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A STUDY OF SOME ABNORMALITIES OCCURRING IN CERTAIN POTATO VARIETIES IN COLORADO

By RUDOLPH DANIEL ANDERSON

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A STUDY OF SOME ABNORMALITIES OCCURRING IN CERTAIN POTATO VARIETIES IN COLORADO*

By RUDOLPH DANIEL ANDERSON

There are a number of apparently new abnormalities occurring in certain potato varieties in Colorado which are causing a considerable loss to growers in those districts in which they have been observed. They have been found in the Brown Beauty, Perfect Peachblow, Bliss Triumph, and Russet Burbank varieties. Since Brown Beauty and Perfect Peachblow are the two main varieties grown in the San Luis Valley, the losses in this section are greater than in any of the other districts. Fields have been observed in this valley which contain as high as 100 percent abnormal plants.

In terms of marketable potatoes the losses vary from a few percent up to as high as 80 or 90 percent. The losses are due to rough, coarse, unsightly potatoes in some cases and extremely small ones in others.

One of these abnormal types produces a large number of tubers of "seed size." Many growers have selected these for seed and either have planted or sold them as such. Since the abnormalities are perpetuated by the seed, they have increased until at the present time they are a serious economic factor. The high prices of 1919 and 1925, leveling of the land, bin selection, and the use of whole seed for planting are largely responsible for this increase.

It was the purpose of the following described experiments to determine, if possible, the nature of each abnormality and the loss in yield and in marketable tubers due to the presence of such abnormalities in a field of potatoes.

Observations made while inspecting potato fields for certification showed that these abnormalities were more common in the San Luis Valley than in any other of the potato-producing regions in the state. Since the growers of certified potato seed are well distributed over the state, the writer had unusual opportunities for study and comparison of these "off-types." Another fact which should be considered is the variation in potato varieties in

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the different sections. The San Luis Valley is the only area in the state where the Brown Beauty variety is grown extensively.

DESCRIPTIONS OF ABNORMALITIES

The abnormalities upon which these investigations are based are as follows:

1. Wilding[a] of Perfect Peachblow and Brown Beauty.
2. Pearl type[b] of Brown Beauty.
3. Ragged giant hill[c] of Brown Beauty.
4. Pinto[d] of Perfect Peachblow.

WILDING

Plants of this type are quite common in the Perfect Peachblow and Brown Beauty varieties. Occasionally they have been observed in Bliss Triumphs and Russet Burbanks. These plants differ strikingly from normal plants.

Figure 1.—Wilding of Brown Beauty in the field.

Under field conditions the abnormal plant has a low, bushy habit of growth (figs. 1 and 2) which is caused primarily by the production of a number of thin stems, usually arising from one sprout of the seed-piece. In the greenhouse the plants retain the same general characteristics (figs. 3 and 4). These thin stems originate at or just below the ground level. The plant is dwarfed and lacking in vigor. The primary leaflet, as well as the first pair of leaflets, is more rounded in outline than the leaflets of normal plants (figs. 5 and 6). This gives the leaflets the heart-shaped appearance which is

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(a) The name "wilding" was used because this abnormality closely resembles a condition by that name found in the British Isles.

(b) "Pearl type" was the name given to this abnormality, as the plants closely resemble those of the Pearl variety.

(c) The name "ragged giant hill" was applied to this abnormal type because it describes in a brief way the appearance of the plants.

(d) This abnormality was designated "pinto" because of the blotched appearance of the tubers.

Figure 2.—Wilding of Perfect Peachblow in the field.

one of the characteristics used in the identification of this type. Usually but one pair of leaflets is present with the primary leaflet, and the folioles generally are absent. If any of the folioles

Figure 3.—Normal Perfect Peachblow, left, and wilding of Perfect Peachblow, right.

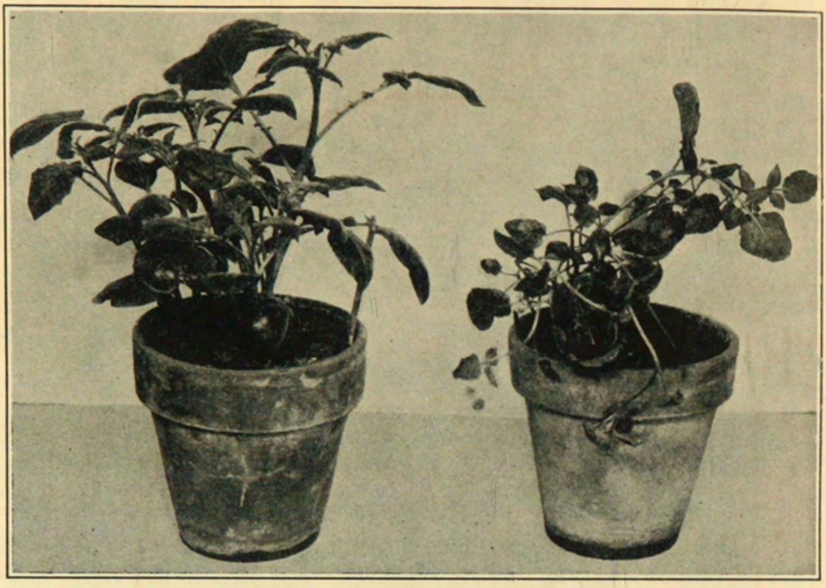

Figure 4.—Normal Brown Beauty, left, and wilding of Brown Beauty, right.

are present, they are very rudimentary. The stems are round and the wings absent. Also these plants produce no flowers.

These plants have a tendency to produce large numbers of undersized tubers, 50 or more not being uncommon (figs. 7 and 8). Very few are of market size. The tubers are smooth, shallow-eyed, slightly flattened, and tend to be longer than normal.

PEARL TYPE

This type of plant is common in the San Luis Valley in the Brown Beauty variety. It has not been observed to any extent in other potato regions in the state, probably because only a limited amount of this variety is grown elsewhere, and the planting stock for this acreage has been developed from a comparatively small original supply of seed.

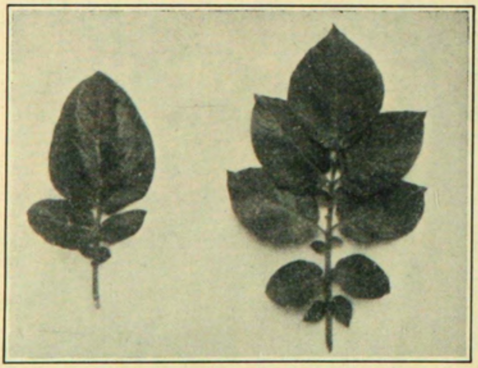

Figure 5.—Leaf from wilding plant of Perfect Peachblow, left, and normal leaf of Perfect Peachblow, right.

Pearl type plants may have an increased number of stems. This may be due to the fact that there seems to be no apical dominance in the tubers. When a tuber is planted all the eyes sprout, and consequently a large number of stems are produced.

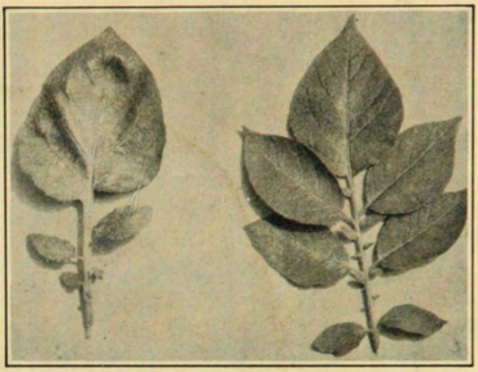

Figure 6.—Leaf from wilding plant of Brown Beauty, left, and normal Brown Beauty leaf, right.

Plants of this type show a striking resemblance to those of the Pearl variety in the appearance of foliage and tubers (fig. 9).

The leaves are fewer in number and more open than those of the Brown Beauty variety (fig. 10). The leaflets are round in outline, whereas the Brown Beauty leaflets are pointed. The secondary leaflets are rudimentary.

The tubers from plants of this type are not radically reduced in size, but they usually are very poor in type (fig. 11). They often show a high percentage of second growth. While the color of the Brown Beauty tuber is creamy yellow, that of the pearl type is dull white. In size alone the tubers are similar to those of the Brown Beauty.

RAGGED GIANT HILL

Ragged giant hill occurs only in the Brown Beauty variety.

Figure 7.—Tubers from normal Perfect Peachblow, left, and wilding Perfect Peachblow, right.

Figure 8.—Tubers from normal Brown Beauty, left, and wilding of Brown Beauty, right.

Figure 9.—Pearl type plant in the field.

Plants thus affected are very ragged in appearance, due partly to the waviness of the margins of the leaflets and partly to their uneven shape (fig. 12). Ragged giant hill plants show a much darker green color than do normal plants, and this coloration is associated with a dull luster in the leaves. The leaf-scales and the base of the stem are purple. The shape of the leaflets varies in different plants. In some the midrib is shortened to the extent that the leaflets are wider than they are long (fig. 13). The stem is triangular and the wings are prominent. The plant itself does not lack vigor. It is coarse in structure (fig. 14) and the leaves are thick and leathery. Ragged giant hill plants flower freely and have an increased capacity for producing seed-balls.

The tubers are rough and deep-eyed, and tend to be round instead of oval (fig. 15). The skin is smoother than normal, and under conditions where tubers from normal Brown Beauties become netted or partly so, those from ragged giant hill remain

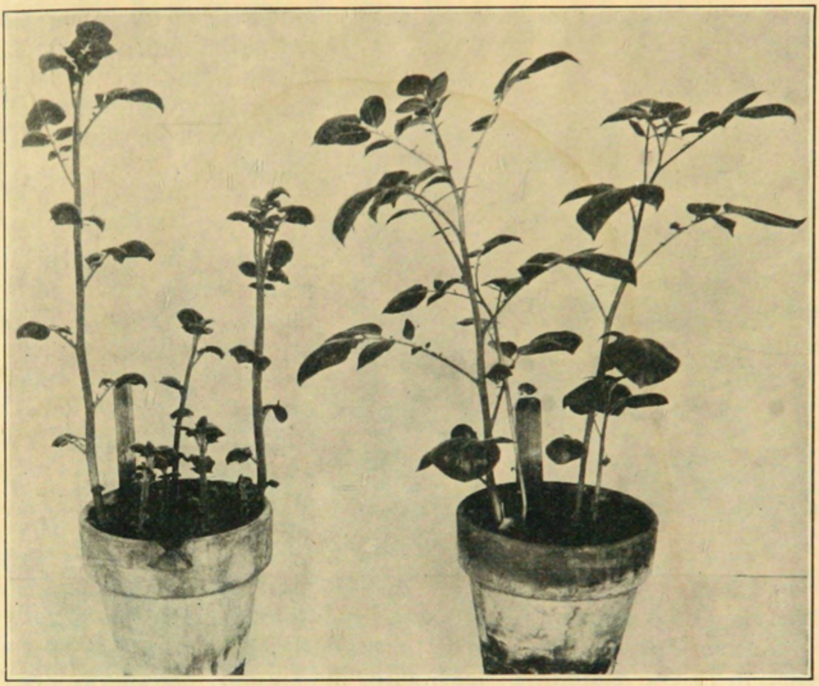

Figure 10.—Pearl type plant, left, and normal Brown Beauty, right.

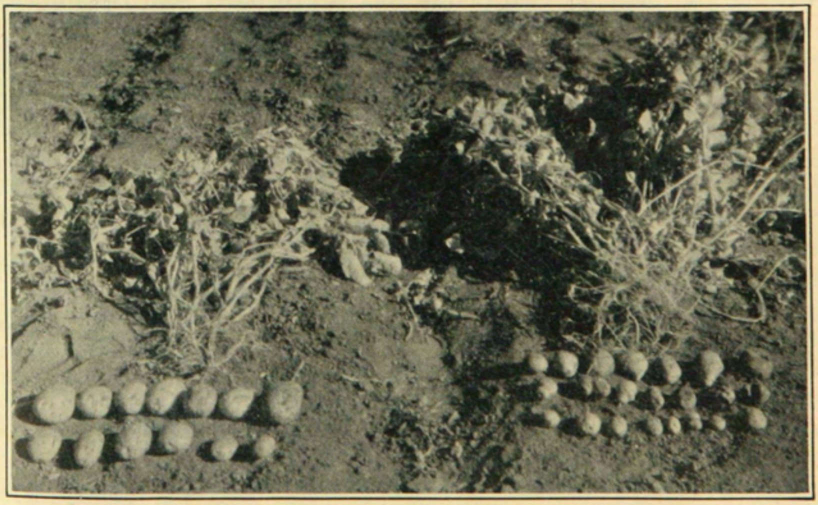

Figure 11.—Tubers from normal Brown Beauty plant, left, and pearl type plant, right.

Figure 12.—Ragged giant hill plant in the field.

smooth. The color of the skin is a light purple. In the bud-eye cluster the coloration is a much darker purple than elsewhere.

PINTO

Pinto plants are common wherever Peachblows are grown. They are very vigorous. Frequently they grow taller and carry more foliage than normal plants. Usually not more than one large stem is present. The wings are more prominent than on normal plants. The leaflets are very smooth and well-shaped, and they tend to be slightly wider for their length than is normal (fig. 16). There is no reduction in the number of leaflets or folioles. If anything, there is an increase in the number of these parts. The plant is lighter green in color; the leaves are duller; and the petioles and leaf-veins do not contain as high a percentage of red pigmentation as the normal plant. Pinto plants bloom profusely and set numerous seed-balls.

The tubers from such plants are rougher and coarser than those from ordinary Peachblows. An increased depth of eyes is noticeable. The tubers are blotched in varying degrees. Instead of a general pink color throughout, they show blotches of white. The general shape is cylindrical and short. They are very firm in texture, a feature which decreases quality considerably.

They are difficult to

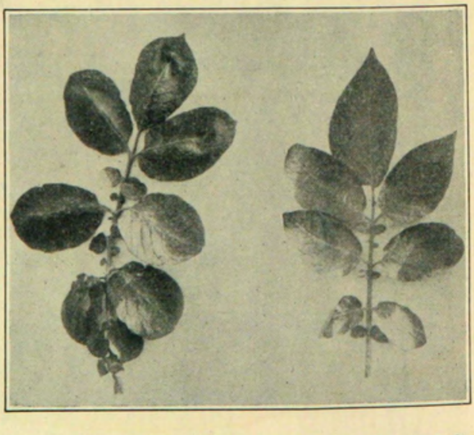

Figure 13.—Ragged giant hill leaf, left, and Brown Beauty leaf, right.

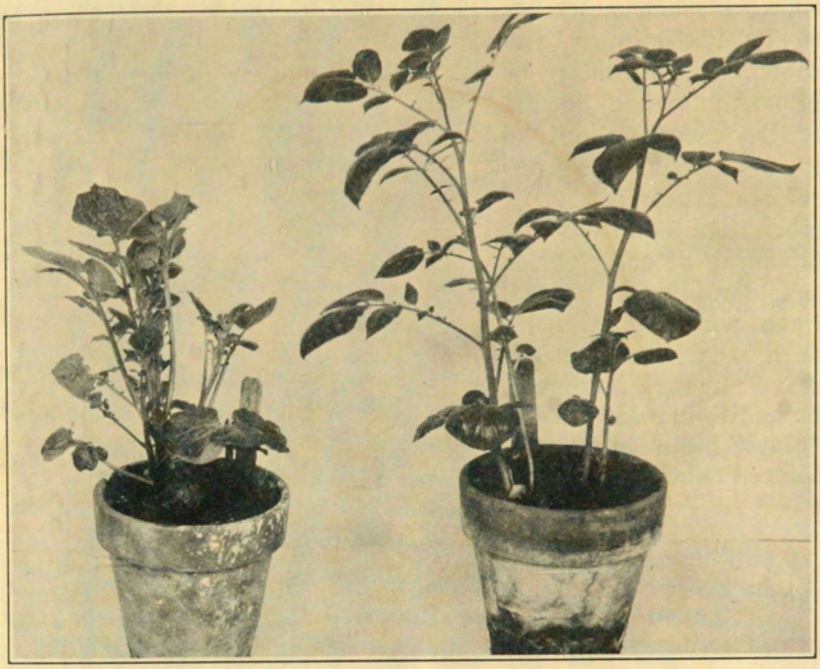

Figure 14.—Ragged giant hill plant, left, and normal Brown Beauty plant, right.

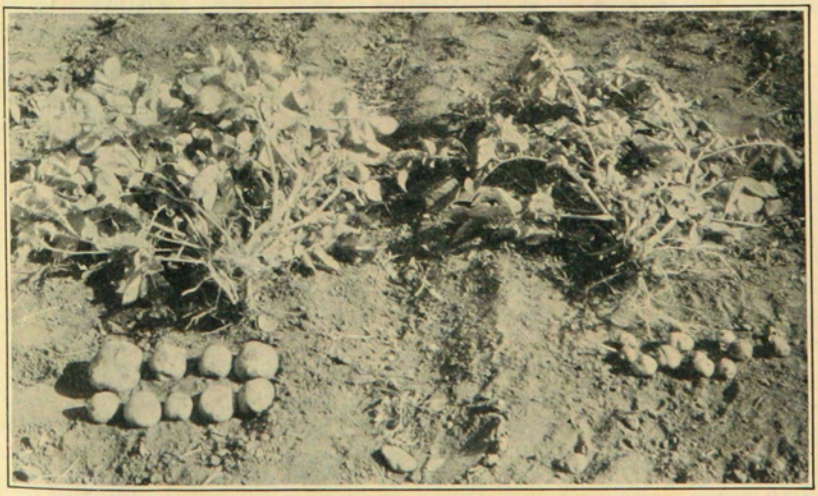

Figure 15.—Normal Brown Beauty, left, and ragged giant hill, right, showing the difference in tubers produced by each.

cut and seem somewhat woody. Preliminary tests show a starch content of 8 percent when normal tubers contain from 16 to 19 percent. Tubers seldom attain a size of more than 5 ounces. The blotching of color varies considerably in degree. Pure whites and solid dark reds have been observed in rare instances, in addition to the usual "pinto" blotched or paricolored conditions.

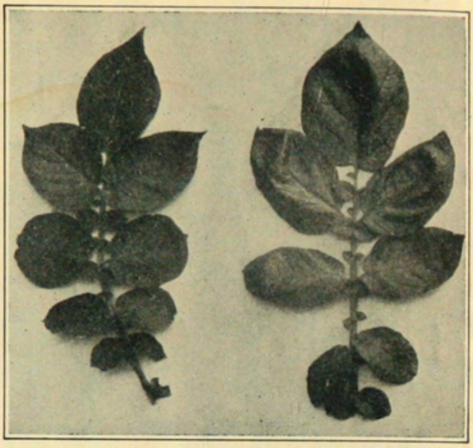

Figure 16.—Pinto leaf, left, and normal Perfect Peachblow leaf, right.

REVIEW OF LITERATURE

RELATED DISEASES

WILDING AND WITCHES' BROOM.—A condition which, from symptom descriptions, appears to resemble closely our wilding is one by that name which occurs in Great Britain. Anderson (1) in Scotland first described this degenerate and called it wilding. Salaman later described it as follows:

> "A wilding plant differs from the normal in the following features:
>
> "(a) It is short, the main stem breaking up into a number of short and weakly secondary axes.
>
> "(b) It is densely compact and cushion-like.
>
> "(c) It does not bear flowers or floral parts, though there are exceptions to this.
>
> "(d) The leaflets are much shorter and broader, and the folioles are few and small. The leaf itself is shortened.
>
> "(e) The stolons are numerous and bear a corresponding excess of small tubers which, however, retain such characteristics of color, shape, and eye as may belong to the original unaltered variety."

The symptoms of the "wilding condition" as described by McIntosh (23) in Scotland conform closely to Salaman's (28) description. McIntosh (23) further states that there is no evidence to show that wildings are the result of disease, and experiments performed by him failed to show that the conditions can be transmitted by foliage or tuber grafts. He suggests that they may be due to alterations of chromosome numbers.

Since wilding of Great Britain and witches' broom of America are somewhat similar, the question arises as to the possibility of their being one and the same. Murphy and McKay (26), in comparing American and European virus diseases of potatoes, found that wilding and witches' broom were identical. McIntosh (24), however, discredits this idea because he thinks that Murphy did not work with wilding but instead worked with typical witches' broom. McIntosh goes further in saying:

> "Murphy's idea that these are due to a virus is wrong. There is a disease, witches' broom, which is somewhat like wildings in appearance; and it is with that, I think, that Murphy worked. At all events he got his material from me; and I know that he did not work with what I call wildings."

There is no direct evidence that the wilding condition has been transmitted from affected to healthy plants, (1), (28), (23).

Young and Morris (42) have investigated witches' broom very thoroughly. In their description of symptoms they say that the plants are flavescent; the tops are often purple; the leaflets show marginal flavescence; and aerial tubers are present. The plants bloom and fruit in abnormal profusion. Transmission experiments performed by them show that witches' broom can be transmitted.

BOLTER, GIANT HILL AND SPINDLE TUBER.—There is another degeneration condition of potatoes occurring in Scotland called "bolter" which may be the same as the abnormality we have termed ragged giant hill.

Salaman (28), Anderson (1), and McIntosh (23) have all described the bolter plant. A description of this degenerate taken from McIntosh (23) is as follows:

> "A bolter differs from the true varietal type in its greater height, later maturity, coarser tubers, and greater capacity for flower bearing. Normally bolters cannot be distinguished from typical plants until the state of full growth is reached."

The bolter condition has never been transmitted by artificial methods, but McIntosh (24) has produced it by taking a very large number of top cuttings from normal plants and striking them in a good seed bed. He found that the tubers from these cutting plants, when grown the following year, gave a small percentage of "bolters."

Murphy and McKay (26), in their comparison of European and American virus diseases, state that bolter is probably the same as giant hill. However, it seems that their evidence was not conclusive enough to state definitely that these were identical.

In checking over the symptoms for giant hill, we find that Coons and Kotila (7) describe it as follows:

> "Giant hill is common in Michigan on Russet Rurals. These plants grow much larger than normal ones and produce a rougher, coarser foliage. The blossoms are more numerous, and the blooming period is much longer than on normal plants. The tubers are large and off-type. The vines stay green longer than do those on normal plants."

Gilbert (13) states that giant hill plants are more spreading in their habit of growth, and their stems are rather conspicuously margined and rough. The leaves are upright, often somewhat rolled or rugose, and usually wavy margined. The tubers are generally thickened and elongated, pointed at one or both ends, and frequently constricted at one point or another on the longer axis. They are provided with numerous eyes which are either flush with the surface or somewhat protuberant.

Tilford (37) adds that in giant hill the upper leaves are small and somewhat folded, and that the tuber-bearing stolons are often exceptionally long.

Barrus and Chupp (3) agree in general with the above symptom descriptions for giant hill.

Young and Morris (43) found the symptoms of giant hill masked in the greenhouse.

All attempts to transmit giant hill artificially seem to have failed. Dana (8) and Kotila (18) attempted a large number of transmissions but were unsuccessful.

The symptoms of spindle tuber as listed by Werner (39) are as follows:

> "The tubers are elongated and cylindrical. In colored varieties the coloring is reduced, frequently causing a blotchy effect. In russet varieties the russeting does not develop. The eyes are more shallow and more numerous. The plants have an erect habit of growth. The leaves are smaller and narrower than normal. They are folded up along the midrib and wavy along the margins."

Goss (14) adds that spindle tuber plants show lateral dwarfing, have a small number of stems, and are delayed in emerging. They blossom freely and show but a slight waviness of the margins of the leaflets.

Spindle tuber has been transmitted. Goss (15) inoculated a considerable number of healthy plants with the disease.

TRANSMISSION OF VIRUS DISEASES

A virus disease in potatoes produces certain symptoms that pass from generation to generation through the tubers. The causal agent is unknown. The only way its presence can be tested is by transmission experiments in which healthy plants are inoculated from diseased ones. The different methods of inoculation used by various experimenters in transmission work are:

1. Core-grafts.
2. Inarch and stem grafts.
3. Insect vectors.
4. Hypodermic needle.
5. Punctures through inoculum.
6. Leaf mutilations.
7. Manometric pressure.

CORE-GRAFTS.—This method, described by Goss(15), consists of the insertion of a core of tissue from an infected tuber into a hole in a healthy seed-piece. The core is cut with a cork-borer, and the hole into which it is inserted is made with a borer one size smaller. The use of the smaller-sized hole insures a firm contact, and the cylindrical shape provides a relatively large surface. The ends of the plug are cut off to avoid the development of sprouts from eyes occurring on the plug. A high percentage of infection has been secured by this method.

Young and Morris (43) used this technique in their work with witches' broom. They state that cutting-knives and cork-borers must be disinfected with a 5 percent solution of 40 percent commercial formalin.

INARCH AND STEM GRAFTS.—Grafting was also used by Young and Morris (43). Herbaceous stems from diseased and healthy plants were grafted in three different ways:

1. By *cleft grafts* which are made by inserting scions into clefts made in the stocks.
2. By *slip grafts* made by inserting scions into slits in the stems of the stocks.
3. By *inarching* which is done by slicing off the cortical layers on one side of each of two stems and binding the cut surfaces together while the roots of both plants remain undisturbed in the soil. The grafts are tightly wrapped with string and painted with hot grafting wax.

INSECT VECTORS.—Schultz (31) used aphids to transmit mosaic from diseased to healthy plants. He secured a 100-percent infection by the following procedure:

> "The aphids were allowed to feed on affected plants and then were transferred to healthy plants by three methods:
>
> "1. By laying one or two leaves, bearing feeding aphids, upon the plant so that the insects could crawl most easily to the new host.

"2. By introducing aphids when the new host was young, 3 to 13 inches tall.

"3. By introducing a rather large number of aphids; by estimate this number was from 40 to 200.

"The average number of days that the insects remained on the plants was 7, 9, and 14. They then were killed by fumigation. The plants were covered during the entire process with muslin cages. These were removed only when aphids were introduced. The cages were removed as soon as the aphids were killed by fumigation. The reason for removing the cages was to allow the plants as much light as possible during their growth after inoculation. This gave the disease symptoms a better chance of developing and also approximated field conditions as closely as possible."

Smith (34) used seven different species of insects in attempting to transmit leafroll. His results were all negative except where aphids were used. With the peach aphid *Myzus persicae* (Sulz.) he secured a high percentage of positive infection.

MeKay, et al., (25) state that aphids seem to be the chief agent in the spread of virus diseases, but giant hill, witches' broom, calico, and psyllid yellows have not been transmitted by them.

Potato virus diseases have been transmitted by many species of insects. Aphids, however, seem to be the vectors most generally used. Since aphids have been able to transmit most of the insect-carried virus diseases, it does not seem necessary to mention the other carriers here.

HYPODERMIC NEEDLE.—This was used by Elmer (9) in his work on the transmission of mosiac from infected to healthy plants. It consisted of injecting filtered juice from the infected plants into the healthy ones by the use of a hypodermic needle. All the apparatus was sterilized by boiling.

PUNCTURE THROUGH INOCULUM.—Elmer (9) states that this is probably the most efficient method of artificial mosiac inoculation in cross-inoculation investigations. Mosiac tissue used as inoculum was macerated in a sterile mortar, and sufficient tap water added to secure a rather liquid, pulpy inoculum. This inoculum was transferred to the plants to be inoculated with a sterilized medicine dropper. The drop of inoculum was placed at the desired points, and punctures were made through it into the healthy tissue with a needle. Mortars, pestles, and medicine droppers were sterilized with heat, and the needle was sterilized by flaming just before the inoculation of each point.

LEAF MUTILATION.—Schultz and Folsom (32), and Young and Morris (43), and Johnson (16) have used leaf mutilation inoculations in transmitting virus diseases of potatoes. Young and Morris (43) describe it as follows:

> "The stems and leaves of affected plants were ground in a sterile food-grinder or in a mortar and placed in sterile dishes. Each inoculation was made by placing some of the freshly macerated material on the leaf and pressing it against the leaf until the latter was ruptured. Usually 20 of these were made on each plant. The plants were reinoculated 2 or 3 times at intervals of 3 to 7 days. The plants were kept damp for 10 to 20 hours after inoculation. All materials used were disinfected."

MANOMETRIC PRESSURE.—This method, used by Elmer (9), consists of injecting inoculum under long-continued pressure. The inoculum was placed in a tube with one end drawn to a capillary point. This point was injected into the plant and the union sealed with melted paraffin. By connecting the tube to a manometer, the inoculum was slowly forced into the plant. A fair percentage of infection resulted.

MUTATIONS

Asseyeva (2), working in U. S. S. R., observed a number of abnormalities in potatoes. She proved that these were mutants by the following process:

> "Tubers were cut into longitudinal halves, from one of which all eyes were removed, while the other half remained intact. The halves were tied together and so kept until the moment of planting. Several whole tubers of each variety were also planted.
>
> "The halves from which the eyes were removed produced plants similar to the variety from which the mutant originated, while the half that was untreated produced mutant plants. The explanation for this is that only the cells composing the outer layers have been affected by the mutation. When the eyes were removed, new buds formed from the deeper layers which were of the same type as the original variety, and the plant resulting was exactly like the original variety."

Asseyeva (2) says that mutations of this type in potatoes have been known to affect the characteristics of plants and tubers as follows:

1. Color of tubers.
2. Structure of tuber skin.
3. Shape of tubers.
4. Color of flowers.
5. Shape of corolla.
6. Shape of leaves.
7. Color of leaves.
8. Color of stems.

She also states that mutations have been known to occur affecting the physiological nature of the potato plant. These were:

1. Productivity.
2. Degree of immunity.
3. Sexual reproduction.

Clark (5) worked with six commercial varieties of potatoes: Blue Victor, Peerless, People's, Russet Rural, Russet Burbank, and Noroton Beauty, in an attempt to determine if they were the result of mutations. His description of the excised-eye method is:

> "In all cases the seed tubers were cut in halves longitudinally about a month before planting, and the halves numbered in duplicate. The eyes were then removed from one series of the halves by scraping away with a sharp knife the outer layers of tissue to a depth of 0.5 millimeter. Both series were allowed to remain in a warm place until the cut surface had suberized. They were then placed in a cool cellar until the time of planting. The treated and untreated halves were placed opposite each other in adjacent rows."

From his results he concluded that mutations in the potato are periclinal chimaeras; i. e., the change affects only the outer layers of tissue. He found that:

1. Noroton Beauty is a mutant from Triumph.
2. Blue Victor is a mutant from Peerless.
3. People's is a mutant from Peerless.
4. Russet Rural is a mutant from Rural N. Y. No. 2.

Salaman (29) used a slightly different method in testing mutations. He writes that

> "The tubers to be examined are allowed to sprout; when the sprouts are about 1 to 2 inches long, a cork-borer with a diameter of ¾ inch is placed over the sprout and a solid core with sprout attached removed; the sprout is now torn off and potted forthwith, acting as the individual control of the eye, which is now shaved away to varying depths. Finally, the further end of the core is boldly cut away, so that there is no question of any eye remaining at the proximal end, and it is allowed to remain in a damp, dark box for 48 hours. At the end of that time the surface has become suberized, and the core is put into sterilized sand and placed under suitable conditions for growth. One to four cores may be obtained from a single tuber. What remains of the tuber can be planted as a general control. In this way any mutation can be directly compared with the normal produce of the particular eye operated on, as well as with the general population of tubers derived from that particular tuber."

Folsom (11) reported two types of leaf mutations. These were both somatic and in a clonal variety. They were sufficiently unstable to revert in part to the normal for the variety. One was a simply-leaved sport, and the other had thick, fleshy, glabrous leaves. Each condition was partly changed to a normal in successive generations.

Kotila (19) observed and studied several bud mutations. These included a fasciation of the stems in the Rural New Yorker; a fusion of leaflets in some of the lower leaves designated as "spinach leaf" in the Green Mountain; white and variegated tubers in the Bliss Triumph; and smooth, white tubers in the Russet Rural.

Fruwirth (12) says that the rate of mutation is different among varieties; that a large proportion of the mutations which he has observed are morphological, but that there may be also internal changes in conjunction or singly; that mutations may occur in all portions of the potato plant; that the maintenance of a mutation is seldom possible without reversion; and that most secondary mutations are reversions to a previous form. New-type, secondary mutations, he says, are more rare; vegetative mutations may or may not breed true, depending on the tissue involved; those that do not breed true are periclinal chimaeras; and the origin of mutations is due either to unequal cell division or to abnormal laying down of tissues.

CYTOLOGICAL INVESTIGATIONS

Longley and Clark (22) made a study of the number and meiotic behavior of chromosomes in the tuber-bearing forms of Solanum. Preparations were made from pollen and root-tips. They found that aceto-carmine smears, made from fresh material, were most satisfactory for the study of chromosome numbers. Killed and fixed material was useful, however, in studying the general type of divisions and the character of the tetrads typical of the different varieties.

They (22) came to the conclusion that all the commercially important varieties in the United States have 24 as the haploid number of chromosomes. They found that three cultivated varieties of Solanum tuberosum grown in South America have 12 as their haploid chromosome number.

Rybin (27) concludes from studies made by his colleague and himself that all European and North American commercial varieties probably have 48 as their somatic chromosome number. He further states that

> "in the forms of wild potatoes investigated it was found that Solanum muricatum Ait, S. chacoense Bitt., S. Jamesii Torr, S. Bukasovii Juz. n. sp., and S. araccpapa Juz. n. sp. have 24 as their somatic chromosome number. S. colombianum Dun. var. Trianae Bitt. n. f., S. palustre Poepp., S. acaule Bitt., var. subexinterruptum Bitt., S. antipovichi Bukasov, S. fendleri Gray, and S. ajuscoense Bukasov have 48 as their somatic chromosome number. The following forms of S. demissum—recurvoacuminatum, longibaccatum, xitlense, tlaxpehualcoense and adpressoacuminatum—have 72 as their somatic chro-

mosome number. S. comersonii Dunn., S. coyoacanum Bukasov n. sp., and S. medians Bitt. have 36 as their chromosome number. S. demissum (not typical), S. demissum x Majestic, and S. edinense Berth have 60 as their somatic chromosome number. The 236 specimens of the cultivated potato collected in Central and South America were found to have either 24, 36, or 48 as their somatic chromosome number."

Stow (36) and Vilmorin (38) arrived independently at the conclusion that 24 is the haploid chromosome number in the common potato.

Smith (33) also concludes that the haploid number of chromosomes in the common potato is 24. He also states that tetraploidy occurs in the Early Ohio variety as shown by the appearance of haploid cells with approximately 48 chromosomes.

The aceto-carmine method of fixing and staining smears from root-tips for chromosome counts is described by Sax (30) as follows:

"Belling's modification of aceto-carmine is used as a fixative and a stain. Root-tips are secured and first fixed in absolute acetic acid for 24 hours. They are then placed in a drop of aceto-carmine on a slide and cut up as fine as possible with a razor blade or sharp needle. The fragments are then crushed with a flat needle. Cover with a number 122 by 40 mm. cover, heat almost to boiling, and press cover firmly with absorbent paper. In favorable material, isolated cells or thin groups of cells can be found showing divisional figures.

"The aceto-carmine is made up as follows:

100 cc glacial acetic acid
100 cc water
Excess of carmine (several grams)

"Bring the above mixture to boil, cool completely and filter. When steel needles are used in crushing cell, enough iron gets into solution to give a dark stain. For a darker solution, add iron alum and haematoxylin, several cc of each to the staining bottle."

YIELD STUDIES

Kirk (17), at the University of Saskatchewan, Saskatoon, Canada, states that reliable results can be secured from yield tests with different strains or varieties of potatoes by using single row plots 132 feet long, with 4 replicates of each distributed at random on the basis of the latin square.

Westover (41) performed an experiment to determine the size of single row plots and the number of replications necessary to reduce experimental error to practical limits. He found that reliable results could be obtained if the sets were planted 10 to 12 inches in the row, the rows spaced 3½ feet apart, using single-row plots 40 feet long replicated 4 times.

Krantz (20), at the Minnesota Agricultural Experiment Station, concludes that rows 4 rods long replicated 3 times were accurate enough for all practical purposes.

Livermore (21), at Cornell University, recommends single-row plots 40 to 50 feet long, systematically arranged and replicated 10 times.

Werner and Kiesselbach (40), in a study of the effect of missing hills on yield, conclude that, under normal conditions, yield reductions were not proportional to stand losses. The plants surrounding vacant hills benefited from lessened competition, and tuber yield was increased.

Bergh (4) concludes that plants adjacent to a missing hill made up approximately 12 percent of the loss from the missing hill, and that varieties show a significant difference in their ability to use the available space.

Collison (6) states that the amount of loss caused by a missing hill varies considerably with the variety, the distance between plants, and cultural, soil, and weather conditions.

MATERIALS AND METHODS

TRANSMISSION STUDIES (1933-34)

From the review of literature pertaining to transmission of virus diseases of potatoes, it appears that certain methods have been more successful than others. These are core-grafting, leaf rubbing (mutilation), and the use of aphids as insect vectors.

The following transmission studies were made in the greenhouse during the winter of 1933-34.

CORE-GRAFTS.—Wilding in Perfect Peachblow and Brown Beauty, ragged giant hill and pearl type Brown Beauty, and pinto in Perfect Peachblow were the abnormalities used. The method followed was essentially that used by Goss (15). In each case two tubers of the normal variety were cut into four pieces, and two plugs from a tuber of an abnormality were grafted into three of the pieces, the fourth being used as a check. The remainder of the tuber from which the plugs were secured was planted as a check on the presence of the disease. The knives and cork borers were disinfected in a 5 percent solution of formalin. Plants were grown to maturity in benches from the tubers so treated, and the tubers produced by these plants were saved for later tests.

In order to check the efficiency of this method, a few tubers of each of a number of the standard virus diseases were secured.*

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*These tubers were secured from E. S. Schultz, senior pathologist, U. S. D. A.

These were mild mosaic, rugose mosaic, interveinal mosaic, witches' broom, calico, leafroll, and spindle tuber. Each of these was core-grafted into healthy Brown Beauty tubers.

LEAF RUBBING.—Five normal plants of Brown Beauty were inoculated with wilding of Brown Beauty by this method. A number of leaves from the wilding plant were crushed in a mortar. The thumb and forefinger were dipped in the juice so obtained and then rubbed on the healthy leaflets until the tissue was broken. A number of inoculations were made on a plant at one time. Three inoculations were attempted at intervals of 1 week. The last time a piece of sterile cheesecloth was dipped into the juice and used to break the tissue of the healthy plants. All materials used were sterilized with a 5 percent formaldehyde solution, and the hands were washed thoroughly with soap and warm water. Tubers produced by the inoculated plants were saved for future planting. The inoculation method used was similar to those reported by Schultz and Folsom (32) and Young and Morris (43).

INSECT VECTORS.—Aphids of the species *Myzus persicae* (Sulz.) and *Macrosyphum solanifolii* (Ashmead) were used in these studies. A number of normal tubers of Brown Beauty and Perfect Peachblow, as well as a few tubers of each of the abnormalities, were planted in a large bed in the greenhouse. As each plant emerged it was covered with a cheesecloth cage (fig. 17). A number of aphids were introduced into each of 3 cages, 1 containing a plant of the wilding type in Perfect Peachblow, 1 a plant of the pinto type, and 1 a plant of the ragged giant hill type. When the normal plants were 6 to 10 inches high, trans-

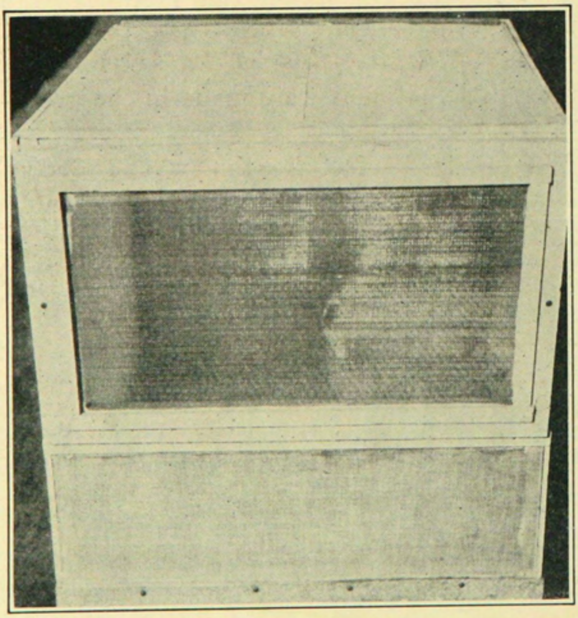

Figure 17.—Type of insect cage used in the greenhouse.

mission by insect vectors was attempted. For example, about 500 aphids were taken from the caged pinto plant, and approximately 100 of them were introduced into each of 5 caged normal Perfect Peachblow plants.

After the aphids had remained on the healthy plants for 2 weeks, the house was thoroughly fumigated and cages removed. Tubers from these plants were saved for later tests.

TRANSMISSION STUDIES (1934-35)

All tubers produced in the greenhouse in the winter of 1933-34 were grown at the Mountain Substation in 1934 to determine if the abnormalities had a long incubation period. They were planted in 42-inch rows, and the plants were spaced from 15 to 18 inches apart in the row.

In the winter of 1934-35 more core-grafts were made, and the tubers were planted in benches and in pots in the greenhouse. Pearl type, ragged giant hill, wilding of Brown Beauty and Perfect Peachblow were the abnormalities used. The method was the same as that used for this type of transmission in 1933-34.

YIELD STUDIES—MOUNTAIN SUBSTATION—1934

Student's method of paired plots* was used in this phase of the work. A uniform piece of land previously in alfalfa was laid out according to diagrams 1 and 2. This field was located ½ mile from any other potatoes, a distance great enough to keep the

Figure 18.—Experimental field at Mountain Substation, Avon.

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*Leonard, W. H., Field Plat Technic, manual for class work at the Colorado State College.

spread of other diseases at a minimum. The land received the usual preparation given potato ground. The field is shown in figure 18.

Pearl type of Brown Beauty, ragged giant hill of Brown Beauty, and wilding of Brown Beauty and of Perfect Peachblow were the four abnormal types in these studies.

Abnormal and healthy tubers were graded to the same size and treated with a standard disinfectant. They were then planted with an Iron-Age planter in the order and at the distances shown on the diagrams.

Uniform cultural treatments were given the plots during the growing season.

All plots were harvested by hand, and weight and number of tubers in each hill were recorded separately. The crop from each plot was graded over a 1⅞-inch top screen and a 1-inch bottom screen. This gave the yield of "markets" and "seed size" tubers for each plot.

MUTATION STUDIES (1934-35)

Ten tubers each of wilding of Perfect Peachblow, wilding of Brown Beauty, ragged giant hill, and pearl type were treated by the method described by Asseyeva (2) and Clark (5). The eyes on one half of each tuber were excised to a depth of approximately 1 mm. The untreated half was used as a check. The treated and untreated halves were marked in duplicate with india ink, and the treated halves were placed in an oven at about 20° centigrade and at a high humidity to facilitate the development of sprouts. The untreated halves were held in a cool room. A number of the tubers in each treated lot failed to sprout. The treated halves which sprouted and the untreated halves were planted in pots at the same time. In this way the plants from the treated halves could be compared directly with those from the untreated halves.

CYTOLOGICAL STUDIES

Root-tips were secured from the abnormal types and also from normal Brown Beauty and Perfect Peachblow. These were taken between the hours of 8 and 9 a. m. They were killed and fixed in glacial acetic acid for 24 hours. At the end of this time temporary smears were made in a drop of aceto-carmine, using the method given by Sax (30).

Chromosome counts were made from the mitotic figures present. Fifteen x and 25 x oculars, and 44 x and 95 x (oil immersion) objectives were used. Camera lucida drawings of the mitotic figures are shown in figure 19.

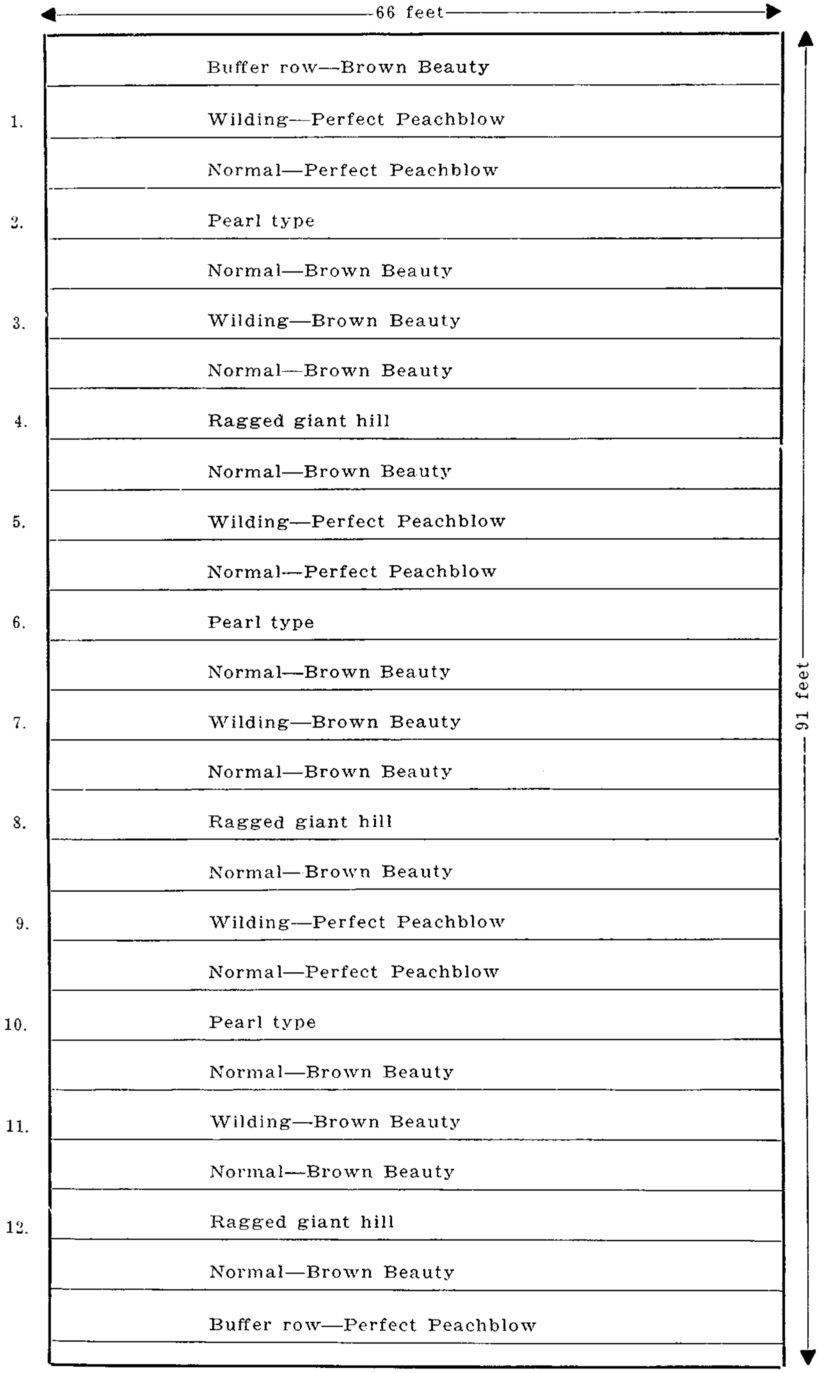

Diagram 1.—Arrangement of field plots at Mountain Substation.

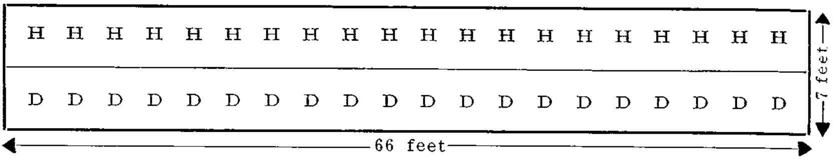

Diagram 2.—Arrangement of one plot.

Diseased and healthy plants opposite each other.

Each row	66 feet by 7 feet
Rows	3½ feet apart
Plants	3 feet apart

RESULTS

TRANSMISSION STUDIES

Transmission by inoculation, as attempted in 1933-34 and 1934-35, was unsuccessful. The results from core-grafts grown in the greenhouse in 1933-34 are shown in table I. It will be seen from this table that in no instance was there transmission of any of these abnormalities. Similarly, inoculation by leaf mutilation showed no infection. The same was true where aphids were used as vectors (table II).

The tubers from inoculated plants produced in the greenhouse in the winter of 1933-34, when grown in the field at the Mountain Substation in 1934, showed no indications of abnormalities. The data concerning these second-generation plants and normal check-plants are given in table III. Data covering additional core-grafts made in the greenhouse in 1934-35 are given in table IV.

When these results are compared with the almost 100 percent transmission obtained from core-grafts of known potato virus diseases, it seems quite probable that these abnormal types are not of virus origin.

YIELD STUDIES

The yielding ability of the abnormalities and the normals of the varieties in which they occur are compared by Student's paired plot method in tables V, VI, VII, and VIII. In table V, normal Brown Beauty is compared with wilding of Brown Beauty. The mean difference in yielding ability per hill is 1.072 pounds in favor of the normal. The odds given indicate that, in this case, such a difference is significant. Table VI gives the comparison between normal Brown Beauty and ragged giant hill. The mean difference per hill in this case is 2.1318 pounds in favor of the normal. The odds in this case also show such a difference to be

Table I.—CORE-GRAFT INOCULATIONS IN 1933-34.

Material used	How treated	Number plants	Symptoms (Yes or no)
Normal Brown Beauty X Wilding Brown Beauty	Core-grafted	6	No
	Check	2	No
	Diseased	2	Yes
Normal Peachblow X Wilding Peachblow	Check	2	No
	Core-grafted	5	No.
	Diseased	2	Yes
Normal Brown Beauty X Ragged giant hill	Core-grafted	6	No
	Check	2	No
	Diseased	2	Yes
Normal Brown Beauty X Pearl type	Core-grafted	6	No
	Check	2	No
	Diseased	2	Yes
Normal Peachblow X Pinto	Core-grafted	4	No
	Check	1	No
	Diseased	2	Yes

Table II.—APHID TRANSMISSION INOCULATIONS IN 1933-34.

Material used	Number of plants	Symptoms (Yes or no)
Normal Brown Beauty X Ragged giant hill	5	No
Normal Peachblow X Wilding Peachblow	5	No
Normal Peachblow X Pinto	5	No

significant. Normal Brown Beauty and pearl type are compared in table VII. The mean difference per hill between the two was 0.1607 pounds in favor of the normal. The odds in this instance were not significant. Pairings for wilding of Perfect Peachblow and normal Perfect Peachblow are given in table VIII. The mean difference in favor of the normal was 0.388 pounds per hill. The odds for this difference are large enough to be considered significant. They are not, however, as great as those for the differences between normal Brown Beauty and the two abnormalities, wilding and ragged giant hill, found in the latter variety.

The number of tubers produced by the various abnormalities, and the normals for the varieties in which they occur, are compared in tables IX, X, XI and XII. Table IX shows that the mean difference between pearl type and normal Brown Beauty is 7.892 tubers per plant in favor of the pearl type. Table X shows that the mean difference between ragged giant hill and normal Brown Beauty is 6.1454 tubers per plant in favor of the former. In table XI wilding of Brown Beauty is compared with the normal. The wilding has a mean difference of 16.80 tubers per hill in its favor. Wilding of Perfect Peachblow is compared with normal Perfect Peachblow in table XII. The mean difference in favor of the wilding in this case is 28.25 tubers per plant. In all the cases cited the odds were great enough to make the differences significant.

The data from the grading experiment are given in table XIII. In this case the comparisons were made by the "deviation from the mean method." Normal Perfect Peachblow produced an average of 32.83 ± 5.86 pounds more "markets" per plot than

Table III.—SECOND GENERATION TESTS OF PLANTS PRODUCED FROM TUBERS SECURED ON INOCULATED PARENTS IN THE GREENHOUSE.

Material used	Type of inoculation	Number plants	Symptoms (Yes or no)
Normal Peachblow X Wilding Peachblow	Aphid transmission	16	No
Normal Peachblow X Pinto	Aphid transmission	13	No
Normal Brown Beauty X Ragged giant hill	Aphid transmission	12	No
Normal Brown Beauty X Wilding Brown Beauty	Leaf rubbing	18	No
Normal Brown Beauty X Wilding Brown Beauty	Core-grafted	24	No
Normal Peachblow X Wilding Peachblow	Core-grafted	25	No
Normal Brown Beauty X Ragged giant hill	Core-grafted	21	No
Normal Brown Beauty X Pearl type	Core-grafted	20	No
Normal Peachblow X Pinto	Core-grafted	10	No
Check plants Brown Beauty	———	39	No
Check plants Perfect Peachblow	———	26	No

did the wilding form in that variety. Normal Brown Beauty produced an average of 37.34 ± 7.26 pounds more "markets" per plot than did its corresponding wilding form. Ragged giant hill was the lowest producer of "markets" of all the abnormalities. The normal Brown Beauty as compared with it in this case yielded an average of 45.87 ± 7.04 more pounds of "markets" per plot. Normal Brown Beauty did not produce more "markets" per plot than pearl type, the difference in this case being 4.34 ± 9.16 pounds in favor of the normal. This difference is not significant.

Table IV.—CORE-GRAFT INOCULATIONS IN 1934-35.

Material used	How treated	Number plants	Symptoms (Yes or no)
Normal Brown Beauty X Wilding Brown Beauty	Core-grafted	11	No
	Check	6	No
	Diseased	4	Yes
Normal Peachblow X Wilding Peachblow	Core-grafted	11	No
	Check	2	No
	Diseased	3	Yes
Normal Brown Beauty X Ragged giant hill	Core-grafted	16	No
	Check	6	No
	Diseased	6	Yes
Normal Brown Beauty X Pearl type	Core-grafted	17	No
	Check	6	No
	Diseased	5	Yes

Table V.—COMPARISON OF YIELDS IN POUNDS BETWEEN PAIRED PLANTS OF WILDING OF BROWN BEAUTY AND NORMAL BROWN BEAUTY.

Plot	Hill Numbers	Wilding	Normal	Difference	(Difference)2
3	1	½	1	+0.50	.2500
	2	2	2¼	+0.25	.0625
	3	1½	2	+0.50	.2500
	4	2¼	½	—1.75	3.0625
	5	2½	3	+0.50	.2500
	6	¼	1½	+1.25	1.5625
	7	3½	2	—1.50	2.2500
	8	2	3	+1.00	1.0000
	9	1½	3¼	+1.75	3.0625
	10	1¾	6	+4.25	18.0625
	11	1	3¼	+2.25	5.0625
	12	4	4¼	+0.25	.0625
	13	4	3¼	—0.75	.5625
	14	2¼	5	+2.75	7.5625
	15	3	3¾	+0.75	.5625
	16	2¾	2½	—0.25	.0625
	17	2¼	6	+3.75	14.0625
	18	2	4	+2.00	4.0000
7	19	3½	3	—0.50	.2500
	20	1½	1½	0.00	.0000
	21	2¼	2½	+0.25	.0625
	22	1	4	+3.00	9.0000
	23	3	3	0.00	.0000
	24	3¼	3	—0.25	.0625
	25	1½	3	+1.50	2.2500
	26	1½	2¾	+1.25	1.5625
	27	2½	3½	+1.00	1.0000
	28	3	5½	+2.50	6.2500
	29	4	2½	—1.50	2.2500
	30	5	5	0.00	.0000
	31	5	5¼	+0.25	.0625
	32	3	5	+2.00	4.0000
	33	2½	3¼	+0.75	.5625
	34	3	4	+1.00	1.0000
	35	3¼	4	+0.75	.5625
11	36	2	2	0.00	.0000
	37	1½	4	+2.50	6.2500
	38	3¼	3	—0.25	.0625
	39	2¼	3	+0.75	.5625
	40	2½	4½	+2.00	4.0000
	41	1½	4	+2.50	6.2500
	42	2½	4	+1.50	2.2500
	43	2½	5	+2.50	6.2500
	44	3¼	4½	+1.25	1.5625
	45	2¾	3	+ .25	.0625
	46	2	4	+2.00	4.0000
	47	3	4	+1.00	1.0000
	48	2	5½	+3.50	12.2500
	49	4	4½	.50	.2500
	50	2¼	5½	+3.25	10.5625
	51	3½	3½	0.00	.0000
	52	2	4	+2.00	4.0000

Mean difference	+1.072
Standard deviation (whole experiment)	1.316
Standard deviation of mean difference	.1843
"t" value	5.81
Odds	100:1

Table VI.—COMPARISON OF YIELDS IN POUNDS BETWEEN PAIRED PLANTS OF RAGGED GIANT HILL AND NORMAL BROWN BEAUTY.

Plot	Hill numbers	Ragged giant hill	Normal	Difference	(Difference)2
4	1	⅛	1	+ .875	.7656
	2	⅛	¾	+ .625	.3906
	3	¼	3¼	+3.000	9.0000
	4	1	2½	+1.500	2.2500
	5	2¼	4	+1.750	3.0625
	6	1¼	5	+3.750	14.0625
	7	1½	4	+2.500	6.2500
	8	Nil	3¾	+3.750	14.0625
	9	1	1½	+ .500	.2500
	10	1½	4	+2.500	6.2500
	11	1	3	+2.000	4.0000
	12	1	5	+4.000	16.0000
	13	2½	3½	+1.000	1.0000
	14	½	4	+3.500	12.2500
	15	½	4½	+4.000	16.0000
	16	1	5	+4.000	16.0000
	17	2½	3½	+1.000	1.0000
	18	3	4	+1.000	1.0000
8	19	2	3	+1.000	1.0000
	20	1½	1½	.000	.0000
	21	2½	2½	.000	.0000
	22	1	2½	+1.500	2.2500
	23	1	2	+1.000	1.0000
	24	1½	3	+1.500	2.2500
	25	1¼	2	+ .750	.5625
	26	1½	1¾	+ .250	.0625
	27	1½	2	+ .500	.2500
	28	1	3	+2.000	4.0000
	29	1	2¾	+1.750	3.0625
	30	½	4	+3.500	12.2500
	31	¾	4¾	+4.000	16.0000
	32	2	6	+4.000	16.0000
	33	1½	3¼	+1.750	3.0625
	34	½	5	+4.500	20.2500
	35	2¼	4	+1.750	3.0625
	36	3	4	+1.000	1.0000
12	37	1¼	2	+ .75	.5625
	38	1	2	+1.00	1.0000
	39	¼	4	+3.75	14.0625
	40	1½	4¼	+2.75	7.5625
	41	¼	5	+4.75	22.5625
	42	3	3¼	+ .25	.0625
	43	1	4	+3.00	9.0000
	44	½	3	+2.50	6.2500
	45	¾	1¾	+1.00	1.0000
	46	1¾	4½	+2.75	7.5625
	47	2	2	.00	.0000
	48	¾	4	+3.25	10.5625
	49	1	3½	+2.50	6.2500
	50	1	4¾	+3.75	14.0625
	51	1	3½	+2.50	6.2500
	52	2½	4	+1.50	2.2500
	53	1¾	4½	+2.75	7.5625
	54	½	3½	+3.00	9.0000
	55	½	4	+3.50	12.2500

Mean difference	+2.1318
Standard deviation (whole experiment)	1.333
Standard deviation of mean difference	.1816
"t" value	11.73
Odds	100:1

Table VII.—COMPARISON OF YIELDS IN POUNDS BETWEEN PLANTS OF PEARL TYPE AND NORMAL BROWN BEAUTY.

Plot	Hill numbers	Pearl type	Normal	Difference	(Difference)2
2	1	2	1½	— .50	.2500
	2	2½	¼	—2.25	5.0625
	3	1	2	+1.00	1.0000
	4	1¼	1½	+ .25	.0625
	5	1½	3	+1.50	2.2500
	6	2½	3½	+1.00	1.0000
	7	2	3½	+1.50	2.2500
	8	2½	1	—1.50	2.2500
	9	1½	3	+1.50	2.2500
	10	4½	4¼	— .25	.0625
	11	4½	4	— .50	.2500
	12	5	4	—1.00	1.0000
	13	3½	3	— .50	.2500
	14	1½	3	+1.50	2.2500
	15	3½	3¼	— .25	.0625
	16	2½	3	+ .50	.2500
	17	3	3½	+ .50	.2500
	18	2¼	3¾	+ .50	.2500
	19	3	1½	—1.50	2.2500
	20	2	4	+2.00	4.0000
6	21	3	3	0.00	.0000
	22	1½	3	+1.50	2.2500
	23	3½	3¼	— .25	.0625
	24	3½	4	+ .50	.2500
	25	3	1¾	—1.25	1.5625
	26	2½	2	— .50	.2500
	27	1¾	1	— .75	.5625
	28	4	2	—2.00	4.0000
	29	4½	2½	—2.00	4.0000
	30	4	6	+2.00	4.0000
	31	2½	2½	0.00	.0000
	32	4	3½	— .50	.2500
	33	5½	4½	—1.00	1.0000
	34	4	3	—1.00	1.0000
	35	3½	4	+ .50	.2500
	36	3	4	+1.00	1.0000
	37	5	4½	— .50	.2500
	38	4	4½	+ .50	.2500
	39	3½	3	— .50	.2500
10	40	4	3½	— .50	.2500
	41	4	3	—1.00	1.0000
	42	2	4	+2.00	4.0000
	43	4	4½	+ .50	.2500
	44	4½	2	—2.50	6.2500
	45	1¾	4	+2.25	5.0625
	46	2½	4	+1.50	2.2500
	47	1½	3½	+2.00	4.0000
	48	2½	4	+1.50	2.2500
	49	4½	2½	—2.00	4.0000
	50	1½	4½	+3.00	9.0000
	51	4½	4	— .50	.2500
	52	3¾	3	— .75	.5625
	53	4¾	5	+ .25	.0625
	54	3¾	5¼	+1.50	2.2500
	55	4	3½	— .50	.2500
	56	3½	6½	+3.00	9.0000

Mean difference	+.1607
Standard deviation of whole experiment	1.32
Standard deviation of mean difference	.1781
"t" value	.902
Odds	4‡:1

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‡Odds are closer to 4 than 3 to 1.

Table VIII.—COMPARISON OF YIELDS IN POUNDS BETWEEN PAIRED PLANTS OF WILDING OF PERFECT PEACHBLOW AND NORMAL PERFECT PEACHBLOW.

Plot	Hill numbers	Wilding	Normal	Difference	(Difference)2
1	1	1	1	.00	.0000
	2	2	1	—1.00	1.0000
	3	1½	¾	— .75	.5625
	4	2½	1	—1.5	2.2500
	5	2½	2½	.00	.0000
	6	2¼	2	— .25	.0625
	7	1	3	+2.00	4.0000
	8	2½	1½	—1.00	1.0000
	9	1	3½	+2.50	6.2500
	10	2¼	3	+ .75	.5625
	11	2	2	.00	.0000
	12	1¾	2	+ .25	.0625
	13	1¾	3¾	+2.00	4.0000
	14	2	2¼	+ .25	.0625
	15	2¼	3	+ .75	.5625
	16	1¼	1¾	+ .50	.2500
	17	2¾	3	+ .25	.0625
	18	2	2½	+ .50	.2500
	19	2¼	2¼	.00	.0000
5	20	1	1	.00	.0000
	21	1	2	+1.00	1.0000
	22	2¼	2	— .25	.0625
	23	1¾	2¾	+1.00	1.0000
	24	1	1	.00	.0000
	25	2	2	.00	.0000
	26	2	1¾	— .25	.0625
	27	2¼	3	+ .75	.5625
	28	2	2	.00	.0000
	29	2¼	2¼	.00	.0000
	30	2¼	1¾	— .50	.2500
	31	3½	2	—1.50	2.2500
	32	2¼	1¾	— .50	.2500
	33	2	3	+1.00	1.0000
	34	2	6	+4.00	16.0000
	35	2½	3¼	+ .75	.5625
	36	3	4	+1.00	1.0000
	37	3	5	+2.00	4.0000
	38	3	5	+2.00	4.0000
	39	3	7	+4.00	16.0000
	40	1½	4	+2.50	6.2500
	41	1	¼	— .75	.5625
	42	3	2	—1.00	1.0000
	43	2	3½	+1.50	2.2500
	44	4	5½	+1.50	2.2500
	45	3½	2¼	—1.25	1.5625
	46	2	2	.00	
	47	3	2½	— .50	.2500
	48	3	4¼	+1.25	1.5625
	49	3	1¾	—1.25	1.5625
	50	3½	2	—1.50	2.2500
	51	1¾	4	+2.25	5.0625
	52	3	4	+1.00	1.0000
	53	2¼	2¼	.00	
	54	3½	2	—1.50	2.2500
	55	1½	2	+ .50	.2500
	56	2½	1¾	— .75	.5625

Mean difference	.388
Standard deviation of whole experiment	1.26
Standard deviation of mean difference	.1700
"t" value	2.282
Odds	—50‡:1

‡Odds closer to 50 than 20 to 1.

Table IX.—COMPARISON OF THE NUMBER OF TUBERS PRODUCED BY PAIRED PLANTS OF PEARL TYPE AND NORMAL BROWN BEAUTY.

Plot	Hill numbers	Pearl type	Normal	Difference	(Difference)2
2	1	54	18	+36	1296
	2	44	20	+20	576
	3	24	48	—24	576
	4	76	34	+42	1764
	5	16	28	—12	144
	6	36	23	+13	169
	7	34	17	+17	289
	8	17	5	+12	144
	9	40	20	+20	400
	10	29	18	+11	121
	11	22	17	+ 5	25
	12	30	31	— 1	1
	13	23	28	— 5	25
	14	54	16	+38	1444
	15	30	12	+18	324
	16	25	24	+ 1	1
	17	8	18	—10	100
	18	19	28	— 9	81
	19	18	28	—10	100
	20	10	21	—11	121
6	21	23	39	—16	256
	22	30	25	+ 5	25
	23	59	19	+40	1600
	24	42	41	+ 1	1
	25	49	23	+26	676
	26	46	29	+17	289
	27	23	13	+10	100
	28	28	16	+12	144
	29	20	25	— 5	25
	30	14	15	— 1	1
	31	75	12	+63	3969
	32	12	17	— 5	25
	33	22	22	0	0
	34	12	16	— 4	16
	35	14	17	— 3	9
	36	11	13	— 2	4
	37	40	37	+ 3	9
	38	24	18	+ 6	36
	39	46	13	+33	1089
10	40	30	20	+10	100
	41	29	23	+ 6	36
	42	27	36	— 9	81
	43	21	31	—10	100
	44	56	29	+27	729
	45	57	28	+29	841
	46	66	44	+22	484
	47	19	23	— 4	16
	48	40	28	+12	144
	49	32	41	— 9	81
	50	28	20	+ 8	64
	51	20	23	— 3	9
	52	34	17	+17	289
	53	25	27	— 2	4
	54	15	28	—13	169
	55	29	33	— 4	16
	56	56	26	+30	900

Mean difference	—7.892
Standard deviation of whole experiment	17.19
Standard deviation of mean difference	2.29
"t" value	3.446
Odds	100:1

Table X.—COMPARISON OF THE NUMBER OF TUBERS PRODUCED BY PAIRED PLANTS OF RAGGED GIANT HILL AND NORMAL BROWN BEAUTY.

Plot	Hill numbers	Ragged giant hill	Normal	Difference	(Difference)^2
4	1	14	24	—10	100
	2	11	15	— 4	16
	3	20	19	+ 1	1
	4	45	17	+28	784
	5	43	17	+26	676
	6	26	22	+ 4	16
	7	28	18	+10	100
	8	6	18	—12	144
	9	35	18	+17	289
	10	40	20	+20	400
	11	20	25	— 5	25
	12	23	25	— 2	4
	13	26	20	+ 6	36
	14	14	23	— 9	81
	15	26	27	— 1	1
	16	19	18	+ 1	1
	17	32	22	+10	100
	18	53	28	+25	625
8	19	27	24	+ 3	9
	20	27	29	— 2	4
	21	44	36	+ 8	64
	22	30	18	+12	144
	23	33	31	+ 2	4
	24	50	18	+32	1024
	25	33	26	+ 7	49
	26	25	21	+ 4	16
	27	21	38	—17	289
	28	34	34	0	0
	29	32	23	+ 9	81
	30	35	42	— 7	49
	31	33	36	— 3	9
	32	16	31	—15	225
	33	51	21	+30	900
	34	21	30	— 9	81
	35	43	24	+19	361
	36	57	20	+37	1369
12	37	20	19	+ 1	1
	38	36	20	+16	256
	39	46	25	+21	441
	40	40	27	+13	169
	41	19	26	— 7	49
	42	42	31	+11	121
	43	21	22	— 1	1
	44	16	13	+ 3	9
	45	29	21	+ 8	64
	46	49	33	+16	256
	47	44	18	+26	676
	48	30	24	+ 6	36
	49	17	23	— 6	36
	50	24	31	— 7	49
	51	16	26	—10	100
	52	50	11	+39	1521
	53	33	18	+15	225
	54	23	42	—19	361
	55	33	35	— 2	4

Mean difference	6.1454
Standard deviation of whole experiment	13.333
Standard deviation of mean difference	1.816
"t" value	3.384
Odds	100:1

Table XI.—COMPARISON OF THE NUMBER OF TUBERS PRODUCED BY PAIRED PLANTS OF WILDING OF BROWN BEAUTY AND NORMAL BROWN BEAUTY.

Plot	Hill numbers	Wilding	Normal	Difference	(Difference)2
3	1	34	15	+19	361
	2	42	26	+16	256
	3	36	18	+18	324
	4	36	16	+20	400
	5	21	10	+11	121
	6	9	17	— 8	64
	7	27	18	+ 9	81
	8	19	15	+ 4	16
	9	37	27	+10	100
	10	40	22	+18	324
	11	22	24	— 2	4
	12	25	25	0	0
	13	76	31	+45	2025
	14	34	20	+14	196
	15	18	16	+ 2	4
	16	30	17	+13	169
	17	24	20	+ 4	16
	18	94	20	+74	5476
7	19	43	25	+18	324
	20	38	16	+22	484
	21	43	12	+31	961
	22	27	26	+ 1	1
	23	23	18	+ 5	25
	24	30	12	+18	324
	25	33	27	+ 6	36
	26	24	14	+10	100
	27	42	36	+ 6	36
	28	31	21	+10	100
	29	41	13	+28	784
	30	39	21	+18	324
	31	43	21	+22	484
	32	29	31	— 2	4
	33	36	25	+11	121
	34	43	13	+30	900
	35	43	21	+22	484
11	36	29	26	+ 3	9
	37	56	33	+23	529
	38	51	16	+35	1225
	39	55	22	+33	1089
	40	102	18	+84	7056
	41	24	28	— 4	16
	42	28	38	—10	100
	43	31	19	+12	144
	44	48	21	+27	729
	45	62	27	+35	1225
	46	20	10	+10	100
	47	24	9	+15	225
	48	30	20	+10	100
	49	36	23	+13	169
	50	43	18	+25	625
	51	60	19	+41	1681
	52	41	42	— 1	1

Mean difference	—16.80
Standard deviation of whole experiment	17.41
Standard deviation of the mean difference	2.438
"t" value	6.890
Odds	100:1

Table XII.—COMPARISON OF THE NUMBER OF TUBERS PRODUCED BY PAIRED PLANTS OF WILDING OF PERFECT PEACHBLOW AND NORMAL PERFECT PEACHBLOW

Plot	Hill numbers	Wilding	Normal	Difference	(Difference)^2
1	1	51	15	+36	1296
	2	58	18	+40	1600
	3	51	30	+21	441
	4	55	15	+40	1600
	5	61	31	+30	900
	6	51	12	+39	1521
	7	50	14	+36	1296
	8	41	16	+25	625
	9	52	25	+27	729
	10	59	20	+39	1521
	11	83	13	+70	4900
	12	78	19	+59	3481
	13	28	14	+14	196
	14	31	20	+11	121
	15	41	25	+16	256
	16	51	9	+42	1764
	17	17	20	— 3	9
	18	74	16	+58	3364
	19	59	30	+29	841
5	20	44	13	+31	961
	21	13	11	+ 2	4
	22	96	16	+80	6400
	23	34	18	+16	256
	24	24	16	+ 8	64
	25	43	30	+13	169
	26	31	12	+19	361
	27	34	13	+21	441
	28	45	11	+34	1156
	29	37	12	+25	625
	30	34	11	+23	529
	31	40	14	+26	676
	32	60	5	+55	3025
	33	44	17	+27	729
	34	38	23	+15	225
	35	22	27	— 5	25
	36	36	13	+23	529
	37	13	14	— 1	1
	38	30	27	+ 3	9
	39	32	19	+13	169
9	40	50	20	+30	900
	41	28	12	+16	256
	42	45	7	+38	1444
	43	19	23	— 4	16
	44	82	26	+56	3136
	45	35	11	+24	576
	46	68	9	+59	3481
	47	42	17	+25	625
	48	58	42	+16	256
	49	62	18	+44	1936
	50	60	12	+48	2304
	51	43	23	+20	400
	52	81	28	+53	2809
	53	24	21	+ 3	9
	54	53	10	+43	1849
	55	26	16	+10	100
	56	53	9	+44	1936

Mean difference	—28.25
Standard deviation of whole experiment	18.97
Standard deviation of mean differences	2.556
"t" value	11.05
Odds	100:1

Table XIII.—THE DIFFERENCE IN POUNDS OF "MARKETS" PRODUCED BY NORMAL PERFECT PEACHBLOW, NORMAL BROWN BEAUTY, RAGGED GIANT HILL, PEARL TYPE, AND WILDING.

Material	Plot	Weight of markets	Mean	d	d2	S. E. (pound)
Normal Peachblow A.	1	32		11.83	139.94	
	5	53		9.17	84.08	
	9	46.50		2.67	7.12	
			43.833			5.69
Wilding Peachblow B.	1	5		6.00	36.00	
	5	16		5.00	25.00	
	9	12		1.00	1.00	
			11.00			1.43
Normal Brown Beauty C.	3	43		10.50	110.25	
	7	54.5		1.00	1.00	
	11	63		9.50	90.25	
			53.50			6.95
Wilding Brown Beauty D.	3	18		1.84	3.385	
	7	18.5		2.34	5.475	
	11	12		4.16	17.305	
			16.16			2.10
Normal Brown Beauty E.	4	56		2.34	5.4756	
	8	46		7.66	58.6756	
	12	59		5.34	28.5136	
			53.66			6.97
Ragged giant hill F.	4	6		1.833	3.3598	
	8	9		1.167	1.3618	
	12	8.5		.667	.4448	
			7.833			1.01
Normal Brown Beauty G.	2	41.5		10.5	110.25	
	6	56		4.0	16.00	
	10	58.5		6.5	42.25	
			52.00			6.76
Pearl type H.	2	36		11.66	135.95	
	6	58		10.34	106.91	
	10	49		1.34	1.79	
			47.66			6.19

Mean all plats	35.70 pounds
Standard error of the whole experiment	8.03 pounds
Standard error of the whole experiment in percentage	22.49
Standard error of three plats in percentage	13.00

A — B = + 32.833 ± 5.86 (significant)
C — D = + 37.34 ± 7.26 (significant)
E — F = + 45.87 ± 7.04 (significant)
G — H = + 4.34 ± 9.16 (not significant)

CYTOLOGICAL STUDIES

Camera lucida drawings made from the root-tips of normal Perfect Peachblow, normal Brown Beauty, pearl type, ragged giant hill, wilding of Brown Beauty, and wilding of Perfect Peachblow are shown in figure 19. Chromosome counts from these drawings give the somatic number as 48. Since this somatic number is consistent in the abnormal types as well as in the normals, the abnormalities studied evidently cannot be due to any variation in chromosome number.

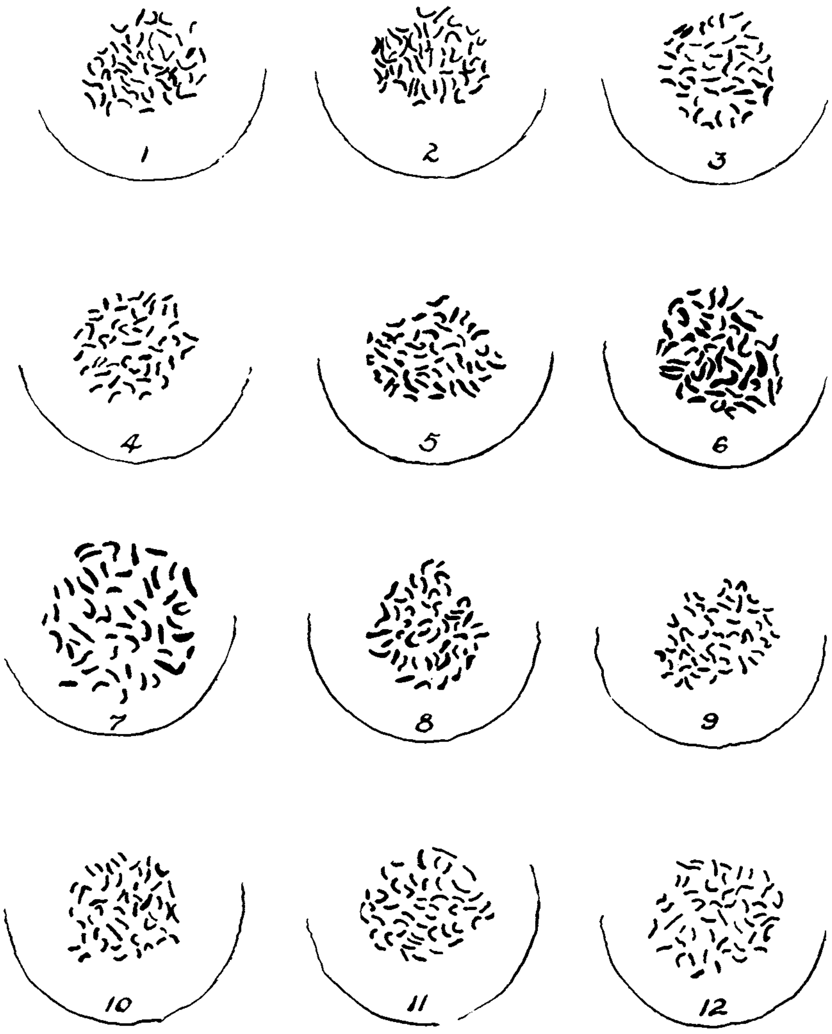

Figure 19.—Camera lucida drawings of chromosome numbers in roots from 1 and 2, Perfect Peachblow; 3 and 4, Brown Beauty; 5 and 6, wilding of Perfect Peachblow; 7 and 8, wilding of Brown Beauty; 9 and 10, ragged giant hill; and 11 and 12, pearl type.

MUTATION STUDIES

The results of the tests to determine if the abnormalities are periclinal chimaeras are given in table XIV. Not all the treated halves produced sprouts; consequently, only a small population resulted. The plants from the treated and untreated halves were alike in each case (fig. 20). Since the tubers were allowed to

Figure 20.—Plants from mutation experiment: 1 and 2, wildings of Brown Beauty—1, plant from untreated half, and, 2, plant from treated half of same tuber; 3 and 4, pearl type plants—3, plant from untreated half and, 4, plant from treated half of same tuber; 5 and 6, ragged giant hill plants—5, plant from untreated half and, 6, plant from treated half of same tuber.

Table XIV.—THE RESULTS OF THE STUDIES TO DETERMINE IF THE ABNORMAL TYPES ARE PERICLINAL CHIMAERAS.

Material used	Treated or untreated	Number of plants	Type of plants
Pearl type	Treated	7	Pearl type
	Untreated	8	Pearl type
Ragged giant hill	Treated	9	Ragged giant hill
	Untreated	10	Ragged giant hill
Wilding of Brown Beauty	Treated	6	Wilding
	Untreated	7	Wilding
Wilding of Perfect Peachblow	Treated	5	Wilding
	Untreated	8	Wilding

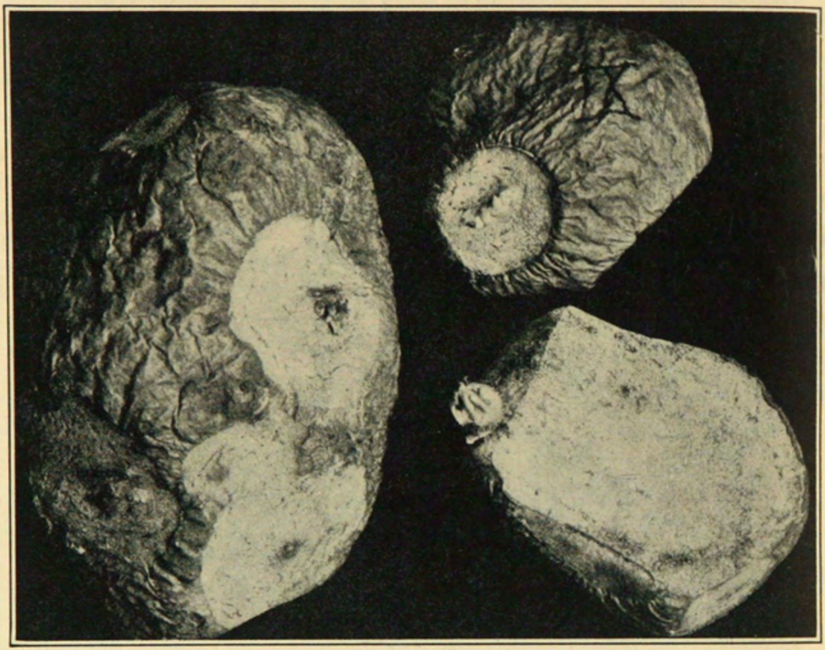

Figure 21.—Buds developing from the treated halves of tubers in the mutation experiments.

sprout before planting, it was a certainty that the buds on the treated halves developed from the layers underneath (fig. 21). If periclinal chimaeras were the cause, different plants would have resulted from treated and untreated halves. Since this did not happen, the abnormalities cannot be due to mutations of this nature.

CHEMICAL STUDIES*

Average weights per tuber for wilding of Brown Beauty, wilding of Perfect Peachblow, and ragged giant hill were found to be less than for Brown Beauty and Perfect Peachblow. The weight per tuber for pearl type, while greater than for the other abnormal types, was still considerably less than the average for normal Brown Beauty tubers (table XV). Variations in moisture and dry matter were slight in all cases.

Chemical analyses showed only a slight variation in amount of protein between the normal Peachblows and Brown Beauties, while the percentage of protein in wilding of Brown Beauty,

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*The chemical tests were made at the chemical division of the Colorado State College Experiment Station by J. W. Tobiska and associates.

ragged giant hill, and pearl type was greater than in the normal tubers. In contrast to these types, wilding of Perfect Peachblow contained less protein than did the normal tubers (table XV).

The starch content varied with ragged giant hill and pearl type and was somewhat higher than in the normal Brown Beauty. The corresponding wilding form was slightly lower. The difference between the normal Peachblow and its wilding form was very small, being but slightly more than 0.05 percent (table XV).

The specific gravity of the tuber juices showed only small variations. Their pH values were the same except for Perfect Peachblow. Here the pH was 0.2 higher.

Table XV.—CHEMICAL ANALYSES OF THE TUBERS FROM ABNORMAL PLANTS AND NORMAL PLANTS.

	Weight per tuber in grams	Percentage of moisture	Percentage dry matter	Percentage of protein	Percentage of starch	Specific gravity of juice	pH of juice
Normal Brown Beauty	149.5	77.94	22.06	2.05	14.521	1.023	6.1
Normal Peachblow	149.9	75.19	24.81	2.08	16.724	1.026	6.3
Wilding Brown Beauty	60.7	77.84	22.16	2.29	14.012	1.026	6.1
Wilding Peachblow	66.7	74.45	25.55	2.01	16.668	1.024	6.1
Ragged giant hill	57.0	78.79	21.21	2.25	15.199	1.022	6.1
Pearl type	119.0	76.95	23.05	2.27	14.860	1.023	6.1

DISCUSSION

As mentioned previously, it seems possible that some of the abnormal types described in the British literature are the same as some of those included in this study. It is unfortunate that detailed comparative studies of these types could not be made. United States Department of Agriculture quarantine regulations prohibit the importation of potatoes from foreign countries; consequently, none of these British types could be secured.

This made it necessary to base all comparisons on description alone, which is an unsatisfactory method. However, careful study of the descriptions of wilding given by Salaman (28) and McIntosh (23) brings out the resemblances which indicate that their wilding and the abnormality we have termed wilding may be identical. Likewise from descriptions and illustrations, ragged giant hill and bolter are probably the same.

An unusual feature of potato production in Colorado, as with all other horticultural crops grown in the state, is that the production areas are all located at high altitudes. The elevations in San Luis Valley range from about 7,500 to 7,800 feet. This is considerably higher than in most other important potato regions. There is a possibility that in these high altitudes conditions exist which induce the appearance of abnormal types in at least two of the varieties studied. These two varieties, Perfect Peachblow and Brown Beauty, are of greatest commercial importance in the San Luis Valley of Colorado. Since X-rays have been shown to induce mutations in other crops (Stadler) (35), there is a possibility that the appearance of many of these abnormalities may be due to the effects of ultra-violet light.

SUMMARY

The results presented in this paper are based on 2 years' study of some abnormalities that are occurring in potato varieties in Colorado. These abnormalities are confined primarily to the San Luis Valley. Fields in this section have been observed which contain as high as 100 percent abnormal plants. They occur principally in the Brown Beauty and Perfect Peachblow varieties. The terms wilding, ragged giant hill, pearl type, and pinto have been tentatively applied to them. The wilding form is found in both the above varieties, while pearl type and ragged giant hill occur only in Brown Beauties. Pintos are found in Perfect Peachblows. Descriptions for each of these abnormalities are given in detail.

A review of literature has been included for the purpose of comparing these abnormal types with other similar conditions previously reported in potatoes. These include virus diseases, mutations, and degenerate conditions of unknown origin. The methods of studying these conditions were also included.

Transmission experiments were performed to determine if any of these abnormalities were of virus origin. Core-grafts, leaf mutilations, and insect vectors were used in this phase of the work. These studies were confined to the greenhouse, with the exception of the testing of the tubers from inoculated plants for an unusually long incubation period. Here the tubers were planted in the field, and the resulting plants checked for the appearance of symptoms.

Yield studies were made in the field to determine:

1. The mean difference in the number of tubers produced per plant between each abnormality and the variety in which it occurs.
2. The mean difference in yield per plant between each abnormality and the variety in which it occurs.
3. The mean difference per plot in the weight of "markets" between each abnormality and the variety in which it occurs.

Student's method of paired plots was used in making the first two determinations, while the deviation from the mean was used for the third.

The abnormal and normal types were studied cytologically to determine the somatic number of chromosomes in each. Rottip smears were made, using a modified aceto-carmine method. Camera lucida drawings showed the number of chromosomes.

Mutation tests were performed on each of the abnormalities to determine if they were periclinal chimaeras. In making these tests all the eyes were excised from halves of a number of tubers of each abnormality. The treated halves were grown and compared with the untreated halves. If the abnormalities were due to mutations of this nature, a different plant would develop from the treated than from the untreated half.

Chemical tests of the tubers were included to show variations from the normal in protein, starch, average weight, dry matter, moisture, specific gravity of juice, and pH of juice.

CONCLUSIONS

The following conclusions are based on 2 years' study of some abnormalities occurring in certain potato varieties in Colorado:

1. These abnormalities are more prominent in the San Luis Valley than elsewhere.
2. They occur mostly in the Brown Beauty and Perfect Peachblow varieties.
3. All are transmitted through the tubers.
4. They are probably not of virus origin.
5. Pearl type is possibly a varietal mixture.
6. No definite conclusions can be drawn for the pinto, except that it is probably not of virus origin.
7. None of the abnormalities appear to be due to mutations

caused by variations in chromosome numbers, although it is possible that wildings, pearl type, and ragged giant hill are due to chromosome aberrations.

8. Asseyeva's periclinal chimaera test failed to give positive tests for wildings, ragged giant hill, and pearl type.
9. Pearl type, wilding, and ragged giant hill plants produce more tubers per plant than the normals for the varieties in which they occur.
10. Normal Brown Beauty outyields wilding and ragged giant hill of Brown Beauty but not pearl type. Normal Perfect Peachblow plants outyield wildings of Perfect Peachblow.
11. Normal Brown Beauty and Perfect Peachblow produce more "markets" than the abnormalities which occur in these varieties, with the exception of pearl type.
12. All the abnormal type are detrimental and should be removed from fields containing them by roguing.

BIBLIOGRAPHY

(1) ANDERSON, T.
1925. Bolters and wildings. Board of Agr. for Scotland, misc. pub. no. 5, p. 43.

(2) ASSEYEVA, T.
1927. Bud mutations in the potato and their chimaerical nature. Jour. Gen., vol. 19, no. 1.

(3) BARRUS, M. F. and C. CHUPP
1926. Potato diseases and their control. Cornell ext. bul. no. 135.

(4) BERGH, O. I.
1922. Missing hills in potatoes. Minn. Agr. Exp. Sta. rpt., pp. 136-139.

(5) CLARK, C. F.
1931. The origin by mutation of some American potato varieties. Proc. Potato Assoc. Amer., pp. 117-124.

(6) COLLISON, L. G.
1919. Missing hills in potato fields; their effect upon yield. N. Y. (Geneva) Agr. Exp. Sta. bul. no. 759. (Original bul. by F. C. Stewart.)

(7) COONS, G. H. and J. E. KOTILA
1923. Michigan potato diseases. Mich. Agr. Exp. Sta. bul. no. 125.

(8) DANA, B. F.
1926. Mosiac and related diseases of potatoes and other crops. Wash. Agr. Exp. Sta. bul. no. 208, pp. 33-34.

(9) ELMER, O. H.
1925. Transmissibility and pathological effects of the mosaic disease. Iowa Agr. Exp. Sta. res. bul. no. 82.

(10) FERNOW, K. H.
1925. Interspecific transmission of mosaic diseases of plants. Cornell Univ. Agr. Exp. Sta. mem. no. 96.

(11) FOLSOM, D.
1923. Mutations of the potato, Jour. Her., vol. 14, no. 1.

(12) FRUWIRTH, C.
1930. Uber durch spontane variabilitat entstandene Kartoffelform und uber spontane variabilitat der Kartoffel uberhaubt. Zutsche. Pflanzenzurcht. 15 (2) : 75-85. 1930. Original not seen. Abstracted by F. A. Krantz and R. M. Bailey in rpt. Potato Assoc. Amer., p. 125. 1930.

(13) GILBERT, A. H.
1925. Giant hill potatoes—a dangerous source of seed. A new phase of spindle tuber. Vt. Agr. Exp. Sta. bul. no. 245.

(14) GOSS, R. W.
1930. The symptoms of spindle tuber and unmottled curly dwarf of the potato. Univ. of Nebr. Agr. Exp. Sta. res. bul. no. 47.

(15) ——————————
1931. Infection experiments with spindle tuber and unmottled curly dwarf of the potato. Univ. of Nebr. Agr. Exp. Sta. res. bul. no. 53.

(16) JOHNSON, J.
1929. The classification of certain virus diseases of the potato. Wis. Agr. Exp. Sta. res. bul. no. 87.

(17) KIRK, L. E.
1929. Field plot technique with potatoes. Sci. Agr. vol. 9, pp. 719-729.

(18) KOTILA, J. E.
1927. Transmission studies of virus diseases of potatoes in Michigan. Proc. Potato Assoc. of Amer., p. 101.

(19) ——————————
1929. Some bud mutations of the potato. Amer. Potato Jour., vol. 6, no. 5, pp. 131-135.

(20) KRANTZ, F. A.
1922. A preliminary study of fiield plot technic in potato yield tests. Proc. Potato Assoc. of Amer., pp. 42-44.

(21) LIVERMORE, J. R.
1932. Plot technic for field experiments with the potato. Proc. Potato Assoc. of Amer., pp. 7-19.

(22) LONGLEY, A. E. and C. F. CLARK
1930. Chromosome behavior and pollen production in the potato. Jour. Agr. Res., vol. 41, pp. 867-888.

(23) MCINTOSH, T. P.
1927. The potato, p. 127. Oliver and Boyd Publishing Co., London, Eng.

(24) ——————————
1934. Information through personal letter.

(25) MCKAY, M. B.; T. P. DYKSTRA; H. E. MORRIS; P. A. YOUNG; B. L. RICHARDS; and H. L. BLOOD
1933. Virus and virus-like diseases of the potato in the Northwest and their control, U. S. D. A. circ. no. 271.

(26) MURPHY, P. A. and R. A. MCKAY
1932. A comparison of European and American virus diseases of the potato. Sci. Proc. of Roy Dub. Soc. vol. 20, pp. 347-358.

(27) RYBIN, V. A.
1929. Karyoligical investigations on some wild growing and indigenous cultivated potatoes of America. Bul. Appl. Bot., Genetics and Plant Breeding, 20: pp. 655-720. 1929. Original not seen. Abstracted in Amer. Potato Jour., vol. 7, no. 6, p. 180, 1930.

(28) SALAMAN, R. N.
1927. Potato varieties, p. 127, Macmillan Publishing Co., New York, N. Y.

(29) ——————————
1930. Somatic mutations in the potato. Rep. Roy. Hort. Soc. meeting.

(30) SAX, K.
1934. Cytological technique. Lab. Man. of Bot. 5 at Bio. Institute of Harvard Univ.

(31) SCHULTZ, E. S.
1919. Investigations on the mosaic disease of the Irish potato. Jour Agr. Res., vol. 17, pp. 247-273.

(32) ———————— and D. FOLSOM
1923. Transmission, variation and control of certain degeneration diseases of Irish potatoes, Jour. Agr. Res., vol. 25, pp. 43-118.

(33) SMITH, H. B.
1927. Chromosome counts in the varieties of Solanum tuberosum and allied wild species. Gen. vol. 12, no. 1, pp. 84-92.

(34) SMITH, K. M.
1929. Studies on potato virus diseases. Insect transmission of potato leafroll. Ann. App. Bio., vol. 16, no. 2.

(35) STADLER, L. J.
1931. The experimental modification of heredity in crop plants. Scientific Agr., vol. XI, no. 9, p. 557, and vol. XII, no. 10, p. 645.

(36) STOW, I.
1927. A cytological study on pollen sterility in Solanum tuberosum. Jap. Jour. Bot., Vol. 3, pp. 217-238. Original not seen. Abstracted by F. A. Krantz in Proc. Potato Assoc. of Amer., p. 210. 1927.

(37) TILFORD, P. E.
1929. Ohio Potato Diseases. Ohio Agr. Exp. Sta. bul. no. 432.

(38) VILMORIN, R. De. and MARC SIMONET
1927. Variations die nombre des chromosomes chez quelques Solanes. Compus Rendus. No. 184, pp. 164-166. 1927. Original not seen. Abstracted by F. A. Krantz in Proc. Potato Assoc. of Amer., p. 210. 1927.

(39) WERNER, H. O.
1926. The spindle tuber disease as a factor in seed potato production. Univ. of Nebr. Agr. Exp. Sta. res. bul. no. 32.

(40) ———————— and T. A. KIESSELBACH
1929. The effect of vacant hills and plot competition upon the yield of potatoes in field experiments. Proc. Potato Assoc. Amer., p. 109.

(41) WESTOVER, K. C.
1924. The influence of plot size and replication on experimental error in field trials with potatoes. West Va. Agr. Exp. Sta. bul. no. 189.

(42) YOUNG, P. A. and H. E. MORRIS
1928. Witches' broom of potatoes and tomatoes. Jour. Agr. Res. vol. 36, no. 10.

(43) ———————
1930. Research on potato virus diseases in Montana. Mont. Agr. Exp. Sta. bul. no. 231.