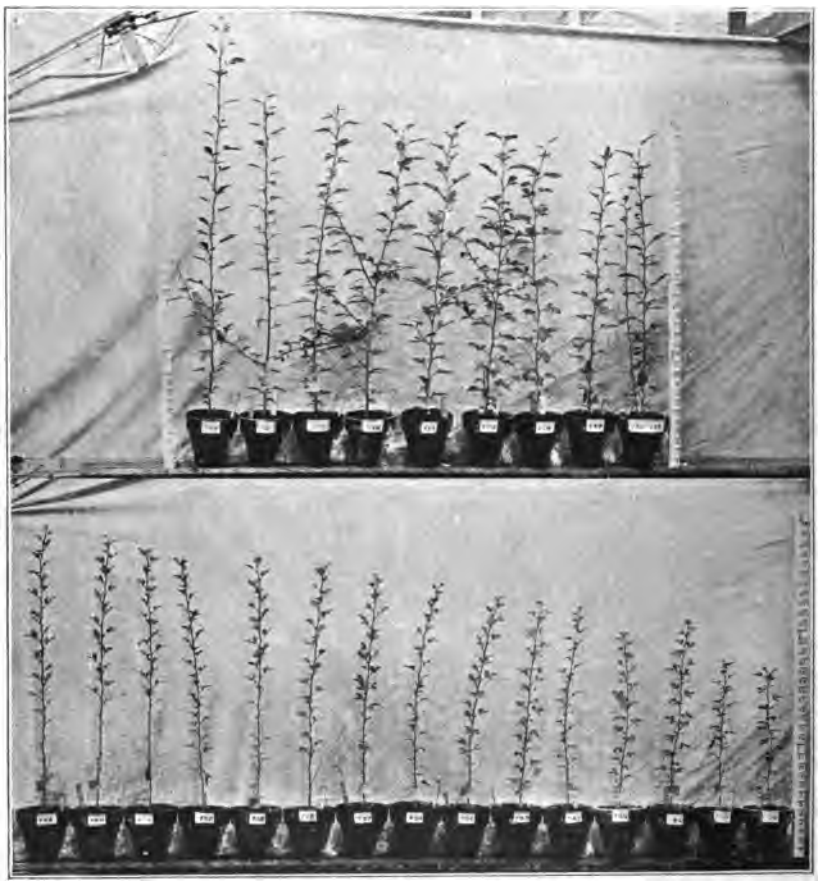

FIG. 3.—TRUE AND FALSE HYBRIDS FROM THE SAME FRUIT OF C. TRIFOLIATA × C. AURANTIUM SINENSIS.

able that the fecundation of a few seeds of a fruit may stimulate the development of other seeds not fecundated, where the only embryos formed are developed adventively, and are not affected by the hybridisation except indirectly so far as the st mulation to development is concerned. In the pots shown in fig. 2, Nos. 1 and 4, two seedlings have developed from a single seed in each case, and in neither case do either show any effect of having been crossed with the Sweet Orange. Those seedlings from hybridised fruits, which show no effect of the male parent, and

seem to come from adventive embryos, I shall speak of here as "false" hybrids for the sake of clearness.

Another feature of importance shown by the true hybrids is their evergreen habit. In March, when the seedlings were transplanted to the south, all of the false hybrids (fig. 3, lower row) were dropping their leaves as true Trifoliate Oranges normally do in the winter. All of the true hybrids, however (fig. 3, upper row), as yet showed no signs of dropping their foliage, and were clearly distinct in this feature. This is also shown well in fig. 2, No. 3, where in two seedlings from the same seed the hybrid is evergreen, while the false hybrid has lost nearly all its leaves.

The increase in vigour, which is so commonly displayed by hybrids between distinct parents, is also shown by these hybrids to a marked degree. Fig. 3 (upper row) shows a representative series of nine of the true intermediate hybrids, which is to be compared with a representative series of the false hybrids shown in the lower row of the same figure. The true hybrids are all much larger and more branched than the false hybrids, which are, as explained above, supposed to be developed from adventive embryos, and thus to be true representatives of the mother parent. The growth is also much more rapid and vigorous than in the normal male parent, which may be seen by comparing fig. 1, where all seedlings are of the same age. No. 845, a cross of two typical Oranges and one of the largest of 500 seedling Oranges of similar kind, is yet far smaller than the medium-sized true hybrid No. 772. No. 780, one of the largest of the twenty-nine false hybrids, affords a relative comparison of size of the true hybrids with the type of the mother parent. The true hybrid No. 772 used here for comparison is not the largest of the hybrids secured, but is of medium size. (See fourth in series, fig. 44, upper row.) In case two or more seedlings develop from the same seed, the one developing from the egg cell and affected by the crossing with the male element, is almost invariably the strongest and largest, which is, of course, what would be expected. (Fig. 2, No. 2, and fig. 4, No. 1.)

The hybrids described above are of *trifoliata* crossed with pollen of Sweet Orange, but the reciprocal hybrids obtained show the same characters and about an equal proportion of intermediate plants or true hybrids. Of fourteen hybrids of Sweet Orange crossed with pollen of *trifoliata* nine seedlings are, so far as can be observed, exactly like the typical mother parent, and are possibly false hybrids, while five are intermediate in nature, resembling the male parent in having trifoliolate leaves, which are much larger than typical *trifoliata*. (Fig. 4, Nos. 1 and 2, and fig. 5, No. 716.) It is interesting to note that here, where the Sweet Orange is used as the mother parent, in the five cases of seedlings showing intermediate nature all are trifoliolate, though coming from seeds of an unifoliolate species, and show almost exactly the same intermediate characters as are shown by the reciprocal hybrids, where the *trifoliata* is used as the mother parent and the Sweet Orange as the father parent.

In crosses of the Tangerine (*Citrus nobilis*) with pollen of the Trifoliate Orange the same feature is exhibited. Of twelve such hybrids eleven resembled the Tangerine in foliage characters, &c., while one has

trifoliolate leaves, somewhat larger than the normal leaves of *trifoliata*, clearly showing the influence of the pollen parent. It is interesting to note here also that the trifoliolate seedling is the largest of the series.

Loose Skin of Mandarin.—A second improvement of importance which it is desired to produce is a fruit having the quality and flavour of the finest varieties of the Common Orange with the loose, easily removable skin of the Mandarin type of Orange (*C. nobilis*). With this object in view a number of hybrids have been made, principally between the Tangerine, the best sort of Mandarin Orange in cultivation, and various varieties of the Common Orange. *Citrus nobilis* is much more closely related to the Common Orange than the *C. trifoliata*, and the hybrids seem to be much more variable in the first generation, some very closely resembling the parents, while others are apparently intermediate as far

1 2 3 4 5

FIG. 4.—HYBRIDS OF SANDFORD'S MEDITERRANEAN (C. AURANTIUM SINENSIS) × C. TRIFOLIATA.

as can be judged from foliage characters. Here, however, the characters of the parents are more nearly alike, and it is only in the extreme variations that the foliage resemblances can be clearly distinguished. In almost every case, however, the great majority of the seedlings resemble the mother parent in the main, while comparatively few show plainly the effect of the male parent. Among 286 hybrids of the Tangerine crossed with pollen of Common Orange 247 seemed mainly to resemble the Tangerine in foliage characters, while thirty-nine show more resemblance to the Common Orange.

The reciprocal hybrids, where the Common Orange was crossed with pollen of Tangerine, show the same features, the majority of the seedlings resembling the mother parent, and only a small percentage of them showing the effect of the male parent. In fig. 6, showing seven seedlings of the Ruby Orange ♀ × Tangerine ♂, the large seedlings in Nos. 1

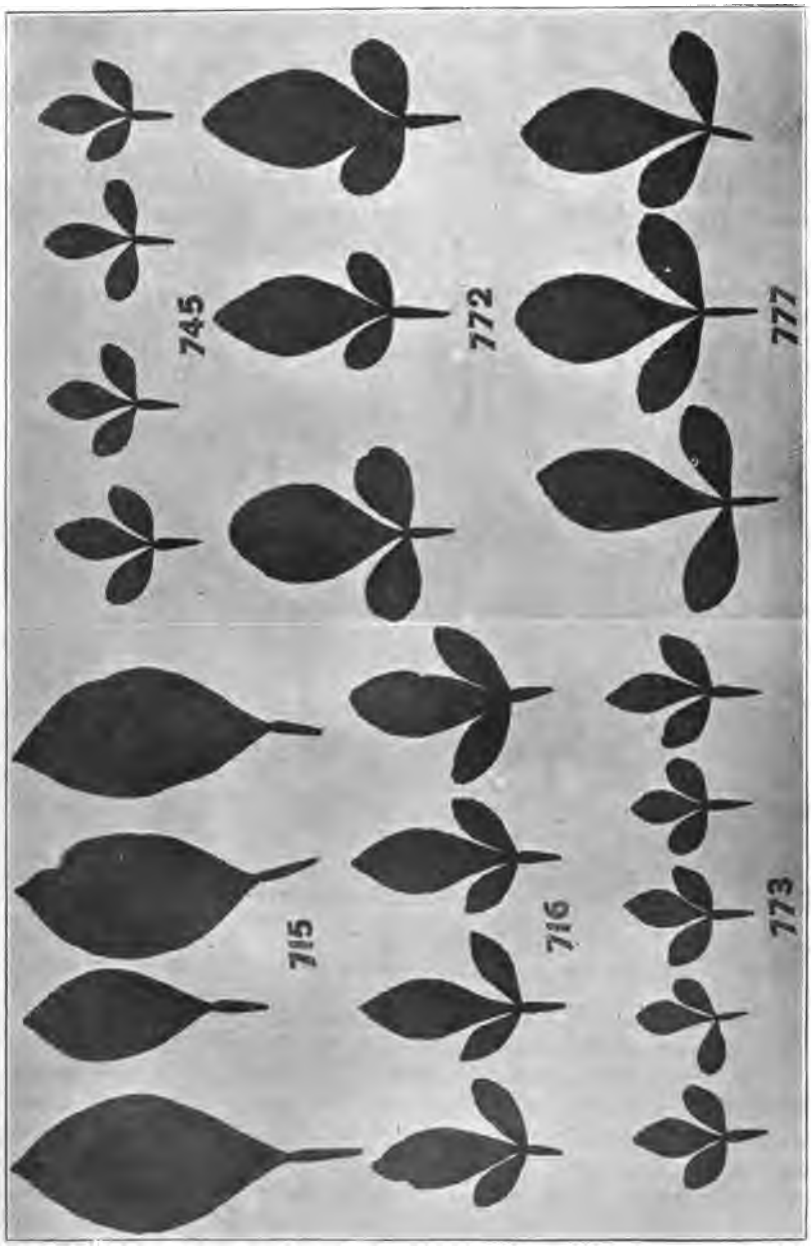

FIG. 5.—LEAVES OF TRUE AND FALSE CITROUS HYBRIDS.

and 3 resemble the mother parent mainly, while the large seedlings in Nos. 2 and 4 show the effect of the father.

It is equally important to secure fruits of the Pomelo type, which have the easily removable skin and easily separable segments of the Mandarin type of Orange, and to secure improvements in this direction many hybrids of the Tangerine and Pomelo have been made. The resulting seedlings, as in the case of the Tangerine Orange hybrids, mainly resemble the mother parent; but the Pomelo foliage being more markedly different from the Tangerine than that of the Orange, the differences are much plainer. Of 116 hybrids of the Pomelo crossed with pollen of Tangerine 111 had plainly the broad-winged petioles and robust foliage of the female parent, while only five showed the foliage characters of the Tangerine or male parent. No reciprocal hybrids were made in this case.

1 2 3 4

FIG. 6.—HYBRIDS OF RUBY ORANGE (C. AURANTIUM SINENSIS) × TANGERINE (C. NOBILIS).

Change of Quality.—Among the varieties of citrous fruits now cultivated are several fairly desirable fruits, quite distinct in their characters, which from their appearance seem to be hybrids of the Orange (*C. aurantium sinensis*) and Pomelo (*C. decumana*). The variety known as the Aurantium-Pomelo is so called because of its supposed hybrid nature. A fairly well-known Jamaican Pear-shaped Pomelo of small size, with orange-yellow skin and Pomelo-like pulp, seems also to be a hybrid between these two species. We have made quite a number of crosses of these species, hoping to secure fruits markedly different from those now in cultivation, and which will prove valuable commercial varieties. Of 126 hybrids of the Pomelo with pollen of the Orange 106 resembled the mother parent and twenty the male parent.

Resistance to Disease.—The Sour Orange (*C. aurantium amara*) has been found by extended observations to be largely immune to the so-called "blight," which is probably the worst Orange disease known in Florida. Hoping to secure desirable sorts of sweet edible Oranges immune to this disease, the Orange was crossed with pollen of the "Bitter Sweet," which is the best variety of the Sour Orange. The twenty-seven hybrids of this parentage are the most variable of any set or combination of citrous hybrids which we have obtained. Some have leaves almost exactly like the Bitter Sweet, others almost exactly like the Orange, others present a totally distinct shape of leaf from either parent. Of these twenty-one resemble in main the mother, and six in main the male parent.

Other hybrids were made for various minor improvements, but it is not desirable to discuss them further here.

Summary of Resemblances of Citrous Hybrids.—In the hybrids of the widely distinct species the seedlings divide themselves plainly into two classes: (1) Those resembling the mother parent entirely, so far as could be determined; and (2) those intermediate in character.

Parentage	Total number of seedlings	Number resembling mother	Number intermediate
Trifoliata ♀ × Sweet Orange ♂ . .	40	29	11
Sweet Orange ♀ × *Trifoliata* ♂ . .	14	9	5
Tangerine ♀ × *Trifoliata* ♂ . . .	12	11	1

In the hybrids of closely related species, such as Orange × Pomelo and Orange × Tangerine, the intermediate nature of the hybrids, if they are intermediate, cannot be easily distinguished. In foliage and other characters, so far as exhibited previous to fruiting, they seem to resemble very closely either the mother or father parent. The following table will show the proportion of their resemblance:—

Parentage	Total number of seedlings	Number resembling mother	Number resembling father
Tangerine ♀ × Sweet Orange ♂ . .	286	247	39
Sweet Orange ♀ × Tangerine ♂ . .	75	69	6
Pomelo ♀ × Tangerine ♂	116	111	5
Pomelo ♀ × Sweet Orange ♂ . . .	126	106	20
Sweet Orange ♀ × Pomelo ♂ . . .	103	95	8
Sweet Orange ♀ × Bitter Sweet ♂ . .	27	21	6
West Indian Lime ♀ × Sicily Lemon ♂ .	11	9	2
Sicily Lemon ♀ × West Indian Lime ♂ .	9	9	0
West Indian Lime ♀ × Pomelo ♂ . .	4	4	0

Pineapple Hybridisation.

The principal problems here presented are to secure—1, better shipping sorts; 2, smooth-leaved sorts; 3, sorts resistant to disease; and 4, sorts having larger fruits of better quality. These objects have been kept clearly in view in all of our work. Pineapples, as is well known, are almost totally seedless. Among the fruits which reach the American markets from the Bahamas, West Indies, and Florida it is

very seldom that a perfect seed is found. So rare is this that most people, and even some botanists, consider it to be a totally seedless fruit. It is interesting to note here that the stigmas are apparently always abundantly dusted with pollen from the same flower, and it is plain that they are either self-sterile or that the pollen is imperfect. A microscopic examination, however, of the pollen of the Red Spanish variety showed the pollen to be perfectly normal so far as could be judged.

In the spring of 1896 I crossed a number of flowers of the Mauritius Pineapple with pollen of the Red Spanish variety simply as a preliminary trial to see whether seeds could be induced to set by crossing different sorts or varieties. In this experiment a number of apparently perfect seeds set, some fifteen of which germinated and grew. In the spring of 1897 Mr. W. T. Swingle made numerous other crosses, and the following year, the spring of 1898, I continued the work myself. As a result of this work we now have some 500 seedlings showing many interesting foliage variations. The 24-month-old seedlings have reached a height of 6 or 8 inches, being as large as the slips commonly used in planting fields, and it would seem from their size that many will fruit in the summer of 1901. If size and rapidity of growth can be taken as an indication they surely will not require eight years from seed to fruit, as I have seen somewhere stated.

In the course of the work it has been observed that certain sorts are apparently sterile to each other's pollen, no seeds setting even when carefully crossed. As an illustration, fifty flowers of Pernambuco crossed with pollen of Porto Rico gave no seeds; and thirty-nine flowers of Porto Rico crossed with pollen of Pernambuco, the reciprocal cross to the above, also gave only one single seed, and that imperfect.

In my own experience the most fertile varieties are the Abbaka and Smooth Cayenne, two of the finest varieties known. Ninety-seven flowers of Abbaka crossed with pollen of Smooth Cayenne gave seventy-seven good seeds, and, in the case of the reciprocal cross, thirty-six flowers of the Smooth Cayenne crossed with pollen of Abbaka gave forty-six perfect seeds. Other sorts used in crossing, such as Golden Queen, Ripley, Red Spanish, Mauritius, &c., gave varying degrees of fertility between these two extremes.

Cotton Hybridisation.

The production of Cotton is one of the most extensive industries of the Southern United States, and furnishes many problems to tax the skill of the plant breeder. The so-called Sea Island Cotton, *Gossypium barbadense*, grown in a limited area mainly on islands near the coast of Georgia and South Carolina, furnishes the longest and finest staple produced anywhere in the world. The Upland Cotton, *Gossypium herbaceum*, which is the kind grown all over the interior, produces a comparatively short and coarse staple. If by hybridising the fine Sea Island with the different varieties of the Upland a race can be secured suitable to growth in the interior regions, and yielding a finer and longer staple, the industry will be greatly benefited. This would seem to be a comparatively simple problem, but it is complicated by the necessity of securing, not only a

M H F

FIG. 7. – COTTON HYBRID AND ITS PARENTS, SHOWING COMPARATIVE VIGOUR.

longer and finer staple, but, to be of any value, it must be borne on a smooth black seed, like the Sea Island type, so that the fibre can be ginned

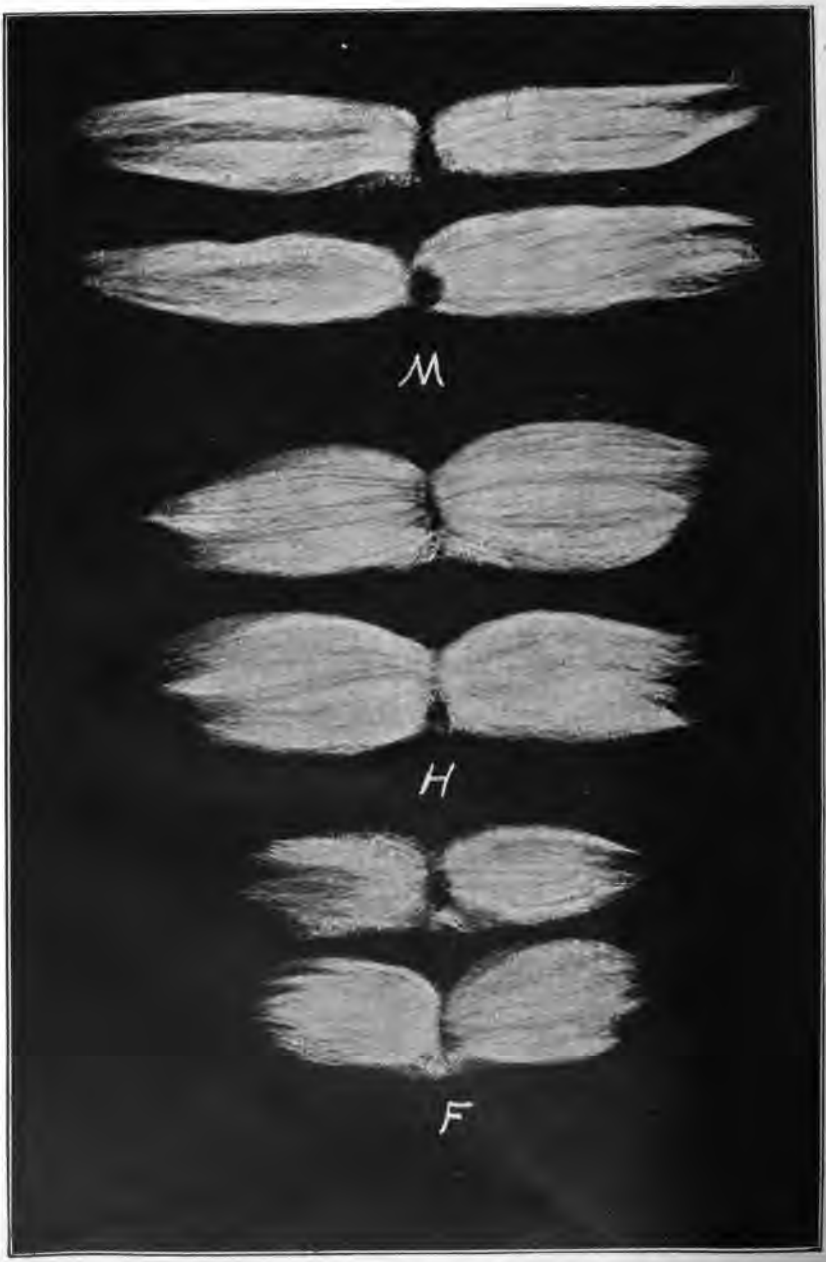

FIG. 8.—SEEDS OF HYBRID COTTON AND OF ITS PARENTS, WITH THE FIBRE PULLED OUT TO SHOW THE RELATIVE LENGTH AND AMOUNT IN EACH CASE.

M, Fibre of 'Sea Island'; F, of 'Upland'; H, of 'Klondyke,' the Hybrid between them.

on a roller gin. In the ordinary Upland, where the fibre varies from ¾ to 1¼ inches long, the seed is covered with a dense coating of short hairs—is a "tufted" seed as the growers say—and this prevents the use of the roller gin, a saw gin being necessitated. The saw gin tears the fibre so seriously that there is no object in increasing its length unless it is borne on a smooth seed, so that the roller gin can be used. Mr. W. A. Clark, a careful planter, of Columbia, South Carolina, who is co-operating with the Department of Agriculture in this work, early realised the difficulties in the problem and took up the first necessary step—the production of a smooth-seeded strain of the Upland Cotton. This he secured, after five or six generations of careful selections, in a strain which he called the 'Klondike.'

In the ordinary sorts of Upland Cotton smooth black seeds, similar to those of the Sea Island Cotton, are occasionally found mixed with the ordinary tufted or green seeds. Originally certain Upland sorts, such as Peterkin, had smooth seeds, and the production of such seeds in sorts commonly having tufted seeds may be due to hybridisation of the ancestors of the plant with the Sea Island or some smooth-seeded sorts of the Upland.

Mr. Clark selected at random and planted a quantity of smooth black seeds from the ordinary Upland Cotton, and the great majority of the resulting plants produced the ordinary tufted seed; but a few had mainly smooth black seed like those from which the plants were grown. Seeds were selected from the few plants which produced mainly smooth black seed, and were planted the second year. This season a much larger proportion of the plants produced smooth black seed, but still many produced the ordinary tufted seed. Seeds were again selected from the plants producing smooth seed and planted the third year, and so on through five generations, when the character was fully fixed and all the plants came true, producing only the smooth black seed.

The 'Klondike' was then hybridised with the Sea Island, and while it is too early to pronounce as to the practical value of the hybrids secured, some are exceedingly promising, having fibre intermediate in length and fineness between the two parents, and more abundant than in either (fig. 7, H). It is also interesting to note that here, again, the increased vigour so commonly resulting from hybridising different species and races is very markedly exhibited in many cases.

A second important problem in Cotton breeding which is receiving attention is the production of a tawny Cotton of a grade similar to the Egyptian, which is extensively imported into the United States, and manufactured largely into fine underwear, &c. The Egyptian varieties so far as yet tested in the United States have failed to give satisfactory results, and it seems that races especially adapted to conditions obtaining there must be secured. Experiments are under way in crossing the varieties of the Sea Island and Upland grown in the United States with the Egyptian races, and with the dark brown Pieura or Peruvian Cotton with a hope of securing brown or tawny races suited for culture in the United States which will take the place of the tawny Egyptian Cotton now imported.

Corn or Maize Hybridisation.

Only very few of the numerous important problems here presented to the plant breeder have as yet been taken up. In the hope of securing better-yielding races the exceedingly large-kernelled Cuzco, or Peruvian Corn recently imported into the United States by the Department of Agriculture, was used in hybridising with certain of our best races. The Hickory King, a very large-kernelled white dent, and Leaming, a well-known yellow dent, were used as the seed-bearing parents. The Cuzco, from which the pollen for the hybrids was obtained, was grown from kernels of a graphite colour, this colour being distinct from that of any race of Corn in the United States with which I am familiar.

The current or immediate effect of pollen (xenia), so commonly reported as occurring in Corn, was shown in these hybrids; and although no check experiments were made (the work not being carried on to demonstrate this feature), there can nevertheless be no doubt that the coloration was due to the effect of the pollen. The seed of the Hickory King and the Leaming used was grown by careful seedsmen, and strict attention was given to keeping it pure and true to type. None of the ears except those which had been crossed showed any indication of impurity. Some of the kernels of the Hickory King ears crossed with the pollen of the Cuzco showed irregular spots of the characteristic graphite colour of the Cuzco, while others were entirely of a slate colour, these being somewhat lighter in colour than those of the typical Cuzco. So far as could be observed, the Cuzco used was not a fixed type, some of the kernels being mottled with red, olive purple, or brown. In a few instances the immediate effect of the pollen was apparent in Leaming crossed with Cuzco,* the kernels showing a peculiar admixture of the colours of the parents, that is of dark olive purple and the orange yellow. In the case of the hybrids of Hickory King with Cuzco grown from kernels showing the immediate effect of the pollen, which were marked when planted, their increased vigour, purple stalks, and whorls of anchor roots (inherited from the Cuzco, the male parent) showed that they were without question hybrids of the two races named. In the same characteristic way the influence of the male parent was evident in many of the hybrids from kernels in which no immediate effect of the pollen was shown. All hybrids showing intermediate characters were very late in flowering, which is another characteristic of the Cuzco, it being a tropical plant, and therefore requiring a long season to develop. These hybrids as a rule matured slightly earlier than the Cuzco plants in the same field.

Other hybrids have been made with a view of securing sorts that will yield better in northern regions, where flint Corn, which ripens early but is a poor yielder, is now grown. Some of these hybrids are very promising; for instance, one of Gilman Flint (a good race of the flint Corn) when crossed with Leaming pollen produced ears almost twice as large as those produced by the Gilman Flint grown under similar conditions, there being sixteen rows of kernels on the ear instead of twelve,

* The crosses of Leaming with Cuzco were made by Mr. E. C. Rittue, gardener of the Division of Vegetable Physiology and Pathology, at my request.

as in the Gilman Flint, and the kernels being much larger. This hybrid ripened nearly as early as the Gilman Flint, being secure from injury by frost three months after it was planted.

It is the intention of the Department to test such hybrids in the regions to which they seem best adapted, and to fix races of such as are found valuable.

Conclusion.

What has been said above will serve to show the character of the work on plant breeding, which it is the intention of the Department of Agriculture to foster, and also to call attention to some of the important problems which are now receiving attention. The vast diversity of soil and climatic conditions afforded by our great extent of territory renders it necessary for us to have very many different sorts of cultivated plants. An important and almost illimitable field is thus opened for the plant breeder, and we hope that the work on this subject in the Department of Agriculture may soon assume such scope and magnitude as its importance demands.

Explanation of Figures.

Fig. 1.—Citrus hybrids, showing comparative vigour: 772, hybrid of *Citrus trifoliata* ♀ × *C. aurantium sinensis* ♂, a medium-sized seedling selected from nine hybrids of same parentage; 780, type of female parent (*C. trifoliata*), one of the largest of thirty seedlings; 845, type of male parent (*C. aurantium sinensis*), one of the largest of nearly five hundred seedlings. These three seedlings are all of the same age.

Fig. 2.—True and false citrous hybrids: No. 1, false hybrids of *C. trifoliata* ♀ × *C. aurantium sinensis* ♂ from same seed, both hybrids resembling the female parent only; No. 2, three hybrids of Tangerine Orange (*C. nobilis*) ♀ × *C. trifoliata* ♂ from one seed, the largest, with trifoliolate leaves, being a true hybrid, while the two small ones, resembling the female parent only, are false hybrids; No. 3, two hybrids of *C. trifoliata* ♀ × *C. aurantium sinensis* ♂, both from same seed, the one on the left, with large leaves, being a true hybrid, and the one on the right, with small leaves, being a false hybrid; No. 4, two false hybrids of *C. trifoliata* ♀ × *C. aurantium sinensis* ♂, both from same seed, resembling female parent only.

Fig. 3.—True and false hybrids from same fruit of *C. trifoliata* ♀ × *C. aurantium sinensis* ♂, showing comparative size. Upper row true hybrids, lower row false hybrids.

Fig. 4.—Hybrids of Sandford's Mediterranean (*C. aurantium sinensis*) ♀ × *C. trifoliata* ♂. Trifoliolate seedlings in pots Nos. 1 and 2 are true hybrids, being intermediate between the two parents; the others are apparently false hybrids, resembling the female parent only.

Fig. 5.—Leaves of true and false citrous hybrids: 715 and 716, false and true hybrids respectively of Sweet Orange (*C. aurantium*) ♀ × *C. trifoliata* ♂; 773 and 745, false hybrids of *C. trifoliata* ♀ × *C. aurantium sinensis* ♂; 772 and 777, true hybrids of *C. trifoliata* ♀ × *C. aurantium sinensis*.

Fig. 6.—Hybrids of Ruby Orange (*Citrus aurantium sinensis*) ♀ × Tangerine (*C. nobilis*) ♂: No. 1, seedling resembling female parent; No. 2,

largest seedling, intermediate between parents, two small seedlings, apparently false hybrids; No. 3, seedlings resembling female parent; No. 4, seedling resembling male parent.

Fig. 7.—Cotton hybrid and parents, showing comparative vigour: F, Upland Cotton, female parent; M, Sea Island Cotton, male parent; H, Hybrid. (These plants were photographed under the direction of Mr. W. A. Clark.)

Fig. 8.—Seeds of hybrid Cotton and of parents, with fiber pulled out to show length and amount: F, ordinary Upland, female parent; M, Sea Island, male parent; H, Hybrid.

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