T H E S I S

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EDINBURGH UNIVERSITY

"PHYSIOLOGICAL AND MORPHOLOGICAL STUDIES
OF THE GENUS SOLANUM WITH SPECIAL REFERENCE TO
THE POTATO (Solanum tuberosum L.)
AND ITS PROBLEMS"

by

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TABLE OF CONTENTS

GENERAL INTRODUCTION

Under the Scheme for the Inspection of Growing Crops of Potatoes in Scotland, crops are examined and certified on the basis of (a) varietal purity and trueness-to-type, and (b) health, especially with regard to virus diseases. The former category includes two sub-classes. These are (i) known varieties other than the one the crop purports to belong, and (ii) natural variations of any undesirable type. The importance of differentiating plants in these two sub-classes lies in the fact that the percentage tolerance for plants in sub-class (i) differs from that of plants in sub-class (ii). It is important, therefore, that potato growers and crop inspectors should be familiar with, and able to identify at sight, the common potato varieties together with their variations. In scientific work also this is important as mistakes have been made and erroneous conclusions drawn because of inaccurate identification. As a contribution to knowledge and to facilitate recognition, the aberrant types found in potato varieties are described and notes on their nature, distribution and importance are made in Part I of this thesis.

It is generally recognised that the major cause of degeneration in potato stocks is the development in them of virus diseases. The difficulties arising during the

production /

production and maintenance of healthy stocks, therefore, become mainly problems of virus control. The general problem of control may be viewed from various aspects, but the chief methods of approach are:-

(a) the breeding of immune or field-immune varieties,

(b) the propagation of virus-tested stocks,

(c) the propagation of selected visibly-healthy plants,

(d) the removal of visibly diseased plants from commercial crops.

Breeding and virus-testing require considerable skill and specialised knowledge and fall to be dealt with by the plant breeder and the virus expert in co-operation. Plant selection and the removal of diseased plants are methods which can be and are adopted by the practical grower. Mild virus infections, however, are frequently difficult to diagnose because symptoms of the disease may be extremely slight. Furthermore, the symptoms induced by the virus tend to vary during the life of the plants. A knowledge of the factors causing these differences in appearance and of the optimum conditions for diagnosing virus infections in the field, must be a valuable asset to the grower who is concerned with maintaining the health of his stocks by roguing and plant selection. Climatic conditions, times of planting, stage of plant development, age of the plants and daylight intensity may influence the manifestation of disease symptoms, and in Part II these different aspects receive attention.

PART I

OBSERVATIONS ON SOME FOLIAGE VARIATIONS OF THE POTATO IN SCOTLAND

CONTENTS

INTRODUCTION

In the historical literature dealing with the potato and its introduction into Britain in the sixteenth century, the opinions expressed by the various writers are not always in agreement but it is clearly suggested that the majority of present day British varieties have been developed from a few types originally introduced. Although the existing varieties are now more numerous than would appear to be necessary to satisfy commercial needs, new improved introductions continue to make their appearance. That potatoes are grown for a variety of purposes and under a wide range of climatic and soil conditions, probably accounts for the existence of so many varieties, each of which have attributes suitable for a special range of conditions. In view of the varied purposes for which the different varieties are grown, the varietal purity of stocks is a matter of some importance but if the special characteristics of a variety are to be maintained, conformity to type must also be considered. Varieties are not absolutely stable and variations occur from time to time. It is true that some possess certain advantages over the normal type and are regarded, therefore, with favour by commercial growers, but the vast majority do not possess the desired characteristics of the normal plant and are considered as degenerate forms. In recent years, the improvement of potato crops through increasing

control /

control of diseases, particularly virus diseases, has absorbed the attention of most scientific workers and the purity and conformity-to-type aspects have been regarded as less deserving of attention but a high standard of purity in seed stocks is demanded by legislation and in the various certification schemes, certain standards for purity and trueness-to-type are laid down by the certifying authorities. Although the permitted tolerances are subject to slight amendment from year to year in the light of increased knowledge or commercial considerations, the importance attached to varietal impurities and variations is made clear by reference to the current certification requirements of the Department of Agriculture for Scotland. In the various grades of certified seed stocks, these are as follows:-

(1) Stock Seed

(a) Not more than .05% of rogues including undesirable variations and bolters.

(b) Not more than .1% semi-bolters.

(c) Not more than 4 plants per acre leaf-roll, severe mosaic and wildings and not more than .25% mild mosaic.

(d) Not more than 5% plants affected with Blackleg.

(e) Complete freedom from infestation with potato root eelworm.

(2) Grade A. (Scot.)

(a) Not more than .5% rogues.

(b) /

(b) Not more than 1% undesirable variations or 1% bolters.

(c) Not more than 2% mild mosaic.

(d) Not more than .5% leaf-roll, severe mosaic and wildings.

(e) Not more than 10% Blackleg.

(f) Complete freedom from visible infestation with potato root eelworm.

(3) Grade H. (Scot.)

(a) Not more than .5% rogues.

(b) Not more than 5% undesirable variations or 5% bolters.

(c) Not more than 2% leaf-roll, severe mosaic and wildings.

(d) Not more than 10% Blackleg.

(e) Complete freedom from visible infestation with potato root eelworm.

(4) Grade B

Not more than 3% but over .5% rogues, otherwise as for grade H. While the figures quoted are those of the Scottish Department of Agriculture, they are very similar to the requirements demanded by the English and Irish Departments.

The importance of differentiating in a crop, plants of other varieties from those which have deviated from the varietal type, lies in the fact that the two categories

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of plants are not regarded with equal importance hence the permitted tolerances of each, in stocks intended for certification, differ. It is important, therefore, in maintaining crops pure and true-to-type, to be able to recognise, at sight, the various commercial varieties together with their abnormal forms. To assist in this assessment, descriptive notes of potato varieties in their normal state have already been published (Salaman 1926; McIntosh 1927; Davidson 1938; Department of Agriculture for Scotland 1944; Whitehead, McIntosh and Findlay 1945). The present work has been prompted by the need to supplement these descriptions with accurate definitions of the more commonly occurring variations which have been encountered in the field. Departures from the normal type may be observed in the tubers, the foliage or both, but since the purity and trueness-to-type of potato stocks are assessed by visual inspection of the plant foliages, only the foliage-aberrant forms of the commercial varieties will be discussed here.

While the official view is that deviations from the varietal character are important, no great body of evidence exists as to the actual effect these have on such practical matters as the yield of a crop, its date of maturity and the size of the tubers produced by it. Here it is proposed to report a preliminary investigation concerned with such effects following on the appearance of

the more important variations.

Review of Literature

The Aberrant Types

The most important aberrancies are, undoubtedly, bolter and wilding types as they occur frequently and are of commercial significance. The other variations, later described, have received little attention. This is probably due to the fact that they are not of such common occurrence as bolters and wildings and hence, from the practical viewpoint, are correspondingly less important.

Bolters and Semi-bolters - The existence of bolters in Scotland has been known since the inception of the potato crop certification scheme of the Board (now Department) of Agriculture for Scotland in 1918 and they were first mentioned in an official publication of that Department (1921). A more complete description was given by Anderson (1925). The official description of bolters, published by the Department of Agriculture for Scotland (1944) is given as follows:-

> "A bolter plant is much taller than a normal plant "and there is greater distance between the branches "of the stems; the haulm is more open, wilder and "more vigorous; it generally bears flowers more "freely and has an increased capacity for producing "berries; it is much later in maturing; it "produces somewhat coarser tubers if allowed to "mature."

Semi-bolters are regarded as intermediate between the normal and extreme bolter type and were first

included /

included in inspection scheme standards in 1946.

Late maturity and the inability to produce an early crop of sizable tubers are notable features of bolters and semi-bolters. These features are particularly undesirable in crops of early varieties of potatoes and they have been the subject of numerous complaints from growers of crops intended for the early ware market. Such complaints have led to the increasing amount of attention which has been paid to bolters in recent years. In other countries also, different types in potato varieties have been observed, but it is doubtful if they have been considered as disadvantageous aberrants since, in several countries, they have been the subject of selection and propagation. Edmundson (1927) observed differences in plants of the same variety and stated that if there was no variation in the seed, it would not be possible to improve stocks by selection other than by the elimination of disease. His statement that stocks have been improved by selecting for vigour, earliness and lateness would appear to indicate that he was dealing with normal and bolter types as lateness of maturity and increased vigour are characteristics of the latter. In New Zealand, Hadfield (1929) and Leitch (1947) have described the propagation of such types selected from the early maturing variety Sutton's Supreme. Two of these selections regardless of their irregular tuber shape have

become /

become widely popular because of their increased cropping power. In Hungary, three types of the variety Early Rose, showing maturity differences, have been looked upon as standard commercial varieties over a long period of years (Cockerham - privately communicated). In this country, a bolter type of Great Scot was grown commercially in 1923 under the name Spion Kop, but although the selection of late maturing forms has been advocated from time to time since then, the practice has not been adopted on a commercial scale as many maincrop varieties of high yielding capacity are already available.

While extreme bolter types are easily identified, semi-bolters are difficult to recognise as their foliage characteristics closely resemble those of the normal plants. The absence of any clear and concise differences between the two latter types has led observers to the belief that, between the normal and the extreme bolter, a range of bolter types exists. Carson and Howard (1944) in breeding experiments with bolters, classified the progeny according to the "wildness" of the root systems and observed a range of types, in this respect, between the normal and bolter. The term "wild" in this instance has no connection with the plant type known as a wilding, but is merely an expression used to indicate the abnormal development of adventitious roots and rhizomes. During an examination of the giant hill condition in American

potato /

potato varieties (giant hill being the American equivalent of bolter) Yarwood (1946) noted that, in the 16 families which he studied, there were clear and consistent differences between them as regards time of maturity, tuber shape and disease resistance.

Perhaps the most obvious difference between plants of normal and bolter types is one of foliage height, the latter having a taller habit of growth. This being so, any treatment of the crop which tends to encourage foliage development serves to increase the difficulty of differentiating normals from bolters and particularly from semi-bolters. Findlay (1946) recorded various cultural treatments which affected the plant foliages in this regard and also had the effect of extending the growing season. Changes in foliage characteristics have been noted by the writer as a result of varying tuber spacings and manurial applications but the effects are temporary and the changes are not reproduced in the progeny.

The increased vigour and foliage development of extreme bolter forms is invariably accompanied by a reduction in tuber production, a feature which has obvious disadvantages for both the ware grower and the grower of seed stocks. This characteristic of bolters has not yet been fully investigated, but a correlation between maturity and "tuberization" was noted by Miller,

McGoldrich /

McGoldrich and Le Clerg (1940) while studying the progenies from potato crosses and selfings. They observed a decrease in tuber production between early and late maturing varieties and formed the opinion that tuber production was adversely affected by increases in plant height and length of rhizomes. This correlation is very apparent when the normal and bolter types within a particular variety are compared.

Most plants which do not conform to the varietal description are noticeable through a morphological change of the normal foliage, but physiological changes have also been observed. East (1910) agreed that differences in the power to resist disease may occur as a result of assexual reproduction but he was of the opinion that disease resistance was unlikely to be obtained by this method. A mutation from the variety "Early Rose" was claimed by Ryx (1918) to exhibit increased resistance to potato blight. The increased resistance of bolters to fungal diseases has been recorded more recently by Yarwood (1946, 1947) who observed that giant hill plants possessed a greater measure of disease resistance than normals. He noted, for example, that normal plants of the Netted Gem variety were killed off at 70-100 days by infection with the blight fungus (Phytophthora infestans). Under similar conditions giant hill plants lived up to 136 days and were less severely affected. Such

observations, /

observations, however, do not necessarily indicate increased resistance to blight. The present writer ventures to suggest that the tall, open habit of giant hill plants may be instrumental in creating an environment within the crop which is unfavourable to the development of the fungus.

Wildings and Feathery Wildings - Wildings have been observed in crops since 1920 and were first described by Anderson (1925). The present official description is as follows, (Department of Agriculture for Scotland 1944):-

> "A wilding plant has a more bushy habit owing to the "production of a large number of thin branches. "In association with this branching habit, there is a "tendency to produce a large number of underground "stolons, associated with a multiplicity of under-"sized tubers. The leaf carries very rudimentary "secondary leaflets; the primary leaflets are "reduced in number and have a rounder contour than "is normal for the variety. Generally, wildings do "not produce floral parts; if these occur, they "are very rudimentary."

In the same publication, feathery wildings are stated to be "similar in habit to the normal plant but stemmy and "more highly coloured and their leaflets are smaller, "narrower and more pointed". Although the two types are grouped together for purposes of crop certification, they bear no close resemblance in foliage characteristics. The production of numerous small tubers, however, is a feature common to both.

Wildings, as distinct from feathery wildings, are frequently divided into two categories, viz., (a) wildings

and /

and (b) wild wildings. The plants in these two categories differ from one another only in degree of "wildness" based on the number and size of the stems and the extent of reduction in the number of leaflets produced, but, as with the bolter types, a range of "wild" types may exist. Such is the opinion of the writer as a result of many years' experience of crop inspection work. McIntosh (in a private communication) records an instance of four wilding types, each differing from the others, being selected from a crop of the variety Golden Wonder.

Wildings have received comparatively little attention in the literature and, in some countries, have not been recognised, although, judging by the frequency with which they occur in British varieties, even in those of recent introduction, it is difficult to believe that they do not exist. Where these variations have been discussed, a considerable amount of confusion seems to have arisen and the synonymity of the types discussed by various workers remains in doubt.

Other Aberrant Types - In this country, only a limited amount of study, and that of a very general nature, has been devoted to the other variations later described. Foreign literature on the subject, excluding the work of Asseyeva (1931), does not exist.

Nature and Cause of Variations

Opinions as to the nature and cause of aberrancies

differ, /

differ, but throughout the literature three main reasons for their appearance are suggested.

Some workers are inclined to the view that chromosomal changes, quantitative or qualitative, are mainly concerned. Carson and Howard (1944) suggested that the bolter condition might be due to the loss or gain of a whole chromosome. Root-tip counts in the varieties Gladstone and Ulster Chieftain, however, showed that the chromosome number of bolter plants was the same as that of normal plants. Although differences of whole chromosomes are not apparently the cause of bolting, Thomas (1945), found that a small fragment of chromosome was present in the nucleus in bolters but not in normal or wilding types. He assumed that bolters arose as a result of the inclusion of this fragment. Chromosomal differences are also indicated, as the cause of bolting, in the studies on photoperiodism of Rasumov (1931) and Hawkes (1947). Rasumov in his study of South American tuber-bearing wild species of Solanum stated that in all cases, the highest vegetative development is attained under long day conditions and that short days afford the best conditions for the formation and development of tubers. He instances the reduced production of South American wild plants growing under Russian conditions compared with their performance under South American conditions where the daylight rarely exceeds 12 to 13 hours. Hawkes cultivated bolter plants under

both /

both long and short day conditions and noted that these types became significantly taller when grown under long day conditions. He indicated that the differences between normal and bolter plants could be completely removed if both were cultivated under short day conditions. The bolter plants then lost most of their characteristic features. From this, it has been suggested that bolters arise as a result of the mutation of one or more genes controlling the response of the plant to length of day and Hawkes takes the view that the bolter is a reversion to the type of plant found growing naturally under the short day conditions of South America.

Another theory tending to explain the appearance of variations is based on the chimerical nature of many potato plants. When chromosomal changes occur in the nuclei of vegetative cells, the plant tissue may be wholly or partially affected. In the latter case, when the mutated tissue surrounds the unmutated tissue, the variation is referred to as a periclinal chimera. Assuming a chimerical make-up, any technique which allows the inner component to develop can be used to separate it from the outer suppressive tissue. Asseyeva (1927, 1930, 1931) adopted a method of excising the eyes of tubers in order to stimulate growth in the deeper tissues, which form the inner component of the chimera, and obtain a plant free from the outer component. By this method,

many /

many variations in the potato were found to be periclinal chimeras. The chimerical nature of such potato varieties as Sefton Wonder and Field Marshal has been discussed by Salaman (1943) who postulates that the change from smooth to russetted skin on the tubers has probably occurred as a result of accidental damage to the "eyes" of seed tubers in the field.

Some divergent forms were considered by a few workers to have resulted from a virus factor. Murphy and McKay (1932) identified wildings with the diseased condition first described in America under the name "Witch's Broom". They stated that the two terms were synonymous and suggested that the use of the term "wilding" should be discontinued. The synonymity of the two conditions, however, has not been proved and doubts still exist regarding the identity of the condition studied by these writers. Some of the material of Scottish origin which Murphy and McKay used in their work was discovered later to be infected with the virus of witch's broom. McIntosh (1932) disputed the pathological theory of the origin of wildings. A virus factor was suggested as the cause of the bolter condition by Hill (1934) and Hansen (1938) but factual evidence has not been produced. Graft tests carried out by McIntosh (1932) and more recently by the present writer failed to transmit the condition to normal plants. Rozendaal (1947)

recorded /

recorded a "stem-mottle disease" of potatoes in Holland which was transmissible to healthy plants by grafting. From the descriptions and illustrations given, the disease symptoms show a close resemblance to the characteristics of the aberrant type described and illustrated later as "mop-top".

For the purposes of potato crop certification in Scotland, all the abnormal forms to be described here are regarded as genetical variations from the normal type and none, so far, have been shown to be caused by disease. As regards the "mop-top" abnormality, however, the possibility of the condition being pathological or physiological must not be excluded.

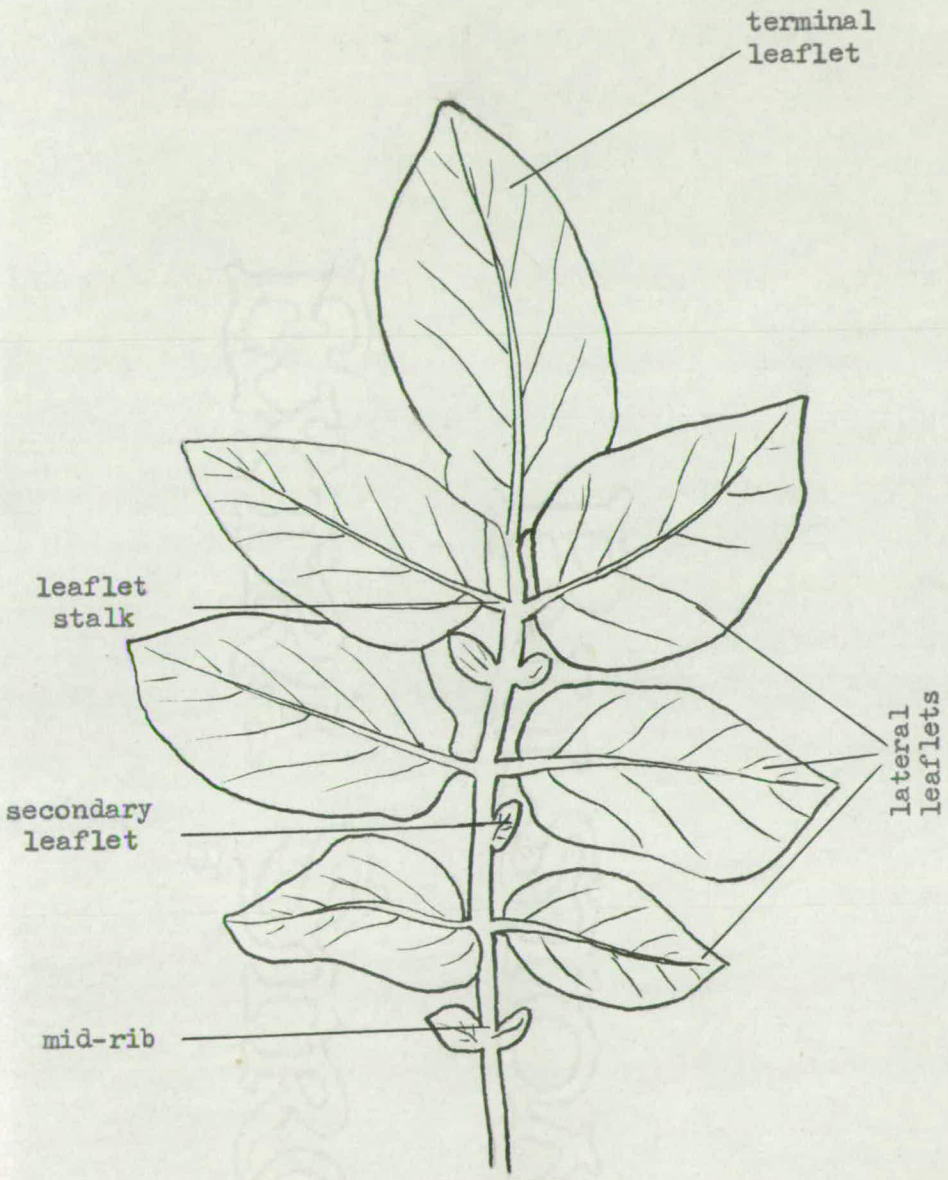

FIG. 1 - POTATO LEAF

EXPERIMENTAL METHODS AND RESULTS

The main objective of this work was the provision of accurate descriptions of the variations found in potato varieties at the present time and the supplementing of these descriptions with photographic illustrations. The compilation of information regarding their nature and cropping power was a useful auxiliary of descriptions but these aspects will be presented separately.

Throughout the whole of the investigation, extensive use was made of the collection of potato varieties maintained at the Plant Registration Station of the Department of Agriculture for Scotland. This collection, probably the largest of its kind in existence, has been built up from plants selected from field crops in Scotland during the past two decades.

A. Descriptions of the Variations

In making descriptive notes, account was taken only of those morphological features which are of value diagnostically. Where no reference is made to characteristics normally mentioned in descriptions of potato varieties, it may be assumed that the parts omitted have little or no value for identification purposes in the present context.

Throughout this section, comparisons are made between

the /

the aberrant form and the normal plant. The term "normal" should be construed as "that type of plant which is generally recognised as being typical of the variety".

Material and Methods

Before attempting to describe the variations, it was first necessary to ensure the uniformity and constancy of the stocks. To this end, a comprehensive collection of naturally occurring types was selected and propagated by the writer from 1944 onwards. The completed collection comprised 51 variants in 22 commercial potato varieties. Foliage descriptions were made and checked each year, during the growing season, from field plots of the variations and their normal controls. The leaf parts referred to in the descriptions are illustrated in figure 1. The bolter and wilding plots each contained 36 plants while the plots of the other variations described, each consisted of 24 plants.

Tuber and sprout descriptions were made during the winter in a store where the tubers could be sprouted under conditions which were not subject to excessive fluctuation. For this purpose, samples of 20 tubers of each variation together with control tubers from normal plants of the varieties were boxed, rose-end upwards, and covered with a single layer of thin paper to prevent strong light interfering with the normal sprout colours.

General Descriptions

Although /

General Descriptions

Although many types of foliage variations are found in present day potato varieties, the majority of them appear to fall into one or other of seven main groups, classified according to the leaf or leaflet types, viz:-

(a) Bolter types.

(b) Wilding types.

(c) Feathery wildings.

(d) Fused-leaflet types.

(e) Coarse-leaflet types.

(f) Sub-divided-leaf types.

(g) Chlorotic-leaflet and raised epidermis types.

(a) Bolter types - Bolters and semi-bolters are included in this category. Their leaflets do not differ markedly from those of the normal plant but they tend to be slightly smaller, broader and rougher, particularly towards the tops of the plants. Salaman (1926) gives the average increase of leaf index of bolters over the normal as 2.6.

(b) Wilding types - Wildings differ from normals in that they produce a greater number of stems and a reduced number of leaflets. The terminal leaflets are frequently large and expanded. The average increase of index over the normal is twice that found in bolters (Salaman 1926). Other abnormal features are (1) reduction in foliage height and (2) almost complete absence of flowers from flowering varieties.

(c) /

(c) Feathery wildings - These variants are more stemmy than normal but the main difference lies in the narrowness of the leaflets compared with those of normal plants.

(d) Fused-leaflet types - Within this category, the actual condition seen depends on the variety concerned, nevertheless, all are alike in that the foliages differ from the normal by having the individual leaflets wholly or partly fused. In some, only the terminal leaflet and one or both of the penultimate pair of leaflets are joined. A more complete degree of fusion appears in the docken-leaf variation where all leaflets are frequently fused into one large blade. In this type, the lateral leaflets which have joined to form the leaf blade are still partly visible, since the apices of the leaflets appear as serrations of the margin of the lamina. Almost complete fusion of the leaflets accompanied by malformation is characteristic of the spinach-leaf variation. In the ivy-leaf variation, there is again fusion and malformation of the leaflets accompanied by a flattening of the leaf mid-rib. In this type, the lamina is short and broad and the petiole unusually long. Flowering is reduced in all plants whose foliage types fall within this category.

(e) Coarse-leaflet types - The coarse-leaflet types take several forms, but fusion of the leaflets is rarely associated with them. They differ from the normal form in bearing leaflets which are stiffer, rougher, more

puckered, /

puckered, frequently more pubescent and often smaller in size. The apparent small size of the leaflets, however, is probably due to the puckering of the surfaces. In some types in this category, the leaflets assume an abnormal light green colour. This is particularly noticeable in the rasp-leaf variation.

(f) Sub-divided-leaf types - Aberrancies showing abnormally divided leaves are less common than those in the previous categories. The leaves are unusually large and expanded, each leaflet being carried on a long stalk, which bears two or three pairs of secondary leaflets, thus resembling in itself a small but normal multiple leaf. The sub-division of the leaves gives the plant a more compact, bushy appearance.

(g) Chlorotic-leaflet and raised-epidermis types - Chlorosis of the leaflets and a raised epidermis are abnormal characteristics not frequently observed. Chlorosis may be extensive, covering the whole of the leaflet surface or, as is more common, may be confined to the leaflet margin. A lead-green colour is typical of plants with raised leaflet epidermis.

Although most deviations from the normal type can be placed in one or other of the above categories, a few exceptions which cannot be classified thus, exist, but they are of very infrequent occurrence.

In the foregoing remarks, a suggested classification

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of the various foliage-abnormalities encountered in potato varieties is given. In the following pages, each is described in detail, under the variety name and photographically illustrated. The names of the various types described (excluding bolter and wilding types) have been given by the writer as they have proved useful in conveying to other observers a "picture" of the form taken.

Specific Descriptions

As the characteristics and diagnostic features of bolters, semi-bolters, wildings and feathery wildings differ, between varieties, only in slight detail, it is proposed to describe these variations without regard to variety.

Bolters

Foliage - Taller, upright, more open and much more robust than normal; stems strong, zig-zag, numerous, branched, and rigid, and in many varieties more intensely coloured than normal probably due to the open character of the foliage, lateral growth is common; leaves often shorter than normal, stiff with more colour than normal in the mid-ribs particularly at the bases of leaflet stalks; leaflets usually thick, small, dull and frequently more pubescent.

Floral characters - Flowers normal but much more profuse than in normal plants of the variety. The inflorescences are large and borne on long stalks. Varieties which normally are without flowers, frequently show profuse flowers in the bolter condition. Plums or berries are more frequently observed than in normal plants of the variety.

Root Systems - Roots are numerous, bulky, markedly matted and associated below ground with numerous long rhizomes.

Tubers - Larger than normal and frequently coarse with irregular shape, deep eyes and a tendency to second-growth. In varieties which normally produce oval or kidney-shaped tubers, the tubers of the bolter are frequently long and spindle-shaped. Tubers from bolter plants sprout much later than normal and the subsequent growth is slow. Apical dominance is not marked and sprouts emerge from all eyes on the tuber.

In /

In the field, bolter plants develop more slowly and require from 14 to 40 days longer than normal to reach maturity, the period varying with variety. Bolters are not obvious in crops during the early part of the season but begin to show clearly about 12 weeks after planting. They appear to be less susceptible to blight (P. infestans) than normal plants, but this may be due to their open-type foliage.

Semi-bolters

Foliage - Those plants are intermediate in height between the normal and the typical bolter. Stem and foliage characteristics closely resemble the normal; leaves more rigid, duller and coarser than normal but nearer to normal size than is found in the bolter; the top rosettes of the plants are stiff, and the topmost leaflets dull, folded and small, in which respect the top foliage resembles the bolter foliage.

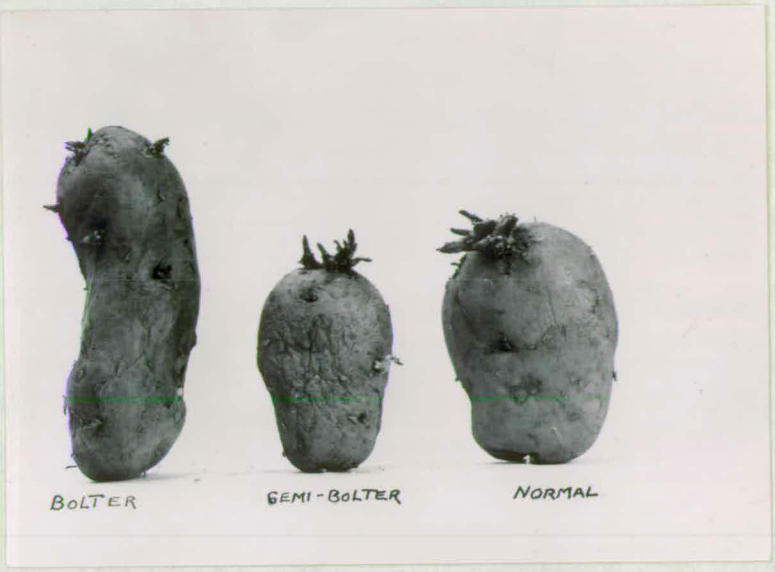
Floral characters - Flowers like the variety and similar to those of normal plants.

Root systems - Very similar to those of normal plants but the rhizomes appear to be longer. This feature, however, is not sufficiently constant to be of diagnostic importance.

Tubers - Similar to normal, sprouting is only slightly slower. As in the normal, apical sprouts are usually more robust and all eyes do not sprout as in the bolter.

Development in the field is somewhat slower than normal but this feature is not marked in all varieties. Semi-bolters, however, are not apparent in crops in the early season. In many respects the semi-bolter can be considered an intermediate state between the normal and bolter habits and matures 7-21 days after the normal plants.

Photographs on next page /



Wildings

Foliage - Differs from the foliage of a normal plant being less tall and very bushy; stems very numerous, thin, spindly; leaves reduced in size and somewhat simplified in that they bear a reduced number of leaflets - sometimes only a terminal leaflet and one pair of laterals; leaflets rounder than normal, the terminals being large and conspicuous; secondary leaflets small and round but often absent.

Floral characters - Flowers small, if present, but usually inflorescences are absent. Where inflorescences are seen they are usually rudimentary; most buds drop unopened.

Roots - Numerous and bushy with many rhizomes.

Feathery Wildings /

Feathery Wildings

Foliage - Often resembles the normal in height but is more open with less cover; stems thin and slightly more numerous than normal; leaves smaller but usually complete; leaflets normal in number but narrow, long and pointed, particularly at the tops of the stems giving the "feathery" appearance; secondary leaflets small, narrow and pointed.

Floral characters - Inflorescences frequent in flowering varieties.

Roots - Numerous, matted and associated with many long rhizomes.

Tubers - Longer and more pointed than normal particularly at the rose-end; eyes numerous and clustered round the apex of the tuber; apical dominance not marked; sprouting is earlier than normal.

ARRAN BANNER

Normal

Rough-leaf Variation /

Rough-leaf Variation

Foliage - More upright than normal with darker green foliage; leaves stiff; leaflets rough and corrugated, terminal leaflets frequently fused with one or both of the first pair of lateral leaflets.

The rate and time of sprouting and length of growing season are similar to those of the normal.

ARRAN CONSUL

Normal

Spinach-leaf Variation

Foliage - Glossy, upright and rigid; leaves dark green, rigid and directed upwards, mid-ribs occasionally flattened; leaflets invariably fused together to form simple, "ladle-shaped" blades at the base of the plant and ivy-shaped blades towards the top.

Floral Characters /

Floral Characters - Buds fairly frequent but drop readily; flowers infrequent.

Rate and time of sprouting and length of growing season similar to normal.

ARRAN PEAK

Normal

Variation - fused terminal leaflets

Foliage - Habit and cover similar to normal plant; leaves long and large; leaflets broad, terminal leaflets fused with one or two pairs of lateral leaflets.

Similar to normal plants regarding time and rate of sprouting and length of growing season.

Photographs on next page /

ARRAN PILOT

Normal

Rasp-leaf Variation

Foliage - Drooping, later becoming prostrate; stems numerous, spindly and mottled blue-purple; leaves short and curved downwards, mid-ribs short; leaflets large, reduced in number, light green and markedly puckered; secondary leaflets few.

Floral Characters - Flowers not observed, buds rudimentary and dropping readily. In this respect, the variation differs from the normal.

Photographs on next page /

"Mop-top" Variation

Foliage - One or more stems may be affected. Affected stems are reduced in height having shortened internodes giving the foliage a compact, rosette appearance; leaflets become thin with lack of uniform colour, light green areas may be observed; mid-ribs may be distorted giving peculiar twists to leaves and leaflets.

Floral Characters - On normal stems, normal flowers may be observed but they do not appear on affected stems where the apex is frequently distorted and the floral parts aborted.

The fact that both normal and abnormal stems may be, and frequently are, seen on the same plant indicates that normal and abnormal tubers are found at the roots, hence in planting out the produce of single roots, the resultant plants are not 100% true-to-type. This variation is also common in the varieties Dunbar Rover, Arran Chief and Craigs Defiance.

Rough-leaf Variation /

Rough-leaf Variation

Foliage - Habit similar to normal plant, but foliage is more rigid; leaves stiff; leaflets broad, markedly wrinkled, thick and fleshy, terminal leaflets broad and rounded.

Floral Characters - Flowers not observed, buds small on a shortened inflorescence stalk.

BRITISH QUEEN

Normal

Spinach-leaf Variation

Foliage - Low-growing, bushy, rigid; stems robust, bronze with green nodes; leaves stiff and directed upwards; leaflets dark-green, reduced in number and fused together in the shape of a ladle, but sometimes one or two pairs of small normal leaflets are apparent in addition, younger leaves ivy-shaped with leaf surfaces undulating.

Floral Characters /

Floral Characters - normal, flowers white, profuse.
Time of sprouting is later than normal. There is less apical dominance in the tuber and more basal eyes sprout. The rate of sprouting is slower than normal and slow growth persists during the growing season. The time of maturity is about the same as the normal.

DI VERNON

Normal

Docken-leaf Variation

Foliage - Low-growing, bushy, with numerous thin stems; leaves of normal length; leaflets dark-green and often fused together to give a docken-like lamina, but one or two pairs of small separate leaflets may be apparent. Leaves of all ages are affected

Floral Characters - Flowers not observed, buds rudimentary.

Photographs on next page /

DOON STAR

Normal

Spinach-leaf Variation

Foliage - Upright, rigid, glossy; leaves reduced in size, rigid and directed upwards; leaflets light-green, smaller and narrower than normal, terminal leaflets frequently fused with one or all pairs of lateral leaflets giving either simple spinach-type leaves or merely enlarged terminals according to degree of fusion.

Floral Characters - Flowers not observed, buds rudimentary.

Rate and time of sprouting similar to normal tubers.

Photographs on next page /

Ivy-leaf Variation

Foliage - Upright, rigid with poor cover; stems clearly visible; leaves dark green, mid-ribs distorted, flattened and reduced in length causing the leaves to "bunch" round the stems, leaf shape closely resembles that of an ivy leaf. Where fusion is complete, the leaf is simple, but sometimes one or two pairs of normal leaflets are present.

Floral characters - Flowers white, normal, infrequent, produced singly or in pairs; buds small and dropping readily.

Rate and time of sprouting slightly later than normal. Field growth of the plants is slightly slower than normal but length of growing season is similar.

DUKE OF YORK

Normal

Sub-divided-leaf Variation

Foliage - Low-growing, drooping as in normal plant; leaves medium to large, expansive; leaflets rounder and smaller than normal, leaflet stalks long, arising from a common point on the mid-rib, and each bearing two or three pairs of secondary leaflets; secondary leaflets round and cupped.

DUNBAR ARCHER

Normal /

DUNBAR ARCHER

Normal

Chlorotic-leaf Variation

Foliage - Upright, rigid, flat-topped, lacking cover and not as tall as the foliage of a normal plant; leaves short, rigid, and projected outwards and upwards; leaflets dark green, "blistered" and cupped upwards; margins of leaflets yellow, later becoming purple particularly on the upper half of the plant.

DUNBAR ROVER

Normal /

DUNBAR ROVER

Normal

"Mop-top" Variation

Foliage - One or more stems may be affected. Affected stems are reduced in height having shortened internodes thereby causing the foliage to be compact and to take on a "rosette" habit; the growing point is frequently distorted; leaflets thin with light green areas, margins sometimes wavy, leaflet stalks often twisted giving the leaf an inverted appearance.

As in other varieties which show this type of variation, the fact that some stems of the plant may be normal, indicates that a proportion of the tuber produce is likewise normal. The tubers of an affected plant, therefore, often produce normals and aberrants.

Spinach-leaf Variation /

Spinach-leaf Variation

Foliage - Upright, stiff, glossy; stems slightly bronzed with green nodes; leaves dark green, rigid and directed upwards; mid-ribs flattened; leaflets fused to form simple "ladle-shaped" blades at the bottom of the plant and ivy-shaped blades near the top.

Floral characters - Flowers not observed; buds drop readily.

DUNBAR STANDARD

Normal

Fused-terminal Variation

Foliage - Upright habit similar in most respects to the normal plant; leaves normal in size; leaflets normal, terminals fused with first pair of secondary leaflets giving the plant the appearance of having slightly less cover than normal.

Photographs on next page /

ECLIPSE

Normal

Rough-leaf Variation

Foliage - Low-growing, bushy; leaves smaller and mid-ribs shorter than in normal plants; leaflets small, light-green, markedly ribbed, leaflet margins wavy; secondary leaflets small.

Floral characters - Flowers infrequent; buds pink and dropping readily.

Time of sprouting slightly later than normal. Sprouts develop slowly, and general growth of the plant is slightly slower than normal but maturity is reached about the same time as the normal plant.

Photographs on next page /

Rasp-leaf Variation

Foliage - Low-growing becoming prostrate; stems spindly, highly coloured brown-purple, wings markedly waved at top; leaves short, mid-ribs tinged brown; leaflets light green, curved downwards, markedly puckered and blistered.

Floral characters - Flowers white, infrequent; flower stalks short, mottled purple; buds faint pink later becoming bright pink before dropping.

Sprouting is much later than normal but it appears that apical dominance is less marked and more basal eyes sprout than in the normal. The growing season is protracted, maturity being reached about 28-30 days after the normal plants have ripened off.

Privet-leaf Variation

Foliage - Low-growing, bushy, with very open foliage; leaves of average length, open; leaflets dark green, very glossy /

glossy and thin with "blistered" surfaces and margins rolling upwards and inwards; secondary leaflets small and infrequent or completely absent; axillary growth profuse.

Floral characters - Flowers not observed; buds infrequent.

Chlorotic-leaf Variation

Foliage - Low-growing, bushy, compact; stems small, spindly with much lateral growth; leaves small; leaflets round, chlorotic with markedly yellow margins.

Floral characters - Flowers not observed; buds rudimentary and dropping readily.

"Knotted-top" Variation /

"Knotted-top" Variation

Foliage - Low-growing and bushy resembling a wilding type; stems numerous, slightly branched, spindly, round with swollen nodes, internodes few and long; wings almost completely absent but, if present, small, straight and normally only two per stem; leaves medium-green, glossy, simple, the blades being large and convexly cupped; secondary leaflets absent; each stem is devoid of leaves but terminates in a rosette of four or five bunched together.

Floral characters - Buds and floral parts almost completely absent.

EPICURE

Normal

Round-leaflet Variation /

Round-leaflet Variation

Foliage - Low-growing, glossy, flat-topped; stems red-purple, short and robust; leaves short and rigid; leaflets round, slightly puckered with yellow upturned margins, terminal leaflets drooping; secondary leaflets circular and saucer-shaped with yellow margins.

Floral characters - Flowers infrequent; buds small, dropping unopened.

GLADSTONE

Normal

Docken-leaf Variation

Foliage - Habit very similar to normal plants but giving reduced cover; lower leaves simplified, the leaflets being perfectly fused together to resemble a dock leaf, the upper leaves are more normal but have enlarged terminal leaflets.

Floral characters /

Floral characters - Flowers not observed; buds infrequent.

Dwarf-foliage Variation

Foliage - Stiff and upright, later becoming prostrate; stems non-branching, four or five per plant; leaves reduced in size with distinctly shortened mid-ribs which twist and bend downwards round the stem. Towards maturity the leaflets, which are dark-green and glossy, tend to roll upwards and inwards as in leaf-roll.

Floral characters - Flowers large, white and profuse.

Sprouting tends to be slightly earlier than in the normal tuber but growth of the plant in the field is less vigorous.

Privet-leaf Variation /

Privet-leaf Variation

Foliage - Medium height, open with reduced cover; stems prominent; leaves long; leaflets very glossy, "blistered" and thin with margins rolling upwards and inwards.

Floral characters - Flowers normal but infrequent.

Sub-divided-leaf Variation

Foliage - Similar in habit to the normal plant; leaves large, broad and expansive; leaflets large, leaflet stalks long, originating from a common point on the leaf mid-rib and bearing numerous secondary leaflets, top leaflets compact.

Floral characters - Flowers large, white and profuse as in normal plant.

GREAT SCOT

Normal

Sub-divided-leaf Variation

Foliage - Similar to normal plant but slightly more bushy; leaves large but slightly shorter; leaflets small; leaflet stalks branch out from a common point on the leaf mid-rib and bear, in addition to the leaflets, one or more pairs of secondary leaflets giving the appearance of a whorl of miniature leaves.

Floral characters - Flowers not observed, buds frequent but drop readily.

Dahlia-leaf Variation /

Dahlia-leaf Variation

Foliage - Open, rigid, upright habit with poor cover; leaves slightly shorter than normal and more rigid; leaflets waxy, dark green, puckered, fleshy, narrower and more pointed than in the normal plant, leaflet margins tend to roll downwards and inwards giving the leaflets a thick appearance.

Floral characters - Flowers not observed; buds rudimentary, few and dropping readily.

Tubers - Similar to normal; sprouts differ from normal in being markedly glossy and waxy and completely devoid of hairs, tips tend to remain closed.

While rate and time of sprouting appears to be normal, the growing season of the plant is shorter and plants reach maturity 10 to 14 days earlier than normal.

Rough-leaf Variation

Foliage - Similar to the normal in general habit, but more rigid; leaflets thick, large, markedly blistered and wrinkled.

HOME GUARD

Normal

Raised-epidermis Variation

Foliage - Habit similar to normal; stems become prostrate towards maturity; leaves reduced in length; leaflets grey-green, thin, slightly blistered with areas of raised epidermis, lateral leaflets reduced in number but broader and larger than normal.

KERR'S PINK

Normal

Many-budded, Round-leaflet Variation

Foliage - Low-growing, bushy, resembling an early variety in habit; stems numerous, thin and branched; leaves short; leaflets small and round with wavy margins, terminal leaflets drooping, lateral leaflets reduced in size and number, frequently only two pairs and one small basal pair per leaf; secondary leaflets few.

Floral characters - Flowers normal but infrequent; buds small and numerous.

The tubers appear normal but sprouting is slower and the sprouts are thin, green and not robust. Sprouting is not confined to the apical eyes but sprouts are observed arising from many lateral eyes. The length of the growing season is shorter than normal, the plants ripening off approximately sixteen days earlier than normal plants of Kerr's Pink.

Spinach-leaf Variation /

Spinach-leaf Variation

Foliage - Medium height, rigid, upright and lacking cover; leaves stiff and deformed, the youngest leaves being spoon-shaped; leaflets glossy and frequently fused together; secondary leaflets scarce; bracts large, frequently encircling the stem; apex of the stem is malformed giving rise to irregular bud clusters and leafy bracts.

Floral characters - Flowers large with petals frequently bi-lobed, sepals 5-10 in number, stamens 5-8; buds large.

Rasp-leaf Variation

Foliage - Light-green, sulphury, hairy; stems coloured red-purple, the tops of the foliages have a "dusty" appearance due to excessive hairiness; leaves long, mid-ribs coloured red-purple; leaflets large, hairy, thick, "blistered" and carried downwards.

Floral characters - Flowers normal but less frequent.

Coarse, Grey-leaflet Variation /

Coarse, Grey-leaflet Variation

Foliage - Medium height, coarse, upright and stiff, cover poor; stems highly coloured and prominent; leaves short, rigid and compact; leaflets broad, thick, dull and grey-green in colour, leaflet surfaces rough and slightly "blistered", some leaflets exhibit localised areas of raised epidermis.

Floral characters - Buds large, frequent and globular; inflorescence and bud stalks highly coloured red-purple and very hairy.

Raised-epidermis Variation

Foliage - Medium height, bushy; stems numerous and thin; leaves short; leaflets lead-coloured, "blistered", reduced in number and rounder than normal, opposite leaflets often of unequal size, one being rudimentary; secondary leaflets rudimentary or absent.

Floral Characters - Flower and bud stalks markedly hairy.

Ivy-leaf Variation /

Ivy-leaf Variation

Foliage - Medium height, stiff, upright and lacking cover; stems prominent; leaves short, rigid and directed upwards, mid-ribs flattened near the terminal leaflet which is fused with one or two pairs of lateral leaflets giving an ivy-shaped leaf blade; leaflets glossy, rough, "blistered" and dark-green with light-green margins.

Floral characters - Flowers not observed; buds drop readily.

KING EDWARD

Normal

"Bindal" Variation

Foliage - similar in habit to a normal plant of the variety but the leaflets are darker green in colour, more glossy, narrower and more pointed; the margins are not markedly waved; foliage tops are not "tufted" as in the normal plant but are flat and open.

Round, Grey-green Leaflet Variation /

Round, Grey-green Leaflet Variation

Foliage - Medium to tall, upright with flat tops; leaves broad giving more cover than normal; leaflets glossy, grey-green, broad, thick and round, margins flat with a tendency to curl downwards and inwards; mid-ribs only faintly coloured at base of leaflet stalks.

Blind-top Variation

Foliage - Low, bushy habit like British Queen, with flat tops and good cover; the small young leaves normally found at stem apices are inconspicuous giving the impression that the top of the plant has been cut away; leaflets flat, thick, broad, glossy, dark-green and with less waving of the margins than normal, margins are often turned upwards to give a white outline to the leaflet, terminal leaflets may be fused with one or both of the penultimate pair of laterals; the tops of the stems are malformed and several leaves arise from a common insertion point.

Plants reach maturity about 12 days earlier than normal.

Rasp-leaf Variation /

Rasp-leaf Variation

Foliage - Medium height, upright later becoming prostrate; stems mottled red-purple; leaves short and fairly close; leaflets light-green, curved downwards and markedly puckered, apical leaflets narrow.

Floral characters - Flowers not observed, buds narrow and dropping readily.

MAJESTIC

Normal

Holly-leaf Variation

Foliage - Medium to low, stiff, upright; stems stiff and slightly bronzed; leaves short, very rigid and all directed upwards; leaflets dark-green and exceptionally brittle breaking with the slightest pressure, directed forwards and upwards and folded to give a sharp prickly foliage.

Floral characters /

Floral characters - Flowers not observed; buds rudimentary.

Docken-leaf Variation

Foliage - Medium height, erect, stiff, lacking cover; wings markedly waved; leaves fairly long and stiff, the top leaves in particular being directed upwards, mid-ribs of young leaves coloured red-purple; all leaflets are lighter-green than normal and frequently fused to give a large leaf blade or at least one large leaflet with one pair of small normal leaflets; secondary leaflets almost completely absent; the lamina has a few large marginal serrations.

Floral characters - Flowers normal but less frequent.

Rough-leaf Variation /

Rough-leaf Variation

Foliage - Habit similar to normal but perhaps slightly taller; leaves more rigid than normal; leaflets dark-green, broad, thick, waxy and slightly "blistered", leaflet veins indistinct.

Floral characters - Red-purple tinge may be observed on the backs of the petals.

Dahlia-leaf Variation

Foliage - Glossy, otherwise of similar habit to normal; stems slightly more bronzed; leaves short and stiff; leaflets very smooth and rounder than normal, dark-green and flat, mid-ribs of top leaflets intensely coloured red-purple.

Floral characters - Flowers normal but less frequent.

Stiff-foliage, Flat-topped Variation /

Stiff-foliage, Flat-topped Variation

Foliage - Medium height but more rigid than normal; leaves short and stiff; leaflets stiff, light-green, round like those in the variety King George, margins flat and distinct; tops of foliage flat and compact.

Floral characters - Flowers not observed; buds small, globular, hairy, grey; sepals long, green and bract-like; petals never unfold from the bud but remain tightly folded, the junctions of the petals show as white lines.

Semi-spinach-leaf Variation

Foliage - In most respects this variation is similar to the normal plant but the leaflets are small and the terminal leaflets are characteristically fused with one or two pairs of lateral leaflets.

Round-leaflet Variation /

Round-leaflet Variation

Foliage - Medium height, upright, stiff; leaves short, stiff and directed upwards; leaflets small, round, flat with distinct margins.

REDSKIN

Normal

Rough-leaf Variation

Foliage - Medium height, stiff, upright, lacks cover; stems and mid-ribs coloured red-purple, nodes green; leaves short and rigid; leaflets dark green, thick and hairy giving a grey metallic lustre to the foliage, leaflet margins excessively hairy particularly in the young tops.

Floral characters /

Floral characters - Flowers fewer than normal; bud stalks, inflorescence stalks and buds red-purple and hairy.

Raised-epidermis Variation

Foliage - Low-growing, bushy, grey-green with a leaden lustre; leaves short, very open; leaflets broad, round, "blistered" and sometimes partly chlorotic, opposite leaflets frequently of unequal size, one sometimes being only rudimentary; secondary leaflets rudimentary or absent.

Floral characters - Flowers normal but less frequent.

UP-TO-DATE

Normal

Rasp-leaf Variation

Foliage - Medium height, light-green, drooping, becoming prostrate towards maturity; leaves long and broad; leaflets markedly curved and puckered.

Floral characters - Flowers normal and fairly profuse. Sprouts normal but rootlets smaller and less numerous than on a normal sprout.

Docken-leaf Variation /

Docken-leaf Variation

Foliage - Medium height, upright, tending to sprawl towards maturity, compact with a level rosetted top; stems robust, mottled purple particularly at bases; wings normally straight but sometimes waved towards the tops of the stems; leaves long, large, mid-ribs green; leaflets light-green, large, broad and slightly puckered, terminals exceptionally large and drooping; the leaf consists mainly of one large blade but there may be one or two pairs of lateral leaflets; secondary leaflets small and few.

Floral characters - Flowers normal but less frequent. This variation is commonly known by the name "Major".

ULSTER CHIEFTAIN

Normal

Docken-leaf Variation

Foliage - Habit similar to normal plant; leaves long; leaflets large and broad, terminal leaflets fused with one or two pairs of lateral leaflets to give dock-type leaves.

Floral characters - Flowers not observed; buds drop readily.

Raised-epidermis Variation

Foliage - Low-growing with less cover than normal; apices of stems malformed; leaves long and distorted; leaflets leaden-grey in colour, mid-ribs of terminal leaflets are flat and divide the leaflets into two unequal parts, opposite leaflets frequently of unequal size.

Floral characters - Flowers not observed; buds rudimentary.

B. Distribution /

B. Distribution

The frequency with which the various foliage-aberrant types arise in potato varieties cannot be assessed accurately in the absence of data related to individual stocks over a number of years, but their distribution throughout present day commercial varieties has been determined by perusal of the crop reports compiled annually.

Semi-bolters are normally observed in varieties of the 1st early and 2nd early maturity groups, no instance being recorded of their appearance in maincrop varieties. The varieties in which they are known to occur are Arran Pilot, Arran Signet, Catriona, Di Vernon, Duke of York, Eclipse, Epicure, May Queen and Sharpe's Express.

Bolters are more widely distributed and are found in all maturity groups with the exception of some late maincrop varieties, viz., Golden Wonder, Kerr's Pink and Dunbar Standard. They are present in all varieties in which semi-bolters occur and in addition in the following:- Ally, Arran Banner, Arran Bard, Arran Peak, Craigs Defiance, Dargill Early, Doon Star, Dunbar Rover, Edzell Blue, Gladstone, Great Scot, Home Guard, King Edward, Majestic, Record, Redskin, Up-to-Date, Vanguard and Witchhill.

Wildings and feathery wildings also have a wide varietal distribution and the former have been observed in most varieties, even in those of recent introduction. Feathery wildings occur in the following varieties:-

Arran Chief, /

Arran Chief, Arran Pilot, Craigs Defiance, Di Vernon, Doon Star, Dunbar Standard, Eclipse, Epicure, Great Scot, Home Guard, Kerr's Pink, King Edward, Majestic, May Queen, Ninetyfold, Redskin and Sharpe's Express.

The other variations mentioned earlier are much less numerous than bolter or wilding types but they are common to all maturity classes and, being out-of-type plants which reproduce themselves vegetatively, are no less undesirable. Of these, the fused-leaflet types are, undoubtedly, the most common. They have been observed in the varieties Arran Banner, Arran Consul, Arran Peak, British Queen, Di Vernon, Doon Star, Dunbar Rover, Dunbar Standard, Gladstone, Kerr's Pink, Majestic, Ulster Chieftain and Up-to-Date.

Variations with leaflets which differ from the normal by reason of their rough, coarse and markedly wrinkled appearance are observed in the varieties Arran Banner, Arran Pilot, Eclipse, Great Scot, Kerr's Pink, King Edward, Majestic, Redskin and Up-to-Date.

Abnormal types of which chlorosis and malformation of the leaflets are characteristic features, are found in a limited number of commercial varieties, e.g., in Dunbar Archer, Eclipse, Kerr's Pink and Redskin.

C. Nature and Cause of Variations /

C. Nature and Cause of Variations

Although the nature of most abnormal forms in potato varieties is still obscure, past investigations have proved some to be periclinal chimeras while a pathological factor has been suggested as the cause of others. Some of the variations discussed here were examined to determine which are periclinal and which, if any, are conditioned by virus infection.

Material and Methods

To determine which types are of the nature of periclinal chimeras, in 1946 and 1947 attempts were made to recover normal plants from each by excising the "eyes" of the tubers before planting and obtaining growth from the inner tissues. The technique was similar to that adopted by Asseyeva. From a sample of 6 tubers of each, the "eyes" were removed to a depth which ensured, as far as practicable, that any subsequent growth came from the deeper tissues. The treated tubers were placed in a mild atmosphere and covered with damp hessian for 48 hours to facilitate suberisation of the wounds, after which they were immersed in damp sand to encourage callus formation. The tubers were examined from time to time and any growth arising from a bud of an incompletely excised eye was removed prior to planting out the tubers in the field.

The following varieties and conditions were included in the investigation to determine whether a virus factor

was the cause of the abnormalities:-

Variety	Condition
Arran Pilot	Bolter
King Edward	Wilding
King Edward	Rasp-leaf
King Edward	"Bindal" variation
Dunbar Rover	Mop-top
Craigs Defiance	Mop-top

Viruses are conveniently transmitted from plant to plant by grafting and this technique was adopted in an attempt to reproduce the above abnormalities in previously selected normal plants of the same varieties. Twenty tubers of each of the above conditions and an equivalent number of normal tubers were set out in pots in a greenhouse. When the plants emerged, scions from the aberrant forms were grafted on to the corresponding normals by the top-graft method. All plants were allowed to mature after which the produce from each pot was harvested separately and stored. In the following year, the tubers from the grafted plants were laid out in field plots adjacent to those saved from the plants under test. The characteristics of the resultant plants were carefully compared to determine whether the abnormalities had been transmitted to the normal plants through the grafts.

Results

Following tests involving excision of the tuber "eyes", plants conforming to the normal type of the variety were regained from the undernoted variations, signifying that the latter are periclinal in character:-

Arran Banner /

Arran Banner (rough leaflets)
Duke of York (sub-divided leaf)
Eclipse (privet-leaf)
Great Scot (dahlia-leaf)
Great Scot (sub-divided leaf)
Kerr's Pink (raised epidermis)
Redskin (raised epidermis)

Normal plants were not recovered from the following variations, therefore they are probably not periclinal chimeras but, as it is sometimes difficult to ensure that growth from the inner tissues has been successfully obtained, repeated excisions may prove otherwise:-

British Queen, Kerr's Pink and Majestic (docken-leaf)

Arran Consul, Doon Star and Dunbar Rover (spinach-leaf)

Arran Pilot, Eclipse, Kerr's Pink, King Edward and Up-to-Date (rasp-leaf)

King Edward (Bindal variation)

Arran Pilot (bolter)

Arran Pilot (semi-bolter)

King Edward (wilding)

King Edward (feathery wilding)

Although all scions showed satisfactory development, from the graft tests the results did not indicate that viruses were concerned in the appearance of the conditions examined. At no time did visible disease symptoms appear on any of the grafted normal plants in the greenhouse and in the field in the succeeding year, no abnormalities in their foliages were apparent. McIntosh (1932, 1940) agrees that bolters and wildings are not the results of virus infection. Although from Rozendaal's description, the

foliage /

foliage abnormalities caused by stem-mottle disease are very similar to those characteristic of the "mop-top" condition included in the graft tests, the two have not yet been proved to be synonymous. One of the varieties in which Rozendaal has observed the disease is Duke of York in which variety the "mop-top" modification has not yet been noted. In the present work, transmission of the "mop-top" abnormality by grafting was unsuccessful. Rozendaal, however, found that transmission of stem-mottle fluctuated between 50% and 100% and was more successfully achieved in autumn than in summer. In view of the apparent difficulty of successful transmission further investigation is necessary. In 1948, the "mop-top" variation was observed frequently in demonstration plots set out by the present writer but in 1949 it was not encountered even though the plots in that year were derived from the progeny of the 1948 stocks. In 1948, however, the young foliages of the plants were severely damaged by frost in May hence, although the appearance of large numbers of "mop-top" plants later in the season may have been fortuitous, it is tempting to suggest frost as a causal factor.

D. Practical Aspects of Variations

Frequency of Occurrence of Semi-bolters

The difficulty of eliminating semi-bolters from varieties in which they occur is due mainly to the fact that they bear

a close resemblance to normal plants at certain stages of growth but, in addition, they appear to arise de novo in crops with disconcerting regularity. In order to assess the approximate rates of production of semi-bolters from normal plants, an investigation was begun in 1946 and continued in 1947.

Material and Methods

For this work, it was necessary to procure a large stock of normal plants, the constancy of the type of which was assured. Preparation of the stock was begun in 1944 from specially selected plants of the variety Arran Pilot and the selection and propagation was continued up to 1946. In that year, a plot of 1,000 plants was laid out. During the growing season, all plants showing characteristics resembling those of semi-bolters were removed from the plot and the tubers stored for planting out in the succeeding year alongside those of normal plants. By comparing the foliages, the type of the "rogued" plants and the constancy of the characteristics were checked. In 1947, 2,000 tubers, selected from the normal plants grown in 1946 were again planted out. Again the apparent semi-bolter types were removed from the plot and their tubers retained for planting and checking in 1948.

Results

The results are summarised below:-

Year	No. of normal tubers planted	No. of suspected semi-bolters	No. confirmed	%
1946	1,000	3	3	.3
1947	2,000	12	6	.3

At /

At no time during the investigation were extreme bolter types observed. It would seem, therefore, that semi-bolters tend to appear anew with greater frequency than bolters in the variety Arran Pilot and that approximately .3% of tubers from normal plants may "mutate" to the semi-bolter condition each season.

Cropping Capacity of Variations

Material and Methods

The 24- and 36-tuber plots which were set out primarily for descriptive work were utilised to obtain some preliminary information on the comparative cropping propensities of normal and aberrant types. In 1946 all plots were harvested on the same day, regardless of maturity, but in 1947 and 1948 each was allowed to mature before lifting took place. The total tuber produce of each plot was graded over variously-sized potato riddles and the weights of tubers in the different size-categories recorded. The plots were not laid down for the prime purpose of yield trials hence the yields could not be statistically interpreted but the differences were often so marked and so consistent that the results are deemed to have a positive relative value.

Results

The yield figures excluding those for bolter and wilding types are given in tables I, II and III.

Table I /

Table I - Tuber Yields from Normals and Variations - 1946

Variety	Type	Yields corrected to 24 plants per plot							
		Over 2" diam.		2" to 1¾"		1¾" to 1¼"		Total	
		lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.
Arran Pilot	Normal	35	4	11	0	12	0	58	4
do.	Rasp-leaf	17	11	7	7	8	0	33	2
Eclipse	Normal	39	8	12	8	11	0	63	0
do.	Rough-leaf	7	2	12	4	24	0	43	6
do.	Rasp-leaf	34	0	21	8	12	8	68	0
British Queen	Normal	55	8	10	8	7	0	73	0
do.	Spinach-leaf	37	4	18	0	13	0	68	4
Dunbar Rover	Normal	48	0	1	8	4	8	54	0
do.	Mop-top	28	0	8	0	8	0	44	0
do.	Spinach-leaf	31	5	10	11	5	5	47	5
Doon Star	Normal	70	0	7	8	3	8	81	0
do.	Spinach-leaf	16	6	14	7	14	12	45	9
do.	Ivy-leaf	51	2	14	10	7	5	73	1
Great Scot	Normal	57	8	13	0	7	8	78	0
do.	Sub-divided-leaf	35	6	12	10	10	2	58	2
do.	Dahlia-leaf	41	0	9	0	5	0	55	0
King Edward	Normal	58	0	16	0	14	0	88	0
do.	"Bindal"	74	12	11	7	10	6	96	9
do.	Blind-top	48	0	20	8	17	8	86	0
Majestic	Normal	76	0	8	0	4	0	88	0
do.	Docken-leaf	44	6	11	8	9	6	65	4
do.	Rough-leaf	76	9	5	11	3	7	85	11
Arran Consul	Normal	64	0	5	2	4	0	73	2
do.	Spinach-leaf	70	14	5	11	3	7	80	0
Kerr's Pink	Normal	55	5	15	10	12	8	83	7
do.	Many-budded, round leaflets	37	7	25	7	21	14	84	12
do.	Spinach-leaf	51	10	19	5	13	9	84	8
do.	Rasp-leaf	53	0	17	0	11	8	81	8
do.	Coarse grey-leaflet	36	0	3	4	2	12	42	0
Up-to-Date	Normal	68	0	10	8	5	0	83	8
do.	Rasp-leaf	64	8	14	0	11	8	90	0

Date planted - 10th April.
Date harvested - 26th August.

Table II /

Table II - Tuber Yields from Normals and Variations - 1947

Variety	Type	Date mature	Yields corrected to 24 plants per plot									
			Over 2" diam.		2" to 1¾"		1¾" to 1¼"		Under 1¼"		Total	
			lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.
Arran Pilot	Normal	2/9	17	2	17	2	22	9	4	0	60	13
do.	Rasp-leaf	2/9	12	0	6	4	19	15	5	7	43	10
do.	Mop-top	2/9	22	7	10	7	20	1	4	3	57	2
Duke of York	Normal	2/9	13	8	10	8	21	8	2	8	48	0
do.	Sub-divided-leaf	2/9	12	14	16	3	20	6	3	5	52	12
Eclipse	Normal	2/9	21	2	18	0	22	15	2	1	64	2
do.	Rough-leaf	2/9	0	0	4	14	29	12	11	12	46	6
do.	Rasp-leaf	30/9	25	13	18	8	24	0	3	2	71	7
Epicure	Normal	2/9	36	4	12	8	6	12	1	0	56	8
do.	Round-leaflets	2/9	18	0	10	0	11	8	2	4	41	12
British Queen	Normal	30/9	33	10	21	14	18	14	1	8	75	14
do.	Spinach-leaf	30/9	37	4	15	12	11	12	1	4	66	0
Dunbar Rover	Normal	30/9	47	0	13	11	13	11	1	0	75	6
do.	Mop-top	30/9	36	14	14	2	13	3	1	8	65	11
do.	Spinach-leaf	30/9	40	8	9	0	6	5	0	14	56	11
Arran Banner	Normal	30/9	80	8	9	13	6	0	1	14	98	3
do.	Rough-leaf	30/9	68	12	6	8	4	4	0	8	80	0
Arran Consul	Normal	30/9	61	12	5	12	4	12	0	12	73	0
do.	Spinach-leaf	30/9	80	8	4	9	4	15	0	11	90	11
Doon Star	Normal	30/9	40	13	23	2	18	0	1	3	83	2
do.	Spinach-leaf	30/9	14	1	12	4	21	2	4	3	51	10
do.	Ivy-leaf	30/9	37	1	14	7	10	15	0	13	63	4
Gladstone	Normal	30/9	34	3	15	15	14	14	0	1	65	1
do.	Docken-leaf	30/9	40	6	14	13	7	10	0	13	63	10
do.	Dwarf foliage	30/9	14	6	9	2	10	15	2	6	36	13
Great Scot	Normal	30/9	53	8	11	8	9	2	0	12	74	14
do.	Sub-divided-leaf	30/9	47	2	12	10	17	2	3	5	80	3
do.	Dahlia-leaf	18/9	44	7	8	7	4	10	0	9	58	1
King Edward	Normal	30/9	45	0	18	13	16	6	1	15	82	2
do.	"Bindal"	30/9	50	14	16	3	18	8	1	9	87	2
do.	Round grey-green leaflet	30/9	38	6	19	5	22	3	2	14	82	12
do.	Blind-top	18/9	25	13	20	1	20	14	3	10	70	6
do.	Rasp-leaf	30/9	38	13	17	6	16	2	2	8	74	13
Majestic	Normal	30/9	68	2	14	10	12	0	1	9	96	5
do.	Docken-leaf	30/9	33	8	10	12	10	0	1	4	55	8
do. /												

Table II (Contd.)

Variety	Type	Date mature	Yields corrected to 24 plants per plot									
			Over 2" diam.		2" to 1¾"		1¾" to 1¼"		Under 1¼"		Total	
			lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.
Majestic	Rough-leaf	30/9	59	12	9	6	10	11	1	5	81	2
do.	Dahlia-leaf	30/9	61	10	8	7	8	7	1	1	79	9
do.	Stiff foliage, flat top	30/9	58	8	14	4	11	12	1	12	86	4
Redskin	Normal	30/9	73	12	12	8	7	4	0	6	93	14
do.	Rough-leaf	30/9	59	0	6	12	5	0	0	4	71	0
do.	Raised epidermis	30/9	78	9	3	13	2	12	4	0	89	2
Arran Peak	Normal	30/9	61	1	10	11	5	8	0	13	78	1
do.	Fused terminals	30/9	54	8	10	4	12	8	1	4	78	8
Dunbar Archer	Normal	30/9	58	7	10	3	7	13	1	5	77	12
do.	Chlorotic-leaf	30/9	38	5	11	7	7	11	0	14	58	5
Dunbar Standard	Normal	16/10	38	12	16	4	12	8	2	4	69	12
do.	Fused-terminal	16/10	57	4	13	6	13	1	1	6	85	1
Kerr's Pink	Normal	16/10	40	12	15	12	13	8	1	12	71	12
do.	Many-budded round-leaflets	30/9	27	0	14	5	20	5	3	0	64	10
do.	Spinach-leaf	16/10	46	8	17	2	14	2	1	13	79	9
do.	Rasp-leaf	30/9	41	0	12	8	14	4	1	8	69	4
do.	Coarse grey-leaflets	16/10	39	2	6	0	5	0	0	9	50	11
do.	Raised-epidermis	16/10	48	4	12	4	6	8	0	4	67	4
do.	Ivy-leaf	30/9	35	4	10	12	7	4	0	12	54	0
Up-to-Date	Normal	16/10	53	7	16	5	16	14	2	0	88	10
do.	Rasp-leaf	16/10	53	6	13	14	14	3	2	3	83	10

Date planted - 8th May.
Date harvested = Date mature.

Table III /

Table III - Tuber Yields from Normals and Variations - 1948

Variety	Type	Date mature	Yields corrected to 24 plants per plot									
			Over 2" diam.		2" to 1¾"		1¾" to 1¼"		Under 1¼"		Total	
			lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.
Arran Pilot	Normal	17/8	16	10	10	15	10	15	2	12	41	4
do.	Rasp-leaf	17/8	5	0	5	4	13	0	7	0	30	4
do.	Mop-top	17/8	14	2	10	4	18	0	4	9	46	15
do.	Rough-leaf	28/8	1	10	3	14	8	12	2	12	17	0
Di Vernon	Normal	17/8	11	12	9	8	16	8	5	0	42	12
do.	Docken-leaf	28/8	12	8	8	12	17	8	5	4	44	0
Duke of York	Normal	17/8	16	8	11	8	14	8	2	12	45	4
do.	Sub-divided-leaf	17/8	11	7	15	4	14	7	2	3	43	5
Eclipse	Normal	28/8	14	10	19	5	16	0	4	11	54	10
do.	Rough-leaf	28/8	1	6	1	6	21	0	8	7	32	3
do.	Rasp-leaf	13/9	18	8	19	0	17	8	2	0	57	0
do.	Privet-leaf	28/8	3	15	10	15	16	7	2	14	34	3
do.	Knotted-top	24/9	20	1	8	14	5	8	0	13	35	4
do.	Chlorotic-leaf	28/8	1	15	5	12	7	1	1	15	16	11
Epicure	Normal	28/8	29	12	9	12	9	12	1	4	50	8
do.	Round-leaflets	17/8	12	0	8	4	9	4	2	4	31	12
Home Guard	Normal	28/8	43	0	3	0	1	0	0	0	47	0
do.	Raised-epidermis	28/8	26	12	3	14	1	10	0	4	32	8
Ulster Chieftain	Normal	28/8	25	0	15	0	13	0	2	0	55	0
do.	Docken-leaf	28/8	32	8	8	8	7	0	0	4	48	4
do.	Raised-epidermis	28/8	22	12	3	8	3	8	0	8	30	4
British Queen	Normal	13/9	42	13	12	0	7	13	1	5	63	15
do.	Spinach-leaf	13/9	27	8	16	8	8	0	2	12	54	12
Dunbar Rover	Normal	13/9	40	8	9	0	5	8	1	8	56	8
do.	Spinach-leaf	24/9	31	4	6	0	2	12	1	0	41	0
do.	Mop-top	24/9	40	15	7	1	4	15	1	13	54	12
Arran Banner	Normal	24/9	59	3	6	8	3	10	0	8	69	13
do.	Rough-leaf	24/9	62	12	3	12	1	12	0	8	68	12
Arran Consul	Normal	24/9	54	4	7	12	3	8	0	8	66	0
do.	Spinach-leaf	24/9	57	0	3	14	3	0	0	5	64	3
Doon Star	Normal	24/9	53	8	11	4	3	12	0	12	69	4
do.	Spinach-leaf	24/9	8	4	7	4	12	8	4	12	32	12
do.	Ivy-leaf	24/9	31	0	12	12	7	4	0	4	51	4
Gladstone /												

Table III (Contd.)

Variety	Type	Date mature	Yields corrected to 24 plants per plot									
			Over 2" diam.		2" to 1¾"		1¾" to 1¼"		Under 1¼"		Total	
			lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.
Gladstone	Normal	24/9	49	12	7	4	3	4	0	4	60	8
do.	Docken-leaf	24/9	44	10	5	8	3	6	0	4	53	12
do.	Dwarf-foliage	24/9	23	8	8	1	4	7	0	4	36	4
do.	Sub-divided-leaf	24/9	49	4	15	4	6	12	1	0	72	4
do.	Privet-leaf	24/9	22	0	10	8	6	8	0	8	39	8
Great Scot	Normal	13/9	54	8	8	8	5	0	1	9	69	9
do.	Sub-divided-leaf	24/9	34	12	8	8	5	4	1	4	49	12
do.	Dahlia-leaf	13/9	42	8	6	0	5	8	0	12	54	12
do.	Rough-leaf	24/9	6	0	13	4	14	0	4	12	38	0
King Edward	Normal	24/9	44	1	16	7	11	3	2	6	74	1
do.	"Bindal"	24/9	51	4	13	4	12	8	1	8	78	8
do.	Round, grey-green leaflets	24/9	35	8	12	12	14	4	3	4	65	12
do.	Blind-top	13/9	36	8	13	0	15	8	3	8	68	8
do.	Rasp-leaf	13/9	33	10	13	0	12	0	3	8	62	2
Majestic	Normal	24/9	63	12	7	4	4	8	1	12	77	4
do.	Docken-leaf	13/9	22	8	8	4	6	0	1	14	38	10
do.	Rough-leaf	13/9	48	0	9	11	6	0	1	11	65	6
do.	Dahlia-leaf	13/9	37	8	14	8	7	4	1	10	60	14
do.	Stiff, flat-topped	24/9	49	5	12	4	6	13	1	5	69	11
do.	Semi-spinach leaf	24/9	52	15	11	3	9	15	2	1	76	2
do.	Round-leaflets	24/9	36	12	14	12	9	12	3	4	64	8
do.	Holly-leaf	5/10	11	0	2	8	3	0	1	0	17	8
Redskin	Normal	24/9	59	12	4	5	3	2	0	9	67	12
do.	Rough-leaf	24/9	47	12	10	11	4	3	1	5	63	15
do.	Raised-epidermis	24/9	37	12	11	4	6	8	0	8	56	0
Arran Peak	Normal	24/9	48	0	10	9	5	11	0	2	64	6
do.	Fused terminals	24/9	56	8	7	12	5	12	0	8	70	8
Dunbar Archer	Normal	24/9	61	11	11	9	5	9	1	5	80	2
do.	Chlorotic-leaf	24/9	39	0	8	12	3	0	0	4	51	0
Dunbar Standard	Normal	24/9	48	4	9	8	8	12	0	12	67	4
do. /												

Table III (Contd.)

Variety	Type	Date mature	Yields corrected to 24 plants per plot									
			Over 2" diam.		2" to 1¾"		1¾" to 1¼"		Under 1¼"		Total	
			lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.
Dunbar Standard	Fused terminals	5/10	56	8	5	8	3	0	1	4	66	4
Kerr's Pink	Normal	5/10	58	15	14	12	7	10	1	1	82	6
do.	Many-budded, round-leaflets	13/9	24	8	12	8	13	5	2	12	53	1
do.	Spinach-leaf	24/9	44	12	10	12	8	12	1	8	65	12
do.	Rasp-leaf	5/10	38	8	10	12	9	0	1	4	59	8
do.	Coarse, grey-leaflets	24/9	25	6	7	15	3	4	1	15	38	8
do.	Raised-epidermis	5/10	39	8	10	8	8	8	2	0	60	8
do.	Ivy-leaf	5/10	28	0	9	8	9	0	1	8	48	0
Up-to-Date	Normal	5/10	58	8	9	8	6	0	1	4	75	4
do.	Rasp-leaf	24/9	48	0	11	5	8	11	2	0	70	0
do.	Docken-leaf	24/9	44	10	11	3	5	8	0	8	61	13

Date planted - 5th April.
Date harvested = Date mature.

The /

The data indicate that, with a few exceptions and where maturity is unaffected, the aberrant forms tend to be inferior to the normals of the varieties as regards cropping ability. The figures for 1946, which were obtained by harvesting the plots immature and which are given in table I, also indicate that the normal plants produce a heavier crop of tubers earlier in the season than do the majority of irregular types investigated. In certain instances where the yield of the variation exceeds that of the normal, the increase appears to be due to the production of a larger number of tubers in the smaller grades which would normally be utilised for "seed" purposes, thus permitting rapid multiplication of these types in stocks. The consistently superior yield of the "rasp-leaf" variation in the variety Eclipse is probably due to its late maturity and longer growing season. Whether or not the differences are significant, it seems unlikely that stocks of superior cropping capacity will be obtained by selecting and propagating such plants which do not conform to the varietal description.

The data obtained from the weighings of the bolter and wilding plots are given in tables IV, V and VI.

Table IV /

Table IV - Tuber Yields from Normals, Semi-bolters and Bolters - 1946

Maturity	Variety	Type	Yields corrected to 36 plants per plot							
			Over 2" diam.		2" to 1¾"		1¾" to 1¼"		Total	
			lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.
1st Early	Arran Pilot	Normal	72	8	15	7	10	13	98	12
	do.	Semi-bolter	87	7	10	5	8	4	106	0
	do.	Bolter	99	12	10	8	6	12	117	0
do.	Duke of York	Normal	32	0	15	8	11	0	58	8
	do.	Semi-bolter	69	10	18	0	7	3	94	13
	do.	Bolter	73	6	16	10	8	5	98	5
do.	Eclipse	Normal	64	0	22	8	11	8	98	0
	do.	Semi-bolter	66	0	25	0	12	0	103	0
	do.	Bolter	67	8	25	8	12	12	105	12
do.	Epicure	Normal	58	8	17	8	9	0	85	0
	do.	Semi-bolter	75	0	11	0	7	8	93	8
	do.	Bolter	87	0	11	8	3	8	102	0
do.	Ninetyfold	Normal	35	4	19	8	12	0	66	12
	do.	Semi-bolter	81	13	20	7	13	1	115	5
do.	Sharpe's Express	Normal	25	8	20	0	20	8	66	0
	do.	Semi-bolter	43	0	18	0	18	8	79	8
	do.	Bolter	43	10	22	15	16	12	83	5
2nd Early	Catriona	Normal	45	0	24	0	22	13	91	13
	do.	Semi-bolter	32	15	22	10	22	2	77	11
	do.	Bolter	62	2	16	9	9	0	87	11
do.	Edzell Blue	Normal	29	13	21	1	22	14	73	12
	do.	Bolter	54	12	17	4	9	0	81	0
Early Maincrop	Doon Star	Normal	64	9	15	6	11	10	91	9
	do.	Bolter	54	0	21	7	11	1	86	8
	do.	Wilding	0	0	3	10	46	3	49	13
	do.	Feathery Wilding	19	10	30	14	30	9	81	1
do.	Gladstone	Normal	66	0	20	8	12	0	98	8
	do.	Bolter	50	6	13	11	6	8	70	9
do.	King Edward	Normal	50	6	24	0	30	0	104	6
	do.	Bolter	53	8	15	14	10	9	79	15
	do.	Wilding	35	0	30	5	33	7	98	12
	do.	"Bindal"	67	8	26	7	17	7	111	6
do.	Majestic	Normal	91	3	13	3	7	13	112	3
	do.	Bolter	51	14	19	1	11	2	82	1
do.	Redskin	Normal	67	12	19	1	5	5	92	2
	do.	Bolter	59	10	14	1	7	5	81	0

Date planted - 10th April.
Date harvested - 20th August.

Table V /

Table V - Tuber Yields of Normals, Semi-bolters and Bolters - 1947

Maturity	Variety	Type	Date mature	Yields corrected to 36 plants per plot									
				Over 2" diam.		2" to 1¾"		1¾" to 1¼"		Under 1¼"		Total	
				lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.
*1st Early	Arran Pilot	Normal*	2/9	28	1	26	3	26	7	3	13	84	8
	do.	Semi-bolter	18/9	44	0	24	7	20	5	4	2	92	14
	do.	Bolter	30/9	81	14	17	3	14	6	1	7	114	14
	Duke of York	Normal*	2/9	12	5	18	12	37	0	4	14	72	15
	do.	Semi-bolter	11/9	39	7	22	1	27	10	3	7	92	9
	do.	Bolter	30/9	76	8	19	8	12	12	5	4	114	0
	Eclipse	Normal*	2/9	18	8	23	0	37	12	3	0	82	4
	do.	Semi-bolter	11/9	26	0	23	6	37	13	4	10	91	13
	do.	Bolter	16/10	87	6	20	14	15	15	1	7	125	10
	Epicure	Normal*	2/9	52	0	16	0	11	0	1	8	80	8
	do.	Semi-bolter	11/9	58	0	13	12	8	4	0	12	80	12
	do.	Bolter	30/9	78	1	8	12	6	6	1	5	94	8
	Ninetyfold	Normal*	2/9	17	12	21	11	41	9	7	2	88	2
	do.	Semi-bolter	18/9	54	5	27	14	35	12	5	6	123	5
	Sharpe's Express	Normal*	2/9	7	0	14	8	39	4	11	0	71	12
	do.	Semi-bolter	18/9	11	10	20	6	47	15	7	15	87	14
	do.	Bolter	16/10	42	7	26	4	33	3	4	6	106	4
ø2nd Early	Catriona	Normalø	2/9	28	1	23	0	29	6	3	3	83	10
	do.	Semi-bolter	11/9	57	2	32	9	23	14	3	13	117	6
	do.	Bolter	16/10	87	13	16	7	12	12	0	15	117	15
	Edzell Blue	Normalø	2/9	58	8	23	0	23	0	4	0	108	8
	do.	Bolter	16/10	132	10	14	11	9	15	0	8	157	12
‡Early Maincrop	Doon Star	Normal‡	30/9	59	6	20	9	18	12	1	0	99	11
	do.	Bolter	16/10	73	11	9	5	7	0	0	11	90	11
	do.	Wilding	30/9	0	14	4	6	51	11	24	6	81	5
	do.	Feathery Wilding	30/9	23	12	27	0	42	8	4	8	97	12
	Gladstone	Normal‡	30/9	61	5	23	10	14	15	2	0	101	14
	do.	Bolter	16/10	82	1	11	15	7	2	1	5	102	7
	King Edward	Normal‡	30/9	47	8	22	4	32	12	5	12	108	4
	do.	Bolter	16/10	52	7	20	6	20	2	3	7	96	6
	do.	Wilding	18/9	22	14	22	10	45	8	10	0	101	0
	do.	Feathery Wilding	30/9	24	14	16	2	30	7	7	11	79	2
	Majestic	Normal‡	30/9	83	1	18	9	12	8	2	1	116	3
	do.	Bolter	16/10	94	12	9	12	6	12	1	4	112	8
	Redskin	Normal‡	30/9	77	0	6	10	10	5	1	1	95	0
	do.	Bolter	16/10	75	7	16	11	10	5	1	5	103	12

Date planted - 7th May.
Date harvested = Date mature.

Table VI /

Table VI - Tuber Yields of Normals, Semi-bolters and Bolters - 1948

Maturity	Variety	Type	Date mature	Yields Corrected to 36 Plants per Plot									
				Over 2" diam.		2" to 1¾"		1¾" to 1¼"		Under 1¼"		Total	
				lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.
*1st Early	Arran Pilot	Normal*	17/8	24	10	19	1	20	6	6	14	70	15
	do.	Semi-bolter	13/9	59	13	18	11	17	8	3	7	99	7
	do.	Bolter	1/10	77	5	14	13	15	6	2	6	109	14
	Duke of York	Normal*	17/8	20	3	24	0	22	10	4	6	71	3
	do.	Semi-bolter	13/9	67	6	22	14	14	11	2	1	107	0
	do.	Bolter	1/10	127	3	13	8	6	5	3	0	150	0
	Eclipse	Normal*	28/8	20	4	27	4	31	4	4	4	83	0
	do.	Semi-bolter	28/8	24	7	23	15	35	4	5	2	88	12
	do.	Bolter	1/10	90	10	20	8	10	14	2	3	124	3
	Epicure	Normal*	28/8	68	4	16	4	9	12	2	4	96	8
	do.	Semi-bolter	28/8	71	4	12	4	9	12	1	8	94	12
	do.	Bolter	13/9	108	8	5	15	3	13	0	13	119	1
	Ninetyfold	Normal*	28/8	59	6	17	0	19	0	5	6	100	12
	do.	Semi-bolter	13/9	89	0	26	4	12	14	3	5	131	7
	Sharpe's Express	Normal*	28/8	13	14	26	8	30	10	3	14	74	14
	do.	Semi-bolter	13/9	38	2	28	14	22	4	2	10	91	14
	do.	Bolter	1/10	75	13	22	6	16	15	1	10	116	12
ø2nd Early	Catriona	Normalø	28/8	36	14	27	5	26	11	3	3	94	1
	do.	Semi-bolter	28/8	70	0	24	8	19	7	3	6	117	5
	do.	Bolter	1/10	102	9	16	15	6	13	0	9	126	14
	Edzell Blue	Normalø	28/8	44	4	23	0	23	12	3	12	94	12
	do.	Bolter	5/10	53	8	7	7	2	10	0	8	64	1
‡Early Maincrop	Doon Star	Normal‡	24/9	76	2	16	3	6	7	0	8	99	4
	do.	Bolter	5/10	84	12	10	7	8	11	1	2	105	0
	do.	Wilding	24/9	2	12	8	8	53	8	26	12	91	8
	do.	Feathery Wilding	13/9	29	12	37	0	29	4	2	12	98	12
	Gladstone	Normal‡	13/9	53	0	22	8	11	0	1	6	87	14
	do.	Bolter	5/10	88	0	6	3	5	14	1	15	102	0
	King Edward	Normal‡	24/9	53	8	22	8	21	12	3	8	101	4
	do.	Bolter	5/10	53	12	19	8	13	0	2	4	88	8
	do.	Wilding	24/9	40	8	26	8	26	8	3	4	96	12
	do.	Feathery Wilding	13/9	12	0	22	10	36	12	11	0	82	6
	Majestic	Normal‡	24/9	103	0	13	4	10	14	1	14	129	0
	do	Bolter	1/10	104	8	14	13	7	9	1	7	128	5
	Redskin	Normal‡	24/9	84	14	11	1	6	3	0	12	102	14
	do.	Bolter	5/10	109	2	10	2	9	0	1	2	129	6

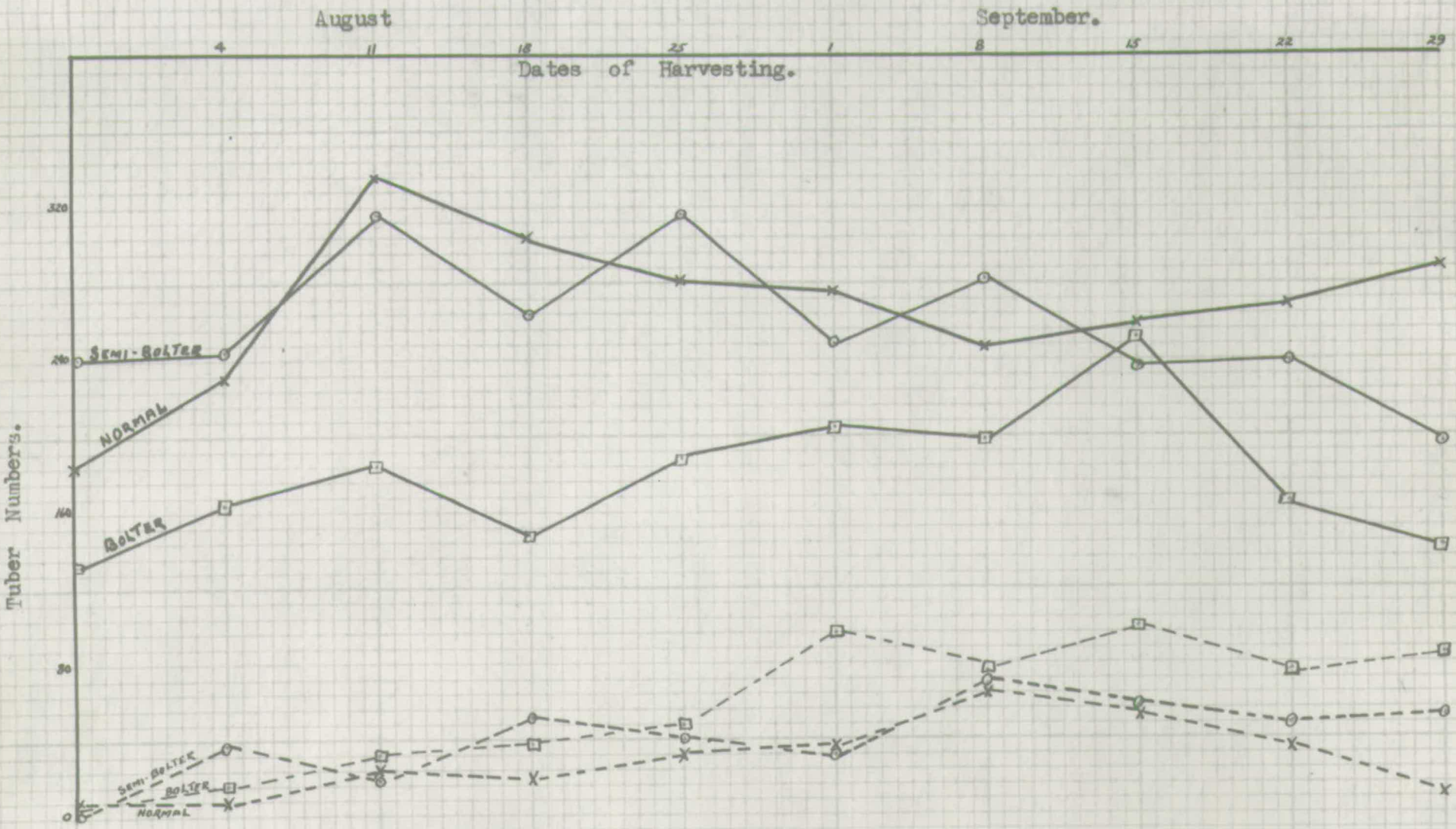
Date planted - 5th April.
Date harvested = Date mature.

Provided /

Provided the plants were allowed to reach maturity before harvesting, bolters of most varieties produced (a) a greater total weight of tubers, and (b) a greater weight of tubers over 2" diameter than normals. Semi-bolter yields appeared to be intermediate between these two types. During the early part of the growing season, however, the normals out-yielded both semi-bolters and bolters as the figures in table IV illustrate. Those figures were obtained by harvesting all plots on the same day - at which time the normals of the early varieties were nearing maturity but the remainder of the plots were still immature - and show that while the bolters of the early varieties had out-yielded the normals, in the main-crop varieties, where growth was incomplete, the normals yields had not at that time been surpassed by those of the bolters. The yields of most commercial varieties, therefore, could be improved by the selection and propagation of bolter stocks but bolters have other features less desirable such as late maturity and coarse, unattractive tubers.

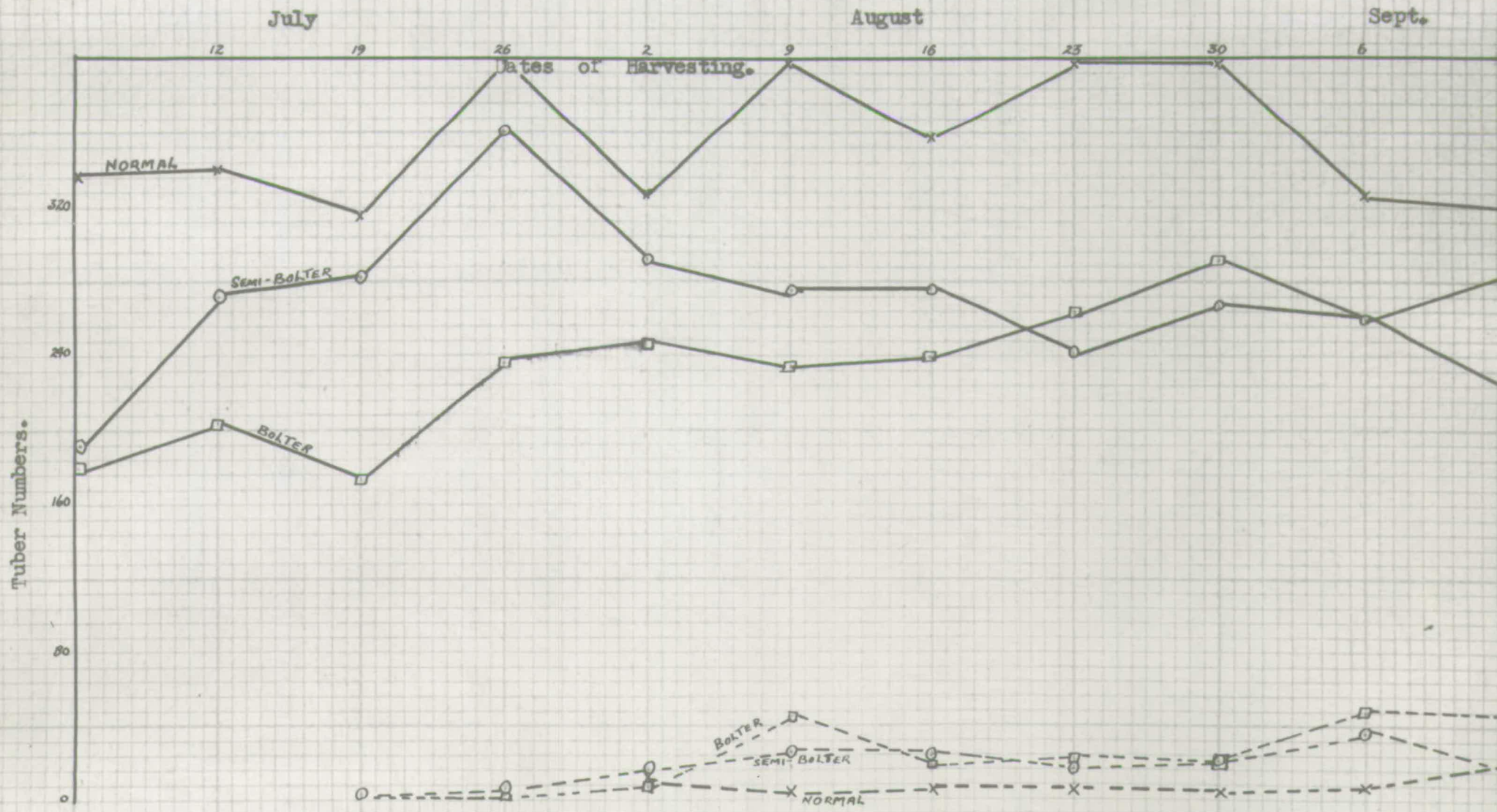
Wildings and feathery wildings are consistently poor yielders which produce large numbers of tubers of small size. This results in a large proportion of their produce being distributed among the "seed" (tables V and VI) thus providing for a high rate of increase of these types in crops.

Fig. 2 - YIELD OF TUBERS FROM EQUIVALENT NUMBERS OF NORMAL, BOLTER AND SEMI-BOLTER PLANTS OF ARRAN PILOT HARVESTED AT WEEKLY INTERVALS-1947.



Total no. of tubers shown thus ——————
Tubers over 2" diam. shown thus - - - - -

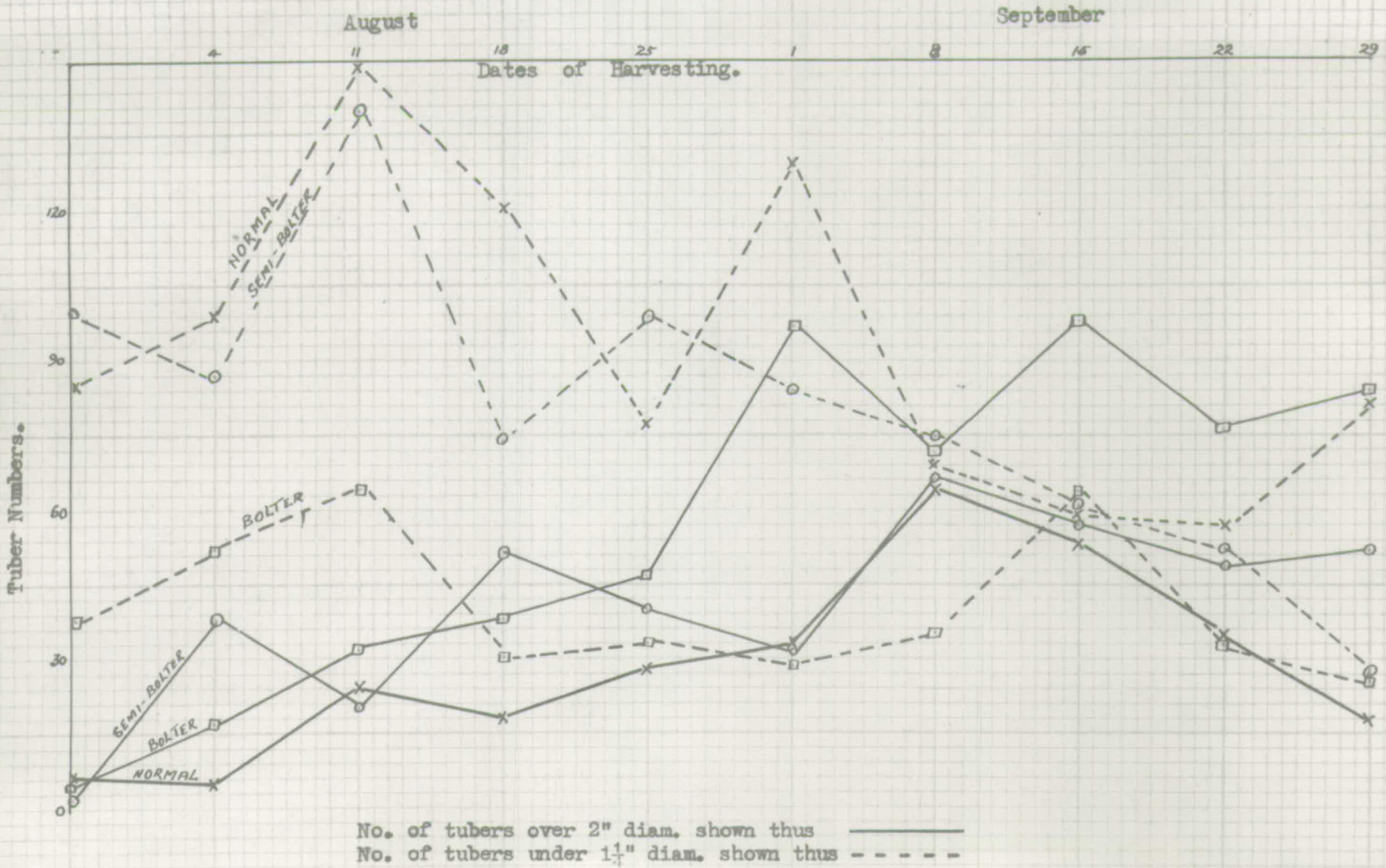
ARRAN PILOT HARVESTED AT WEEKLY INTERVALS-1948.



Total no. of tubers shown thus ————

No. of tubers over 2" diam. shown thus - - - - -

Fig. 4 - YIELD OF TUBERS FROM EQUIVALENT NUMBERS OF NORMAL, BOLTER, AND SEMI-BOLTER PLANTS OF ARRAN PILOT HARVESTED AT WEEKLY INTERVALS-1947.



No. of tubers over 2" diam. shown thus ——————
No. of tubers under $1\frac{1}{4}$" diam. shown thus - - - - -

Fig. 5 - YIELD OF TUBERS FROM EQUIVALENT NUMBERS OF NORMAL, BOLTER, AND SEMI-BOLTER PLANTS OF ARRAN PILOT HARVESTED AT WEEKLY INTERVALS-1948.

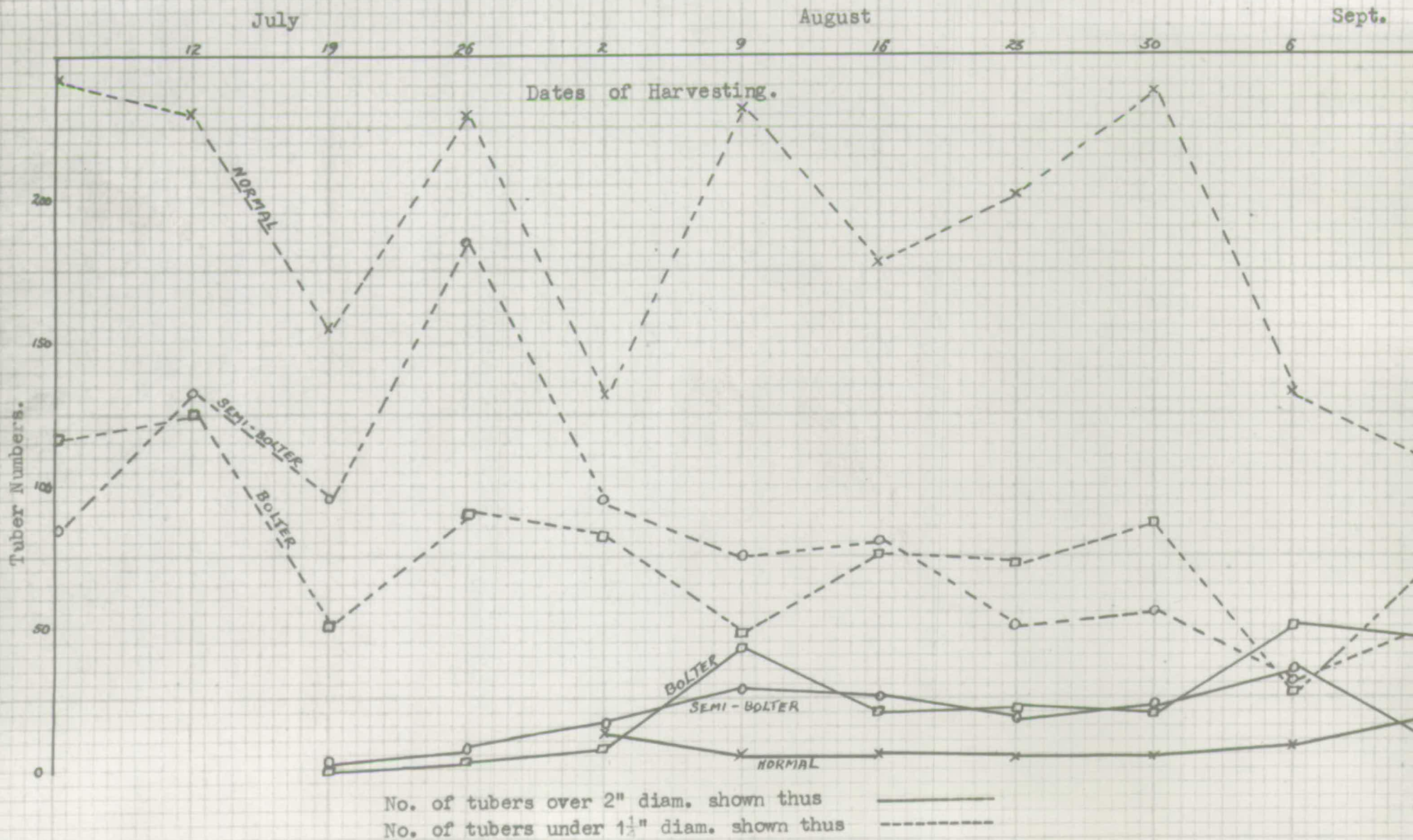


Fig. 6 - YIELD OF TUBERS FROM EQUIVALENT NUMBERS OF NORMAL, SEMI-, AND FULL BOLTERS OF ARRAN PILOT HARVESTED AT WEEKLY INTERVALS-1947.

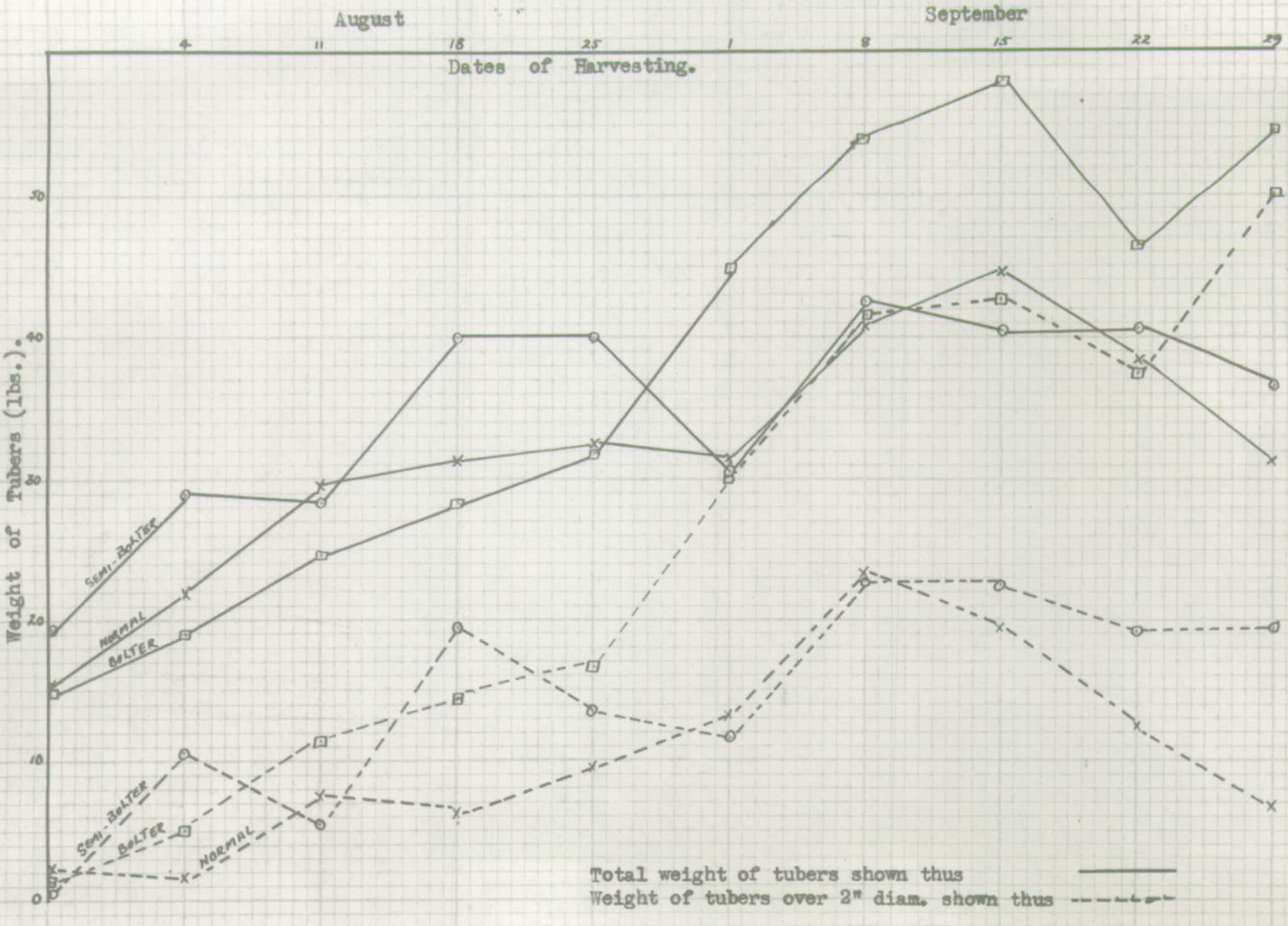
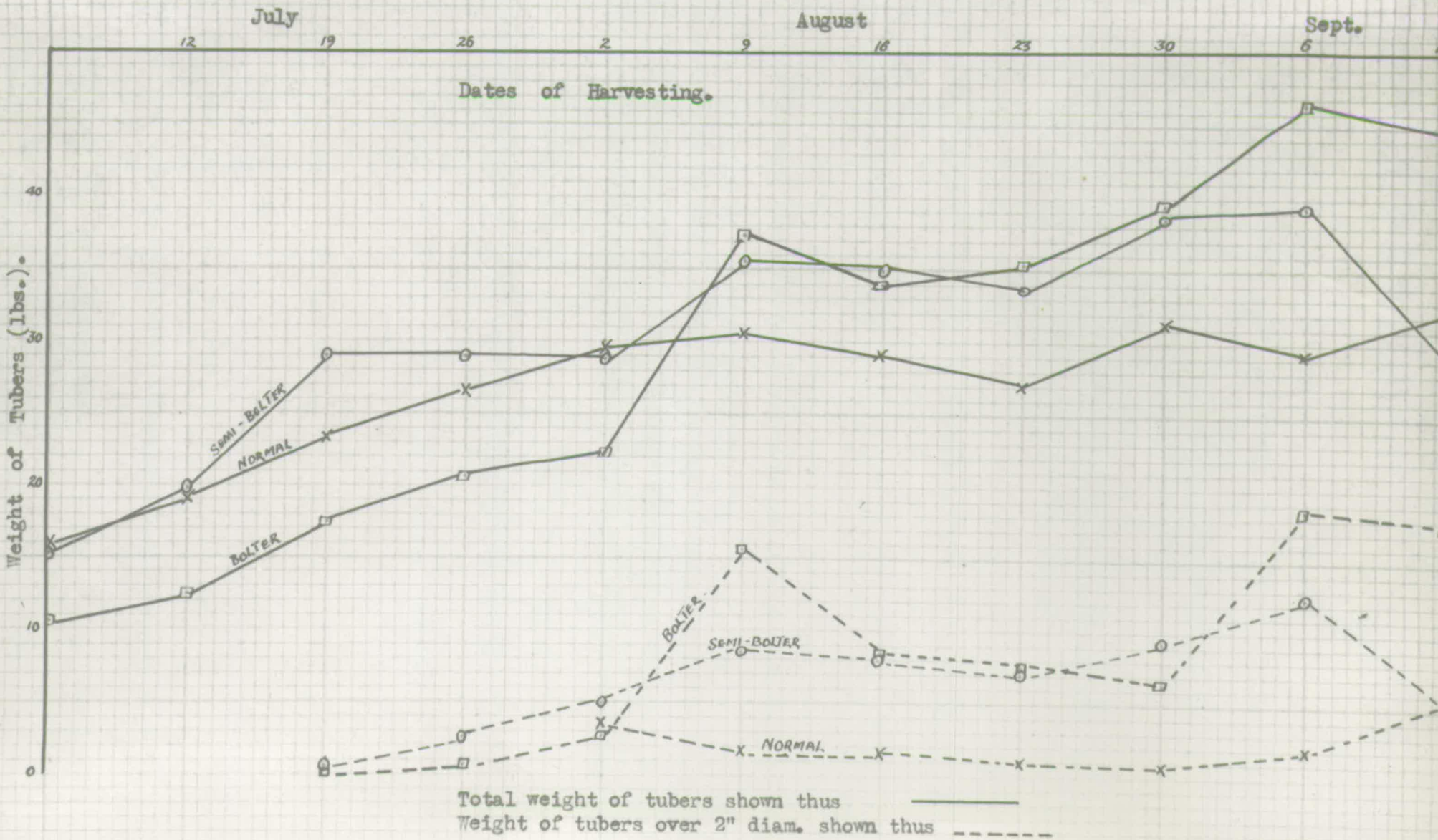


Fig. 7 - YIELD OF TUBERS FROM EQUIVALENT NUMBERS OF NORMAL, BOLTER, AND SEMI-BOLTER PLANTS OF ARRAN PILOT HARVESTED AT WEEKLY INTERVALS-1948.



Total weight of tubers shown thus ——————
Weight of tubers over 2" diam. shown thus - - - - - -

Rate of Tuber Production and Development in Normals, Semi-bolters and Bolters

Material and Methods

In 1947 and 1948, on the 8th May and 5th April respectively, large plots of some 300 plants of each of the three types in the variety Arran Pilot were set out. The material for the investigation consisted of normal and semi-bolter tubers - the former saved from the selected stocks used in the "Frequency" experiment, the latter prepared by selection and propagated from 1944 to 1946 - with the addition of a specially selected stock of bolter tubers. Bolter plants are comparatively easy to identify when fully grown, hence the rigorous selection necessary to ensure uniformity and constancy of type in the normal and semi-bolter stocks was unnecessary in the preparation of the bolter material. Throughout the growing season, 20 plants of each condition were harvested at weekly intervals. The produce of each group of plants was graded by riddle and the weights, numbers and sizes of tubers recorded.

Results

The results are shown graphically in figures 2 to 7. Figures 2 and 3 show that the total numbers of tubers produced by normal and semi-bolter plants reached a maximum in 12 to 15 weeks from the date of planting and that thereafter, the total number of tubers remained fairly constant. Following on the period of maximum tuber production, the changes which apparently took place were

mainly /

mainly changes in the sizes of the tubers already formed, some remaining small and others increasing in size. The weekly decreases in the numbers of small tubers (under 1¼") subsequent to the period of maximum tuber production and the corresponding increases in the numbers of tubers over 2" in diameter are shown in figures 4 and 5. In the case of the bolter plants, the same trends were observed but the period of maximum tuber production was reached approximately 5 weeks after that of the normal and semi-bolter plants.

The data, therefore, indicate that tuber production is not a continuous process, but that most of the tubers are formed during the early part of the growing season. The increase in yield of a plant from week to week in the early period of growth, therefore, may be determined mainly by the rate of tuber production, but in the later period by the rate of development of the tubers previously formed. These observations are in agreement with the findings of Doncaster and Gregory (1948). Although the results are not statistically interpreted, they suggest that (a) the superior yields of normals and semi-bolters over the bolters in the early season (figures 6 and 7) may be, to some extent, the result of more rapid tuber production in the two former types (figures 2 and 3) and (b) that the superior yield of bolters in the late season may be due to more rapid development of the tubers previously formed. In the absence of more detailed work correlating the rate of tuber

production and development with the stage of growth of the plants, however, the limitations of the present preliminary investigation are realised.

The slight decrease in total weight of tubers towards the end of the growing season (figures 6 and 7) has been observed on several previous occasions. Doncaster and Gregory attribute this to the loss of water from the plant and tubers as the foliage begins to wither. The decrease in tuber numbers often noted towards maturity is likewise explained by assuming that some of the small tubers are re-absorbed as the plant ripens. These are likely explanations with which the present writer agrees.

Although the scope of this investigation was too limited to yield definite information regarding the optimum time for harvesting for seed purposes, it is clearly indicated that both the total yield and total number of tubers, produced by bolters at the time most early maturing varieties would be harvested (July - August), is markedly below that of semi-bolters and normals.

DISCUSSION

Before attempting to describe variations or to compare with the normal, their cropping capacities and general performance under field conditions, it is first necessary to ensure that the material used is uniformly of the required type. With most variations few difficulties arise in this regard, as their foliage characteristics are not readily confused with those of normal plants. The differentiation of bolters and semi-bolters from normals, however, is less easily accomplished. This is occasioned by the facts that (a) these types are only apparent in crops late in the season, (b) that they differ from the normal type only in detail and (c) that the habits of normal plants can be altered, by various cultural practices and manurial treatments, to resemble the taller habit of the semi-bolter. In short, there is no clear line of demarcation between the normal and semi-bolter or between the semi-bolter and bolter. It is, therefore, only by repeated cultivation over more than one season that the uniformity of stocks can be established.

It has been shown that most abnormal forms tend to produce smaller tubers and give poorer yields than normal plants. During grading operations, the produce of these aberrant types becomes distributed among the main bulk of the "seed" and as the various conditions are carried over

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to the progeny by vegetative propagation, they appear naturally in increasing numbers in successive crops. The fact that a crop is completely free from variations, in any one year, cannot be taken as an indication that the same desirable condition will hold in succeeding seasons. These variations arise spontaneously in crops and it has been shown in an earlier section that the semi-bolter type may arise de novo to the extent of .3%. While the mechanism responsible for the appearance of variations remains obscure, Whitehead, McIntosh and Findlay (1945) suggested that variations may be induced to occur in crops as a result of injury to the tuber "eyes". This theory has been accepted by Bewell of the Canadian Department of Agriculture, who (in a private communication) stated that normal and giant hill stems had been observed emerging from the same sett and that there was a distinct difference in the tuber types obtained from the normal and giant hill stems of the same seed tuber. Both normal and bolter stems have been observed by the present writer emerging from the same seed tuber in the varieties Gladstone and King Edward. The tubers from the individual stems, when harvested and planted separately in the following year, gave rise to both normal and bolter plants. No confirmatory evidence is available in support of this hypothesis and more research on the subject is required, but as variations can be produced artificially

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by excising the "eyes" of normal tubers, the explanation given may prove correct. To some, the problem may not appear serious and it is admitted that many variations have not yet appeared in such quantity as to cause serious alarm, but to the seed potato grower much trouble and expense is brought about by the regular appearance of bolters, semi-bolters and wildings in crops. The question of the effect of surface diseases such as skinspot (Oospora pustulans) and corky scab (Spongospora subterranea) on the occurrence of variations also requires to be investigated. Such fungi frequently attack the tuber "eyes", killing the buds completely and often resulting in the formation of callus growths similar to those obtained when the tuber "eyes" are excised. If such factors be concerned then, obviously, the frequency of occurrence of out-of-type plants will vary with the incidence of the causative disease.

In the improvement of potato stocks by plant selection, the choice of plants is normally decided by appearance and the type selected is an important factor if a high yielding stock is to be obtained. There are, however, other aspects which receive little attention and about which information is seriously lacking. Are there, for instance, differences in prolificness between apparently "normal" plants of the same variety, and are these differences related to seasonal growth conditions?

If one accepts the statement that a gradation of bolter types occurs between the normal and the extreme bolter, even although only one intermediate type, the semi-bolter, is at present recognised, then it is logical to assume that some types exist which are physiologically different but which so closely resemble the normal forms as to be indistinguishable from them by eye. The second question has a direct practical bearing on the present system of rejuvenating crops by raising stocks from single plants since, if individual "normal" plants differ in their requirements of conditions for maximum production, as practical experience suggests, then the raising of potato stocks from single plants may have disadvantages and to ensure a satisfactory crop under all conditions, stocks derived from mixed individuals may prove more satisfactory.

SUMMARY

1. Many foliage variations occurring naturally in potato crops are described and illustrated.
2. Their varietal distribution is discussed.
3. The nature of some abnormal types is investigated and those of a periclinal chimerical nature noted.
4. The rate of mutation, of tubers from normal plants, to the semi-bolter condition is investigated and provisionally noted at .3% in the variety Arran Pilot.
5. The yields of variations, excepting bolter and semi-bolter types, are noted as being generally inferior to those of normal plants.
6. A comparison of the cropping capacities of normals, semi-bolters and bolters is made and the rates of tuber production discussed.

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PART II

THE EFFECT OF CLIMATIC CONDITIONS AND CULTURAL PRACTICES IN SCOTLAND ON THE SYMPTOMS OF SOME VIRUS DISEASES OF THE POTATO

CONTENTS

INTRODUCTION

The scheme for the inspection of potato crops was first introduced in Scotland in 1918, by the Board (now Department) of Agriculture for Scotland, with a view to providing an adequate supply of reasonably pure stocks of potato varieties. It was not until 1932 that general health grading was begun and virus diseases taken into consideration in the award of crop certificates. At first, only the severe virus diseases such as leaf-roll and severe mosaic were included. From 1932 to 1936 the main improvement made in the scheme consisted of a lowering of the permitted tolerance of these diseases. In 1937, with the issue of a new higher grade certificate, mild mosaic was first introduced into the disease standards and officially recognised. From 1937 up to the present time the regulations governing the issue of health certificates have been gradually made more stringent in order to effect further improvements in the health of commercial potato stocks.

In all potato crop certification work, the virus disease content of the crops is assessed by visual examination of the plants. In this regard, inspectors recognise four grades of mild mosaic, viz., negligible mottle - which is disregarded for certification purposes - mild mosaic (lower limit), mild mosaic, and mild mosaic

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(upper limit). While the lower and upper limits are fixed degrees of severity, the designation "mild mosaic" includes a limited range of severity between these two extremes. Diseases showing symptoms more severe than those in the last-mentioned category are classed as severe mosaic.

The classification of diseases according to the severity of the symptoms seen may be open to criticism in the light of present day knowledge, but from the point of view of the working of a practical scheme, there is little room for improvement and it has been shown that the severity of the symptoms is a reasonable guide to the reduction in yield which the presence of the disease will cause. Scott (1941) has shown that infections with mild viruses or mild strains of virus may result in the yield of ware potatoes being reduced by from 16 to 40 per cent. Severe mosaic is shown to reduce ware yields by from 40 to 85 per cent. while leaf-roll results in a reduction in the ware of 75 to 90 per cent.

The operation of the potato inspection scheme has resulted in a marked change in the proportion of virus-infected plants in commercial crops. The scheme has served a useful purpose by reducing the incidence of severe diseases such as severe mosaic and leaf-roll and by removing the sources of further infection. As the symptoms of mild infections are less easily seen,

however, /

however, constant roguing of the more obvious diseased plants has resulted, unfortunately, in the unintentional selection of mild virus strains in the majority of commercial seed stocks.

The main weakness now apparent, in such a scheme, is seen as a direct result of this unintentional selection. As the mild symptoms of infection are unstable and often difficult to observe, differences in the health grading of related stocks of potatoes are of frequent occurrence. This is a most serious cause of discontent among growers who, often wrongly, attribute the differences to variation in the disease standards applied by the inspectors. It would seem that this anomaly must continue to exist until the health of potato stocks can be further improved to the extent of eliminating the mild viruses but this cannot be achieved by visual inspection of the crops.

Improvements, however, can be accomplished in two ways (a) by breeding immune or field-immune varieties and (b) by producing virus-free stocks from greenhouse tested plants. The former method is a long-term project which brings no quick solution to the present problem, but it is the only practical method which will produce satisfactory and permanent results. The propagation of stocks from virus-tested units also must be comparatively slow in effect. The success of this method depends on

a continual release of tested material to the growers since fresh infections will make their appearance in the field stocks. In the meantime, for the majority of growers, roguing and plant selection remain the only practical methods of improving the health of their potato crops but in dealing with the milder types of infection, great care must be exercised. While roguing and selection are unlikely to be completely satisfactory, the repeated removal of visibly diseased plants must lead to an improvement in the health of stocks particularly if attention is paid to the factors responsible for variations in symptoms. It was with a view to furthering this knowledge that the present investigation was undertaken.

One of the main factors leading to weaknesses in the present system of grading crops by visual examination is the existence of strains of virus X each of which may differ in the type and severity of symptom produced. Bawden (1946) states that "different strains may cause such dissimilar symptoms in the same plant, that from the appearance of the plants alone, one would not suspect any relationship". On the other hand, different viruses may produce similar disease symptoms (Bawden and Sheffield, 1944). The number of strains of virus X is doubtful, but Kohler (1949) puts the figure at 40. Further changes in symptoms occur as a

result /

result of the unstable nature of virus X itself. Mutants of the virus may arise from time to time, hence the appearance of diseased plants in a crop need not be the result of fresh infections, but may be caused by the segregation of a more virulent form from the virus previously present in the plants.

Minor difficulties in diagnosing virus symptoms may arise as a result of non-virus factors, such as frost or mineral unbalance, simulating disease symptoms. Such occurrences, however, would appear to be rare and in the fourteen years' experience of the writer of crop inspection work, only once has difficulty arisen through this cause. Cockerham (in a private communication) has mentioned one instance of the appearance of mosaic-like symptoms on a crop of Arran Pilot in 1931 and expressed the opinion that frost was the causal agent. McKay and Clinch (1945) have more recently produced circumstantial evidence of frost injury simulating virus mottles. They quote instances of crops, derived from certified seed, showing wholesale mottling of the foliages and indicate that this may have been due to the effect of near-zero or below-zero temperatures since glasshouse tests showed the affected plants to be free from virus or, in some instances, to contain only a very mild strain of virus X such as would be unlikely to result in the appearance of the severe symptoms seen. Other instances

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of non-virus factors - mainly of a manurial nature - causing mottling or rolling of the leaves of plants, have been recorded by various workers, notably Owen (1937), Rigot (1947), Dennis (1948) and Hanley (1949).

The apparent differences in the disease content of potato stocks of the same origin and the apparent variations in the standards applied by inspectors in grading the crops may be due to causes other than those mentioned. Amongst these are (a) differences in the efficiency with which roguing is carried out, (b) the effects of different environments under which the crops are grown and (c) differences in cultural methods used in producing the crops, e.g. time of planting, etc. It is understandable that the differences between stocks grown from similar seed may be the result of efficient roguing on the one hand and inefficient roguing on the other. The effects of environment and cultural practices on the apparent disease content of crops, however, are not well understood. The present work, therefore, has been undertaken to obtain further information on these factors.

The general effect of environment in causing symptoms to vary in severity, has been noted often but specific details are difficult to find in the literature. In 1947, a preliminary experiment was conducted, by the writer, to show that environment was responsible for apparent differences in the mosaic content of potato

crops /

crops grown from the same seed. A consignment of Majestic grade "H" seed was divided up and planted on six different farms in the counties of Angus and Kincardine. The differences at any one time in the amounts of visible mottle and mosaic, between the six centres, were very marked although it is clear the actual disease contents were fairly similar. The following year, when samples from each crop were grown together at the one centre, the percentages of visible mosaic were reasonably similar for all progenies regardless of date of examination. The results are given briefly below in Tables VII and VIII.

Table VII

Location of Crop, 1947	Maximum % observed during season		% on 21st August	
	1	2	1	2
Forfar	96	24	52	11
Fettercairn	93	27	81	27
Arbroath	90	26	58	18
Brechin	99	28	99	25
Menmuir	90	28	54	14
Carnoustie	75	13	72	13

Table VIII /

Table VIII

Location of Crop, 1948	Source of Stock	Maximum % observed during season		% on 9th August	
		1	2	1	2
East Craigs	Forfar	55	14	41	10
" "	Fettercairn	43	12	40	12
" "	Arbroath	63	16	52	16
" "	Brechin	54	11	42	11
" "	Menmuir	76	23	50	22
" "	Carnoustie	72	18	47	14

1 = % all mottles
2 = % mild mosaic

Davidson (1933) states that symptoms of mosaic infection are more clearly seen during periods of moist cloudy weather and that bright sunshine may completely mask virus mottles. It is uncertain whether this writer is referring to the difficulty of observing symptoms in bright sunshine or whether he suggests that the mottles actually become less severe and disappear altogether. However, as sunshine and air temperature are closely linked, it will be seen from the present investigation, that the latter is to be expected. In India, Vasudeva (1947) has observed that diseased plants may cease to show symptoms for a time but that later, symptoms may appear. Some preliminary work on the environmental effect on

symptoms /

symptoms has been conducted by Matthews (1949) who concludes that the factors concerned can cause variations in symptoms which are only equalled by the different manifestations of symptom severity resulting from the effect of different strains of virus.

From the work of others, it is observed that the symptoms of leaf-roll infection also are dependent on environmental factors for their true manifestation. Felton (1948) has shown that certain combinations of temperature and moisture may influence the time of appearance of symptoms and even mask the symptoms. It is shown that at temperatures around 60°F. to 70°F., leaf-roll symptoms appear quicker in wet than in dry soils. When temperatures are abnormally high, the appearance of symptoms may be delayed in plants grown on wet soils while those on dry soils may not show symptoms at any time.

Leaf-roll symptoms not resulting from virus infection have been the subject of a study by Le Clerg (1944) who mentions the difficulty of differentiating virus leaf-roll from non-virus leaf-roll towards the latter half of the growing season. He suggests that non-virus leaf-roll may be a heritable character but that the expression of rolling on the leaves may be dependent on environmental factors. Although this statement is not based on factual data, it seems to bear out observations made by crop

inspectors /

inspectors in this country during the summer inspections of potato crops. False-rolling is frequently encountered and seems to be a feature of certain varieties of which Gladstone is the best known. The condition is not always observed and is most prevalent in certain years and on certain soils particularly when dry conditions prevail.

The mechanism responsible for variations in symptoms is unknown and attempts to explain it are purely speculative. From the practical point of view, however, the nature of the process may not be of great importance but it would seem to merit investigation.

MATERIAL AND METHODS

The objectives aimed at in this investigation may be stated generally as follows:-

(a) to examine the effect of climatic factors on leaf-roll and mosaic symptoms.

(b) to examine the effect of time of planting on these disease symptoms and to correlate the symptoms with the age and stage of growth of the plants.

(c) to examine the effect of shading on disease symptoms.

Variety - For the purpose of the experiment, the variety of potato chosen was Majestic. There are three main reasons for this choice. Firstly, the variety is extremely popular with growers and widely cultivated. Secondly, it is susceptible to the leaf-roll virus and to virus X. The latter virus is mainly responsible for the mosaic diseases and exists in a number of strains which produce symptoms ranging from mild mottles to severe mosaics all of which are clearly expressed in Majestic.

Diseases - As aforementioned, the diseases investigated are the virus diseases, leaf-roll and mosaic. Symptoms of the former are reasonably stable and uniform when fully expressed, but the latter exhibits a range of severity of symptoms depending on the particular strain of the virus concerned. For test purposes, the different severities of

mosaic /

mosaic symptoms, ranging from slight to severe, were given the following designations:-

1. negligible mottle
2. mild mosaic (lower limit)
3. mild mosaic
4. mild mosaic (upper limit)
5. severe mosaic.

These are in keeping with the standards of symptom severity applied in grading crops for health under the scheme of the Department of Agriculture for Scotland.

Healthy plants derived from tubers, previously tested and found to be free from virus infection, were used as controls.

Selection of Material - During the summer of 1946 material for this investigation was selected from field crops of the variety Majestic. The selections included specimens of leaf-roll and a series of plants showing different severities of mosaic infection. Two types of symptom are generally recognised in leaf-roll (a) primary symptoms which are observed only during the growing season in which the plants first became infected and (b) secondary symptoms which appear each year thereafter. As the selections were made a year prior to that of the commencement of the investigation, it will be understood that throughout the investigation the leaf-roll symptoms discussed are of the latter type. The choice of mosaic-infected plants was decided by visual examination and no attempt was made to select according to the specific

viruses /

viruses or virus strains present in the plants although the mosaic symptoms were almost certainly due to virus X. The material selected in 1946 became the foundation of the whole of the investigation although fresh selections were made from its produce in 1947 and 1948 where contamination with leaf-roll had taken place.

Treatment - As no two tubers can be assumed to be alike in virus content even though derived from the same plant, each tuber to be planted was cut into 3 parts in orderthat the corresponding plants in the various plots could be developed from portions of the same parent tuber and, therefore, would be comparable. To ensure that the seed pieces were as nearly alike as possible, the cuts were made longitudinally from rose-end to heel-end in such a way that each portion was approximately of equal size and weight and had approximately the same number of eyes although, in previous preliminary experiments, it was observed that portions of the same tuber however cut, gave rise to plants with disease symptoms which, from visual examination, appeared to be similar. The possibility of spread of virus from tuber to tuber by the cutting knife was eliminated by sterilising the blade after each cutting. Each cut tuber was placed in a partitioned box and separated from its neighbours by sterile paper sheets. The cut pieces were prevented from drying-out by leaving a "hinge" of tissue uncut which served to hold the three parts of the

tuber /

tuber together, until planting time when they were broken apart. On completion of the cutting, the seed pieces were covered with damp sacking for 48 hours to facilitate healing of the wounds, then set aside to sprout. During the preparation of the material, the cut portions of the tubers were given identification marks. This enabled planting to be carried out in such a way that, during the growing season, the origin of each plant was known and plants derived from pieces of the same parent tuber could be compared.

Plot lay-out - In conducting the investigation into climatic effect in 1947, a series of plots was laid down at East Craigs, Corstorphine, and replicates planted at Boghall Farm, Lothianburn and Sweethope, Musselburgh. The corresponding plants at each centre were derived from portions of the same tuber. These sites were chosen as being sufficiently far apart to show some differences in climatic conditions while being close enough to enable the plants to be examined weekly and on the same day. The weather records for the three centres proved remarkably similar. Soil samples from each centre were analysed and manurial mixtures applied, at planting time, in such quantities as to make the manurial content of the soils as nearly alike as possible. It is realised that no two soils are alike or can be made identical by the application of fertilisers but as long as no serious deficiency existed at any one

place, the interference with plant symptoms was estimated to be negligible. In 1948 and 1949, the plots were located at East Craigs only.

To investigate the effect of date of planting, age of plant and stage of growth on disease symptoms, each portion of the same tuber was planted at the same centre but in separate plots and at different times. The same procedure was adopted in examining the effect of shade, except that all portions of the same tuber were planted at the same time and two of the three series of plots later shaded, the third being used as a control.

All the disease categories, previously mentioned, together with healthy controls were included in the plots in 1947 and 1948, 6 tubers of each category being used. In 1949, the groups classified as "mild mosaic (upper limit)" and "severe mosaic" were omitted, since the symptoms exhibited were too severe to enable variations to be recognisable. Each year, all plots were planted on the same day except, of course, those concerned with different times of planting. The planting plans given in figure 8 will serve to make the lay-out clear.

Methods of Recording Results - In making symptom observations on mosaic plants, particularly in different localities, the difficulty of making an accurate comparison was foreseen. To obviate this difficulty, "standard mosaic diagrams" were prepared. These diagrams, numbered

1 /

1 to 6, showed pictorially, the various severities of mosaic and could be carried from place to place thus ensuring that a uniform standard of symptom severity was applied in making comparisons. Elaborate notes were dispensed with in favour of tabulated charts on which were entered numbers from 1 to 6 according to the severity of symptom indicated by the appropriate diagram. As the disease symptoms in any mosaic group did not differ substantially in appearance between plants, it is not proposed to set down the results for each of the plants examined during the investigation (1,400), but specific figures indicative of the results obtained will be given. In the case of leaf-roll where symptoms are more uniform, charts were not required and only 4 stages in the development of the disease (indicated by the numbers 1 to 4) were recognised. In order to eliminate the personal element involved, the decisions of the writer were recorded by a second person thus making reference to previous notes impossible.

Meteorological Data - Rainfall, humidity, air and soil temperature records for each locality in which plots were grown, were kept, the data for Boghall and Musselburgh being augmented by information kindly supplied by H.M. Meteorological Office, Edinburgh.

Figure 8.

Plot Lay-out

Plot Series A	Plot Series B	Plot Series C	
1	1	1	
2	2	2	
3 ———	3 ———	3 ———	Negligible Mottle
4	4	4	
5	5	5	
6	6	6	
1	1	1	
2	2	2	
3 ———	3 ———	3 ———	Mild Mosaic (lower limit)
4	4	4	
5	5	5	
6	6	6	
1	1	1	
2	2	2	
3 ———	3 ———	3 ———	Mild Mosaic
4	4	4	
5	5	5	
6	6	6	
1	1	1	
2	2	2	
3 ———	3 ———	3 ———	Mild Mosaic (upper limit)
4	4	4	
5	5	5	
6	6	6	
1	1	1	
2	2	2	
3 ———	3 ———	3 ———	Severe Mosaic
4	4	4	
5	5	5	
6	6	6	
1	1	1	
2	2	2	
3 ———	3 ———	3 ———	Leaf-roll
4	4	4	
5	5	5	
6	6	6	
1	1	1	
2	2	2	
3 ———	3 ———	3 ———	Healthy (Control)
4	4	4	
5	5	5	
6	6	6	

1. To Examine Environmental Effect:-

   a) Lay-out as above.

   b) 1947 - A = East Craigs; B = Boghall;
   C = Musselburgh.

   1948 and 1949 - A, B and C at East Craigs.

   c) The corresponding plants in each disease category were derived from portions of the same tuber, e.g. in negligible mottle group A1 = B1 = C1 etc.

2. To Examine Date of Planting Effect:-

   a) Lay-out as above.

   b) A = early planted plots
   B = mid-planted plots
   C = late planted plots
   } Series A, B and C planted at same centre

   c) The corresponding plants were derived as explained in 1. above.

3. To Examine Shading Effect:-

   a) Lay-out as above.

   b) Series A and B shaded. Series C - control.

   c) Only 3 tubers of each disease category used instead of 6.

   d) The corresponding plants were derived as explained in 1. above.

Fig. 9 - WEATHER RECORD (EAST CRAIGS) 1947

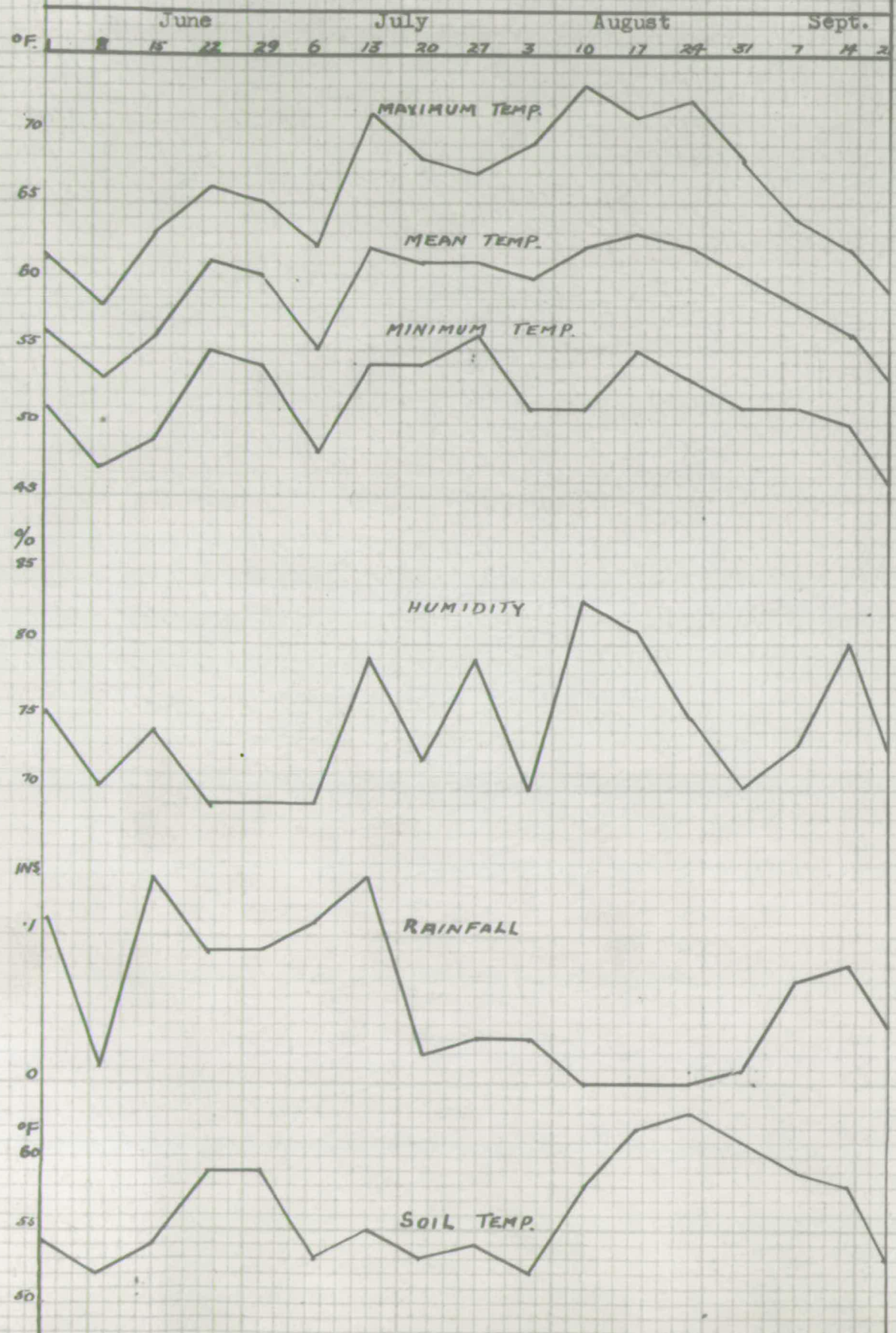


Fig. 10 - WEATHER RECORD (BOGHALL) 1947.

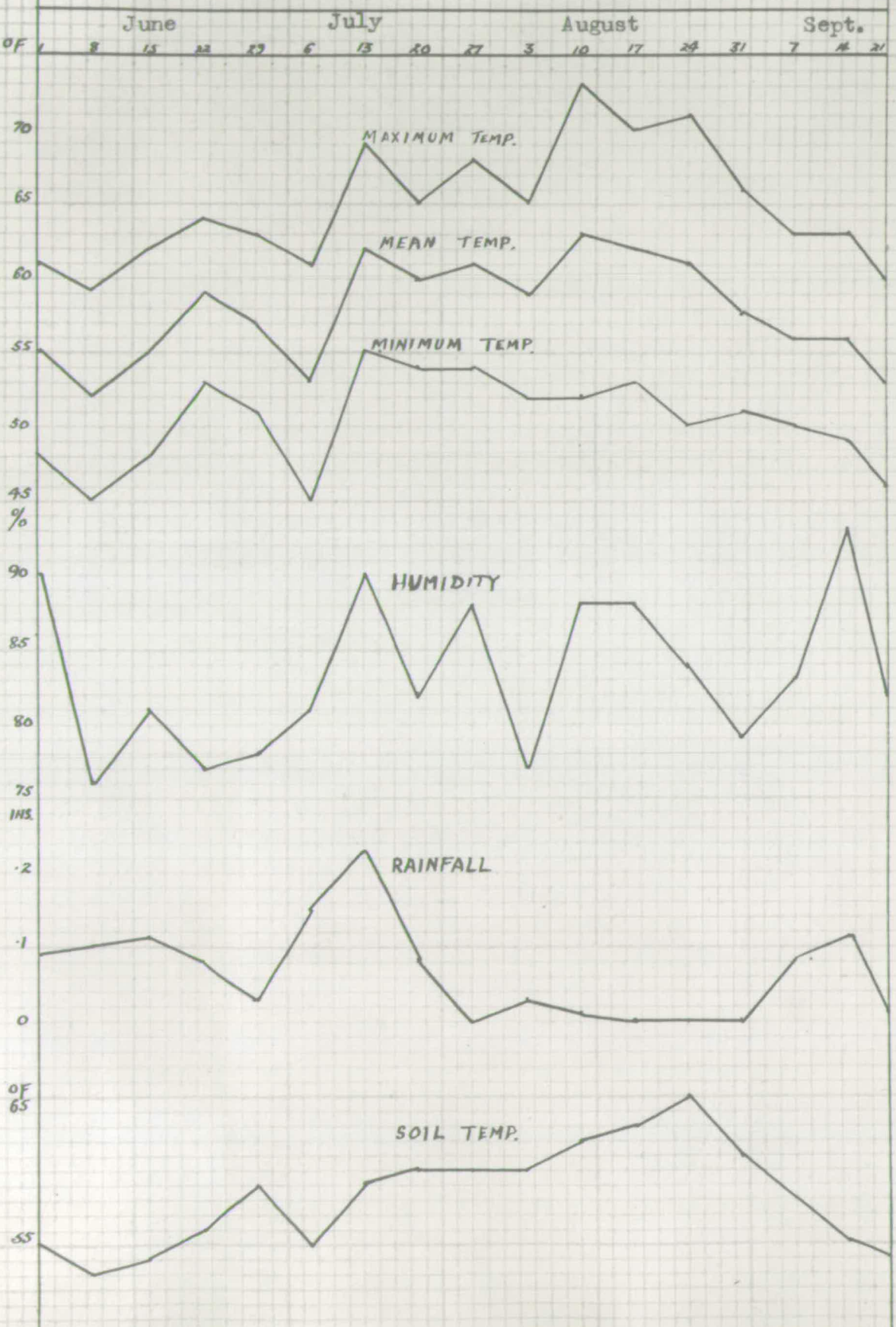


Fig. 11 - WEATHER RECORD (MUSSELBURGH) 1947.

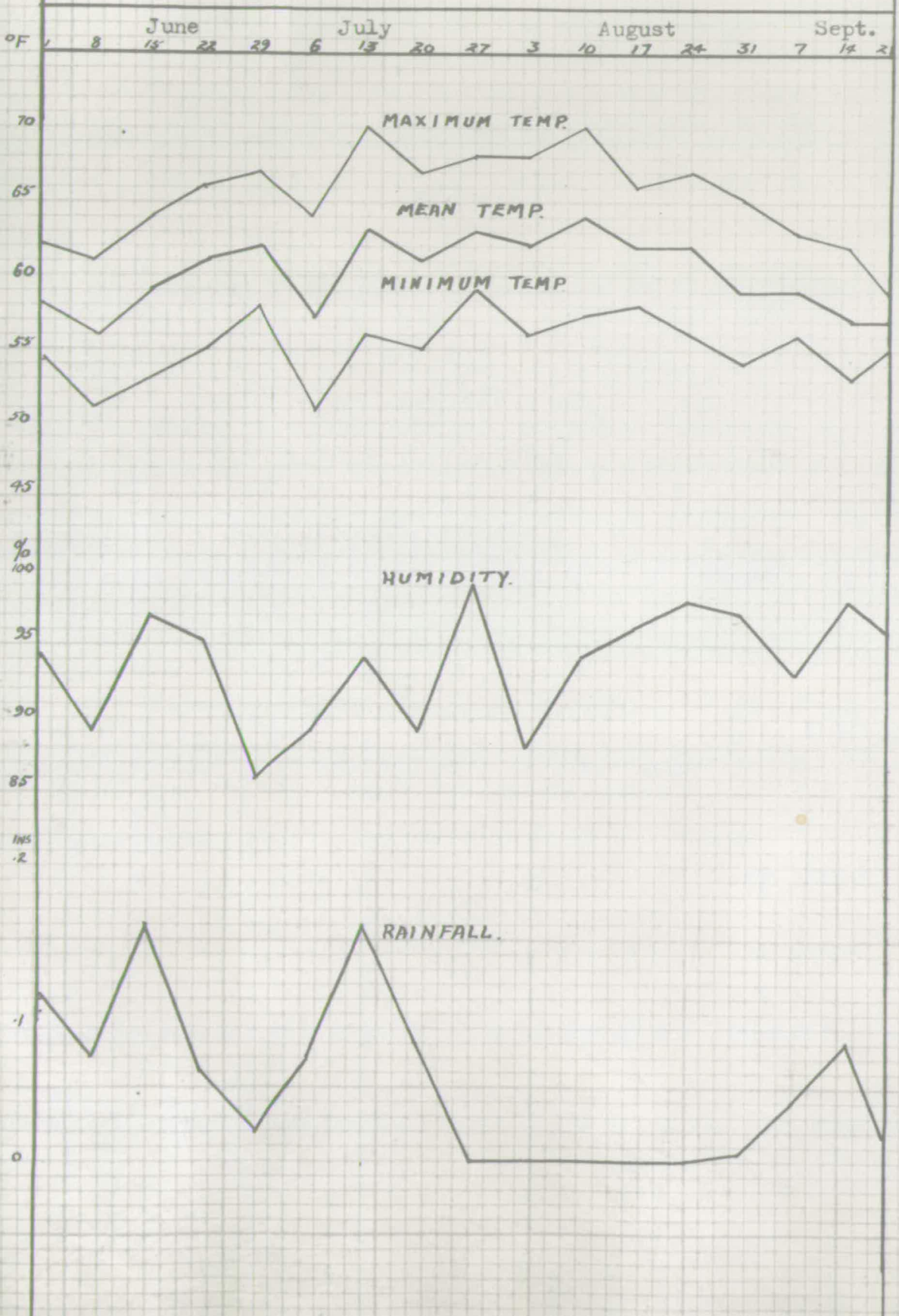


Fig. 12 - WEATHER RECORD (EAST CRAIGS) 1948.

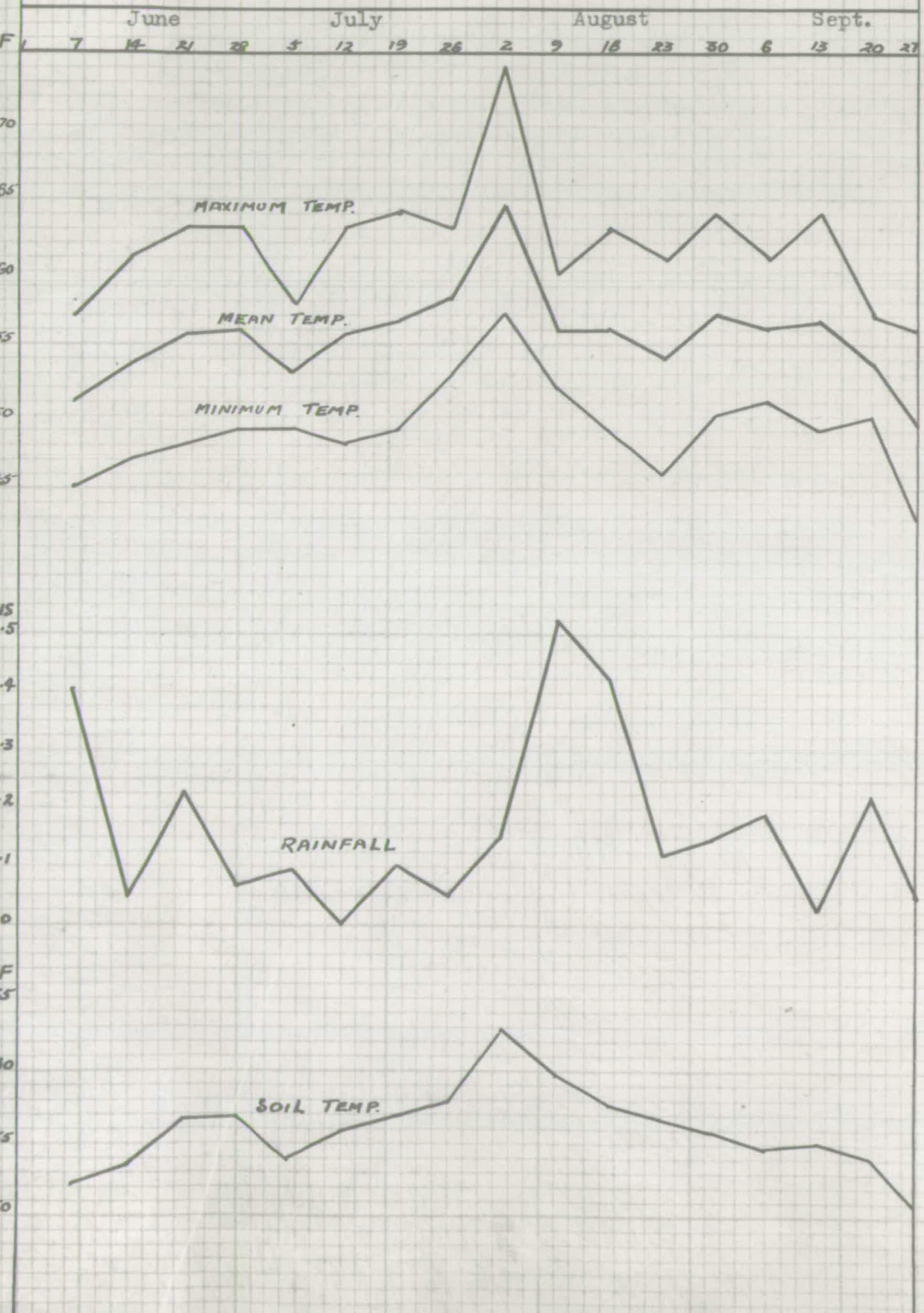
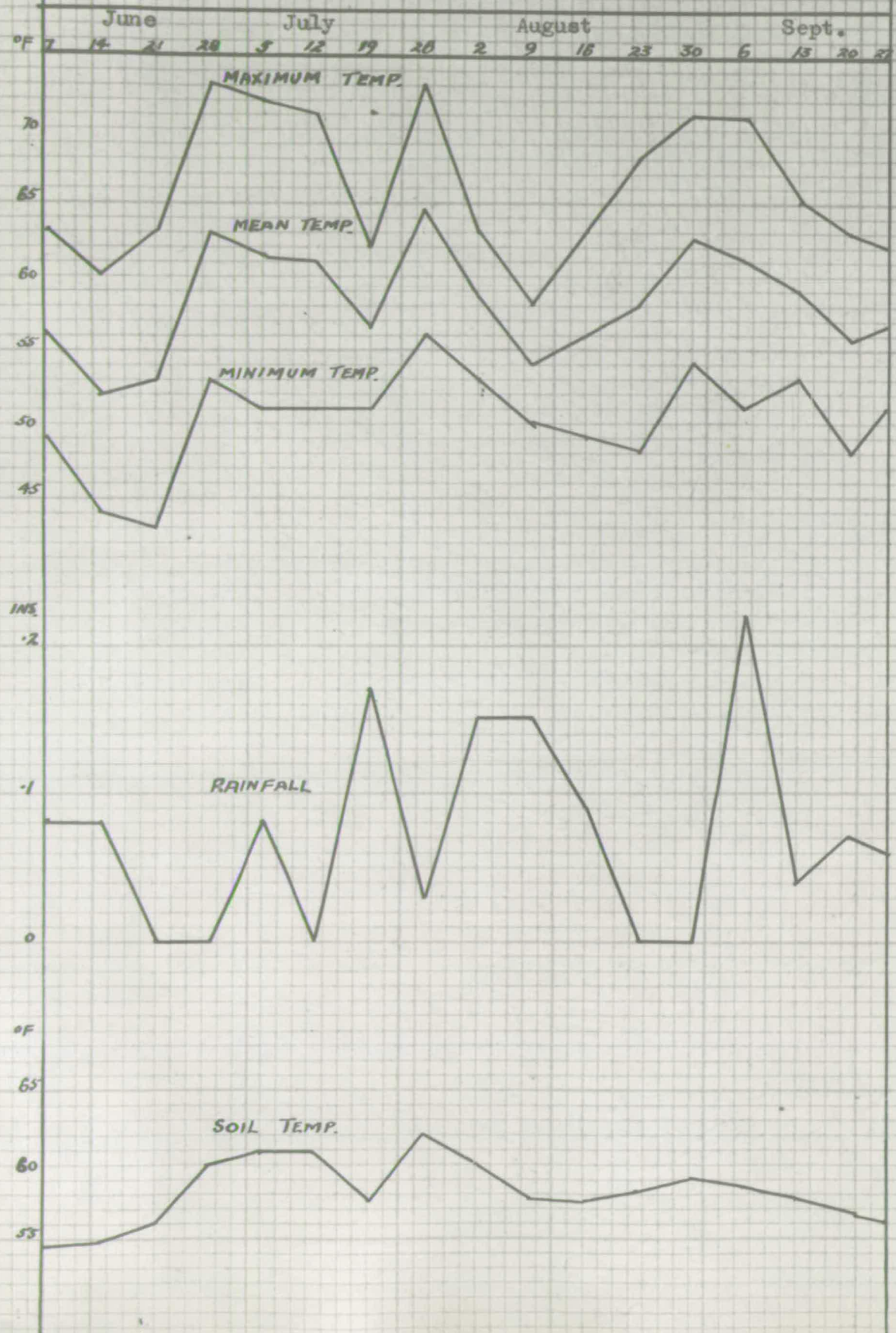


Fig. 13 - WEATHER RECORD (EAST CRAIGS) 1949



EXPERIMENTAL RESULTS

Effect of Some Climatic Factors on Disease Symptoms

This experiment was conducted to examine the effect of certain climatic factors on the disease symptoms of plants affected with leaf-roll and mosaic viruses. The method of planting is shown in figure 8. Six tubers of each of the mosaic disease categories, previously mentioned, with the addition of leaf-roll and healthy controls, were each cut into 3 portions. In 1947 one portion of each tuber was planted at East Craigs, the remaining two pieces being planted in replicate plots at Boghall and Musselburgh. The preparation of the seed pieces and the plot area has already been described under "Material and Methods".
In 1948 and 1949 one centre only was utilised in which case all 3 pieces of each of the cut tubers were planted in the same area but in 3 separate plots, however, as no significant differences in symptoms were apparent between the related mosaic plants, only one set of results are given. Weekly notes on the disease symptoms showing on the various groups of plants were made. During the course of the experiment, records of air temperature, soil temperature, rainfall and humidity were made. These data are shown in the graphs at figures 9-13.

For leaf-roll, the degrees of severity or the progress stages of the symptoms were indicated by the figures 1 to 4.

The /

The figure 1 was used to indicate very slight symptoms. Here the plants showed only an unnatural rigidity of the apical leaves which were carried stiffly upwards. The figure 2 was used where the symptoms were moderate in severity as shown by rigid top foliage on the plants and a diffuse yellow colouring on the apical leaves. Where the symptoms were severe as shown by stiffness and yellowing of the top foliage together with slight upward rolling of the edges of the leaflets of basal leaves of the plants, the figure 3 was used. Figure 4 indicated very severe symptoms. In this case all the previous symptoms were accentuated and the basal leaflets were markedly rolled and carried stiffly upwards.

To cover the wider range of symptoms in the mosaic infected plants, the different degrees of severity were indicated by the figures 1 to 6 where 1 indicated an almost invisible mottle, 6 very severe mottling and distortion of the leaflets, and figures 2 to 5 the various stages of mottle and/or distortion falling between the two extremes.

Leaf-roll

The symptoms appearing on the leaf-roll infected plants are given in Tables IX and X.

Table IX /

Table IX - Symptoms on Leaf-roll Infected Plants

Date	East Craigs						Musselburgh						Boghall					
	Plot A						Plot B						Plot C					
	Plant No.						Plant No.						Plant No.					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1947																		
June 24	0	0	0	0	0	0	2	0	0	0	1	1	1	0	1	1	0	0
July 1	0	0	3	3	3	2	2	0	2	2	2	2	2	1	3	3	1	1
" 8	2	2	3	3	3	3	3	2	3	2	3	3	3	1	3	3	1	3
" 15	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 22	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 29	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Aug. 5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 12	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 19	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 26	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Sept. 2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 9	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 16	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 23	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

The figures in Tables IX, X, XIV, XV and XXI are used to indicate the degree of severity, the extremes being:- 1 - "very slight" (slightly rigid) and 4 - "very severe" (complete rolling of lower leaflets and stiffness and yellowing of apical foliage). The figure 0 indicates that no symptoms were apparent on the date examined. Blank spaces indicate that the plants had not emerged.

Table X /

Table X -

Symptoms on Leaf-roll Infected Plants at East Craigs

Date	Plot A						Plot B						Plot C					
	Plant No.						Plant No.						Plant No.					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1948																		
June 22	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1
" 28	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
July 6	3	3	3	2	2	3	3	3	3	2	3	3	3	3	3	3	3	3
" 13	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 19	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
1949																		
June 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
" 27	1	4	4	1	4	4	4	4	4	4	4	4	4	4	4	4	4	4
July 13	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 19	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 25	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

The tables show that in 1947 and 1948 the symptoms increased in intensity during the first three weeks of observation at each centre and that there were no marked differences between the centres or between related plants at the same centre (East Craigs 1948). At all centres the stage of full development of secondary leaf-roll (grade 4) was reached in 4 weeks from the time of emergence of the plants and was maintained thus to the end of the season. In 1949 the intermediate severities of symptoms were not observed but as two weeks elapsed between the first and second observations, such symptoms may have appeared though only for a short time. Apart from a gradual increase in symptom severity, no variations in symptoms were observed although fluctuations in air temperature, soil temperature and rainfall occurred.

Reference /

Reference to the data for plots grown at East Craigs during the three years of the experiment, shows a difference in the time of appearance and rate of development of symptoms between the years. These differences are clearly shown in Table XI.

Table XI - Yearly Differences

Year	Date Planted	Weeks from planting to appearance of full symptoms	Progress of Symptoms			
1947	15th May	8	-	2-3	3	4
1948	14th April	12	1	2	3	4
1949	19th April	9	-	1-4	4	4

In 1947 the development of symptoms from nothing visible to stage 4 occupied a period of 4 weeks. In 1948 the symptom severity rose from stage 1 to stage 4 in the same period of time. In 1949, however, the symptom severity increased more rapidly rising from nothing visible to full secondary symptoms in only two weeks.

Conclusions - The meteorological data given in the graphs in figures 9-13 seem to indicate that conditions existing during 1949 were more suited to rapid plant growth than were the conditions during the 1947 and 1948 growing seasons when the air and soil temperatures were somewhat lower.

It would seem, indeed, that climatic conditions, through their effect on growth and development of the potato plant, may cause marked seasonal variations in the time of onset of typical secondary leaf-roll and also have

a retarding or accelerating effect on the progress of symptom development. After symptoms are well established, however, the typical grade 4 symptoms appear to be unaffected by day to day changes in the weather.

Mosaic

The results of the observations made on the various categories of mosaic infected plants are given in Tables XII and XIII.

Table XII - Symptoms on Mosaic Infected Plants

Date Examined	East Craigs				
	Negligible Mottle	Mild Mosaic (lower limit)	Mild Mosaic	Mild Mosaic (upper limit)	Severe Mosaic
1947					
June 24	0	0	1	5	6
July 1	1	1	2	5	6
" 8	1	2	3	5	6
" 15	0	1	3	5	6
" 22	1	1	3	5	6
" 29	2	3	4	5	6
Aug. 5	1	2	4	5	6
" 12	1	2	3	5	6
" 19	3	3	4	5	6
" 26	2	3	3	5	6
Sept. 2	2	1	3	5	6
" 9	2	3	4	5	6
" 16	2	3	4	5	6
" 23	2	3	4	5	6
1948					
June 22	0	1	2	5	6
" 28	1	2	3	5	6
July 6	2	3	3	5	6
" 13	2	3	3	6	6
" 19	3	3	4	6	6
" 26	3	3	4	6	6
Aug. 3	2	3	4	6	6
" 10	4	4	4	6	6
" 17	3	3	4	6	6
1949					
June 13	0	1	1	-	-
" 27	0	0	0	-	-
July 13	0	3	3	-	-
" 19	0	4	3	-	-
" 25	0	3	3	-	-
Aug. 2	0	4	3	-	-
" 16	0	3	3	-	-

The figures shown in Tables XII, XIII, XVII, XVIII and XIX indicate the degree of severity, the extremes being:- 1 - "very slight mottle" and 6 - "very severe mottle accompanied by puckering of the leaflets". The figure 0 indicates no symptoms. A blank space indicates that the plants had not emerged.

Table XIII - Symptoms on Mosaic Infected Plants

Date Examined	Boghall				
	Negligible Mottle	Mild Mosaic (lower limit)	Mild Mosaic	Mild Mosaic (upper limit)	Severe Mosaic
1947					
June 24	1	0	2	5	6
July 1	1	1	3	5	6
" 8	1	1	2	5	6
" 15	1	2	2	5	6
" 22	2	3	4	5	6
" 29	2	3	4	5	6
Aug. 5	2	3	4	5	6
" 12	1	2	4	5	6
" 19	2	3	4	5	6
" 26	3	3	4	5	6
Sept. 2	2	3	4	5	6
" 9	2	4	4	5	6
" 16	3	4	4	5	6
" 23	3	4	4	5	6
	Musselburgh				
1947					
June 24	0	0	2	5	6
July 1	0	1	3	5	6
" 8	1	2	3	5	6
" 15	1	2	3	5	6
" 22	1	2	3	5	6
" 29	3	3	4	5	6
Aug. 5	2	3	3	5	6
" 12	2	3	3	5	6
" 19	2	3	3	5	6

The /

The closest correlation was observed when air temperature and symptom severity were compared. Soil temperature and rainfall appeared to have little effect on the symptoms although those two factors at times showed a certain correlation with the air temperature which is, no doubt, partly determined by the temperature of the soil and the amount of rain falling. Repetition of the experiment, using equipment which would permit of these factors being controlled independently of each other, would probably show further correlations.

If the air temperature curves are compared with the mosaic figures listed in Tables XII and XIII, the effect of air temperature fluctuations on the symptoms of mosaic diseased plants will be seen. In the early stages of growth when the plants were only a few inches high, examination of the symptoms was difficult since the leaves were not completely unfolded and results, therefore, were not very reliable. As the plants became better established, however, the symptoms were easier to detect by visual examination.

Considering, first, the results obtained on the plots located at East Craigs in 1947 (Table XII) it was observed that a fall in the air temperature between the 24th June and the 8th July corresponded with an increase in the severity of symptoms on plants in the "negligible mottle", "mild mosaic (lower limit)" and "mild mosaic" categories.

Symptoms /

Symptoms of a more severe type showed no perceptible change. Between the 8th and 15th July the temperatures rose steeply. This was reflected in the reduction of symptoms on the plants particularly in the lowest grade of mosaic where the symptoms completely disappeared. During the week ended 22nd July, the temperature dropped and a reappearance of symptoms was observed on the plants in the lowest group without any perceptible difference in the severity of symptoms on the other groups of plants. As the temperature continued to drop, however, the effect became visible on the "mild mosaic" group of plants also. The rise of temperature between the 29th July and the 12th August again resulted in a falling off of symptoms, but the fall in temperature during the following week caused a reappearance of stronger symptoms. From the middle of August until the end of September, there were minor fluctuations in temperature but the general trend was one of steady decrease until the end of the month. During this time, the symptoms showed little variation. The plants were then fairly mature and showing signs of ripening.

During the investigations of 1948, a similar correlation between air temperature and mosaic symptoms was observed. From the 28th June to the 6th July, the symptoms on the plants showed a gradual increase in severity. This corresponded with a drop of 5°F. in the

average weekly maximum temperature. The gradual rise in temperature up to the 26th July appeared to have little effect on the symptoms but those on the milder infected plants were reduced during the week ended 2nd August when the temperature rose steeply. This was followed by an increase in the severity of the symptoms during the following week when the mean temperature dropped almost 9°F. A slight rise in temperature between the 9th and 16th August resulted in a lessening of the symptoms on plants with mild virus infections, by which time the plants were ripening and the yellowing of the foliages made the identification of mosaic difficult and further observations unreliable.

In 1949, the summer temperatures were comparatively high and it was observed that at no time during the season did mosaic symptoms, however mild, appear on any of the plants originally classed in the "negligible mottle" category. The slight symptoms which were apparent on the plants in the "mild mosaic" group completely disappeared between the 13th and 27th June. During this period, the air temperature had risen considerably and the average maximum temperature for the week had reached 73°F. By the 19th July severe symptoms had appeared on many of the plants corresponding to a drop in temperature. For the remainder of the growing season the symptoms remained fairly stable and the plants

ripened off early on account of the dry conditions prevailing.

During 1947, apart from minor differences, the weather data recorded at Boghall and Musselburgh were remarkably similar to those noted at East Craigs. At these centres, the effect of temperature fluctuations on mosaic symptoms was again evident although the variations in symptoms were less marked. Again the greatest variation appeared in the less severely infected plants. The changes in symptoms were often so slight that, although apparent to the eye, they were difficult to record by means of the standard figures used throughout the experiment.

At Musselburgh, the open sandy nature of the soil resulted in the plants suffering from drought during the latter part of the season and as the plants became limp and difficult to examine, the observations were discontinued.

Conclusions - During the course of the investigation, it was evident that climatic changes had a much greater influence on mosaic symptoms than on leaf-roll symptoms. The symptoms of the latter disease, once established, did not vary with climatic conditions but mosaic symptoms appeared to be much less stable. It is noted from the results obtained that high air temperatures tended to suppress mosaic symptoms while the symptoms appeared to

increase in intensity as a result of a drop in temperature. The figures also show that the milder symptoms were more subject to variation, as a result of fluctuating air temperatures, than were those of the more severe infections. Whether the changes in symptoms coincided with, or followed after a time, the fluctuations in temperature was not ascertained in the present investigation as records were made only at weekly intervals. When observing symptoms of mosaic, it was noted that the variations in the severity of symptoms occurred more readily on the foliage at the apex of the plants and that symptoms on the older leaves showed narrower limits of variation. On occasions when the symptoms on the top foliage disappeared completely, mottles were still in evidence on the lower leaves although the severity of the symptoms had been reduced. It is suggested that this is probably due to the amount of daylight which is able to penetrate the dense foliage of a potato crop in full leaf and to the fact that the apical foliage is young growth. It will be shown in a later section that shade may intensify symptoms and that symptoms appear to be less stable when the plants are young. Plants in the categories "mild mosaic (upper limit)" and "severe mosaic" showed symptoms so severe that variations in climatic conditions appeared to have little effect on their expression as far as visual observations could ascertain.

Certainly, /

Certainly, if any change did take place, it was not apparent to the observer. The group of plants used as controls, remained completely free from any symptoms of disease, with the exception of two plants in the Musselburgh plots. These two plants latterly exhibited a very mild mottling of the leaves. A greenhouse analysis of the foliage, however, showed the presence of a mild strain of virus X indicating that the plants had become infected during the course of the investigation.

Effect of Time of Planting on Disease Symptoms

The lay-out of the plots used in this experiment is shown in figure 8. The material consisted of six tubers of each of the following disease groups, viz., leaf-roll, negligible mottle, mild mosaic (lower limit), mild mosaic, mild mosaic (upper limit) and severe mosaic. Healthy plants previously tested and found to be free from virus infection formed the control plot. As previously described, each tuber was cut into 3 portions, each seed piece being identified by the number 1, 2, 3, 4, 5 or 6 marked on it. The first series of plots consisted of one piece of each tuber, each group of 6 pieces forming a separate plot. The second and third series of plots were similarly made up from the two remaining pieces of each tuber. The plot lay-out was so designed, therefore, that 6 specimens of each disease group and

healthy control were included in each series of plots and the corresponding plants in each were derived from the same parent tuber. In 1947 this lay-out was replicated at East Craigs, Boghall, and Musselburgh and in 1948 and 1949 the experiment was repeated at East Craigs. Each series of plots was planted on different dates. The time elapsing between the plantings varied from 1 to 4 weeks.

The method of recording results was as described under "Material and Methods". Notes on the severities of the symptoms were made at regular intervals.

Leaf-roll

The results of observations made on the leaf-roll plots are given in Tables XIV, XV and XVI.

Table XIV /

Table XIV - Date of Planting Related to Leaf-roll Symptoms

Date Examined	East Craigs																	
	Plot A Planted 15.5.47						Plot B Planted 9.6.47						Plot C Planted 23.6.47					
	Plant No.						Plant No.						Plant No.					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1947																		
June 24	0	0	0	1	0	0												
July 1	0	1	3	3	0	0	0	0	0	0	0	0						
" 8	1	3	3	3	3	3	0	0	0	2	2	2						
" 15	4	4	4	4	4	4	0	2	0	2	2	2	0	0	0	0	0	0
" 22	4	4	4	4	4	4	0	4	0	2	4	2	0	0	0	2	0	0
" 29	4	4	4	4	4	4	4	4	4	4	4	4	3	3	4	4	3	3
Aug. 5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 12	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 19	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Planted 14.4.48						Planted 12.5.48						Planted 9.6.48					
1948																		
June 22	1	1	1	1	1	1	0	0	1	1	0	1						
" 28	2	2	2	2	2	2	2	2	2	2	2	2						
July 6	3	3	3	3	3	3	2	2	3	3	2	3	2	2	2	2	0	0
" 13	4	4	4	4	4	4	3	3	3	4	3	4	2	2	2	2	2	2
" 19	4	4	4	4	4	4	4	4	4	4	4	4	2	2	2	2	2	2
" 26	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	4
Aug. 3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 10	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 17	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Planted 19.4.49						Planted 26.4.49						Planted 3.5.49					
1949																		
June 13	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1
" 27	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
July 13	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 19	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
" 25	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Table XV /

Table XV - Date of Planting Related to Leaf-roll Symptoms

Date Examined	Plot A Planted 15.5.47						Plot B Planted 9.6.47						Plot C Planted 23.6.47					
	Plant No.						Plant No.						Plant No.					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
	Boghall																	
1947																		
June 24	0		0	0		0												
July 1	0	0	0	3	3	0	0	0	0	0	0	0						
" 8	2	2	0	3	3	0	0	0	0	0	0	0						
" 15	4	3	4	4	4	4	0	1	4	1	0	3	0	0	0	0	0	0
" 22	4	4	4	4	4	4	0	1	4	1	3	3	0	0	0	0	0	0
" 29	4	4	4	4	4	4	4	4	4	4	4	4	2	2	0	2	2	3
Aug. 5	4	4	4	4	4	4	4	4	4	4	4	4	2	2	3	2	2	3
" 12	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	Musselburgh																	
1947																		
June 24	0	0	0	0	0	0												
July 1	0	0	0	1	0	0	0	0	0	0	0	0						
" 8	1	3	2	2	2	2	2	0	0	1	0	0						
" 15	3	3	3	4	4	4	3	1	3	1	1	1	0	0	0	0	0	0
" 22	4	4	4	4	4	4	4	1	3	1	1	3	0	0	0	0	0	0
" 29	4	4	4	4	4	4	4	4	4	3	3	4	0	1	0	1	1	1
Aug. 5	4	4	4	4	4	4	4	4	4	3	3	4	0	3	2	3	3	3
" 12	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Table XVI /

Table XVI - Date of Planting Related to Time of Appearance of Leaf-roll Symptoms

Plot	Date Planted	Stage of Severity	Time of Appearance		
			East Craigs	Boghall	Musselburgh
A	15.5.47	1	40 days	46 days	47 days
		4	60 "	61 "	61 "
B	9.6.47	1	29 "	36 "	29 "
		4	43 "	50 "	43 "
C	23.6.47	1	29 "	36 "	36 "
		4	36 "	49 "	43 "
A	14.4.48	1	69 "		
		4	90 "		
B	12.5.48	1	41 "		
		4	62 "		
C	9.6.48	1	27 "		
		4	55 "		
A	19.4.49	1	55 "		
		4	85 "		
B	26.4.49	1	48 "		
		4	78 "		
C	3.5.49	1	40 "		
		4	70 "		

Time of Appearance of Leaf-roll Symptoms from Date of Planting

Consider first the results obtained from the 1947 investigation. At all three centres, plot A was planted

on /

on 15th May. The second planting (plot B) was carried out after a lapse of 25 days from the date of the first planting and plot C was set out 14 days later or 39 days after the first planting. From Tables XIV and XVI, it will be seen that in Plot A the appearance of symptoms at East Craigs was noted in 40 days from the date of planting and that the fully developed symptoms were evident 20 days later. In Plot B, the first symptoms of leaf-roll were apparent 29 days after planting and 14 days later the stage of full development of secondary leaf-roll had been reached. The first leaf-roll symptoms appeared on plants in plot C in a similar time from the planting date to those in plot B but the maximum severity of symptom was noted 7 days later as compared with 14 days in the case of plot B.

At Boghall (Tables XV and XVI) symptoms on all plots were later in appearing than at East Craigs by approximately one week although the plots had been planted on the same days at both centres. In 46 days from the date of planting, symptoms began to appear on the plants in plot A and in 61 days full development of secondary leaf-roll symptoms was noted. In plot B, the first appearance of symptoms of leaf-roll infection showed 36 days after planting, followed 14 days later by complete rolling of the lower leaflets of the plants. The first symptoms on plants in plot C appeared in 36 days as did

those in plot B and the full symptoms were observed 13 days later.

At Musselburgh (Tables XV and XVI), variations in the time of appearance of symptoms, similar to those observed on the plots at the other two centres, were recorded. In plot A, the first signs of the disease were apparent 47 days from the planting date and the fully developed symptoms of secondary leaf-roll appeared 14 days later. The symptoms in plot B appeared in 29 days and reached full expression in 43 days. Although the first symptoms on plants in plot C were later in appearing than those in plot B, symptoms were fully expressed in the same number of days from planting, viz. 43 days. When the plots were located at East Craigs in 1948 and 1949, the times of appearance of leaf-roll symptoms on plots A, B and C showed similar variations (Table XVI). Both the initial symptoms and the fully developed symptoms of secondary leaf-roll appeared on the plants in less time from the date of planting, in the later planted plots.

Rate of Progress of Leaf-roll Symptoms - The data given in Table XVI show a marked correlation between the date of planting and the time of appearance of symptoms whether mild or severe and also indicate that the time of planting may have some effect on the rate of progress of the disease. Tables XIV and XV show that all 4 stages of severity were not always recorded on all plants. As the

notes /

notes on the symptoms were made at intervals of one week or longer, it is suggested that the advance of symptoms was probably so rapid in some instances that, occasionally, some of the intermediate stages were missed. The rate of progress of the symptoms, however, can be judged by observing the length of time taken for the symptoms to advance from the initial mild stage to the final severe stage. In Table XVI, the data recorded at East Craigs in 1947 show that in plot A, which was planted on the 15th May, 20 days elapsed between the time the symptoms were first evident and the time they had reached the upper extreme. In the later planted plot B, the symptoms were fully developed in 14 days from the time of their appearance while in plot C the symptoms covered the full range in 7 days. The results recorded at the other two centres showed the same tendencies although the differences were not so marked.

Conclusions - It is concluded, from the results obtained that, in effect, late planting results in a quicker appearance of disease symptoms from the time of planting and hastens the progress of the symptoms through the several stages of severity. It cannot be deduced, however, that the date of planting is the main factor concerned in deciding the time of appearance of symptoms or the rate of progress of the disease. It may be that the rate of growth of the plants is the major deciding

factor /

factor and this in turn will be controlled largely by the prevailing environmental conditions. Later planting, provided this operation is not carried out when the season is too far advanced, usually coincides with climatic and soil conditions which are more congenial to plant growth.

Apart from the observation that the disease symptoms increased in severity as the plants aged, there did not appear to be any clear correlation between the age of the plants and the manifestation of the symptoms. Tables XIV and XV show that plants of different ages may exhibit similar symptoms.

During the experiment, it was noted also that the time of appearance of symptoms and the degree of severity did not appear to be determined by the stage of growth of the plants. In 1947, secondary leaf-roll symptoms appeared on the plants when the foliages were fully grown and the flower buds were being formed. In 1948 symptoms became visible when the plants were in full flower but in 1949 the appearance of symptoms coincided with a plant height of only 6" to 8" at which stage no flowering parts were visible. Plants derived from portions of the same parent tuber often showed identical degrees of severity of symptoms even when at different stages of development.

Mosaic

Mosaic

The data correlating mosaic symptoms and date of planting are given in Tables XVII, XVIII, XIX and XX. Unfortunately, the appearance of leaf-roll in the mosaic plots in 1948 and 1949 rendered the results invalid.

Table XVII - Date of Planting Related to Mosaic Symptoms

Date Examined	East Craigs														
	Plot A Planted 15.5.47					Plot B Planted 9.6.47					Plot C Planted 23.6.47				
	Negligible Mottle	Mild Mosaic (lower limit)	Mild Mosaic	Mild Mosaic (upper limit)	Severe Mosaic	Negligible Mottle	Mild Mosaic (lower limit)	Mild Mosaic	Mild Mosaic (upper limit)	Severe Mosaic	Negligible Mottle	Mild Mosaic (lower limit)	Mild Mosaic	Mild Mosaic (upper limit)	Severe Mosaic
1947															
June 24	0	0	2	5	6	0	0	0	0	0	0	0	0	0	0
July 1	0	1	2	5	6	0	0	0	0	0	0	0	0	0	0
" 8	1	1	3	5	6	1	1	3	2	4	0	0	0	0	0
" 15	1	3	3	5	6	1	1	2	5	6	0	0	3	4	0
" 22	1	3	3	5	6	1	2	3	5	6	1	1	3	5	6
" 29	2	3	3	5	6	2	2	3	5	6	1	2	3	5	6
Aug. 5	2	3	3	5	6	1	2	3	5	6	0	1	3	5	6
" 12	1	3	3	5	6	1	3	2	5	6	0	2	3	5	6
" 19	2	3	3	5	6	2	3	3	5	6	0	2	2	5	6
" 26	2	3	3	5	6	2	2	3	5	6	0	1	2	5	6
Sept. 2	2	3	3	5	6	2	3	3	5	6	0	1	2	5	6
" 9	2	3	3	5	6	2	3	3	5	6	1	2	2	5	6
" 16	3	3	3	5	6	2	3	3	5	6	2	2	3	5	6
" 23	3	3	3	5	6	2	3	3	5	6	2	3	3	5	6

Table XVIII /

Table XVIII - Date of Planting Related to Mosaic Symptoms

Date Examined	Boghall														
	Plot A Planted 15.5.47					Plot B Planted 9.6.47					Plot C Planted 23.6.47				
	Negligible Mottle	Mild Mosaic (lower limit)	Mild Mosaic	Mild Mosaic (upper limit)	Severe Mosaic	Negligible Mottle	Mild Mosaic (lower limit)	Mild Mosaic	Mild Mosaic (upper limit)	Severe Mosaic	Negligible Mottle	Mild Mosaic (lower limit)	Mild Mosaic	Mild Mosaic (upper limit)	Severe Mosaic
1947															
June 24	0	0	3	5	6	0	0	0	0	0	0	0	0	0	0
July 1	0	1	4	5	6	0	0	1	0	0	0	0	0	0	0
" 8	1	1	2	5	6	1	1	2	0	0	0	0	0	0	0
" 15	1	1	3	5	6	0	1	3	3	6	0	0	0	0	0
" 22	1	1	4	5	6	0	0	4	4	6	0	1	4	5	6
" 29	2	3	4	5	6	2	3	4	5	6	1	2	4	5	6
Aug. 5	1	1	3	5	6	1	2	3	5	6	0	0	2	5	6
" 12	1	2	3	5	6	1	2	3	5	6	1	1	3	5	6
" 19	2	3	4	5	6	2	3	3	5	6	1	1	4	5	6
" 26	2	3	3	5	6	2	2	3	5	6	0	1	4	5	6
Sept. 2	2	3	4	5	6	2	3	3	5	6	0	3	3	5	6
" 9	2	3	4	5	6	2	3	3	5	6	1	3	3	5	6
" 16	3	3	4	5	6	3	3	3	5	6	2	3	4	5	6
" 23	3	3	4	5	6	3	3	3	5	6	3	3	4	5	6

Table XIX /

Table XIX - Date of Planting Related to Mosaic Symptoms

Date Examined	Musselburgh														
	Plot A Planted 15.5.47					Plot B Planted 9.6.47					Plot C Planted 23.6.47				
	Negligible Mottle	Mild Mosaic (lower limit)	Mild Mosaic	Mild Mosaic (upper limit)	Severe Mosaic	Negligible Mottle	Mild Mosaic (lower limit)	Mild Mosaic	Mild Mosaic (upper limit)	Severe Mosaic	Negligible Mottle	Mild Mosaic (lower limit)	Mild Mosaic	Mild Mosaic (upper limit)	Severe Mosaic
1947															
June 24	0	1	1	5	5	0	0	0	0	0	0	0	0	0	0
July 1	0	1	1	5	6	0	0	0	0	0	0	0	0	0	0
" 8	0	2	2	5	6	0	2	2	2	3	0	0	0	0	0
" 15	1	2	3	5	6	1	2	2	4	5	0	0	0	0	0
" 22	1	2	3	5	6	0	3	3	4	6	0	2	3	3	2
" 29	1	3	4	5	6	2	3	3	5	6	1	3	4	5	6
Aug. 5	0	2	3	5	6	0	3	3	5	6	0	2	2	5	6
" 12	1	2	3	5	6	2	3	3	5	6	0	2	3	5	6
" 19	1	2	3	5	6	1	2	3	5	6	0	2	3	5	6

Table XX - Date of Planting Related to Time of Appearance of Mosaic Symptoms

Plot Series	Date Planted	Time of Appearance		
		East Craigs	Boghall	Musselburgh
A	15.5.47	40 days	40 days	40 days
B	9.6.47	29 days	22-29 days	29 days
C	23.6.47	22 days	22-29 days	29 days

Time of Appearance of Mosaic Symptoms - The results given are in keeping with those obtained for leaf-roll and show that, judged from the date of planting, symptoms of mosaic infection tended to appear quicker when planting was delayed.

Rate /

Rate of Progress of Symptoms - As mosaic symptoms appear to vary as a result of fluctuations in climatic conditions, any attempt to correlate the rate of progress of symptoms with the planting date must necessarily prove valueless under the present investigational conditions.

Age of Plants - Reference to Tables XVII and XVIII will show that, where the plots have been planted sufficiently early to enable the plants to have a reasonably long growing season and to reach maturity, most of the variations in symptoms took place between June and mid-August. Thereafter the symptoms remained fairly stable or continued to increase in severity but rarely became less severe. The young plants in plots C, however, continued to show variable symptoms.

Conclusions - The remarks made, under leaf-roll, regarding the effect of late planting on the time of appearance of symptoms, would apply to mosaic, viz., that the main factor deciding the time of appearance of symptoms may be the rate of growth of the plant as determined by environmental factors and that later planting merely coincides with environmental conditions which are conducive to rapid plant growth.

While there is nothing in the results obtained to suggest that the age of the plants is a factor directly concerned with the severity of symptoms appearing at any particular time, it would seem that the symptoms tend to

vary more when the plants are young. As they reach maturity, the symptoms become more stable and appear to be less affected by fluctuations in environmental conditions.

No correlation between stage of growth and severity of symptoms is indicated from the results. If, however, the minor variations in symptom severity are disregarded, it is observed that the symptoms increase in severity as the plants increase in age and it was generally noted, during the experiment, that the maximum severity of symptoms appeared when the plants had reached their full growth. This was mainly true of plants which were infected with the milder strains of virus. It will be noted by reference to Tables XVII, XVIII and XIX that infections with severe strains of virus resulted in the appearance of severe symptoms when the plants were comparatively young and that the symptoms appeared to remain unchanged as the plants increased in age.

The results listed in those same tables again show that symptom variations occur more readily on the mildly infected plants than on the plants infected with severe strains of virus.

Effect of Shade on Disease Symptoms

A preliminary field experiment was conducted at East Craigs to examine the effect, if any, of shade on symptoms. The test consisted of three series of identical plots A, B and C. The lay-out of the plots and the preparation of the material used here was exactly similar to that described under "Time of Planting". In this experiment, however, only three tubers of each disease group and healthy control were used and each of the three pieces of each tuber were planted in separate plots on the same day. Here, therefore, three plants constituted a plot and a plot-series consisted of seven 3-plant plots, viz., 1 plot of each of the six disease groups and 1 plot of healthy plants. The plots in series A and B were covered by sheets of hessian material. Series C, being the control set of plots, was untreated. The coverings were placed in position on 23.7.47 and removed on 5.8.47. The sheets were so adjusted as to restrict the light while maintaining, as closely as possible, the normal temperature conditions.

Leaf-roll

The results of observations made on the leaf-roll plots are given in Table XXI.

Table XXI /

Table XXI - Effect of Shade on Leaf-roll Symptoms

Date Examined	Plot A			Plot B			Plot C		
	Plant No.			Plant No.			Plant No.		
	1	2	3	1	2	3	1	2	3
1947									
June 24	1	1	1	1	1	1	1	2	1
July 1	1	1	1	1	1	1	1	2	1
" 8	2	2	2	2	2	2	2	2	2
" 15	3	3	3	4	3	4	4	4	4
" 22	4	4	4	4	4	4	4	4	4
" 29	3	0	0	3	1	3	4	4	4
Aug. 5	0	0	0	0	0	2	4	4	4
" 12	3	4	3	4	4	4	4	4	4
" 19	4	4	4	4	4	4	4	4	4
" 26	4	4	4	4	4	4	4	4	4

The table shows that, prior to covering the plots on 23rd July, all plants in each of the three plots were showing fully developed secondary leaf-roll symptoms (stage 4). By 29th July, the symptoms on plants in the shaded plots had begun to diminish and were almost completely absent on 5th August. Leaflets which previously had been severely rolled were now completely normal and flat in appearance. On removing the shades on 5th August, symptoms re-appeared and severe rolling was observed on 12th August.

Conclusions - Although facilities and equipment for controlling conditions were not available, this preliminary experiment does indicate that environment has an effect on symptom expression and that the differences in symptoms may well be related to shade as one of the factors involved.

This /

This fact is also suggested as a result of field observations made by the writer in 1946 during the course of a leaf-roll survey of commercial potato crops. During the survey, the leaf-roll contents of over 300 crops were carefully assessed. The crops inspected were located in several counties in the East of Scotland from Aberdeen to Berwick and were selected because several crops in the different localities had been derived from the same parent stock. Where the disease content had not been altered by roguing, related stocks were found to contain similar percentages of leaf-roll infected plants. The manifestation of the symptoms, however, differed between stocks derived from the same source. Crops grown on shallow soil were poorly developed and under-grown. Infected plants in such crops showed severe rolling of the lower leaflets. Crops from the same source but grown on rich soils were vigorous and tall with large leaves and abundant foliage. Leaf-roll infected plants in these crops were difficult to identify as the symptoms on the top leaves were slight and rolling symptoms on the basal leaves were often completely absent. Although no factual data were obtained, it is tempting to suggest that the disappearance of symptoms in the shade is due to (a) the absence of photosynthesis and (b) the removal of stored carbohydrate in the form of starch. It has been shown (Murphy 1924) that rolling is due to starch accumulations probably

brought about by interference in sugar translocation through the necrotic effects of the leaf-roll virus on the phloem. Translocation is not completely impeded, however, (Barton, Wright and McBain 1933, Cockerham 1933, 1939) and consequently in the absence of photosynthesis, the conversion of starch to sugars and translocation of the latter may take place slowly, so reducing the starch content of the leaves and leading to their unrolling.

Mosaic

Under the conditions of a natural environment in which this test was conducted, the results did not prove entirely satisfactory. It has been shown earlier that mosaic symptoms are prone to vary as a result of a change in certain factors of environment. This being so, the fluctuating symptoms on the control plot did not permit of a strict comparison being drawn between the symptoms and those on the shaded plots. Although the change of symptoms on the shaded plots could not, therefore, be attributed to the effect of shade, the general impression obtained was that shade tended to accentuate the symptoms of mosaic particularly where the infection was due to a mild virus strain. The severely infected plants appeared to show no symptom change. That low light intensity may accentuate mosaic symptoms, has been suspected for some time. During the inspection of field crops of potatoes, it is common to find quite visible mottles on plants growing in the shade of trees when symptoms are absent from the remainder of the crop plants growing in the open.

DISCUSSION

The results indicate that the manifestation and appearance of both leaf-roll and mosaic symptoms are influenced by several factors of environment and it seems reasonable to assume that the few factors studied by no means constitute a complete list. In the tests carried out, the severe diseases appeared to produce symptoms which were fairly stable once maximum expression had been reached, but the investigation was conducted in the field under the weather conditions obtaining for the district and it would not be surprising to find the severe symptoms similarly affected under more variable conditions. Nevertheless, the major problem facing seed growers is the elimination of the mild mosaic infections which are often symptomless or show variable symptoms. Such symptom variations are responsible for differences in the estimated percentages of disease in crops of the same derivation, which percentages form the bases of most health grading schemes. That such apparent differences occur is a source of much dissatisfaction among growers, but it would appear that this anomaly will continue to be present unless strict attention is paid to the factors affecting symptoms and unless the time of inspection of the crop is timed to take place when optimum conditions for the appearance of symptoms exist. Obviously the

inspection /

inspection and certification of potato crops on a country-wide scale is too large an undertaking to enable full effect to be given to these considerations. The solution, therefore, appears to lie with the individual growers who need concern themselves only with their own crops and thus are able to choose the times of roguing to coincide with the best conditions for the work. The differences in the mosaic content of different crops derived from the same parent stock seem more apparent than real and are, more likely, due to variations in symptoms than to the absence of virus infection. The elimination of the severe diseases does not present a major problem as the symptoms do not vary to such an extent as to render them invisible.

It has long been the practice to grow valuable seed stocks in high-lying districts where insect vectors are scarce as this helps to keep stocks free from aphis-transmitted diseases such as leaf-roll. Virus X, however, which is responsible for most mild mosaic infections is not insect transmitted but is spread by contact, and consequently district environmental conditions can have little effect on the spread of the disease from plant to plant except by their effect on the size of foliage and hence the amount of leaf contact. It is purely coincidental, therefore, that such districts are also favourable for the elimination of mild mosaic from crops in so far as the normally low temperatures

prevailing /

prevailing are now known to favour the expression of symptoms and so make diagnosis of diseased plants easier.

The study of factors which tend to mask mosaic symptoms and of others which cause the appearance of non-virus mottles resembling mosaic, has been undertaken by a few workers, but there is yet much to be done in this field. On the other hand, research on the subject of the masking of leaf-roll symptoms has been neglected almost completely in this country. It would appear, however, that this subject is sufficiently important to justify much more investigation. Likewise, the existence of strains of the leaf-roll virus has been suspected but not proved. During the current work, the differences in the appearances of certain groups of plants infected with leaf-roll was so marked that the possible existence of strains of the virus was again brought to mind. In all infected plants, rigidity, brittleness and rolling of the leaflets was apparent, but while certain plants derived from the same parent tuber were markedly stunted and dwarfed, others derived from portions of a different tuber remained fairly tall and robust. As the plants under test were all of the same variety, the differences could not be attributed to varietal reaction to the infection and it may be that different strains of the virus were concerned. On the other hand, a virus complex may have been involved.

SUMMARY

(1) Day-to-day variations in air temperature, soil temperature, relative humidity and rainfall are shown to have no marked effect on leaf-roll symptoms after these are fully established.

(2) The time of appearance of leaf-roll symptoms varies with the season and with the date of planting. This fact apparently bears no relationship with age of plant or with stage of growth, but it seems to be correlated with the rate of growth of infected plants and it is related, therefore, to environmental factors influencing rate of growth.

(3) Shading was found to reduce and even eliminate symptoms of leaf-roll.

(4) Variations in certain climatic factors particularly air temperature are observed to have an effect on the manifestation of mosaic symptoms. Increases in air temperature seem to bring about decreases in the severity of symptoms, while a fall in temperature has the effect of accentuating symptoms.

(5) Symptoms of infection with mild strains of virus are noted to be influenced by changes in air temperature more so than those resulting from infection with severe strains.

(6) /

(6) As with leaf-roll, the time of appearance of mosaic symptoms appears to be related to the rate of plant growth and hence to the environmental factors influencing rate of growth.

(7) Mosaic symptoms appear to be more subject to fluctuation, as a result of changing climatic conditions, when the plants are young. The symptoms become more stable as the plants mature.

(8) It is suggested that shade may be a factor concerned in the fuller expression of mosaic symptoms.

(9) The possible existence of strains of the leaf-roll virus is noted and considered worthy of further investigation.

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