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Contribution from the Bureau of Plant Industry
WILLIAM A. TAYLOR, Chief

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POTATO BREEDING AND SELECTION

By

WILLIAM STUART, Horticulturist,
Office of Horticultural and Pomological Investigations

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CONTENTS.

INTRODUCTION.

The increasing commercial importance of the Irish potato as an article of human diet and its adaptation to widely varying climatic conditions have served to extend its cultivation throughout most of the agricultural sections of the United States.

Although the potato crop now ranks sixth in agricultural importance in the United States, it has by no means assumed the position that its wide use as a table food would seem to justify. Our present average annual production of potatoes is only about one-fifth that of Germany. This wide variation in production between Germany and the United States may be partially accounted for by the fact that 50 per cent or more of the German crop is used either for stock food or for conversion into starch, alcohol, or other industrial by-products. The American potato crop, on the other hand, has no such outlet for its surplus tubers, since less than 1 per cent of the crop is used for industrial purposes. Moreover, the per capita consumption of potatoes in Germany is about two and one-half times as great as it is in this country. These two factors account in large measure for the very material variation between the total potato production of the two countries.

The modern tendency toward the development of potato-growing centers in widely separated sections of the United States, as, for example, Aroostook County, Me., the Norfolk and Eastern Shore trucking regions of Virginia and Maryland, the Red River Valley of Minnesota and North Dakota, the Kaw Valley of Kansas, the Greeley and Carbondale districts of Colorado, and the San Joaquin and Sacramento Valleys of California, has created a demand for varieties of potatoes especially adapted to cultivation in those sections. This condition, coupled with the presence of numerous diseases of the vines and tubers, from which frequent and oftentimes severe losses have resulted, has caused many inquiries to be made regarding the possibility of developing new varieties or strains possessing certain specific qualities not embodied, at least to the same degree, in those varieties now under cultivation.

This demand upon the plant breeder has served to emphasize the necessity, as well as the desirability, of attempting to develop, either through breeding or selection, new varieties or strains of potatoes which shall possess a greater degree of resistance to the parasitic fungi which now prey upon the plants and tubers. Another fruitful field of investigation well worth the attention of the plant breeder is the development of potato varieties that are better adapted to certain sections of our country. These adaptational characteristics may be either earliness or lateness, drought resistance or heat resistance, or an ability to succeed in heavy or in light soil; they may be productiveness, shape of tuber, quality of tuber, starch content, or, in fact, any distinct quality which would make a variety especially desirable for cultivation in a given locality.

POTATO BREEDING AND SELECTION DEFINED.

In order that there may be no confusion in the mind of the reader as to what is meant in this bulletin by the term "breeding," the writer has thought it best to make a clear-cut distinction between "breeding" and "selection."

Breeding is here employed in the sense of sexual reproduction.

Selection implies, in the case of the potato, the isolation and asexual propagation of desirable strains or types.

Breeding can only be successful when it goes hand in hand with selection. Selection, on the other hand, is not dependent upon breeding for results.

LIMITATIONS OF BREEDING AND SELECTION.

Broadly speaking, the limitations of breeding are not simply those found within the confines of our cultivated varieties of potatoes, but those embraced by the whole range of the tuber-bearing solanums.

In the case of selection, the limitations are those found within the varieties themselves.

Potato breeding, therefore, may be said to involve the raising of seedlings from hand-pollinated or self-fertilized seeds. It becomes intelligent breeding only when it deals with seedlings produced from hand cross-pollinated flowers protected from insects and borne on plants possessing certain characteristics which it seems desirable to combine in the resultant progeny. In other words, intelligent plant breeding requires the same careful consideration of the parent plants that is given to the selection of the male and female by the progressive up-to-date animal breeder. Selection plays a very important rôle in this kind of breeding.

EARLY ATTEMPTS AT POTATO BREEDING.

The first serious attempt at potato breeding in the United States of which the writer has any knowledge was made by Rev. C. E. Goodrich, of Utica, N. Y.[1] The incentive for this effort was furnished by the widespread occurrence of potato blight, both in this country and abroad, during the period between 1840 and 1847, and the consequent almost total failure of the potato crop in some seasons. In the opinion of Mr. Goodrich the apparent greater susceptibility of the vines and tubers to this disease was largely due to the lessened vigor of the plants, induced by long-continued asexual reproduction. He conceived the idea that the only way in which the vigor of the potato plants could be restored was by sexual reproduction. Through the kindly offices of the American consul at Panama a number of promising South American varieties of potatoes, presumably from Peru and Chile, were secured. A seedling grown from one of these plants in 1853, descriptively known as the Rough Purple Chili, was introduced into cultivation in 1857 under the name of Garnet Chili. Other introductions from the seed of these importations were the Amazon, Calico, Cuzco, Central City, New Kidney, Coppermine, Pink-eye, Rusty Coat, etc. Between the years 1849 and 1856 Goodrich raised 8,400 seedlings.[2]

The importance of Goodrich's work to the potato industry of this country lies not so much in the new varieties which he himself introduced as in the impetus he imparted to plant breeding and in the efforts of those who followed in his footsteps. Much of this zeal was the result of the origination and introduction of the Early Rose, a variety which was produced in 1861 by Albert Bresee, of Hubbardton, Vt., from a naturally fertilized seed ball of Goodrich's Garnet Chili. Thus there was obtained in the second generation from the imported South American potato, described by Goodrich as the

[1] Goodrich, C. E. Raising seedling potatoes. *In* The Horticulturist, n. s., v. 7, 1857, p. 273–276.

[2] Goodrich, C. E. Op. cit., p. 276.

Rough Purple Chili because of its rough skin, purple color, and supposed place of origin, a variety which upon its introduction in 1867 did more to awaken a keen and widespread interest in potato breeding in America than any other variety which has since been produced. This statement is well substantiated by a perusal of our agricultural literature and the seed catalogues issued between 1867 and 1884. The same publications also show that this period was marked by greater activity and more painstaking efforts in potato breeding than have characterized the more recent years. The interest was greater, more work was accomplished, and the parentage of the new introductions was much more carefully recorded than has been the case in subsequent years. Since 1884 comparatively few of the introductions have been obtained from hand cross-pollinated seed. In the main they have sprung from naturally fertilized seed or have come as sports or mutations from varieties already in cultivation.

So far as the writer is aware, Goodrich did not attempt hand pollination of the potato blossoms, and in that respect he may be said to have failed in the performance of the highest type of plant breeding. His was a pioneer work which served to blaze the way for those who followed. Among the men who later took up the work may be mentioned C. G. Pringle, of Charlotte, Vt., and E. S. Brownell, of Essex Center, Vt.

The work of Pringle deserves rather more than passing mention, inasmuch as he brought to bear upon the problem all the skill that the then existing knowledge of plant breeding furnished. His was no haphazard work. He selected his varieties for crossing with a definite purpose in view. Each variety was supposed to possess one or more desirable qualities which it was proposed to combine by crossing with certain other desirable qualities of another variety. Not only were the varieties selected with a definite purpose in view, but equally as much attention was paid to the selection of particularly healthy and typical parent plants. So skillful did Pringle become in the breeding of potatoes that we find him contracting with a leading New York seedsman in the early seventies to produce hybridized potato seed at $1,000 per pound. A considerable quantity of such seed was produced and through the agency of the seedsman was widely disseminated. There is every reason to believe that this seed, falling into the hands of amateur plant breeders, resulted in the production of a large number of promising new varieties. Of the potatoes which Pringle originated and which were introduced by B. K. Bliss & Sons, the Snowflake was perhaps most widely known. This variety was noted for its high table quality, but on account of a rather weak constitution and medium productiveness it became popular only as a family table potato.

Brownell originated many new varieties, but from what the writer was able to learn some years ago from his contemporary fellow workers it would appear that many of his seedlings were produced from naturally fertilized seed balls. Be this as it may, however, his productions were numerous and in their day were widely grown. Among the best known may be mentioned Brownell's Best, Beauty, Eureka, and Winner.

In this brief survey of the early attempts at potato breeding, it would scarcely be fitting to omit the names of a few other men who have gained a more or less enviable reputation through the origination of a variety or varieties which are still rather widely grown and who have exerted considerable influence on the development of the potato-growing industry of this country. Among these men are Alfred Reese, Luther Burbank, and E. L. Coy.

In 1870 Alfred Reese grew a seedling from a naturally fertilized seed ball of the Early Rose, which was introduced by Gregory in 1875 under the name of Early Ohio. This potato is perhaps more extensively grown at the present time throughout the central and middle Western States than any other variety. In fact, in certain sections, such as the Kaw Valley of Kansas, the Red River Valley of Minnesota and North Dakota, and in most of the early-market sections of the territory mentioned, it is almost exclusively grown. In the Early Ohio we have a third-generation seedling from Goodrich's imported Rough Purple Chili.

The early fame of Luther Burbank rests very largely upon the Burbank potato, which he originated in 1873. This potato was introduced by Gregory in 1876 as Burbank's Seedling. The story of its origin is not a record of any particular effort on the part of the originator. Indeed, according to Burbank's own version, it reads like this: In the summer of 1872, in a small plat of Early Rose potatoes in his mother's garden at Lancaster, Mass., Burbank observed one plant upon which a seed ball was developing. When he next visited the plant the berry was gone, but after diligent search of the ground in the vicinity of the vine he was fortunate enough to find it. The seeds of this berry were planted the following spring and from them grew 23 seedlings, one of which was later named Burbank's Seedling. In Burbank's Seedling we again have the third-generation progeny of the Rough Purple Chili.

E. L. Coy, of West Hebron, N. Y., is perhaps best known as the originator of the Beauty of Hebron, a variety which in its day was one of the most popular of the "medium earlies." Although the exact date of the origin of this variety is not known, it was probably about 1873 or 1874. It was introduced in 1878. Coy claims that the Beauty of Hebron was raised from a naturally fertilized seed ball of the Garnet Chili, thus making it a second-generation seedling of the Rough Purple Chili.

In view of the testimony already presented regarding the parentage of a few of our better known varieties of potatoes, there seems to be every justification for claiming that Goodrich's efforts were epoch making.

TECHNIQUE OF POTATO BREEDING.

The floral organs of the potato are of such simple structure as to render the task of manipulating the flowers a comparatively easy one. The two organs immediately concerned in plant breeding are the pistil and the stamens. The potato plant bears perfect flowers; that is, each flower when normally developed has both pistil and stamens, or female and male organs of reproduction.

STRUCTURE OF THE PISTIL.

Each flower bears but one pistil. The style of the pistil varies from 6 to 9 lines in length and from one-third to two-thirds of a line in thickness. Generally speaking, the shorter the style, the more fleshy it is. Some styles are greatly curved, while others are only slightly so, and a few are perfectly straight. The 2-lobed stigma also varies very greatly in size. Some stigmas are very slightly enlarged and somewhat cup shaped, while others are considerably enlarged, having well-rounded lobes covered with short papillæ.

STRUCTURE OF THE STAMENS.

The potato flower normally possesses five stamens, though occasionally four or six have been noted. The stamens have short, thick filaments with large, fleshy, erect anthers which stand close together around the style, like a cone in the center of the flower (Pl. I, fig. 1, *A*). The placenta, which divides the anther longitudinally into two equal parts, is rather thick and fleshy. The halves or lobes of the anthers have small terminal pore openings, through which the ripe pollen grains normally escape. In many varieties, the anthers are so poorly developed that the terminal pores do not open, although they are not so undeveloped as to be devoid of pollen. In such cases the membranous outer covering of each lobe of the anthers may be slit open and the pollen grains scraped off into a watch glass by means of a scalpel, forceps, or needle.

The color of the stamens varies greatly with different varieties. Some are a pale lemon yellow, while others are a bright orange yellow, with all the intergradations of color between these two. Only one instance has come to the writer's attention in which the color of the stamens did not answer to the above description, and that was in the case of a wild Mexican species, *Solanum cardiophyllum lanceolatum* (Berth.) Bitter, where the anthers were chocolate brown with a slight tinge of purple. Generally speaking, varieties with pale lemon-yellow flowers do not produce pollen freely and as a rule their pollen is not viable.

HAND TECHNIQUE.

The technique of cross-pollinating potatoes by hand is comparatively simple, but since relatively few of our commercial varieties develop viable pollen, the percentage of success is correspondingly small. Obviously the first step in the cross-pollination of the potato is the selection of the seed-bearing plants. Strong, healthy plants should be chosen for this purpose, of a variety possessing certain definite characters which it is desirable to combine with certain other desirable characters of another plant.

The next step is the selection and emasculation of the flowers and the bagging of the same. The proper stage at which emasculation should be performed is shown in Plate II, figure 1. This varies somewhat with the variety or species. Generally speaking, it should be done before the pistil protrudes through the bud, or a day or two in advance of the opening of the flower. The only instrument necessary for the removal of the stamens is a pair of sharp-pointed forceps. The operation is most easily accomplished by clasping the bud by the lower portion of the calyx with the forefinger and thumb of the left hand and then opening up and pushing back the corolla with a pair of sharp-pointed forceps; after this the stamens are easily removed by pressing each of them away from the pistil until the filament snaps off at its base. Plate I, figure 1, *B*, shows a potato blossom from which the stamens have been removed in this way. It is usually desirable to emasculate as many flowers in each cyme as are at the right stage of maturity. All the immature buds and mature flowers should be removed before inclosing the emasculated flowers in a paper bag (Pl. II, fig. 2). A 1-pound bag—that is, a paper sack having the capacity mark of 1 pound—is large enough for this purpose. To facilitate the work of putting on the bags, it has been found convenient to punch holes through the sides of the bags and to draw strings through these holes prior to going to the field (Pl. III, fig. 1). It has also been found desirable to inclose in the bag the young shoot bearing the flower cyme, or, where this is not feasible, to include as much foliage as possible around the flowers.

The flowers are usually ready for pollinating one to two days after emasculation, depending upon the stage of maturity when emasculated and upon the character of the weather subsequent thereto.

During the first few years in which the writer was engaged in potato breeding, various methods of removing the pollen from the anthers were practiced. One method was that of collecting in the early morning flowers from plants selected as pollen parents and bringing them into the laboratory, where they were allowed to wilt slightly, after which it was generally found that the pollen could be jarred out of the terminal pores into a watch glass. In varieties which developed pollen sparingly, the cells of the anthers were opened and the pollen grains removed. Pollen secured in this way gave very indifferent results, as a rule, and the method was superseded by the one which is now in use.

The present method consists in gathering the flowers from the plants about as needed. When considerable numbers of crosses are to be made and when good flowers are abundant, a number of them are gathered from each male parent to be used. These flowers are kept in small paper bags similar to those used for covering the emasculated flowers, each bag being properly labeled with the name or field number of the variety. In this way the operator may carry a considerable quantity of readily available material with him. When pollen of any particular variety is desired, a flower is selected from the proper bag and the corolla is pushed back between the forefinger and thumb and held in such a way that the stamens lie directly across the thumb-nail. After removing the pistil, the anthers are tapped sharply with the forceps, and the pollen is jarred out, falling upon the thumb-nail (Pl. III, fig. 2), whence it is readily applied to the previously uncovered stigmas of the emasculated flowers (Pl. I, fig. 2). The bag is then replaced over the pollinated flowers, again inclosing as much foliage as possible. Usually the success or failure of the cross can be determined about one week after the pollen is applied. If there is a seeming affinity between the plants crossed and if an abundance of good viable pollen has been used, one will frequently find an almost full-grown seed ball at the end of seven days. As a rule, the crosses should be examined in five to seven days from the date of pollination. In most cases, at the expiration of this time, either the flower will have dropped off or the ovary will have swollen sufficiently to show that the cross has been successful. In such cases the paper bags should be removed and all seed balls that are developing should be inclosed in loose cheesecloth sacks, which should be securely tied to the stems of the plants. It is hardly necessary to say that a record should be made of each step in the process and that each cross should be properly labeled. In Plate IV a cluster of seed balls is shown and also lateral, sectional, and basal views of individual seed balls.

In connection with the methods just presented for the protection of the flowers from insect visitors or other possible sources of outside pollination, it should be stated that two leading plant breeders claim that it is unnecessary to cover the potato blossom. It has been suggested by one of these breeders that the flowers are

FIG. 1.—POTATO FLOWERS: A, BEFORE EMASCULATION; B, AFTER EMASCULATION.

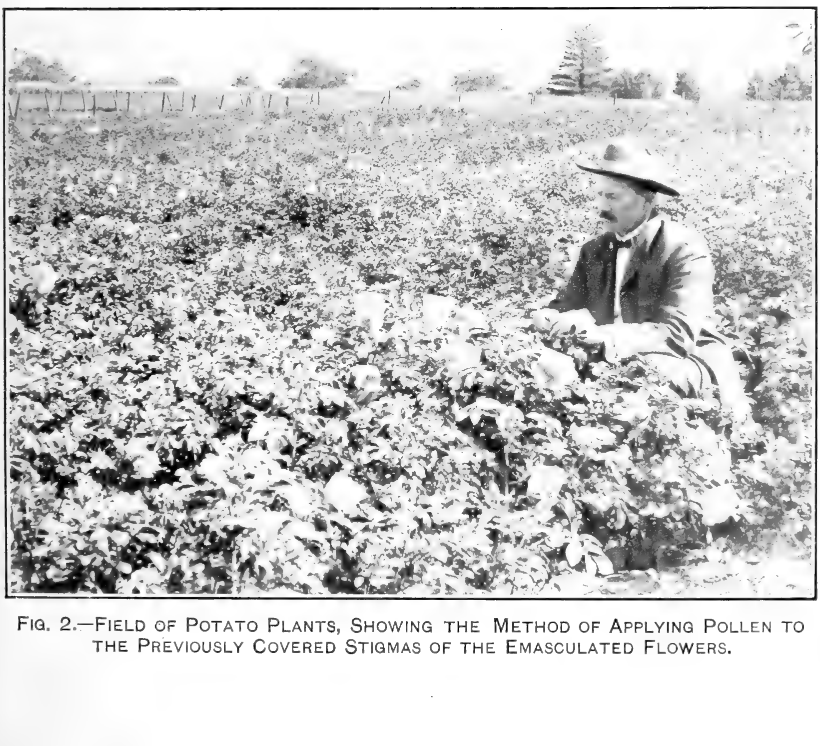

FIG. 2.—FIELD OF POTATO PLANTS, SHOWING THE METHOD OF APPLYING POLLEN TO THE PREVIOUSLY COVERED STIGMAS OF THE EMASCULATED FLOWERS.

FIG. 1.—TWO POTATO FLOWER CYMES, SHOWING THE PROPER STAGE AT WHICH THE BLOSSOM SHOULD BE EMASCULATED.

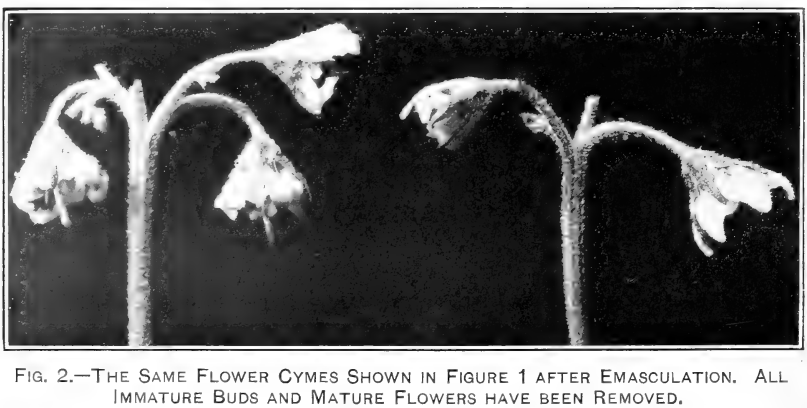

FIG. 2.—THE SAME FLOWER CYMES SHOWN IN FIGURE 1 AFTER EMASCULATION. ALL IMMATURE BUDS AND MATURE FLOWERS HAVE BEEN REMOVED.

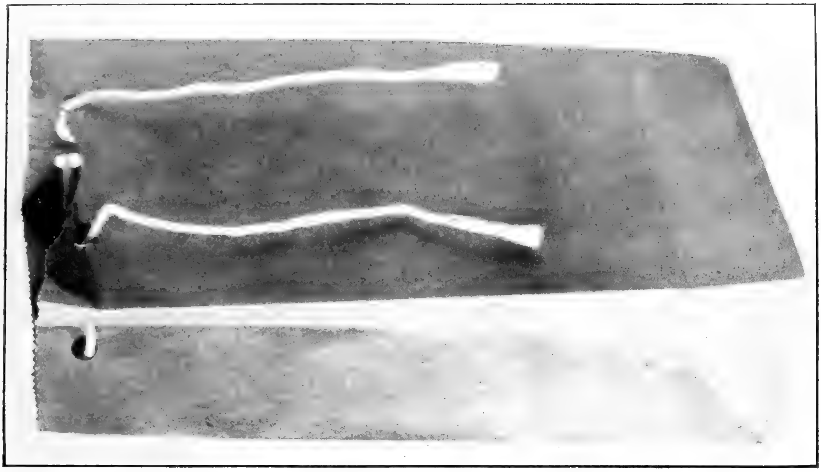

FIG. 1.—ONE-POUND PAPER BAG IN WHICH EMASCULATED POTATO FLOWERS ARE INCLOSED, SHOWING THE METHOD OF STRINGING.

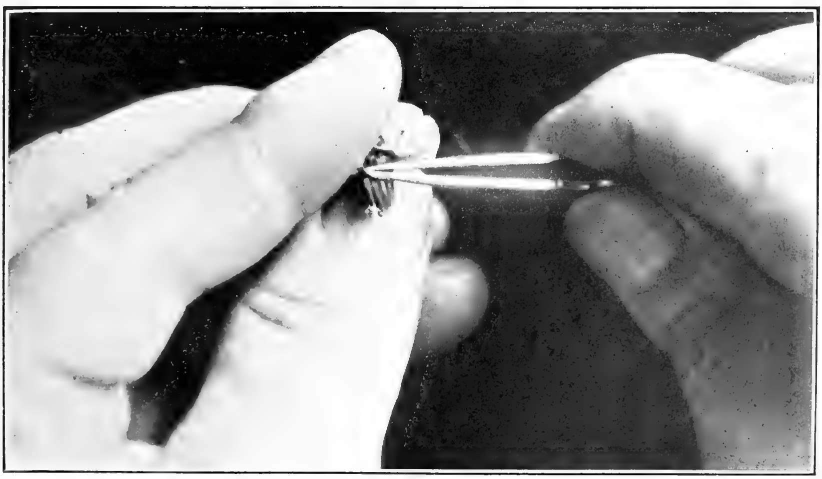

FIG. 2.—ANTHERS OF A POTATO BLOSSOM, SHOWING THE METHOD OF REMOVING THE POLLEN.

After the pistil is removed, the anthers are tapped sharply with the forceps and the pollen is jarred out, falling on the thumb nail.

POTATO SEED BALLS, SHOWING A CLUSTER, AND LATERAL, SECTIONAL, AND BASAL VIEWS.

much more likely to be broken off when inclosed in bags.[1] On this subject Salaman says:

All my work has been carried on without placing the flowers in bags. The reasons for not adopting special precautions were that when bagged the flower invariably drops, that bees and the like never approach a potato flower, though a small fly often lives in the bottom of the corolla, that the flower is constructed for self-fertilization, and that the quantity of pollen is so scanty as to render fertilization by the wind in the highest degree improbable.

East[2] makes the following statement regarding the covering of the flowers and emasculation:

We may conclude that if we cut off all the uppermost cymes from the plant stems and use for pollination only emasculated flowers of those borne next in order, the relative probability of our crosses being interfered with is negligible for all practical purposes. This removes the necessity of shutting out light and air circulation by means of bags. It is also worthy of note that the chances of success are much greater if the calyx and corolla are not removed during emasculation, as the style is very slender and is likely to be injured.

While the above assertions concerning the structure of the flower and the comparative absence of insect visitors are admittedly true, it has not been found that the bagging of the flowers necessarily causes a greater number of them to drop off, provided one follows the instructions already given and incloses a portion of the stem or foliage with the flowers. The beneficial effects of inclosing foliage with the flowers are believed to be twofold: (1) It serves to fill the sack and thus acts as a cushion for the flowers in windy or rainy weather; (2) the inclosure of so much foliage in a paper bag insures a goodly percentage of moisture from leaf transpiration and this indirectly prevents the drying out of the pistil and supplies favorable conditions for the germination of the pollen.

POLLEN-PRODUCING VARIETIES.

One of the chief difficulties confronting the potato-plant breeder is that a great many of our most desirable commercial varieties bloom either very sparingly or not at all and that few of those which do bloom develop viable pollen. In this connection East[2] makes the following statement:

If we regard blossoming as invariable at some period of their life under the proper conditions, we can then divide potato varieties into four classes:

1. Varieties whose buds drop off without opening.
2. Varieties in which a few flowers open but fall immediately.
3. Varieties whose flowers persist several days but rarely produce viable pollen.
4. Varieties which always produce viable pollen.

[1] Salaman, R. N. The inheritance of color and other characters in the potato. *In* Jour. Genetics, v. 1, no. 1, p. 7–46, 29 pl., 1910. (See p. 8.)

[2] East, E. M. Technique of hybridizing the potato. *In* Proc. Soc. Hort. Sci., 1907, p. 35–40, 1908. (See p. 37.)

East estimates that about 60 per cent of the potato varieties belong to the first class and says that of the remaining 40 per cent only about 60 per cent have their blossoms persistent for more than a day. Our observations do not substantiate these statements, but this does not necessarily refute them if we regard East's data as applying merely to the particular locality in which his studies were made. The percentage of varieties belonging to any given class varies with the region and is very largely dependent upon the climatic conditions under which the plants are grown. In the opinion of the writer, most varieties will produce some blossoms when grown under optimum conditions for the normal development of the plant, particularly if these conditions prevail during the stage at which flower buds are formed. In any considerable varietal collection it is inevitable that many varieties should find the conditions unsuitable for their maximum development.

In studying the microscopic appearance of the pollen of different varieties, East[1] found that there was a great variation in the size and apparent vigor of the pollen grains. In describing them, he says:

> Normal healthy pollen is round and about 36 μ in diameter, while unhealthy pollen is scarcely ever over 20 μ in diameter and is shriveled and irregular.

It was further observed that among the normal healthy pollen were some grains with from one to five slight protuberances which contained nuclei. It was also noted that the viability of the pollen was greater when these multinucleate pollen grains were present, and the suggestion is made that microscopic examination to determine the presence of such nuclei affords an easy and satisfactory method of determining whether the pollen of a given variety can be successfully employed.

The observations of East in regard to crosses have been fully corroborated by the writer, and further reference to them will be made in a later portion of this bulletin. The present almost total absence of seed balls on most of our commercial varieties, in the light of our present knowledge, is explainable on the basis that comparatively few of them develop viable pollen.

In a rather recent publication Salaman[2] announces that male sterility in the potato is a dominant Mendelian character. The data presented by Salaman would seem to amply justify this assertion. This evidence is in close harmony with what is actually encountered in the field, as it fully accounts for the striking scarcity of varieties which can be successfully employed as pollen parents.

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[1] East, E. M. Op. cit., p. 40.

[2] Salaman, R. N. Male sterility in potatoes a dominant Mendelian character . . . *In* Jour. Linn. Soc. [London], Bot., v. 39, no. 272, p. 301–312, 1910.

RESULTS OF EXPERIMENTAL CROSSING.

Although many crosses were made by the writer prior to 1909, the results secured were of such a meager nature as to be unworthy of mention. In 1909, however, so many successful crosses were made as to cause the writer to inquire the reason thereof. This inquiry he has been unable to answer more satisfactorily than to suggest that it may have been due to more favorable growing conditions at the time the plants were developing buds and flowers, thus furnishing the right conditions for the development of viable pollen.

One of the main objects of the 1909 experiments was to secure as many crosses as possible between the disease-resistant German varieties and those American varieties which would cross with them. The anxiety to succeed was perhaps responsible for the use of a few undesirable pollen parents, which always afforded an abundance of viable pollen and could therefore be depended upon to effect a cross when all other sources failed. The abundant results secured served to convince the writer of two facts which had previously been rather puzzling: (1) It demonstrated conclusively that the ovaries and pistils of many of the varieties in the collection were normally developed and that lack of success was not due to this cause, and (2) it emphasized the necessity of paying greater attention to all varieties which produce viable pollen, as well as to those which produce it sparingly or not at all. A further observation was also made with respect to the secretion of stigmatic fluid by the glands of the stigma. Practically every writer who has had occasion to describe the potato flower in connection with the subject of plant breeding has told his readers that the stigma is in a receptive condition when it is covered with a fluid secretion. This condition of the stigma has rarely been observed and then only when the pistil has passed beyond the stage of successful fertilization. It is doubtful whether the secretion of a stigmatic fluid is a normal function of the potato blossom at the present time.

The accompanying record of the 1909 crosses, which is presented as Table I, gives the parentage, number of flowers crossed, number of seed balls developed, percentage of success, and the number of seedlings that produced tubers.

A study of Table I discloses some rather interesting data, particularly with respect to the behavior of seed-bearing plants when pollinated with different varieties. In the first cross recorded, Geheimrat Theil × Keeper, six flowers were pollinated and five seed balls were developed, from which 502 tuber-bearing plants were produced. The same variety when mated with XX Early developed only one seed ball from 11 pollinated flowers, and this did not produce a single tuber-bearing plant. When crossed with *Solanum maglia*, a wild South American species, it failed to set fruit, and the same negative results were obtained when pollen of the unnamed Mexican species of Solanum was used. We know that *S. maglia* produces pollen very sparingly and that frequent attempts to germinate the pollen in the laboratory have been unsuccessful. The Mexican species is known to produce viable pollen in abundance, however, so that in this case the failure to set fruit was probably a clear example of nonaffinity. The next female parent, Sophie, crossed with Keeper, gave excellent results. Sophie is a German variety possessing qualities of vine and tuber strongly resistant to late-blight. From 20 pollinated flowers 16 seed balls were developed. The seeds from the 16 seed balls produced 2,244 tuber-bearing plants, or an average of 140.3 plants per berry. The 4 pollinated flowers of Sophie × Fuerst Bismarck failed to develop a single berry. A similar result was obtained from 8 flowers pollinated with Empire State and from 4 pollinated with Garnet Chili. Sophie × Irish Seedling produced 4 seed balls from the 4 flowers pollinated. The seeds from these berries gave 707 tuber-bearing plants, or an average of 176.8 plants per berry. Three flowers pollinated with Venezuela failed to set fruit. It is clearly evident that the varieties Fuerst Bismarck, Empire State, Garnet Chili, and Venezuela either did not develop viable pollen or the pollen tubes were unable to reach the ovules of the flower. It is known that all of these varieties produce pollen sparingly, and it is probable that an insufficient quantity of viable pollen was present to effect the cross.

TABLE I.—*Record of potato crosses made at Burlington, Vt., in 1909.*

Parentage of cross.	Number of flowers crossed.	Number of seed balls developed.	Percentage of success.	Number of tuber-bearing seedlings.	Average number of seedlings per seed ball.
Geheimrat Theil × Keeper	6	5	83.3	502	100.4
Geheimrat Theil × XX Early	11	1	9.1	0	0
Geheimrat Theil × *Solanum maglia*	3	0	0	0	0
Geheimrat Theil × *Solanum* sp[1]	2	0	0	0	0
Sophie × Keeper	20	16	80	2,244	140.3
Sophie × Fuerst Bismarck	4	0	0	0	0
Sophie × Empire State	8	0	0	0	0
Sophie × Garnet Chili	4	0	0	0	0
Sophie × Irish Seedling	4	4	100	707	176.8
Sophie × Venezuela	3	0	0	0	0
Professor Maerker 506 × Apollo	12	9	75	275	30.6
Professor Maerker × Early Silverskin	15	15	100	555	37
Professor Maerker × Keeper	13	12	92.3	326	27.2
Professor Maerker × Rand's Peachblow	4	0	0	0	0
President Kruger × Apollo	8	4	50	159	39.8
President Kruger × Gem of Aroostook	13	0	0	0	0
President Kruger × Green Mountain	8	0	0	0	0
President Kruger × Keeper	11	9	81.8	640	71.1
President Kruger × Star of the East	8	0	0	0	0
President Kruger × *Solanum etuberosum* Lind	21	0	0	0	0
Fuerst Bismarck × Apollo	12	5	41.7	188	37.6
Fuerst Bismarck × Harris Snowball	5	0	0	0	0
Fuerst Bismarck × June	3	0	0	0	0
Apollo × Early Silverskin	16	4	25	50	12.5
Apollo × Empire State	8	0	0	0	0
Apollo × Irish Seedling	7	3	42.9	243	81
Daisy × Keeper	5	4	80	453	113.3
Daisy × Early Silverskin	12	5	41.7	329	65.8
Daisy × Round Pinkeye	8	4	50	180	45

[1] Mexican species.

TABLE I.—*Record of potato crosses made at Burlington, Vt., in 1909*—Continued.

Parentage of cross.	Number of flowers crossed.	Number of seed balls developed.	Percentage of success.	Number of tuber-bearing seedlings.	Average number of seedlings per seed ball.
Factor × Keeper	10	0	0	0	0
Factor × Gastold	5	0	0	0	0
Factor × Apollo	11	0	0	0	0
Factor × Keeper	16	0	0	0	0
Factor × Norcross	5	0	0	0	0
Factor × Alexander's No. 1 Red	8	0	0	0	0
Factor × *Solanum etuberosum* Lind	4	0	0	0	0
Factor × Round Pinkeye	7	0	0	0	0
Factor × *Solanum maglia*	8	0	0	0	0
British Queen × Star of the East	7	0	0	0	0
Up-to-Date × Fuerst Bismarck	9	0	0	0	0
Up-to-Date × Keeper	79	11	13.9	457	415
Up-to-Date × Norcross	3	0	0	0	0
Up-to-Date × Early Silverskin	12	2	16.7	50	25
Up-to-Date × Empire State	21	0	0	0	0
Up-to-Date × Irish Seedling	17	7	41.2	89	12.7
Up-to-Date × Round Pinkeye	14	3	21.4	75	25
Delaware × Keeper	13	11	84.6	537	48.8
Delaware × Round Pinkeye	58	9	15.5	388	43.1
Gem of Aroostook × Keeper	85	46	54.1	1,562	34
Gem of Aroostook × Rand's Peachblow	17	0	0	0	0
Gem of Aroostook × Round Pinkeye	114	55	48.2	1,873	34
Blight Proof × Fuerst Bismarck	9	0	0	0	0
Blight Proof × Apollo	10	0	0	0	0
Blight Proof × Early Silverskin	9	1	11.1	4	4
Blight Proof × Garnet Chili	4	0	0	0	0
Green Mountain × Apollo	20	4	20	102	25.5
Green Mountain × Keeper	15	3	20	90	30
Green Mountain × Early Silverskin	11	7	63.6	373	53.3
Green Mountain × Round Pinkeye	34	5	14.7	221	44.2
Green Mountain × Alexander's No. 1 Red	8	0	0	0	0
Green Mountain × Apollo	2	0	0	0	0
Harris Snowball × Fuerst Bismarck	16	0	0	0	0
Harris Snowball × Apollo	16	3	18.8	102	34
Harris Snowball × Early Silverskin	3	3	100	146	48.7
Harris Snowball × Round Pinkeye	10	6	60	127	21.2
Holborn Abundance × Apollo	8	3	37.5	561	18.7
Holborn Abundance × Early Silverskin	10	3	30	268	89.3
Holborn Abundance × Irish Seedling	14	9	64.3	778	86.4
Keeper × Fuerst Bismarck	15	3	20	0	0
Keeper × Keeper	7	2	28.6	30	15
Keeper × Norcross	5	2	40	13	6.5
Keeper × Early Silverskin	21	9	42.9	340	37.8
Keeper × Empire State	6	0	0	0	0
Keeper × Irish Seedling	13	7	53.8	121	17.3
Keeper × Round Pinkeye	14	9	64.3	227	25.2
Keeper × Venezuela	9	1	11.1	10	10
Norcross × Apollo	9	0	0	0	0
Norcross × Keeper	51	12	23.5	480	40
Norcross × Round Pinkeye	34	2	5.9	60	30
Rural New Yorker No. 2 × Early Silverskin	6	1	16.7	39	39
Star of the East × Round Pinkeye	62	26	41.9	990	38.1
Alexander's No. 1 Red × Irene	12	2	16.7	49	24.5
Alexander's No. 1 Red × Apollo	15	0	0	0	0
Alexander's No. 1 Red × Keeper	14	4	28.6	154	38.5
Alexander's No. 1 Red × Factor	6	0	0	0	0
Professor Maerker 652 × Apollo	12	5	41.7	122	24.4
Professor Maerker 652 × Keeper	4	3	75	66	22
Professor Maerker 652 × *Solanum etuberosum* Lind	44	0	0	0	0
Professor Maerker 652 × *Solanum maglia*	13	0	0	0	0
Professor Maerker 652 × Alexander's No. 1 Red	9	0	0	0	0
Rural Blush × Star of the East	4	0	0	0	0
Manly × Irene	11	5	45.5	242	48.4
Manly × Alexander's No. 1 Red	3	0	0	0	0
Early Excelsior × Apollo	14	6	42.9	133	22.2
Early Excelsior × Keeper	19	10	52.6	237	23.7
Early Excelsior × *Solanum etuberosum* Lind	27	0	0	0	0
Early Excelsior × Keeper	4	0	0	0	0
Early Excelsior × *Solanum etuberosum* Lind	5	0	0	0	0
Empire State × Fuerst Bismarck	6	0	0	0	0
Empire State × Keeper	9	6	66.7	144	24
Empire State × *Solanum maglia*	9	0	0	0	0
Garnet Chili × Keeper	9	1	11.1	38	38
Garnet Chili × Fuerst Bismarck	16	0	0	0	0
Garnet Chili × Early Silverskin	9	2	22.2	57	28.5
Garnet Chili × Rand's Peachblow	12	0	0	0	0
Round Pinkeye × Keeper	37	22	59.5	553	25.1
Venezuela × Keeper	12	8	66.7	457	57.1
Venezuela × *Solanum maglia*	3	0	0	0	0
Whiton's White Mammoth × Keeper	9	4	44.4	76	19

TABLE I.—*Record of potato crosses made at Burlington, Vt., in 1909*—Continued.

Parentage of cross.	Number of flowers crossed.	Number of seed balls developed.	Percentage of success.	Number of tuber-bearing seedlings.	Average number of seedlings per seed ball.
Solanum utile Klotzsch[1] (wild) × Keeper	11	8	72.7	70	8.8
Solanum utile Klotzsch × Seedling 962	12	6	50	75	12.5
Solanum utile Klotzsch × Seedling 949	1	1	100	15	15
Total or average	1,599	458	28.6	18,947	41.4

[1] Called *S. utile* by Pierre Berthault, Recher. bot. sur le Solanum tuberosum. *In* Ann. de la Sc. Agron., 6th Ann., p. 181, fig. 1, 1911. Mexican species.

In the first cross of the third seed parent, Professor Maerker × Apollo, both the seed and pollen parents are of German origin, the latter being one of the most disease-resistant varieties in the collection. Nine seed balls are recorded from 12 flowers pollinated and 275 tuber-bearing plants were obtained from this lot, or an average of 30.6 plants per berry. Fifteen flowers pollinated with pollen from Early Silverskin produced 15 seed balls, from which 555 plants were obtained, an average of 37 plants per berry. When crossed with Keeper, 12 seed balls were developed from 13 flowers and these gave 326 plants, or an average of 27.2 plants per berry. Pollen from Rand's Peachblow proved ineffective.

It is interesting to compare the results from the two crosses, Sophie × Keeper and Professor Maerker × Keeper. In the first instance the percentage of success is 80 and in the latter 92.3. Carrying the comparison farther, however, we find that the first cross averaged over 140 plants per berry, while the latter averaged only 27.2. These data make it at once apparent that some varieties develop fewer ovules than others.

Two of the most interesting crosses in Table I are those of *Solanum utile* Klotzsch with seedlings 949 and 962, from which some 90 tuber-bearing plants were produced. *Solanum utile* is a wild Mexican species producing tubers rather sparingly on long, spreading stolons. The tubers rarely exceed or even reach the size of a small hen's egg and when well developed are of a purple color. Immature tubers do not show color, and owing to this characteristic Heckel[1] was led to conclude that he had secured a mutant when white-colored tubers were observed to produce colored ones. The seedlings of these two crosses, while varying considerably from the seed parent, nevertheless bore a very striking resemblance to it. A number of them made a much stronger and larger vine growth and produced larger tubers, some of which bore a more or less distinct resemblance to the pollen parent. Seed balls were borne rather sparingly on some of the seedlings. Up to the present time these seedlings offer little, if any, promise except in the possibility of their possessing greater resistance to disease.

[1] Heckel, É. M. Sur les Origines de la Pomme de Terre Cultivée, 82 p., illus., 8 pl. Marseille, 1907. (See p. 71.)

RECIPROCAL CROSSES.

In the reciprocal crosses presented in Table II, some additional light is shed upon the prolificacy of certain seed parents.

TABLE II.—*Comparative behavior of reciprocal crosses of 1909 grown in 1910.*

Parentage of cross.	Number of flowers crossed.	Number of seed balls developed.	Percentage of success.	Number of tuber-bearing seedlings.	Average number of seedlings per seed ball.
Keeper × Norcross	5	2	40.0	13	6.5
Norcross × Keeper	51	12	23.5	480	40
Keeper × Round Pinkeye	14	9	64.3	227	25.2
Round Pinkeye × Keeper	37	22	59.5	553	25.1
Keeper × Venezuela	9	1	11.1	10	10
Venezuela × Keeper	12	8	66.7	457	57.1
Keeper × Keeper	7	2	28.6	30	15

The reciprocal cross between Norcross and Keeper shows that when Keeper was fertilized with pollen from Norcross, 2 seed balls were secured from 5 flowers fertilized, and from these 2 seed balls 13 tuber-bearing plants were produced. When Norcross was crossed with Keeper, 12 seed balls were secured from 51 flowers crossed, and from these 12 seed balls 480 tuber-bearing plants were obtained, or an average of 40 plants per seed ball, as against 6.5 from the reciprocal cross. From these data we may either assume that Keeper is not as prolific a seed parent as Norcross or else that Norcross does not produce sufficient viable pollen. On the basis of the first assumption, we may compare the behavior of both seed parents to other pollen. Keeper when pollinated with Irish Seedling gave an average of 17.3 plants per seed ball (Table I), and when crossed with Round Pinkeye it produced 25.2 plants per berry. Norcross when crossed with Round Pinkeye gave an average of 30 plants per berry (Table I). This evidence would seem to indicate that the Norcross was a more prolific seed parent than Keeper; but it also points to the conclusion that Keeper is the best pollen parent, at least in so far as pertains to the production of viable pollen.

The reciprocal crosses between Round Pinkeye and Keeper are of considerable interest, owing to their apparent similarity. Keeper × Round Pinkeye gave 9 seed balls out of 14 blossoms fertilized and these averaged 25.2 plants per berry. Round Pinkeye when crossed with Keeper produced 22 seed balls from 37 flowers pollinated, and from these an average of 25.1 plants were produced. The rather low number of plants forming tubers from these reciprocal crosses would indicate that neither parent seemed to possess potency. Apparently, the mating of these two varieties was not a congenial one in either case.

In the reciprocal cross between Venezuela and Keeper, with Venezuela as the seed parent, 12 pollinated flowers developed 8 seed balls, from which an average of 57.1 plants was secured. Nine flowers of Keeper crossed with Venezuela resulted in but 1 seed ball, from which 10 plants were obtained. It is evident from these figures that the pollen of Keeper was much more potent than that of Venezuela.

VARIETAL AFFINITY.

It is apparent to those familiar with plant breeding that certain types or strains of a given class of plants possess greater sexual affinity for each other than do other types or strains which are apparently as closely related. This phenomenon has been observed by potato breeders and has been taken advantage of in making crosses. One of the most interesting observations upon this point that has come to the writer's attention is that made by Taylor,[1] who says:

> Careful experiments this season with that fine potato named Factor have proved that it is not only sterile to its own pollen, but also sterile to all the Up-to-Date type, of which class Factor is probably the best example. . . . It will cross with some of the colored-skinned varieties, which have also flowers of a similar tint, but the seed vessels mature very slowly and never attain a large size. Where pollen of white-flowered sorts can be obtained, such as the Admiral, Provost, Abundance, and Cumberland Ideal, a good set can be obtained on Factor and the pods soon attain full size; indeed, the growth of the so-called "plum" is remarkable in comparison with that of the others already noted . . . the pollen of Factor has been found to be absolutely sterile to some 30 other varieties of potatoes having flowers and tubers of different colors and none of them of the Up-to-Date class.

In this connection, Findlay[2] says of the Up-to-Date potato:

> Its organs of reproduction are 90 per cent of them malformed. The stamens or pollen cases are small and never, so far as I have seen, contain one grain of pollen. The pistil is also of the same character. . . . the Up-to-Date potato beat me off so far as being able to effect my purpose, compelling me to fall back, as a last resource, on its male parent, or rather a natural seedling from the same. I then effected my object, and got two or three plums. But, as showing how much the Up-to-Date was off this job of seed production, the plums were small, containing few seeds, and of these few only about 53 per cent germinated.

The following data obtained from crosses made in 1909 seem to fully corroborate the observations made by Findlay with respect to the poor seed-bearing qualities of the Up-to-Date (Table I). From 155 hand-pollinated flowers of this variety, only 23 seed balls were secured, and one of this number was found to be seedless. The seeds secured from the 22 successful crosses produced only 671 tuber-bearing seedlings, or an average of a little over 30.5 tuber-bearing plants per berry. Seven pollen parents were used in making the crosses, and three of these, the Norcross, Empire State, and Fuerst Bismarck, did not produce a single seed ball. These are varieties that produce pollen very sparingly or not at all. Successful crosses were secured with Keeper, Early Silverskin, Irish Seedling, and Round Pinkeye, all of which produce pollen abundantly. The Irish Seedling gave the highest percentage of successful crosses (41.2 per cent), but for some reason produced a woefully small

[1] Taylor, G. M. The cross fertilization of the potato. *In* Gard. Chron., v. 48, 3d ser., 1910, p. 279.

[2] Findlay, A. The potato: Its history and culture. *In* North British Agriculturist, Jan. 25, 1905, p. 17.

FIG. 1.—POTATO SEEDLINGS 6 WEEKS OLD.

FIG. 2.—POTATO SEEDLINGS IN POTS, READY TO SET IN THE FIELD.

FIG. 1.—SETTING POTATO SEEDLINGS ON THE POTOMAC FLATS, WASHINGTON, D. C., IN 1911.

FIG. 2.—PLANTING 20,000 POTATO SEEDLINGS AT HONEOYE FALLS, N. Y., IN 1911.

FIG. 1.—POTATO SEEDLINGS ON THE POTOMAC FLATS, WASHINGTON, D. C., 1910.

FIG. 2.—STUDYING AND DESCRIBING THE PROGENY OF POTATO SEEDLINGS AT ARLINGTON FARM, WINTER OF 1910-11.

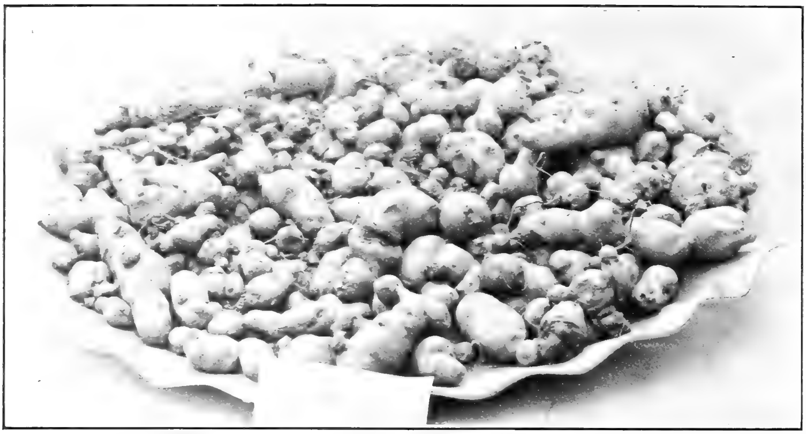

FIG. 1.—UNPROMISING FIRST-YEAR SEEDLING, CROP OF 1910.

FIG. 2.—ANOTHER UNPROMISING FIRST-YEAR SEEDLING, CROP OF 1910.

FIG. 3.—A LOW-YIELDING BUT NOT NECESSARILY UNPROMISING SEEDLING, CROP OF 1910.

FIG. 1.—AN EXTRA-PROMISING FIRST-YEAR SEEDLING, CROP OF 1910; 24 TUBERS.

FIG. 2.—A PROLIFIC AND FAIRLY PROMISING FIRST-YEAR SEEDLING, CROP OF 1910; 112 TUBERS.

A Very Prolific Seedling Plant, Crop of 1911; 244 Tubers, Weighing 6 Pounds 7 Ounces, and 213 Seed Balls, Weighing 2 Pounds 11 Ounces.

number of tuber-bearing plants, less than 13 per seed ball. On the other hand, Keeper, which gave only 13.9 per cent of successes, produced an average of 41.5 tuber-bearing plants per seed ball. As both of these pollen parents are known to produce an abundance of viable pollen, it would seem as if a greater affinity existed between Keeper and Up-to-Date than between Irish Seedling and Up-to-Date. In the case of Factor, a total of 74 hand-pollinated flowers, with pollen from 9 varieties, 1 of which was Keeper, produced but 1 seed ball, and that was devoid of seed.

It is apparent from these data that the Up-to-Date class of plants are, as a rule, poor seed bearers. Frequent examination of the flowers of both Factor and Up-to-Date failed to disclose at any time the presence of viable pollen. To all intents and purposes, varieties of this class may be considered as belonging to the male sterility group, and in consequence thereof they can not be successfully employed as pollen parents.

POTATO CROSSES MADE IN 1910.

In 1910 a few crosses were made by W. V. Shear and the writer between several varieties of potatoes growing on the Potomac Flats, Washington, D. C. The success of some of these crosses was so striking that it seems desirable to mention them in the present discussion. The specific crosses to which attention is called are those numbered 8708, 8709, and 8718, the data concerning them being presented in Table III.

TABLE III.—*Results of potato crosses Nos. 8708, 8709, and 8718, made on the Potomac Flats, Washington, D. C., in 1910.*

Field notes.						Laboratory notes.			
						Seed ball.			
Number of cross.	Parentage of cross.	Date emasculated.	Date pollinated.	Number of flowers crossed.	Number of seed balls developed.	No.	Number of seeds.	Number of plants potted.	Percentage of seeds germinated.
8708	Irish Cobbler × Irish Seedling	July 28	July 30	6	6	*a*	133	105	78.9
						b	108	86	79.6
						c	160	136	85.0
						d	57	47	82.5
						e	256	221	86.3
						f	250	176	70.4
	Total						964	771	80
8709	Irish Cobbler × Irish Seedling	July 28	July 30	7	5	*a*	289	264	91.3
						b	200	155	77.5
						c	192	166	86.5
						d	169	121	71.6
						e	134	116	86.6
	Total						984	822	83.5
8718	Eureka × Keeper	July 28	July 30	7	5	*a*	256	189	73.8
						b	297	238	80.1
						c	167	122	73.1
						d	189	159	84.1
						e	245	196	80
	Total						1,154	904	78.3

The 6 seed balls from cross 8708, Irish Cobbler × Irish Seedling, in which but 6 flowers were pollinated, produced a total of 964 seeds, or an average of 160.7 seeds per berry. The number of seeds in each berry varied from 57 in seed ball *d* to 256 in seed ball *e*. A fair degree of uniformity in the percentage of germination is to be noted.

The cross 8709, Irish Cobbler × Irish Seedling, resulted in 5 seed balls from 7 flowers pollinated, and these developed 984 seeds, or an average of 196.8 seeds per berry. The number of seeds from the individual seed balls ranged from 134 to 289 and the percentage of germination from 71.6 to 91.3.

In the third cross, 8718, Eureka × Keeper, 5 seed balls resulted from 7 flowers pollinated, and these produced 1,154 seeds, or an average of 230.8 seeds per berry, the percentage of germination varying from 73.1 to 84.1.

The highest number of seeds from an individual seed ball was from 8718–*b*, which produced 297 seeds. Another point of interest in these crosses which has not as yet been emphasized is that the seed balls were produced in each case on the same cyme or flower cluster. It is generally believed by potato breeders that the raising of more than one or two seed balls in a cluster is undesirable. On this point East [1] says:

> It is also desirable to stimulate the growth activity in the flower stalk by pollinating four or five flowers on one cyme; then after the berries are partially developed, pinch off the poorest and allow only two to develop to maturity.

In a more recent publication [2] East states that the propriety of this procedure is doubtful.

In view of the data which have just been presented it does not appear that the development of seed was curtailed in the slightest, with the possible exception of 8708–*d*, or that the germination was impaired, at least not so far as any data are available to refute it. It is true that the germination as a whole is not high for solanaceous seeds; yet if we take into consideration the fact that every seed removed from the seed ball was counted and that the number of seedlings given is the actual number that reached the potting stage, the showing made should be considered very satisfactory.

METHOD OF GROWING AND TESTING SEEDLINGS.

In order to insure a good development during the first season it is rather essential that the seedling should be allowed a long growing period. To do this it is necessary to start the seeds in a greenhouse or in a hotbed. In the latitude of Washington, in order to insure stocky plants in 3-inch pots, ready to be transferred to the field early

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[1] East, E. M. Technique of hybridizing the potato. *In* Proc. Soc. Hort. Sci., 1907, p. 35–40, 1908. (See p. 39.)

[2] East, E. M. Some essential points in potato breeding. Conn. Agr. Exp. Sta., 31st and 32d Rpt. (1907–08), p. 429–447, pl. 41, 1908. (See p. 441.)

in May, it is desirable to sow the seed in the greenhouse about March 20 to 25. (Pl. V.) The plants are usually spaced in the field in rows 3 feet apart and are set 2½ feet apart in the row. (Pl. VI, fig. 1.) In the ensuing year the tubers are spaced 18 inches apart in the row. (Pl. VI, fig. 2, and Pl. VII, fig. 1.)

The method which has been pursued in determining the merits of the seedlings which have been grown by the Department of Agriculture since 1910, some 60,000 in all, has been rather more comprehensive than is considered advisable from a commercial standpoint. Out of some 28,000 seedlings grown in 1910, nearly 19,000 developed tubers; most of the remaining 9,000 either failed to grow after being transferred from the greenhouse to the open ground or else they failed to produce tubers. All of those which developed tubers were saved, described, and grown in 1911. At harvest time all were again saved for further study and description. This entailed a large amount of work and the recording of many data. Some idea of the way in which these studies were performed may be secured from Plate VII, figure 2. The object in taking so many data and in growing a large number of seedlings which would ordinarily be discarded was to note whether any change occurred in the seedling in the second and subsequent generations. In other words, it was thought desirable to determine whether one might safely discard all unpromising looking seedlings the first season. The results secured indicate that there is little likelihood that a first-year seedling producing pronged, irregular-shaped tubers similar to those in Plate VIII, figures 1 and 2, will ever develop into a smooth-tubered variety. It is also equally apparent that a deep red or blue skinned seedling is never likely to become a desirable commercial variety. On the other hand, the hybridist is not always justified in discarding a seedling which has produced only two or three small tubers, weighing in the aggregate possibly not over 1 ounce, provided the tubers are smooth, shapely, and white skinned. (Pl. VIII, fig. 3). It is an easy matter, however, to decide on the advisability of retaining such seedlings as those shown in Plate IX. Occasionally a seedling is found that is unusually prolific in both tubers and seed balls; such a potato is shown in Plate X.

The data secured from the 1910 and 1911 seedlings have served to make it possible to discard first-year seedlings rather freely, with a fair degree of reliance, it is believed, both with respect to those discarded and those retained.

These seedlings were tested in 1913 and 1914 at three rather widely separated points—Houlton, Me., 1913; Caribou, Me., 1914; Honeoye Falls, N. Y., and Jerome, Idaho. Of the 35,000 seedling plants grown in 1910 and 1911, there now remain less than 150 numbers at the first two points and about 120 at the last point. Since 1911 the practice has been to discard all those which show undesirable traits, such as straggly or weak vine growth, susceptibility to fungous diseases of either vine or tuber, deep eyes, imperfect shape or color of skin, poor yield, lack of uniformity in size or type, and poor quality. Among those which now remain there appear to be a number of very promising varieties, three of which are shown in Plates XI, XII, and XIII.

SEEDLING INHERITANCE IN THE F_1 GENERATION.

The study of these seedlings both in the laboratory and in the field has furnished an excellent opportunity for observing the inheritance of parental characters. It has been a source of considerable surprise to the writer to find in a class of plants of the cultivated varieties of *Solanum tuberosum* L., which do not normally reproduce true from seeds, such a preponderance of the seedlings showing marked resemblances to either one or the other of the parents. These resemblances have been sufficiently marked in the case of both vines and tubers to permit those familiar with the parental characters to recognize the parentage of a group of seedlings, either in the field or in the laboratory, simply by the preponderance of certain characters peculiar to one or the other of the parents.

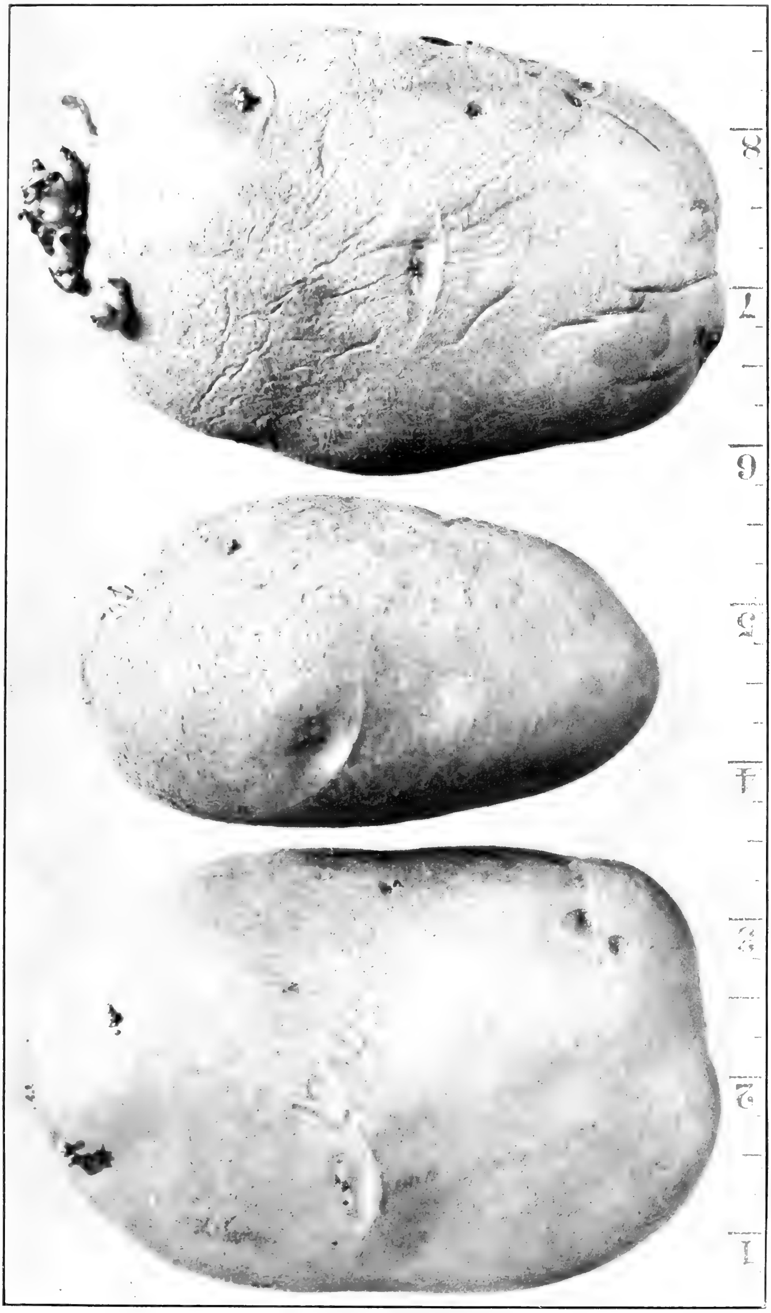
Some rather interesting data have been obtained relative to color inheritance in the tubers. Comparatively recent studies by Salaman[1] on color inheritance in the potato seem to warrant the deduction that a white skin is a recessive character. In this connection the statement is made that a white skin denotes the absence of a color pigment or of a factor necessary to color expression. Salaman found that when certain white-skinned varieties were selfed, their seedlings were all white skinned.

TABLE IV.—*Color inheritance in tubers of F_1 seedlings of 1910 crosses, season of 1911.*

Parentage of crosses.	Number of seedlings.								Tubers.	
	Total.	White to cream yellow.	Russet.	Mottled.	Flesh.	Red.	Purple.	Violet to black.	Without color.*	With color.
									Per ct.	*Per ct.*
Irish Cobbler × McCormick	32	16	....	2	11	3	....	....	50.0	50.0
Irish Cobbler × Irish Seedling	1,425	982	18	36	229	104	55	1	70.2	29.8
Irish Cobbler × Keeper	870	589	17	23	141	98	2	....	69.7	30.3
Irish Cobbler × Wild Chilean	214	73	....	72	38	8	12	11	34.1	65.9
Extra Early Eureka × Keeper	680	480	....	91	67	37	5	....	70.6	29.4
Green Mountain × Keeper	88	69	1	11	6	1	....	....	79.5	20.5
Gold Coin × Keeper	322	257	....	28	32	5	....	....	79.8	20.2
McCormick × Chilean Seedling	8	3	....	4	1	....	....	....	37.5	62.5

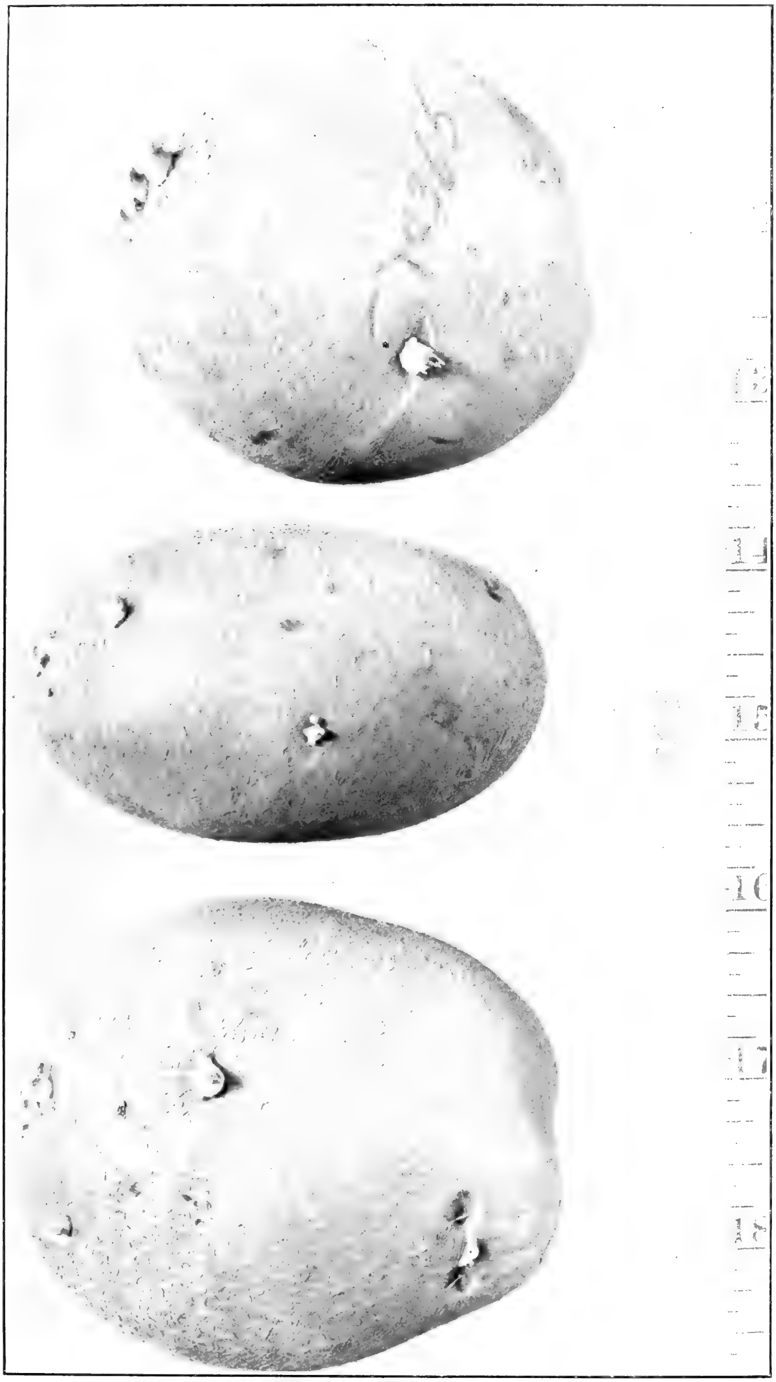
* This percentage is based on the number of white to cream yellow and russet tubers.

[1] Salaman, R. N. The inheritance of color and other characters in the potato. *In* Jour. Genetics, v. 1, no. 1, p. 7-46, 29 pl., 1910. (See p. 30.)



A PROMISING 4-YEAR-OLD SEEDLING OF EARLY EXCELSIOR × APOLLO.

ANOTHER PROMISING 4-YEAR-OLD SEEDLING OF EARLY EXCELSIOR × APOLLO.



A PROMISING 4-YEAR-OLD SEEDLING OF EMPIRE STATE × KEEPER.

PLANTING A POTATO VARIETY COLLECTION ON THE TUBER-UNIT BASIS AT HONEOYE FALLS, N. Y., IN 1911.

The results secured from our own studies as presented in Table IV are not entirely in accord with Salaman's deductions. For example, in a population of 1,425 seedlings from a cross between Irish Cobbler and Irish Seedling, the first parent having a creamy white skin and purplish tinged sprouts and the latter with flesh-tinted skin and purplish sprouts, color was absent in 70.2 per cent of the tubers. Of those showing color, 36 were mottled with white, 229 were flesh, 104 were red, 55 were purple, and 1 was violet-black. In another instance, out of a population of 870 seedlings of Irish Cobbler crossed with Keeper, color was absent in 69.7 per cent of the tubers. The pollen parent, Keeper, being a red-skinned variety, it would seem that if white were recessive a larger proportion of the F_1 generation should have shown color. Almost identical figures were secured when Extra Early Eureka and Keeper were crossed. In this case, in a population of 680, color was absent in 70.6 per cent, or a difference of but nine-tenths of 1 per cent between the two crosses. In view of the fact that the writer regards Irish Cobbler and Extra Early Eureka as one and the same variety, the parentage of the two crosses is thus identical. When it is considered that the data for the two crosses were secured and tabulated independently of each other, the uniformity of the data is all the more remarkable. When the Irish Cobbler is crossed with a Chilean seedling, a different set of data is obtained. In a population of 214, only 34.1 per cent of the tubers were free from color.

When white-skinned and white-sprouted varieties were crossed with red-skinned varieties, the proportion of white-skinned seedlings was larger, as is shown in the following crosses: Green Mountain × Keeper produced 88 seedlings, of which 79.5 per cent were devoid of color; of those which did show color, 11 were mottled, 6 flesh, 1 russet, and 1 red. Gold Coin × Keeper produced 322 seedlings, of which 79.8 per cent were devoid of color; and of those which showed color 28 were mottled, 32 were flesh, and 5 were red. The remarkable similarity of color expression of these two crosses is again accounted for by the fact that the varieties Green Mountain and Gold Coin are regarded as identical or so nearly so as to be practically indistinguishable from each other.

While numerous other examples might be cited, it is believed that sufficient data have been presented to justify the assertion that white is not a recessive character in the seedlings of the crosses just named.

POTATO IMPROVEMENT BY SELECTION.

The improvement of the potato by selection alone restricts the operator to such variations as may occur within the variety. Fortunately, this field of endeavor is not such a limited one as it might at first appear to a layman, since considerable variation already exists within most of our cultivated varieties. This is particularly true with respect to uniformity in shape and size. In addition to this, it is well known to all observant potato growers that there is a great variation in the number of tubers produced by individual plants. Some plants produce 2 or 3 large tubers, with no small ones; others the same number of large tubers, but with a half dozen or more small ones; while others may be found producing from 6 to 10 or more medium-sized merchantable tubers and practically no small ones. It is clearly evident that the latter plant is the most desirable, provided that it has the power of reproducing this character. Probably very few plants have a productive capacity in excess of the average optimum expression of the variety. The abnormal yield is generally due to one or more of several causes, such as a larger or more vigorous seed piece, a slightly greater supply of plant food or moisture, or both, minimum injury from insect pests and fungous diseases, or any other favorable condition which enables that particular plant to reach or exceed the optimum or normal production of the variety. Failure to take these factors into consideration may lead the selectionist to interpret his results erroneously or to be unduly elated or depressed over the behavior of his selections in the first and second years of their isolation.

In addition to productiveness and uniformity in shape and size, there may be still other qualities which it is possible to secure through intelligent selection. Some of the more important of these qualities are as follows:

(1) Disease resistance of vine.
(2) Drought resistance of vine.
(3) Heat resistance of vine.
(4) Vigor of plant.
(5) Greater adaptability to peculiar environmental conditions of soil or climate.

Undoubtedly other objects of selection could be mentioned, such as tubers with shallower or less numerous eyes; but the foregoing may suffice to show the possibilities for selective work in the improvement of the potato. That the subject is not a new one and that its possibilities have not been unrecognized by earlier investigators is self-evident from the few examples which are cited on the following pages.

EARLY SELECTION EXPERIMENTS.

One of the earliest recorded experiments in which a definite effort was put forth to increase the productive capacity of the potato plant was that carried on from 1868 to 1882 by Hallet,[1] who reports as follows:

In the case of the potato, I have also applied my system, starting every year with a single tuber, the best of the year (proved to have been so by its having been found to

[1] Hallet, F. P. Food-plant improvement. *In* Nature, v. 26, no. 656, p. 91–94, 1882. (See p. 92.)

produce the best plant) for now fourteen years. My main object here has been absolute freedom from disease, and these potatoes are now descended from a line of single tubers, each the best plant of the year and absolutely healthy; and concurrently with the endeavor to wipe out all hereditary tendency to disease, I have always kept in full view the point of increasing productiveness. The result may be thus shortly stated: Dividing the first twelve years into three periods, the average number of tubers upon the annual best plant selected was, for the first period of four years, 16; for the second period of four years, 19; for the last period of four years, 27; or nearly double the number produced during the first series of four years. And if, as I might very fairly have done, I had confined the first period to the first three years (instead of four), the last period would have shown an average of 27 tubers against 13 in the first period, or more than double.

The care with which this experiment was apparently conducted and the selection of the strongest, most disease-free, and productive plants would seem to indicate that Hallet, at least, had a very clear conception of the advantages of selection in building up vigorous and productive strains of potatoes.

Carrière says:[1]

The potato furnished us with examples of modifications just as remarkable as those which we have reported for beans and for corn. . . . Every year, in reality, when we harvest the tubers and wish to conserve the purity of the variety, we are obliged to purify, that is to make a choice and reject those which, as we say, have degenerated. . . . The modifications in the potato may occur equally well in the underground parts; that is what has happened in the variety called Pousse-debout. The name Pousse-debout has been given to this variety because the tubers which it produces, instead of being placed flat, or nearly so, in the soil, are arranged one against the other, much like pieces of wood are disposed for transformation into charcoal.

It is further stated that the Marjolin potato is a variety possessing the peculiar quality of never flowering and of being very early, but notwithstanding this fact it is continually producing plants which flower and produce seed, and which, owing to this fact, are not as early as the parent plant. In yet another variety, the Chardon, Carrière observed transformations in color of flowers, shape of tubers, and season of ripening, and this, too, in a strain which had been under observation for a long time without having previously shown any variation whatsoever.

Goff's [2] experiments in 1884 and 1885 demonstrated that tubers from productive plants gave larger yields than tubers from unproductive plants, the total gain being a little more than 24 per cent.

In 1897 Fischer [3] began some selection work with the potato, in which variations in productiveness, shape, and starch content of

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[1] Carrière, E. A. Production et Fixation des Variétés dans les Végétaux, 72 p., illus. Paris, 1865. (See p. 40–41.)

[2] Goff, E. S. Experiments with tubers taken from productive and unproductive hills. N. Y. (Geneva) Agr. Exp. Sta., 3d Ann. Rpt., 1884, p. 301–305, Albany, 1885; 4th Ann. Rpt., 1885, p. 232–235, Albany, 1886. (A copy of this 4th Rept. was published also at Rochester. In this copy the reference will be found on p. 204–207.)

[3] Fischer, Max. Kartoffelzuchtungs- und Anbauversuche. *In* Fühling's Landw. Ztg., Jahrg. 49, 1900. Heft 8, p. 301–307; Heft 9, p. 343–352; Heft 10, p. 369–372.

tuber, and also in the growth habit of the vine, were studied. The work of Fischer was very largely carried on in pots, under as nearly uniform conditions as it was possible to obtain, and yet the variations in the yield of tubers were in some instances in the ratio of 100 to 233.3.

The individual deviation within the variety itself was found in the case of the Saxon onion potato to be associated with certain definite characters; for example, flat-round tubers rich in starch were found to be correlated with a more or less restricted vegetative growth and tuber yield. Long tubers poor in starch were, on the other hand, found to be correlated with strong vegetative growth and a high tuber yield as compared with that of the flat-round ones. This is strikingly shown in the following data, which give the relative proportion of dry stalks and tubers from the two types of mother tubers:

I. Flat-round mother tubers rich in starch (18.68 per cent); dry stalks, 100; tuber yield, 100.

VII. Long mother tubers poor in starch (11.83 per cent); dry stalks, 141.5; tuber yield, 204.

The deviations within these types were also noted by Fischer, and data were presented (Table V), a study of which shows that, while considerable deviation existed within the two types, the maximum yield of the flat-round tubers rich in starch did not approach very closely either in weight of dry stalks or of tubers to that of the lowest yield from the long tubers poor in starch.

TABLE V.—*Individual deviations in the development of vine and tuber within the same strain of a variety.*[1]

Strain No.	Character of strain.	Dry stalks.	Tuber yield.	Average gain of long over flat-round tubers.	
				Dry stalks.	Tubers.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
II	Flat-round tubers rich in starch	100	100		
III	.....do	114.5	167		
V	Long tubers poor in starch	142	216.7	48	62.5
VI	.....do	175.5	233.3		

[1] Table compiled from Fischer, Max. Op. cit., p. 305.

Fischer also noted that the plants from the flat-round tubers were shorter jointed and matured earlier than those from the long tubers. This would indicate that the latter represented a later maturing strain.

In December, 1904, Eustace[1] reported the result of a season's study on "Productive vs. unproductive hills." The method of selection pursued by Eustace was as follows: At harvest time in the

[1] Eustace, H. J. An experiment on the selection of "seed" potatoes: Productive vs. unproductive hills. *In* Proc. Soc. Hort. Sci., 1903–4, p. 60–62, 1905.

fall of 1903 a field of potatoes was selected the variety of which was known to be pure, and in a place where the soil was uniform 100 consecutive hills were dug and weighed separately. From these 100 hills the 25 heaviest and 25 lightest yielding hills were selected. This process was repeated until 125 hills of each had been secured. In the following spring 10 rows of 232 plants each were planted from the heaviest yielding hills and 5 from the light-yielding ones. The resultant yields averaged $362\frac{1}{4}$ bushels per acre from the productive hills and $339\frac{1}{6}$ bushels from the unproductive, the gain in favor of seed from the heaviest yielding hills being at the rate of $23\frac{1}{12}$ bushels of marketable tubers per acre.

It was found that the amount of variation in the yields of adjacent hills in the 1904 crop was almost as great as in that of the original stock. The 1904 variations were 11.9 ounces, or 39.18 per cent, as against 9.37 ounces, or 39.44 per cent, in the 1903 crop. In this connection Eustace says:

> That the variation was not materially reduced by the uniform conditions under which the experiment was made was a surprise. The conclusion is that factors which are apparently unimportant produce wide differences in yield.

From our present knowledge of the behavior of individual hills of potatoes, it seems quite certain that Eustace would have secured much more uniform results had the progeny of each individual hill been planted separately. In mass plantings individual variations are obscured, rather than emphasized, as in the tuber-unit or progeny-row method.

At the annual meeting of the American Breeders' Association, in 1907, Waid [1] reported the results of studies which he had undertaken at the Ohio Agricultural Experiment Station, in which the progeny from productive and unproductive plants in 1903 had been carefully studied during 1904, 1905, and 1906. The results of this work showed quite clearly that with few exceptions low-yielding plants remained unproductive.

The 3-year average from high and low yielding plants was found to be 1.38 pounds for the former and 0.73 pound for the latter, or a difference of over 89 per cent. A comparison of yields from the productive plants and plants from common stock showed a gain of over 25 per cent for the former.

A further study of Waid's data reveals the fact that the average weight of the 10 original high-yielding hill selections was 2.38 pounds per plant, whereas the 3-year average of their progeny was only 1.38 pounds per plant. This suggests that in the selection of high-yielding hills one is not at all certain what proportion of the hills is likely to maintain their seemingly productive character.

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[1] Waid, C. W. Results of hill selection of seed potatoes. *In* Amer. Breeders' Assoc., 3d Ann. Rpt., 1907, p. 191–198.

In this connection East [1] suggests the possibility that Waid's results may have been influenced by the following factors: (1) The size of the seed pieces, and (2) since Waid apparently used a commercial stock, he was not absolutely certain that he was dealing with a single variety, or, in other words, with a pure strain. This latter fact East thinks may account for differences in the results secured by Waid in the second and third seasons. He is inclined to believe that the differences were purely physiological phenomena of development, entirely separate from questions of inheritance.

On page 131 of the report just cited East gives his experience with high and normal yielding hills selected from a select strain of Rural New Yorker No. 2. His statement with respect to this work is as follows:

> In 1906 we had in stock a supply of the well-known variety Rural New Yorker No. 2, which had been grown from a single hill in 1904. A selection of tubers from the five best yielding hills was planted in 1907 and compared with five normal hills producing only one-half as much. The five best yielding hills averaged 1,200 grams (2 pounds 10 ounces) of tubers per hill, with an average set of eight tubers. The check hills averaged 600 grams, with a set of four tubers each. Ten hills were planted in each case, two tubers being planted from each hill. In every case pieces of about the same weight were planted. The yield from the high-yielding selections was at the rate of 101 bushels per acre, while the yield from the check hills was at the rate of 128 bushels per acre.

In 1908 the progeny from the high-yielding strain averaged 96 bushels per acre and that from the check 90 bushels. In 1909 the yields were, respectively, 115 and 120 bushels per acre. The average yield for the three seasons was at the rate of 104 bushels per acre from the high-yielding and 113 bushels per acre from the check lot. In view of these facts, East believes that great caution should be exercised in recommending asexual selection as a means of increasing the yield or improving the variety. He further states that of the many investigations reported none have furnished indisputable evidence of improvement.

In a more recent article Berthault [2] has published the results of a rather exhaustive study of the potato. The portions of Berthault's studies with which the present article is concerned are those relating to the hereditary transmission of characters, variations through asexual and germinal reproduction, and the normal variations within the variety itself.

On page 49, Berthault summarizes his observations upon asexual reproduction, which, roughly translated, are as follows:

> (1) That the form of the tuber is not a stable character in our cultivated varieties.
>
> (2) That the color, generally maintained through asexual propagation, sometimes varies.

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[1] East, E. M. The transmission of variations in the potato in asexual reproduction. *In* Conn. Agr. Exp. Sta. 33d and 34th Rpt. (1909–1910), p. 119–160, 1910. (See p. 130–131.)

[2] Berthault, Pierre. Recherches botaniques sur les variétés cultivées du Solanum tuberosum . . . Ann. Sci. Agron., s. 3, ann. 6, t. 2, 1911, no. 1, p. 1–59; no. 2, p. 87–143; no. 3, p. 173–216; no. 4, p. 248–309.

(3) That the depth of the eyes, a character almost always maintained in asexual reproduction, also offers, without apparent cause, examples of bud variation.

SELECTION METHODS.

TUBER-UNIT METHOD OF SELECTION.

A method advocated by Webber,[1] known as the tuber-unit method of selection, has recently received considerable attention. This method consists in planting select tubers of a variety in such a way that the plants from each tuber will be definitely isolated from each of the other tuber units. The tuber is cut longitudinally through its axis into four as nearly equal parts as possible, aiming in all cases to cut through the cluster of eyes surrounding the terminal one. The quarters are planted consecutively, and a double space is left between the four units of each tuber in order that they may be more easily distinguished from one another. When the plants have reached their full development, each unit should be carefully dug and again examined. If it is found that some of the marked units produce a uniform lot of tubers, both as to shape and size, and are equal to or more productive than the general average of the variety, they should be saved for further trial. By this method it is claimed that not only can uniformity in size and shape be secured but the productiveness of the variety may be increased, because of the fact that selection tends to weed out all of the unproductive plants. By continuing this line of work one may finally secure an excellent commercial strain of potatoes.

HILL SELECTION.

Another method, varying slightly from the one first described, consists in making individual hill selections in the potato field at digging time. The particular qualities sought after are practically the same, viz, greater uniformity in size and shape and a maximum number of merchantable tubers. The selected hills are kept separate. Each should be given a number and should be sufficiently described to permit further comparison when the progeny is harvested. It will be found that many a promising first-year selection will bring disappointment in the second season. A few, however, will maintain their superiority, and these should be saved and propagated.

This line of work has proved almost as fascinating to the writer as the broader one of combining desirable characters through cross-fertilization or hybridization. It is a field of endeavor open to any wide-awake potato grower and within its limitations offers greater promise of results for the time and effort expended than that of the production of seedling plants.

Cards, the character of which is shown by the accompanying samples, have been prepared by the writer for the purpose of recording

[1] Webber, H. J. Method of improving potatoes. *In* N. Y. (Cornell) Agr. Exp. Sta., Bul. 251, p. 322–332, 1908.

such data in regard to individual tubers of hill selections and tuber units as will enable one to judge accurately of their merits or demerits with respect to their transmission of the desired characters for which they were originally selected.

Potato hill-selection progeny record (1st, 2d, 3d year).

Accession No. .... Field No. ...... Locality... Year, 191..

Selection made ...., 191.., from accession No. ...., variety..

Locality, ...; by..

Hill selected contained ...... tubers, of which ...... were large (weight, ... lbs., ...oz.); ...... were small (weight, ... lbs. ...... oz.); ...... were true to type.

Progeny record of tuber unit.—No. .... Weight, ... oz. Planted .... Plants not uniform; vigorous, weak; large, small; erect, decumbent; healthy, diseased. Vines ripe .... Harvested .... Number of tubers from each plant of unit not uniform ...., vary from .... to ...., size not uniform, shape not uniform, ... true to type. Total tubers ...., of which .... were large (weight, ... lbs. ...... oz.); ...... were small (weight, ... lbs. ...... oz.); total weight, ... lbs. .... oz. Average weight per plant, ... lbs. .... oz. Not desirable to continue another season.

Observer.— ....

Remarks.—...

....

....

....

....

Potato tuber-unit progeny record (1st year selection).

Accession No. .... Variety, ... Selected by...

Selected tubers planted ...., 191.., P. O. address, ...

Character of soil, ...

Tuber No.	Weight of tuber (ounces).	Sprouts.		Plants.					Tubers.									Unit saved rejected.
		Appear (date).	Strong Weak	Number.	Strong Weak	Healthy Diseased	Uniform Variable	Desirable Undesirable	Uniform Variable	Large (number).	Weight.		Small (number).	Weight.		Total.		
											Pounds.	Ounces.		Pounds.	Ounces.	Pounds.	Ounces.	

General observations.— ....

....

....

....

....

Potato tuber-unit progeny record (2d or .. year selection).

Accession No. .... Tuber-unit No. .... Variety .... Selected ....191...

Selection made by .... P. O. address ....

Selected unit yielded ...... tubers, of which ...... were large (weight, ... lbs. ...... oz.); ...... were small (weight, ... lbs. ...... oz.).

Selected tubers planted, ..., 191... Character of soil..................................

Tuber No.	Weight of tuber (ounces).	Sprouts.		Plants.					Tubers.									Unit saved rejected.
		Appear (date).	Strong Weak	Number.	Strong Weak	Healthy Diseased	Uniform Variable	Desirable Undesirable	Uniform Variable	Large (number).	Weight.		Small (number).	Weight.		Total.		
											Pounds.	Ounces.		Pounds.	Ounces.	Pounds.	Ounces.	
Total...																		
Average ..																		

General observations.— ....

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DEPARTMENTAL INVESTIGATIONS.

During the season of 1911 rather extensive studies were undertaken by the Office of Horticultural Investigations and the Arlington Experimental Farm (now the Office of Horticultural and Pomological Investigations), looking toward the standardization of a considerable varietal collection by the tuber-unit method. This work was carried on at Honeoye Falls, N. Y. Hill selections were also made the same season in a field of Irish Cobblers near Portsmouth, Va.

TUBER-UNIT STUDIES.

In 1911 some 150 standard commercial varieties of potatoes were planted on the tuber-unit basis (Pl. XIV), in order that their purity and uniformity in size and type might be more closely studied. The seed used was grown in Burlington, Vt., in 1910, on land which had not grown a cultivated crop of any kind for at least 35 years. In addition to this, the seed was selected from the most promising hills at the time the crop was harvested. The tubers as a whole were remarkably uniform in size and there could, therefore, have been little difference in the size of the seed pieces used. Any variation, therefore, which occurred between the plants of the various tubers which were planted would seem to be due to some inherent tendency in the tuber itself. The remarkable dissimilarity between the growing plants of the individual units of a variety planted contiguously in the row was so surprising that some three dozen units were photographed and when these were harvested the tubers were also photographed. It was found that the divergency in yield was just as great as in the size and vigor of the plants. In 1912 five units were planted from both the strong and the weak plants, and it was found in practically every instance that the low-yielding 1911 plants gave poor germination, a feeble vine growth, and a still lower yield than in 1912 (Pl. XV). Table VI gives the data obtained during 1911 and 1912 from 12 strong and weak tuber-unit plants of well-known commercial varieties.

TABLE VI.—*Potato yields from strong and weak tuber-unit plants in 1911 and 1912.*

[Weight of tuber yields in pounds.]

Accession No.	Variety.	Strong plants, 1911.			Strong plants, 1912.			Weak plants, 1911.			Weak plants, 1912.		
		Primes.	Culls.	Total.	Primes.	Culls.	Total.	Primes.	Culls.	Total.	Primes.	Culls.	Total.
4245	Beauty of Hebron	4.0	1.5	5.5	2.9	1.2	4.1	0.4	0.9	1.3	0.7	1.0	1.7
4235	Carman No. 1	2.6	1.6	4.2	4.4	.8	5.2	.....	.8	.8	.....	.14	.14
4972	Gold Coin	3.4	2.0	5.4	3.0	.54	3.54	.....	1.1	1.1	.4	.25	.65
4968	Green Mountain	3.8	1.3	5.1	2.0	.6	2.6	.....	1.1	1.1	.14	.17	.31
8686	.....do	4.3	.3	4.6	4.8	.9	5.7	.....	.8	.8	.....	.04	.04
4970	Irish Cobbler	3.8	.3	4.1	1.7	2.0	3.7	.9	1.0	1.9	.25	.38	.63
5036	Keeper	2.6	2.0	4.6	2.9	.85	3.75	.....	.6	.6	.....	.02	.02
6158	McCormick	2.8	1.3	4.1	2.1	.4	2.5	1.5	.3	1.8	.12	.29	.41
5460	Norcross	3.9	1.4	5.3	3.94	1.1	5.04	.....	.5	.5	.....	.03	.03
5462	.....do	4.4	1.4	5.8	4.1	1.7	5.8	.....	.9	.9	.12	.08	.2
5480	Rural Blush	1.5	2.7	4.2	3.9	.64	4.54	.2	1.3	1.5	.04	.33	.37
6690	Twentieth Century	3.1	1.0	4.1	2.7	.64	3.34	.....	.1	.1	.....	.....	.....
	Total	40.2	16.8	57.0	38.44	11.37	49.81	3.0	9.4	12.4	1.77	2.73	4.50
	Average	3.35	1.4	4.75	3.2	.95	4.15	.25	.78	1.03	.15	.23	.38

Two-year tuber-unit average:
Strong plants—3.28 pounds primes; 1.18 pounds culls; total, 4.46 pounds.
Weak plants—0.20 pound primes; 0.51 pound culls; total, 0.71 pound.
Gain in primes in favor of strong plants, 1,540 per cent; total gain in favor of strong plants, 528.2 per cent.

The average yield of merchantable or prime tubers from the strong plants was 3.35 pounds in 1911, with 1.4 pounds of culls, while the yield from the weak plants was 0.25 and 0.78 pound, respectively. In 1912 the yields were 3.2 pounds of primes and 0.95 pound of culls from the strong plants and 0.15 and 0.23 pound, respectively, from the weak plants. The average production for 1911 and 1912 was 3.28 pounds of primes and 1.18 pounds of culls from the strong plants and 0.20 pound of primes and 0.51 pound of culls from the weak plants. These yields represent a gain in primes of over 1,500 per cent in favor of the strong plants and a total gain of over 500 per cent. The graphic chart shown in figure 1 illustrates quite clearly the marked differences in vine and tuber production. It would be misleading to leave the

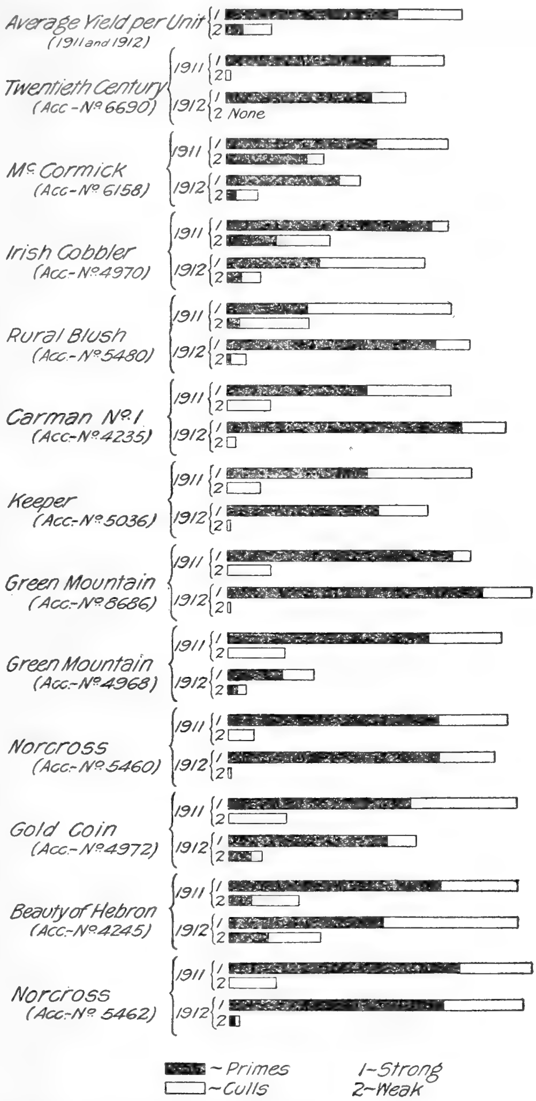

FIG. 1.—Diagram showing the relative yields between strong and weak tuber-unit plants at Honeoye Falls, N. Y., in 1911 and 1912.

impression that these data represent the gains that are likely to accrue through selection. The lesson that these data should convey is that tubers from weak, unproductive, or diseased plants produce similar or even worse progeny and that the greatest benefit derived from selection work is the weeding out of these undesirable strains. It is not at all unlikely that from 5 to 10 per cent of weak, diseased, or unproductive plants may be found in all unselected seed potatoes. It is also equally certain that in nine cases out of ten in ordinary field

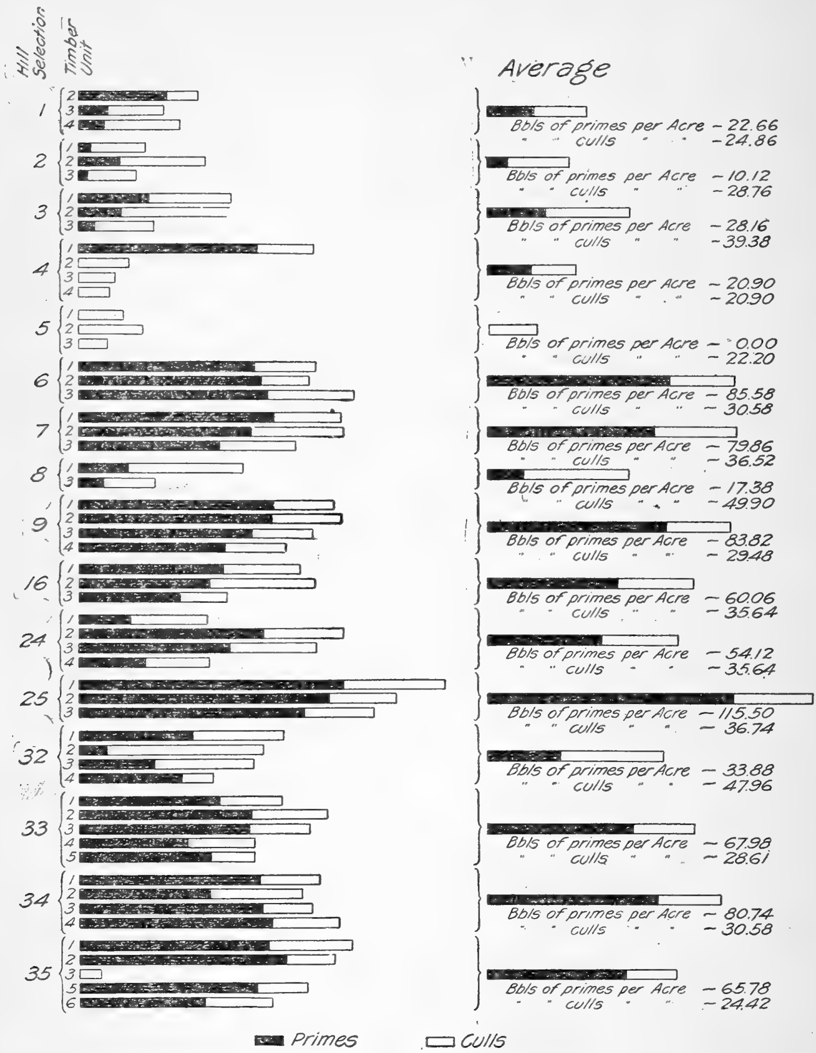

FIG. 2.—Diagram showing the hill-selection performance record, season of 1912.

practice these are unrecognized, because the weak or diseased plants are scattered here and there throughout the field and are obscured by surrounding healthy plants. Their resultant effect on yield is also unnoted and will probably remain so until we demand a practically perfect stand.

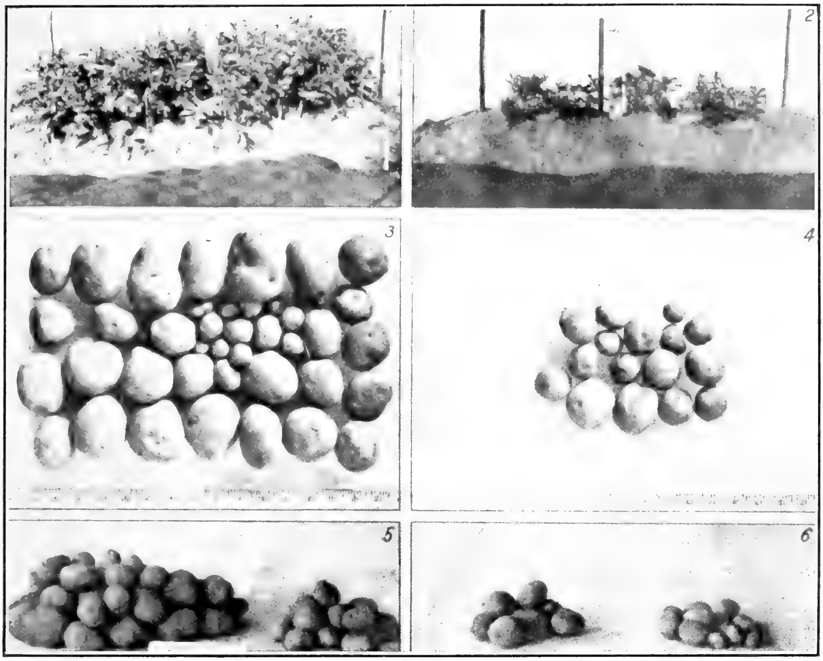

FIG. 1.—STRONG AND WEAK TUBER UNITS OF THE GOLD COIN VARIETY OF POTATOES.

Nos. 1 and 2 represent strong and weak tuber units in 1911; Nos. 3 and 4 represent yields from tuber units 1 and 2; Nos. 5 and 6 represent yields in 1912 from five tuber units of Nos. 3 and 4.

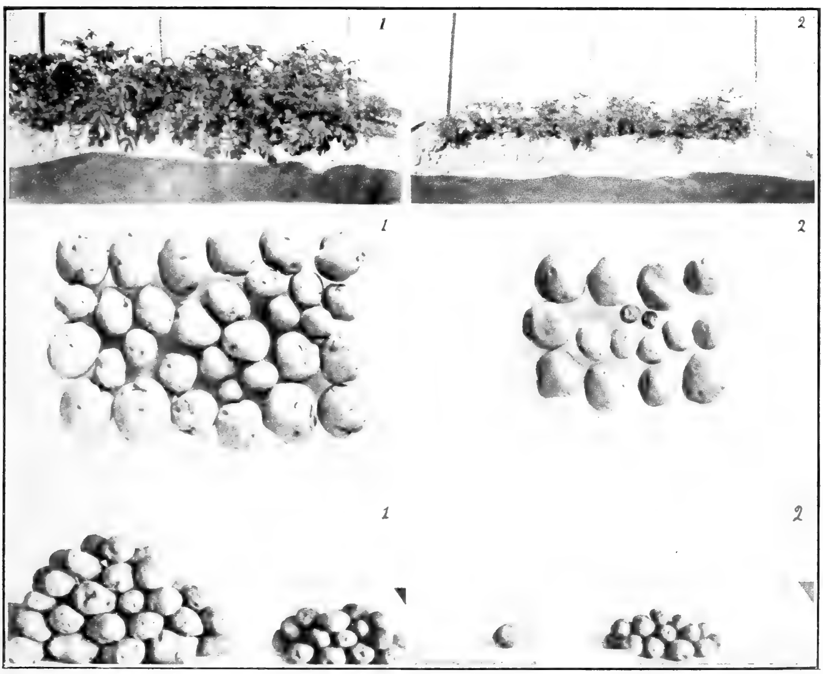

FIG. 2.—STRONG AND WEAK TUBER UNITS OF THE RURAL BLUSH VARIETY OF POTATOES.

No. 1 represents a strong tuber unit in 1911, with its 1911 yield and the 1912 yield from five of its tuber units. No. 2 represents a weak tuber unit in 1911, with its 1911 yield and the 1912 yield from five of its tuber units.

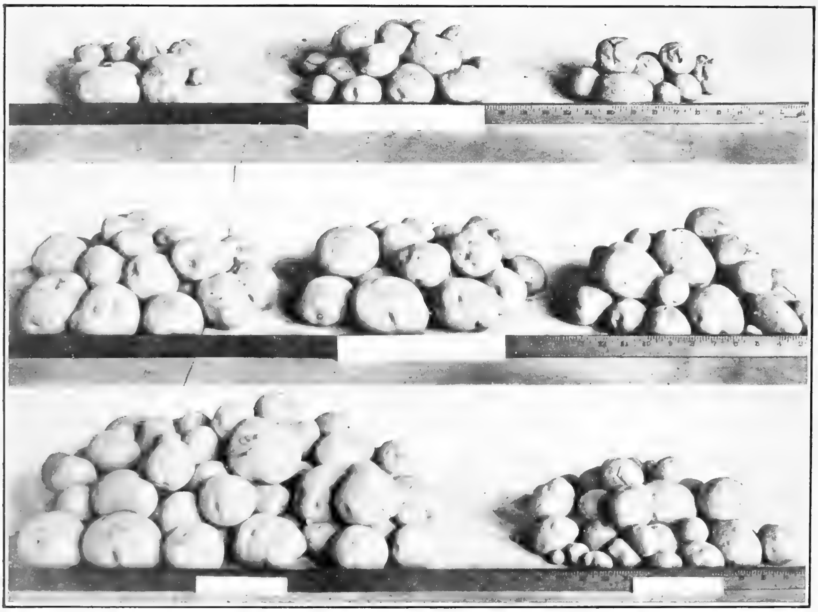

FIG. 1.—PROGENY OF THREE TUBER UNITS EACH OF HILL SELECTIONS NOS. 2 AND 25.

The upper cut shows the progeny of selection No. 2, the center one that of No. 25, and the lower cut the combined progeny of No. 25 on the left and of No. 2 on the right.

FIG. 2.—VARIATION IN YIELD BETWEEN TUBER UNITS FROM THE SAME HILL.

The upper cut shows the progeny of two tubers from hill selection No. 35; the lower cut that from hill selection No. 4.

HILL-SELECTION STUDIES.

In June, 1911, the writer, through the courtesy of a potato grower near Portsmouth, Va., was enabled to make some hill selections in a field of Irish Cobblers. These selections were made with two objects in view: (1) To increase the yield and (2) to determine the feasibility of carrying over the first-crop seed for the next season's planting. Unfortunately, the results of this work were practically eliminated by a severe freeze in April, 1913, which cut the young shoots to the ground, killing many of them outright. The 1912 crop was so promising, however, that it seems worthy of mention. The 1911 selections were all planted on the tuber-unit basis. Plate XVI and figure 2 show the results secured from some of the more promising. Of the 16 selections shown in figure 2, Nos. 6, 7, 9, 25, and 34 are the most promising, and among these No. 25 is far superior to the others. The 1912 yields of the 16 selections, computed on a per acre basis from the average of the units planted of each selection, are as follows:

Selection No. 1, 3 units planted, yielded at the rate of 22.7 barrels primes and 24.9 barrels culls.

Selection No. 2, 3 units planted, yielded at the rate of 10.1 barrels primes and 28.8 barrels culls.

Selection No. 3, 3 units planted, yielded at the rate of 28.1 barrels primes and 39.4 barrels culls.

Selection No. 4, 4 units planted, yielded at the rate of 20.9 barrels primes and 20.9 barrels culls.

Selection No. 5, 3 units planted, yielded at the rate of 0 barrel primes and 22.2 barrels culls.

Selection No. 6, 3 units planted, yielded at the rate of 85.7 barrels primes and 30.6 barrels culls.

Selection No. 7, 3 units planted, yielded at the rate of 79.9 barrels primes and 36.5 barrels culls.

Selection No. 8, 2 units planted, yielded at the rate of 17.4 barrels primes and 49.9 barrels culls.

Selection No. 9, 4 units planted, yielded at the rate of 83.8 barrels primes and 29.5 barrels culls.

Selection No. 16, 3 units planted, yielded at the rate of 60.1 barrels primes and 35.6 barrels culls.

Selection No. 24, 4 units planted, yielded at the rate of 54.1 barrels primes and 35.6 barrels culls.

Selection No. 25, 3 units planted, yielded at the rate of 115.5 barrels primes and 36.7 barrels culls.

Selection No. 32, 4 units planted, yielded at the rate of 33.9 barrels primes and 48 barrels culls.

Selection No. 33, 5 units planted, yielded at the rate of 68 barrels primes and 28.6 barrels culls.

Selection No. 34, 4 units planted, yielded at the rate of 80.7 barrels primes and 30.6 barrels culls.

Selection No. 35, 5 units planted, yielded at the rate of 65.8 barrels primes and 24.4 barrels culls.

It is evident from the data presented that other causes than that of inherent unproductiveness must have operated to lower the yield in selections 1 to 5. This fact is made still clearer by the behavior of selection No. 4, in which the first unit gave a reasonably good yield of primes or merchantable tubers, while the remaining ones did not produce any. It is believed that the seed tubers from the 1911 selections were either infected with some obscure disease or happened to have been planted in previously infected soil. All the selections were grown in the same or in contiguous rows, so there is little likelihood that the moisture or plant-food content of the soil was deficient in the one case and not in the other. The behavior of the plants during the growing season strongly corroborated the disease theory and sustains a previous statement in this bulletin in connection with varietal tuber-unit studies, namely, that the chief value of such studies consisted in the elimination of diseased and weakened plants. It would seem probable from the behavior of No. 25 that a strong, vigorous, and productive strain had been isolated. The term "probable" is used advisedly, because, as previously stated, the best selections, including, of course, No. 25, were unfortunately cut to and below the ground by a very severe freeze late in April, 1913. The injury sustained was so severe that very few of the plants survived, and those that did survive made a very unsatisfactory growth and crop. These selections have therefore been lost, and a new start has become necessary.

Thus far, all selections that have been made for disease resistance have proved undesirable, as they either did not retain this quality or else they were unproductive commercially or otherwise. The highest degree of success can only be attained from either the tuber-unit or hill-selection method by working with rather large numbers. It is hardly conceivable that there exist many strains within a variety that are especially productive or commercially desirable, or that are markedly resistant to disease. Occasionally one may be fortunate enough to isolate such a strain with a minimum amount of effort, but the chances are strongly in the opposite direction. This statement is not made for the purpose of discouraging anyone from attempting to improve his seed stock by up-to-date seed-selection methods. The intention is rather to encourage the selectionist to make a larger number of selections and thereby increase his chances of securing a superior strain.

The selection of a large number of high-yielding hills which are then thrown together for mass planting the ensuing year is not likely to result in any marked improvement except by the elimination of the diseased or the unproductive plants. The only certain method of securing a superior strain is to plant each selection separately, as recommended in Circular 113 of the Bureau of Plant Industry and Farmers' Bulletin 533, United States Department of Agriculture.

Every progressive potato grower should have his selection plat, in which to grow his yearly selections; and, in addition, he should have his increase plat, where the promising selections may be increased for the field-crop planting.

SUMMARY.

The data presented seem to justify the following statements:

(1) That the potato crop of the United States is of sufficient economic importance to demand a most careful study of all favorable and unfavorable factors influencing the yield.

(2) That the economic use made of the potato in this country is relatively unimportant when compared to that of Germany.

(3) That deterioration of our cultivated varieties through improper cultural practices and through disease necessitates the improvement of existing varieties through the exercise of greater care in the selection of the seed and through the development of new seedling varieties possessing greater disease resistance or better commercial qualities.

(4) That the term "plant breeding," when applied to the potato, should be construed as sexual rather than asexual reproduction. In other words, it is believed that a distinction should be made between "breeding" and "selection."

(5) That the work of Goodrich as a potato-plant breeder was epoch making, in that it resulted in giving us the progenitor of the world-famous Early Rose.

(6) That while the growing of seedling potatoes may offer greater possibilities than selection alone, the latter method can be practiced with much greater ease than the former. Breeding can be indulged in only by the few, while selection may be engaged in by the many.

(7) That the almost total failure of our present-day commercial varieties to produce seed balls is due to male sterility rather than to imperfect pistils or ovaries.

(8) That the commonly accepted theory regarding the inadvisability of allowing more than one or two seed balls to develop on a cyme, on the assumption that weak seedlings would result, is not substantiated in crosses 8708, 8709, and 8718, which developed five and six seed balls apiece.

(9) That the data secured from some of the crosses indicate very strongly that some varieties are prolific seed bearers, while others are not.

(10) That the tuber-unit and hill-selection methods of seed selection are chiefly valuable in pointing out the weak, unproductive, and diseased seed tubers.

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