PREFACE

By PROFESSOR J. A. S. WATSON

Ever since its introduction as a field crop, the potato has filled an important rôle in British agriculture. To-day, as the author of this book points out, potatoes are one of the two important foodstuffs in regard to which our country is still practically self-supporting.

In recent years a great deal of progress has been made towards a solution of the many problems that confront the potato grower. Stimulated by the menace of wart disease, the raisers of new sorts have redoubled their efforts and are steadily improving their methods. The same threat of disease has led to great advances in regard to the classification and identification of the varieties in commerce, a line of work with which the author has been particularly concerned. Investigation of the virus diseases has provided, at least in outline, the answer to the ancient riddle of the degeneration of stocks. It may even be hoped that blight, against which three generations of farmers have waged an inconclusive war, will soon be reduced to a condition of comparative impotence.

Much of the newer knowledge about these and about other aspects of potato culture lies scattered in scientific Journals and other publications that are not readily accessible to the farmer. This book not only assembles the information in convenient and systematic form, but is written out of the many years' experience of an acknowledged expert who has been intimately connected with the certification of Scottish seed potatoes and the potato work of the Board of Agriculture for Scotland. It will, I feel sure, be welcomed by the teacher and by the student of agriculture no less than by the practical grower for whose guidance it is primarily intended.

SCHOOL OF RURAL ECONOMY, OXFORD, August 1927.
AUTHOR'S NOTE

Farmers, merchants, students and gardeners alike are interested in the potato. There exists, however, no modern work which is adapted to such a wide range of readers. The present volume attempts to satisfy this want.

The author is indebted to many friends for material: in particular to Mr W. J. Will, B.Sc., N.D.A., for chapters XV and XVI; Mr Will's experience and qualifications have rendered him specially suitable for the task which he has undertaken; to Dr W. G. Smith, Edinburgh and East of Scotland College of Agriculture, and Dr P. A. Murphy, Royal College of Science, Dublin, the author is also deeply grateful for many helpful suggestions; to Mrs N. L. Alcock, Mr T. Anderson, M.A., B.Sc., Mr J. T. Steele, M.A., B.Sc., and Mr A. McGlashan, Board of Agriculture for Scotland, and to Mr P. F. Kendall, B.Sc., Edinburgh and East of Scotland College of Agriculture, thanks are due for assistance in various ways; and, finally, the author is much indebted to Mr J. M. Caie, M.A., B.L., B.Sc., Assistant Secretary, Board of Agriculture for Scotland, for many useful ideas and for reading and correcting the proofs.

Chapters I, VI, VII and VIII, have already appeared in their present form in The Gardeners' Chronicle, to which paper thanks are due for authority to reprint. The descriptions of common commercial varieties have been adopted, with minor adjustments, from Miscellaneous Publications, No. 3, Board of Agriculture for Scotland. Permission to reproduce these and also the various extracts from recent official publications has been obtained from the Controller, H.M. Stationery Office.

As far as possible an attempt has been made to render each chapter complete in itself, so that it may be read independently; with this object in view, a little repetition has been found to be unavoidable.

Edinburgh, August 1927.
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<td>3. <em>Agriotes</em> Wireworm (side view). (4 times nat. size.)</td>
</tr>
<tr>
<td></td>
<td>4. <em>Agriotes</em> Wireworm (upper surface). (4 times nat. size.)</td>
</tr>
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<td></td>
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</table>
INTRODUCTION

The importance of the potato as a food for mankind is well known: of all common crops it holds first place for weight of produce. The following table shows the relative production—but not the food value—of the five most important food crops in the world:

<table>
<thead>
<tr>
<th>Crop</th>
<th>1900-18 Area Average</th>
<th>1925 Area</th>
<th>Production, 1900-12 Average</th>
<th>Production, 1925</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potatoes</td>
<td>37,810,000</td>
<td>41,843,000</td>
<td>146,126,000</td>
<td>184,716,000</td>
</tr>
<tr>
<td>Wheat</td>
<td>263,987,000</td>
<td>268,565,000</td>
<td>99,242,000</td>
<td>104,247,000</td>
</tr>
<tr>
<td>Maize</td>
<td>174,711,000</td>
<td>179,349,000</td>
<td>102,228,000</td>
<td>95,566,000*</td>
</tr>
<tr>
<td>Rice</td>
<td>119,035,000</td>
<td>135,112,000</td>
<td>76,231,000</td>
<td>83,956,000</td>
</tr>
<tr>
<td>Oats</td>
<td>141,761,000</td>
<td>140,815,000</td>
<td>64,112,000</td>
<td>66,537,000</td>
</tr>
</tbody>
</table>

* 1924 figures.

The relative significance of the potato is even greater in Europe, and in Great Britain it is the most important crop on arable land. Its value has probably never been more appreciated than it was during the great blight epidemic of 1846, when famine prevailed in Ireland, and during the Great War. Germany could not have made war had it not been for the huge reserve of food material, both for human beings and live stock, represented by her potato production for industrial use in peace time.

The potato is grown mainly in Europe and in North
America. The following table shows the area and production in the more important potato-growing countries:

**TABLE II.**

*Area and Production in Various Countries.*


<table>
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<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Germany</td>
<td>6,924,000</td>
<td>6,941,000</td>
<td>43,323,000</td>
<td>41,059,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Austria</td>
<td>284,000</td>
<td>433,000</td>
<td>1,275,000</td>
<td>2,036,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Belgium</td>
<td>385,000</td>
<td>393,000</td>
<td>2,379,000</td>
<td>3,052,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Denmark</td>
<td>1,41,000</td>
<td>136,000</td>
<td>835,000</td>
<td>1,290,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Serb-Croat-Slovene State</td>
<td>28,000</td>
<td>570,000</td>
<td>46,000</td>
<td>1,204,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Finland</td>
<td>182,000</td>
<td>167,000</td>
<td>448,000</td>
<td>712,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>France</td>
<td>4,660,000</td>
<td>3,619,000</td>
<td>14,111,000</td>
<td>14,055,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Great Britain and N. Ireland</td>
<td>746,000</td>
<td>790,000</td>
<td>4,648,000</td>
<td>5,377,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Hungary</td>
<td>599,000</td>
<td>644,000</td>
<td>1,911,000</td>
<td>2,272,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Irish Free State</td>
<td>420,000</td>
<td>380,000</td>
<td>2,158,000</td>
<td>2,138,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Italy</td>
<td>709,000</td>
<td>855,000</td>
<td>1,629,000</td>
<td>2,124,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Lithuania</td>
<td>294,000</td>
<td>493,000</td>
<td>783,000</td>
<td>1,559,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Netherlands (for consumption)</td>
<td>411,000</td>
<td>334,000</td>
<td>2,346,000</td>
<td>2,239,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Netherlands (for seed)</td>
<td>87,000</td>
<td>87,000</td>
<td>877,000</td>
<td>877,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Poland</td>
<td>5942,000</td>
<td>5,829,000</td>
<td>24,398,000</td>
<td>28,646,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Rumania (simple culture)</td>
<td>26,000</td>
<td>460,000</td>
<td>90,000</td>
<td>1,534,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Rumania (intercropped)</td>
<td>36,000</td>
<td>161,000</td>
<td>32,000</td>
<td>81,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Sweden</td>
<td>377,000</td>
<td>392,000</td>
<td>1,542,000</td>
<td>2,159,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Czechoslovakia</td>
<td>2,579,000</td>
<td>2,579,000</td>
<td>7,380,000</td>
<td>7,380,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Soviet Russia (a)</td>
<td>7,092,000</td>
<td>11,510,000</td>
<td>19,547,000</td>
<td>43,374,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Soviet Russia (total)</td>
<td>7,228,000</td>
<td>11,510,000</td>
<td>19,547,000</td>
<td>43,374,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Canada</td>
<td>483,000</td>
<td>546,000</td>
<td>2,086,000</td>
<td>1,892,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>United States of America (a)</td>
<td>5,677,000</td>
<td>5,113,000</td>
<td>9,582,000</td>
<td>8,750,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) Exclusive of Turkestan, Transcaucasia and Extreme Orient.

It will be seen from the above that the potato crop of Great Britain and Ireland amounts only to about 4.5 per cent. of the world's crop. Despite this, however, the potato is the most valuable producer of human food in this country; moreover, together with fresh milk, it enjoys the distinction of being the only important article of diet in which Great Britain is self-sufficing. The annual value of the potato
crop in Great Britain is computed to be about £30,000,000. Table III. shows the area and production of the principal British arable crops.

**TABLE III.**

*Area and Production of Wheat, Oats, and Potatoes in Great Britain.*

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area 1925</th>
<th>Production, 1925</th>
<th>Yield per Acre. Average of 10 years, 1915-24.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acres</td>
<td>Tons</td>
<td>Cwt.</td>
</tr>
<tr>
<td>Wheat</td>
<td>1,548,000</td>
<td>1,414,000</td>
<td>18.3</td>
</tr>
<tr>
<td>Oats</td>
<td>2,794,000</td>
<td>2,095,000</td>
<td>15.0</td>
</tr>
<tr>
<td>Potatoes</td>
<td>633,000</td>
<td>4,209,000</td>
<td>132.0</td>
</tr>
</tbody>
</table>

Apart from its immediate value, however, the potato is of immense importance in retaining labour on the land; in this respect it is again the most useful crop we have; on an average, potatoes require one and two-thirds times the amount of manual labour necessary for the same area of roots and cabbages, four times that for cereals, and ten times that for hay.

It has been the aim of the writer to give consideration first to the fundamental principles of potato culture, using that word in its widest sense, and then to treat as next in importance those problems which are of more immediate interest to British readers. It is hoped therefore that the usefulness of this book will not be restricted by geographical limitations.

The potato is a very adaptable plant, and it can be grown within a wide range of climates and conditions. It has, however, certain peculiarities as compared with many other crops: its cropping and price fluctuate more than those of any other common crop, it is more prone to the onslaughts of diseases than any other field crop, and there is more capital involved per acre with the potato than with any other farm crop. With no other species of agricultural plant is it more necessary therefore to have accurate
and complete information. In this volume an attempt is made to assemble in a readable form the diverse facts concerning the potato, hitherto scattered through a wide range of literature, and to present some information which, as yet, has not been published.

Two aspects of the subject have been omitted intentionally, viz., marketing and synonymous nomenclature. Readers anxious to be informed on these subjects are referred to those excellent publications:


2. "List of Names of the Varieties of the Potato known to have been grown or tested in Great Britain, together with their Synonyms," Board of Agriculture for Scotland (Miscellaneous Publications, No. 4), 1924.
PART I

HISTORICAL
CHAPTER I

ORIGIN, EARLY HISTORY AND DEVELOPMENT OF THE POTATO

Most people, if asked the question, "Who introduced the potato into Britain?" would probably reply "Sir Walter Raleigh," and certainly they would be warranted in so doing by the sanction of long-standing tradition. Even a superficial study of the history of the potato in this country, however, will reveal the fact that this opinion is based on very inconclusive evidence, and in this chapter an attempt will be made to sift the various theories regarding the origin of the potato and its introduction into Europe and to arrive if possible at a solution of the problem.

Origin.

There appear to be several schools of opinion concerning the locality in which the potato originally grew in a wild state. A great many authorities claim Chili, and others Peru, as its original home. Krichauff\(^1\) states that the potato has been found wild in Mexico. Wight,\(^2\) who made exhaustive inquiry into the matter and a critical examination of material in American and European herbaria, and who, for the purpose of gaining first-hand information on the subject, made a trip through Chili, Peru, Bolivia and Ecuador, has expressed the opinion that there is no evidence of a single specimen of the potato (\textit{Solanum tuberosum}) having been collected in an undoubtedly wild state, or that the species is now growing anywhere in its original indigenous condition. It is thus practically impossible to fix the original

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habitat with any certainty; the probabilities are, however, that the potato is native to the district embraced by the following countries: Peru, Ecuador, Bolivia and North Chili. W. E. Safford, in a recent article, describes how along the arid desert which forms the Pacific coast of Peru and North Chili there is a succession of cemeteries in which mummies are found, accompanied not only by desiccated plants but also by funeral vases of terra-cotta, some of which represent food staples and fruits of the ancient inhabitants. Dried potatoes were found by Safford in graves at Arica on the coast of North Chili. Funeral vases representing potatoes have been found in abundance in graves in Northern Peru.

Some authorities, including Labergerie, Heckel, Planchon and Verne, claim to have found the ancestors of the cultivated potato. Since 1904 these investigators have worked with wild species of Solanum, and are of opinion that these species, especially Solanum commersonii and Solanum maglia, can give rise to the common potato, Solanum tuberosum, by simple mutation. This theory, which may have had its origin in the use of impure material, is certainly not confirmed by the experience of a very large number of botanists and growers, including Sutton, Berthault, Baker, Wittmack and Stuart.

Early History.

The first definite mention of the potato in literature is that given in Cieca’s “Cronica de Peru,” published in Seville, 1553. Cieca sailed with an expedition from Spain to Carthagena, where he landed in 1533. He began to record his experiences in a diary during 1541. From his diary it is evident that the potato, or “papas” as it was called by the natives, was grown to a considerable extent throughout those regions through which he travelled. It is clear also that the plant had been cultivated for some time.

4 Stuart, The Potato, 1923.
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prior to his visit. The country traversed by Cieca extends from the southern portion of what is known as Colombia to the region of Lake Titicaca. Reference is also made to "papas" by Joseph d'Acosta, whose work was published in Seville in 1590, and by Garsilasso de la Vega, who was brought up in South America, and whose writings appeared in Lisbon during the year 1604.

There are many stories concerning the introduction of the potato into the Old World, and owing to the lack of exact historical record it is very difficult to separate the truth from fiction. Two separate modes of entry have been suggested, viz., (a) by the Spaniards, and (b) by the English. That there were two introductions may be inferred from the fact that the original English potato had yellow tubers and light violet flowers, whereas the tubers of the European plant were red and the flowers violet. The Spanish conquest of Peru by Pizarro took place between 1531 and 1541. The first appearance of the Spaniards in Peru, however, dates back to 1526. The probabilities are strongly in favour of the introduction occurring towards the end of that period, or, what is more likely, after it, and not at its beginning. The selection of the later date is based on the assumption that the plant could scarcely have escaped the notice of European botanists of that time for any considerable period.

Introduction into Spain.

Louden, quoting Sir J. Banks, states that the potato came to Spain in the early sixteenth century. From Spain, where they were called "battatas," they appear to have found their way to Italy, in which country they received the name "taratoufle." Authorities differ, however, with regard to the actual date, which Krichauff and De Candolle place between 1580-85. Hieronymus Carden, a monk, is supposed to have been the first to introduce the potato into Spain from Peru. Although there is no actual record, so far as the

2 J. C. Louden, Encyclopaedia of Agriculture, 1825.
writer is aware, of a direct introduction into Spain from South America, the probabilities are so strong as to amount almost to a certainty. It would have been very exceptional if the Spaniards, coming in contact so much with the tuber, had not taken specimens back to their native land.

Introduction into England.

Apart from the presumed introduction into Spain, the potato is supposed to have found its way into Europe from another and entirely different source. It has been stated very frequently that the potato was brought to England in 1586 by one of Sir Walter Raleigh's ships on its return journey from the colony which Sir Walter established in Virginia in 1584. This statement has been subjected to a very thorough examination by Mitchell. In 1584, under Royal patent granted by Queen Elizabeth to Raleigh, there sailed on 27th April a contingent of colonists who landed in July on an island called Wokoton. Subsequently, they removed to another island, Roanoak, 21 miles distant. They took possession of this latter island on the 13th July and named the district Virginia. The following year, Raleigh reinforced these colonists by sending seven ships to Virginia under Sir Richard Grenville. This flotilla reached Wokoton on 26th June and Roanoak immediately afterwards. Grenville remained until 5th August, when he returned to England, leaving 107 persons behind him. These settlers remained on the island for a year under the government of Ralph Lane. Ships were sent to deliver provisions to the colonists, but in some way they were delayed. In the meantime, however, Admiral Drake, returning from an expedition against the Spaniards at Carthagena and the West Indies, called to see how his fellow-countrymen fared and took them on board his ships. They left Roanoak on 18th June 1586, and arrived in Portsmouth on the 27th July of the same year. Sir R. Grenville, with three ships, arrived at Roanoak later to find the colonists gone. A fourth voyage was made in 1587 and a fifth during 1590, but no subsequent

1 W. S. Mitchell, "Origin of the Potato," Gardeners' Chronicle, 1886,
attempt at colonising was made until 1606. Raleigh gave up his patent on 7th March 1590.

It is reasonable to assume that if the potato came to England from Virginia in Raleigh's ships some reference to it would be made in the writings of the returned colonists. However, the only record of a plant, which in any way resembled the potato, is that given in the report of Thomas Heriot, dated February 1587, published in De Bry's *Collection of Voyages*. Heriot describes a plant, called "openauk." His description, however, is written from memory, as when the settlers left Roanoak, the difficulties of embarkation were such that writings, etc., were left behind or thrown away. Heriot was a mathematician and his observations would probably be fairly accurate. He states:

"Openauk are a kind of roots of round forme, some of the bignesse of walnuts, some farre bigger, which are found in moist and marsh grounds, growing many together, one by another in ropes, as though they were fastened with a string. Being boiled or sodden, they are good meat."

But he does not say that his "openauk" was introduced to England, nor is any reference to it contained in contemporaneous literature. Some authorities have assumed that the potato was intended, but many others suggest that the description more aptly fits the Jerusalem artichoke, which is indigenous to some parts of North America. The inference has also been drawn that the English botanist, Gerarde, who described the potato in his catalogue in 1596 and his *Herball* in 1597 referred to the "openauk." It is worthy of notice, however, that, although Gerarde mentions that he obtained potatoes from Virginia—indeed, he gives them the name "Potatoes of Virginia"—he does not use the word "openauk," nor does he say from whom or in what year he received the potatoes. There is no proof of any connection between the "openauk" of Heriot and Gerarde's potato. The only facts about which one can be certain concerning Gerarde, according to Mitchell, are (1) that he learned from Clusius that the potato grew naturally in America, and (2)

that he obtained roots from Virginia which he grew in his garden. In considering the question, moreover, the possibility of some mistake by mixing in Gerarde's garden must not be overlooked. Safford has demonstrated that Heriot's "openauk" was not a Solanum at all, but Glycine apios (Linn.), a tuber-bearing legume. The tubers of Glycine apios were an important food of all the Indian tribes of Eastern North America from the Gulf of Mexico to the St. Lawrence river. By the English colonists they were called Indian potatoes, big potatoes, or ground nuts. The various Indian tribes had each its name for them: "openawk," "openaug," "penag" and "penac" were their Algonquin names. The ground nut corresponds exactly with Heriot's description, and while there is no species of tuber-bearing Solanum indigenous in East North America, Glycine apios is still to be found in abundance throughout the woodlands of that district. The confusion between the "openauk" of Virginia and the "papas" of Peru can be traced to Clusius, who, although not suggesting that they were identical, remarked that the tubers called "papas" observed by Cieca were apparently not unlike the roots which the Virginians called "openauk." Clusius was referred to by Gerarde, as though he were responsible for identifying the Peruvian "papas" with the Virginian "openauk."

It will be seen from the above how the presumption of a Virginian origin of the potato has arisen. Authorities are agreed that the potato is not indigenous to North America, and that if it did come from Virginia, it must have been imported there in some way. Raleigh personally had probably nothing to do with the introduction of the potato and he never visited Virginia, although he tried to do so and failed, on his return from his expedition to Guiana in 1585.

A monument has been erected to the memory of Admiral Sir Francis Drake in Offenburg, Germany, with the inscription: "Introducer of the Potato into Europe in 1580." It is true that Sir Francis Drake encountered potatoes in November 1578 as a food in use by the natives of South

Chili, but it would appear that he did not consider them worthy of serious attention.\(^1\) A menu card is still extant showing the fare at a banquet which Drake gave in November 1580 in honour of Queen Elizabeth on board his ship. In this menu no mention of potatoes is made.

It is not surprising that there is so much vagueness in literature concerning the introduction of the potato into England; the principal actors of the drama could have no inkling of the great future in store for the plant. It is, however, possible to reconcile the above traditions in the following manner: potatoes may have been brought to Virginia by Drake, having been plundered from the Spanish, or they may have been obtained by the colonists from the Spaniards who had also settled in the southern states of North America,\(^2\) or by English pirates who had pillaged Spanish ships. The potatoes could then have been brought to England in ships under Drake's command and by Raleigh's people, not, however, by Raleigh himself. This solution to the very difficult question concerning the introduction of the potato into England is, when all matters have been duly considered, quite as probable as any other of the suggestions submitted, if not more so. Gerarde grew potatoes in his garden before 1597, and the return of the colonists in 1586 is a likely date for their arrival. Safford, however, after a critical study of the available evidence, comes to the conclusion that the introducer and exact date of introduction of the potato into England cannot be determined.

The above does not exhaust by any means the stories concerning the entry of the potato into this country. Putsche (1819) maintained that Sir John Hawkins introduced the potato into Ireland in 1565, having obtained it from Santa Fé de Bagotá. Safford, however, points out that Hawkins never visited Santa Fé de Bagotá, but called for provisions at a port called Santa Fé on the coast of what is now Venezuela, where he obtained, amongst other things, sweet potatoes. Sir Joseph Banks also in a lecture given to

the Horticultural Society, London, in 1805, criticised the suggestion that Hawkins introduced the potato, and stated that what the sailor did handle was the sweet potato. Another tradition has it that the first coming of the potato to Britain was accidental, tubers having been washed ashore from a trading vessel returning from a transatlantic voyage and wrecked on the Galway coast. The first published description of the potato was given by Bauhin in 1596. Bauhin was the first to give the potato its present botanic name, *Solanum tuberosum*. Gerarde in his *Herball* (1597) was the next to depict it, and in 1601, Clusius in his *Rariorum Plantarum Historia* described the plant, naming it "Papas Peruanorum."

So far, therefore, we can state with certainty only three facts, viz.: (1) the plant is indigenous to South America; (2) it was introduced into Europe in the latter part of the sixteenth century; (3) two independent introductions took place, one into England and one into Spain.

**Introduction into other Countries.**

While in a book published in Italy in 1584 no mention is made of the potato, we know from Clusius that it was taken from Italy by the Papal delegates to Belgium, where some were received by Philip de Sivry, Prefect of Mons, who, in 1588, sent two tubers to Clusius in Vienna. Clusius, in turn, sent specimens to various botanic gardens in Germany. Bauhin grew potatoes at Basle, Switzerland, in 1596 and from there it passed into France. The first mention of it in French literature is in 1600, by Oliver de Serres in his *Théâtre d’Agriculture et Mesnage des Champs*. According to Krichauff, the potato was first placed on the Royal table of France in 1616. In Germany it made much more rapid progress than in France. Sweden was late in adopting the potato. In India it would appear to have been grown during the Governor-Generalship of Warren Hastings (1772-85). With regard to North America, the evidence is that the potato was unknown to American agriculture either in the sixteenth or seventeenth centuries, and that it was not until
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the early part of the eighteenth century that it was first introduced. According to Bailey,¹ the tuber was not brought into cultivation in New England until the arrival of the Presbyterian immigrants from Ireland in 1718. In all countries there appears to have been strong opposition to the introduction of the potato: some objected to it on account of its presumed harmful effect on the mind, and others because it was not mentioned in the Bible. Frederick the Great of Prussia and his father found it necessary to use compulsion to secure its growth, but although the Royal decrees had their effect, it was the famine caused by the Silesian wars, especially the Seven Years' War, which established potato culture in Prussia. In Russia the prejudice was so strong that the tubers were referred to by peasants as the "Devil's Apples."² In France also the potato was at first regarded with no favour; in fact, it was commonly spoken of in that country as food fit only for animals and poor people. It was Parmentier, an apothecary, who really introduced the cultivation of the potato into France, and it was not until his time that the prejudice was removed. Parmentier was a prisoner of war in Germany during the Seven Years' War. During his confinement he was fed on potatoes and learned to like them. In 1771³ a high price was offered by the Academy of Besançon for the discovery of a new food which would fill the place of cereals in time of famine. In the succeeding year Parmentier presented to this Academy his celebrated memorandum on the culture of the potato.⁴ Louis XVI. gave him 50 morgen of land to plant them on. When showing the first flowers of his potatoes on 25th August 1785, the King used them as a button-hole bouquet, Queen Marie Antoinette had them in the evening in her hair, and at once princes, dukes and high functionaries went to Parmentier for such flowers. All Paris talked of nothing but potatoes and the cultivator of them.

¹ L. H. Bailey, *Cyclopedia of Agriculture*, 1912.
² Gardeners' Chronicle, 1882.
Early History in Britain.

According to Sir Joseph Banks, Sir Robert Southwell, President of the Royal Society, informed the members of the Society at a meeting on 13th December 1693, that his grandfather introduced the potato into Ireland, having obtained it from Sir Walter Raleigh. It would appear, therefore, as practically certain that the entry into Ireland took place very shortly after the potato had been brought to England. Louden\(^1\) states that the potato was first planted by Sir Walter Raleigh in his estate of Youghall, near Cork, Ireland, and was, according to Gough in his edition of *Camden's Britannia*, “cherished and cultivated” for food in that country before its value was known in England. Gerarde planted potatoes in his garden in 1596, but he recommended them as a delicate dish and not for common food. It is stated that owing to ignorance when the potato was first cultivated in Ireland, the fruit, *i.e.* the berry, was regarded as the edible portion of the plant. It is reported in the *Gardeners' Chronicle*, 1882, that Sir Walter Raleigh's gardener, annoyed at the unpleasant taste of the berries, complained bitterly and asserted that the plant was not worth a place in his garden. However, when he proceeded to dig it out he found the tubers, with the merits of which he soon became acquainted. A similar story concerning some of Sir Francis Drake's friends appears in the 1874 volume of the same paper. For a long time potatoes remained a dainty in Britain, and in a written book\(^2\) for housekeeping kept by Queen Anne, wife of James I. (1603-25), it is stated that a small quantity of potatoes were purchased at 2s. per lb. The Government, through the Royal Horticultural Society, tried to push the cultivation of the potato in 1663, but progress was very slow. Potatoes are mentioned by John Reid in *The Scots Gard'ner*, Edinburgh, 1683, from which the following quotation is taken: “Potatoes, being cut in as many pieces as you please provided there be an eye at each piece, must

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be planted in March, five rows in a bed; plant not deep, neither in wet or stiff ground.” In 1699 Evelyn recommended growers to plant potatoes in their worst ground. It is a noteworthy fact that in English books on gardening of the year 1719, as in that by the famous nurserymen, London & Wise, the potato is not even mentioned, and Bradley, who wrote extensively on horticultural subjects about the same time, speaks of them as inferior to skirrets and radishes. Only later in the eighteenth century did the potato become better known and cultivated in Great Britain. According to Krichauff they were chiefly found in the gardens of peers and rich men up to about 1784. However, Bradley in his Complete Body of Husbandry, published in 1727, recommends potatoes to follow carrots and onions in field culture, and it is to be assumed, therefore, that field culture was in vogue in England during the first quarter of the century, although perhaps to no great extent. In Chambers' Cyclopædia (1781) it is mentioned that the cultivation had been general for the “past forty or fifty years.” More definite records exist concerning Scotland. In his Agricultural State of Scotland (1814), Sir J. Sinclair states that potatoes were first brought from Ireland to the county of Lanark towards the end of the seventeenth century by Major Hamilton of Raplock, but they were very sparingly cultivated for more than sixty years. Sir John continues: “It is asserted in the Statistical Account of Scotland, vol. xviii., p. 282, that Mr Robert Graham of Tamrawer, in the parish of Kilsyth and county of Stirling, was the first person in Scotland who cultivated potatoes in the open field, by dibbling and hand-hoeing. His first essay, in this husbandry, was in the year 1739, when he planted potatoes by means of the dibble, on about half an acre of croft, or old infield land, at Neilston in that parish.” In a letter by the Hon. Baron Hepburn, dated 20th March 1808, addressed to Sir J. Sinclair, and appearing in the Communications to the Board of Agriculture, it is stated that potatoes were first imported into Leith in the year 1740 and after that they were for some time grown in gardens only, the first field culture being carried out by a farmer, called Hay, at Aberlady about 1753 or 1754. The last-mentioned date
corresponds approximately with that given by Louden 1 for field culture in Scotland. It is to be presumed that both statements are records of fact, and that Baron Hepburn was unaware of the earlier introduction. Louden further adds that a few potato plants existed about Edinburgh in the year 1725-26 and these were left in the ground from year to year, as recommended by Evelyn, a few tubers being removed for use in autumn and the parent plants being well covered with litter to save them from the frost in winter. Louden remarks that in the year 1796, in the county of Essex alone, about 1700 acres of potatoes were planted for the London Market. A study of the potato in Rees’ Cyclopædia, 1819, reveals some interesting facts: varietal yield trials had been conducted before the date of publication, and experiments with different sizes of seed were made in 1790. It would appear also that manuring experiments on potatoes began as early as 1771.

With regard to the cultivation of the crop, the following extracts will serve the useful purpose of showing progressive early development.


“The first thing to be observed in the culture of them, is to plow or dig the ground well before winter. If ley-ground is plowed up, it will require two or three plowings before planting, and all roots of perennial weeds gathered out as clean as possible, and cross plowed and harrowed well. If the ground is stiff, it should be laid up in ridges all winter.

“Before the last plowing or digging it should be dunged with half-rotten dung. Some people, where dung is not plenty, lay it in the furrow or trench above or below the potatoes, but it is a bad practice to lay it above. . . . Many plant them after the plow, every other furrow and others miss two furrows according to the goodness of the ground. . . . If the ground is digged and the plantation not large, it will be better to plant them with a garden line, and dibble, eighteen inches or two feet between the rows, and from a foot to eighteen inches in the rows. The quickest method for planting them is to have a foot-dibble shod with iron pretty thick to go, but about five or six inches, into the ground. If the line is stretched, one runs along the line with the dibble and another follows and drops the seed into the holes, drawing in the earth with his foot as he goes along.”

1 Encyclopædia of Gardening, 1824.
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B. Chambers' Cyclopaedia (1781).

"The most advantageous way of propagating potatoes is the planting them at large distances and digging and horse-hoeing the ground several times between them. . . .

"In the spring just before the last ploughing, a good quantity of rotten dung should be spread on the ground, which should be ploughed in the beginning of March, if the season be mild, or towards the latter end of the month, if there be a probability of frost. In the last ploughing the ground should be laid even, and then the furrows should be drawn at three feet distance from each other, and about seven or eight inches deep. In the bottom of this furrow the roots should be laid at about a foot and a half asunder; then the furrow should be covered in with the earth. About the time when the shoots are expected to appear above the ground, it should be well harrowed over both ways, in order to break the clods, render the surface smooth, and destroy the young weeds. The hoe-plough may likewise be introduced between the rows; and this operation should be repeated twice early in the season before the stems of the plants begin to trail upon the ground, and a hoe may be made use of to stir the ground and destroy the weeds between the plants in the rows."

C. Agricultural State of Scotland, 1814, by Sir John Sinclair.

"1. The universal mode of growing potatoes in the best managed districts is in drills, as described below.

"2. The land gets one ploughing after harvest, with the view of making it mellow, by the influence of the atmosphere during winter. It is cross ploughed in spring, and gets, or ought to get, as many ploughings and harrowings as are necessary to reduce it into fine tilth, and to remove couch and other vivacious roots.

"3. After the land has been effectually cleaned and reduced, it is formed into hollow drills and ridgelets, and the dung is laid on and spread, in the same manner as already described for turnips. The sets are laid, by hand, upon the dung, in the bottom of the hollow drills, at various intervals, from four to eight inches; the ridgelets are then split open by the plough, to cover in the seed.

"4. The sets are commonly cut, seldom whole; though some prefer the latter.

"5. Some time after setting, and before the plants begin to push up, the land is harrowed down flat. After the plants are fully up in the rows or drills, the intervals are horse-hoed, and the rows hoed by hand. These operations are repeated at intervals, and, when the plants have acquired some strength, the intervals are split open by the double-mould-board plough earthing up the plants. The cleaning process, however, ought not to continue long, else the crop will be injured by disturbing the radicles when in search of food. And if the soil be kept too loose the whole summer, the plants will not bulb well."
6. They are taken up after harvest in October or November usually by the plough, laying open the drills, when they are gathered, or they are carefully dug up, root by root, with flat-grained three-pronged forks, each digger having one or two children to gather them.

7. "Potatoes are stored up for winter in dry, cool out-houses or cellars, covered up with straw, and secured from all access of frost, or in what are called pits, pies or clamps."

The further history of the potato is concerned mainly with the development of new varieties, with the struggle against diseases, particularly late blight (*Phytophthora infestans*), with the improved methods of culture, and with the gradual distribution of the plant throughout the world, due to a universal recognition of its value as a source of food for the human race.
CHAPTER II

A HISTORICAL NOTE ON SOME POTATO VARIETIES AND BREEDERS

The Agriculturists' Manual, published in 1836 by Messrs P. Lawson & Son, Edinburgh, contains a classified list of 146 potato varieties cultivated at that date. Very few of these retain a place in modern agriculture. The common Yam is still grown in some districts, while Shetland Black and Irish Lumpers, which are cultivated on a small scale at the present time, may, with reasonable certainty, be stated to be identical with the varieties mentioned by Lawson under these names, although Lawson's description of the tuber of Shetland Black does not correspond entirely with that of the modern variety. Murphy¹ states that there is no reason to doubt that the Yellow Potato, frequently mentioned by Arthur Young (1776-1779), is identical with the variety bearing that name to-day. The above constitute the exceptions: the life of a commercial variety is normally short, not extending usually beyond twenty-five years.

Many factors operate in determining the period for which a variety may retain a place on the market. Degeneration induced by diseases is the chief cause of failing popularity of potato varieties. But although diseases undoubtedly play an important rôle in determining the length of time during which a variety is cultivated, it must not be forgotten that popular fancy has also a strong influence. Many varieties have had short lives, not owing to any want of intrinsic merit, but because they have failed in some way to attract the public attention. Public taste is a factor which varies much.

¹ P. A. Murphy, "Investigations on the Leaf Roll and Mosaic Diseases of the Potato," Journal Dept. Lands and Agriculture, Dublin, Feb. 1924.
It is not the same in any two countries, hence varieties which have found extensive cultivation in one country may be regarded as worthless in another: nor is it the same in one country at different periods. Even within a country there exist variations in taste. In eastern Germany, for instance, white-skinned and white-fleshed varieties are in demand, whereas in the western portion of that country, red-skinned, yellow-fleshed tubers find favour. Yield, palatability and adaptability to the various methods of cooking are first considerations, and the actual food value, based on the composition of the tuber, is not considered. In this matter it may be stated, therefore, that the public to some extent leads the breeder, and not vice versa.

Rees' Cyclopaedia or Universal Dictionary of Arts, Science and Literature, published in 1819, contains an article on potatoes, in which it is stated that new varieties derived from the seed were frequently coming on the market at that time—a remark which might be made with even greater emphasis concerning any subsequent period. Since the introduction of the potato, thousands of varieties have been cultivated in this country alone. It appears, therefore, that to trace the history of all varieties would be an impossible task, and it is the intention to limit the discussion in this chapter to such varieties as have had extensive cultivation or which are of importance in other ways.

Potato-growing may be said to have been in its infancy during the eighteenth century, and so far as the production of varieties goes, breeding on more or less scientific lines began only during the nineteenth century. The most epoch-making varieties which have been placed on the British market are: Ox-Noble, Rocks, Yam, Lapstones, Ashleaf Kidney, Cups, Fluke, Victoria, Early Rose, Magnum Bonum, Beauty of Hebron, Champion, Regent, Abundance, Up-to-Date, British Queen, Maincrop, Epicure, Duke of York, May Queen, Arran Chief, Great Scot, King Edward, Majestic and Kerr's Pink. A study of the history of potato varieties, however, shows that while old varieties have been constantly replaced by new ones, there are distinct periods during which the activities of breeders have been more marked
than at others. The great stimulus to potato-breeding in Britain during the nineteenth century was the severe epidemic of blight which reached its climax in 1846, and which brought about a wholesale destruction of the crop, causing famine to prevail in Ireland. This circumstance, although of very great importance, was not the only factor which contributed to the remarkable activity in potato breeding in the second half of the nineteenth century. During this period an enormous number of American varieties was imported into this country. All were great croppers, and, although few possessed high quality, all materially helped to swell our potato supplies. Raisers were awakened to the need of doing something to counteract the flooding of our trade with American sorts, and worked energetically to produce varieties which would surpass these strangers in all points, being not averse from utilising the American types for breeding purposes. America, however, was not the only country from which potatoes were imported; in the days before Magnum Bonum, thousands of tons of potatoes were sent to Britain from Germany, Belgium and elsewhere. In the present century, a great renewal of activity amongst breeders has taken place as a result of the rapid spread of wart disease.

There exists no very definite record, so far as the writer is aware, concerning the introduction and origin of some of the older of the varieties mentioned, viz., Ox-Noble, Yam, Rocks, Lapstones, Ashleaf Kidney, Cups and Regent. A study of various lists, however, is sufficient to convince one of their previous importance. The Ox-Noble and the Yam were cultivated before 1795, and are mentioned in Lawson's Agriculturist's Manual (1836). The Rock Potato is probably the oldest on the market. It was grown originally in Ireland, and was stated to have been introduced into Scotland by Paterson in 1848. This variety appears to be synonymous with the Yellow Potato mentioned by Arthur Young. The Lapstone is not mentioned in Lawson's book,

1 Somerville (of Haddington), "The Best Kinds of Potatoes," etc., Report of the Committee of the Board of Agriculture concerning the Culture and Use of Potatoes, 1795.
but it was in cultivation before 1841. It is mentioned in a classification appearing in The Gardeners' Magazine in 1882, and again by Fraser in his Twentieth Century Potatoes. Regarding the Ashleaf Kidney, which is considered by some authorities to be the same as Myatt's Ashleaf, there are records of a variety with such a name being cultivated in 1820, although there is no certainty that the two varieties were identical. There is, however, no doubt that the old Ashleaf Kidney had a considerable vogue. The Cups, also mentioned by Lawson, would appear to have filled an important place during the first half of last century. Not much appears to be known about the Regent, which was a later introduction.

Before going further, however, two varieties call for special treatment, viz., Paterson's Victoria and Garnet Chili. Of these two, the latter still retains a place in cultivation. The interest concerning these varieties consists not only in the fact that they were extensively grown, but also that they represent the parent forms from which a great number of varieties have been directly or indirectly derived.

Paterson's Victoria and its Derivatives.—According to the late Mr A. Findlay, Paterson's Victoria was a natural seedling of the Fluke. If so—and there is no reason for doubting Findlay's word, as Paterson was known to have worked with the Fluke, and as the Fluke was about the only variety grown at that time which bore natural berries—the Fluke must share equal glory with Paterson's Victoria. The story of the origin of the Fluke is told in The Gardeners' Chronicle (1858 and 1864). A certain J. Turner, handloom weaver and occasional farm worker, of Birch, near Middleton, Lancashire, first raised this variety from a "plum" taken indiscriminately from a field of potatoes grown in 1841 on the Langley Hall Farm, near his residence. He sowed the seeds in his garden, and produced twelve plants, one of which was the Fluke. Turner never knew from what variety he took the "plum." The proprietor of Langley Hall Farm stated that at the time the seed was taken he was growing the Pink Eye to which

1 The Gardeners' Chronicle, 1886.
2 A. Findlay, The Potato, its History and Culture, 1905.
the Fluke had some resemblance. It was a late, white-skinned variety, fairly resistant to blight, and very commonly grown about 1854. Victoria was introduced in 1863 by Paterson, and it had considerable success as a commercial variety. Historical records show that directly or indirectly the following varieties of note have been derived from it: Champion, Schoolmaster,¹ Up-to-Date, British Queen, Bishop, Jeannie Deans, Field-Marshal, Great Scot, Leinster Wonder and Ninetyfold. Probably all Findlay's varieties had Victoria "blood." The Victoria has been used largely by continental breeders.² It is the male parent of Richter's Imperator and Juwel, the former having been grown in this country under the name of Charles Fidler. Further, Richter's Imperator has been largely utilised for breeding purposes by other continental raisers.

Garnet Chili and its Derivatives.—The severe epidemic of late blight in 1845 led the Rev. Chauncey Goodrich, Utica, New York, to conceive the idea that the potato, as a result of long continued asexual propagation, had become so weakened in vigour as to be able no longer to resist successfully the attack of disease. He believed that it could be rejuvenated only through sexual reproduction, and began to make his plans for the growing of seedling potatoes, with the idea of developing more vigorous and productive varieties that would be able very largely to resist disease. He obtained, through the American Consul at Panama, in 1851, a small quantity of South American potatoes for breeding purposes. Among this lot was a variety which, from its appearance and presumed place of origin, was designated Rough Purple Chili. From natural seed of this variety, produced in 1852, he grew some seedlings in 1853, and from these one was selected as being worthy of propagation. This seedling was introduced in 1857 under the name of Garnet Chili, which variety is still grown in some parts of America.

From a naturally fertilised seed ball of Garnet Chili,

¹ Schoolmaster is stated in The Gardeners' Chronicle, 1878, to be a cross between Early Rose and Victoria.
² Dr K. Snell, Kartoffelsorten, 1925.
Albert Bresse of Hubbarton, Vermont, U.S.A., grew Early Rose, in 1861. On the authority of Messrs James Thorburn & Co., New York, by whom it is stated to have been raised,\(^1\) Late Rose is said to be a seedling of Early Rose. A number of other American varieties, including Burbank and Early Ohio, are natural seedlings of Early Rose. Early Rose is still grown in Britain and America. In addition, however, it is also cultivated in Italy and Germany. It has been utilised to a large extent by British and foreign breeders. Magnum Bonum and Maincrop (Langworthy) are stated to have been derived from a "plum" taken from Early Rose. Beauty of Hebron was also derived from Garnet Chili, by E. L. Coy, Hebron, N.Y., and has been grown largely in this country as Puritan. To Garnet Chili therefore we are indebted directly and indirectly for a large number of first-class varieties, including, in addition to the above, Abundance, Fiftyfold, Early Market, Reading Russet, Golden Wonder, Templar, Rector, Bishop, Epicure and Crusader. Early Rose has been used as a parent for the following continental varieties\(^2\): Richter's Imperator (Charles Fidler), Juwel and Schneeflocke, and Cimbal's Ella, Fecodora, Iris and Vesta. Cimbal's Lucie is the result of a cross between Early Puritan (Beauty of Hebron) and Wilhelm Horn.

*Wm. Paterson.*—Born in 1810 at Seafield, Dundee, Paterson\(^3\) commenced experimenting with potatoes when in his 'teens. He took up business on his own account in 1833. During the "blight" years he worked with Government officials to inquire into the cause of the disease, and, if possible, to find an antidote. He was of opinion that there was no cure, blight being caused by atmospheric action on the plant, which, having the germs of the disease within itself, was destined to serve only its generation, and that without constant and regular renewal from the true seed the potato would die out. He imported potatoes from Central America, Chili and other places, and planted these promiscuously with the Rock Potato. Most of the plants

\(^1\) *The Gardeners' Chronicle*, 1872.
\(^2\) Dr K. Snell, *Kartoffelsorten*, 1925.
\(^3\) G. Gibb, *Scottish Farmer*, February 1922.
produced flowers but only a few carried plums. From the seed thus obtained, many of his varieties were derived. Paterson put the following varieties on the market: York Regent, White Rock, Blue, Early Red Kidney, White Kidney, Early Napoleon, Regent, Alexandra, Red, Zebra, Early Perfection, Princess of Rome, British Queen (the first), New Perthshire Red, Red Regent, Irish Blue, Scotch Blue, Blue Kidney, New Albert, Fortyfold, Bovinia and Victoria. Victoria was his greatest success. It had a very hardy constitution, was a very good cropper and bore flattish, oval tubers, which, when cooked, were mealy and richly flavoured.

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J. Clark, Christchurch.—The raiser of Magnum Bonum, Maincrop (Langworthy) and Abundance, is deserving of an honoured place amongst potato raisers. The first of these varieties, Magnum Bonum,\(^1\) was raised from seed taken from an Early Rose plant, presumed to have been crossed with Paterson's Victoria. The crossing, however, was not carried out by any human agency, and, as it is well known that the amount of natural crossing which takes place is relatively small, it may reasonably be assumed that the variety is just a seedling of Early Rose. Clark sent tubers of Magnum Bonum to the trial ground at Stoke Newington, which was managed by Mr Shirley Hibberd. Hibberd was so taken with the variety that he introduced it to Messrs. Sutton & Sons of Reading, who purchased the stock and introduced it in 1875. Compared with other varieties of that date, Magnum Bonum was a good disease resister. It is still grown on the Continent, and was widely grown in England about 1890. Maincrop Kidney, according to Salaman,\(^2\) was derived from the same seed ball as Magnum Bonum. Langworthy (Niven) is identical with Maincrop Kidney, and Golden Wonder (Brown) differs from it only in having a russet skin. The parents of Abundance, introduced by Messrs Sutton & Sons in 1886, were Magnum Bonum and Fox's Seedling. Clark also raised Epicure (Magnum Bonum x Early Regent). Epicure was placed on the market in 1897 by Messrs Sutton & Sons. In the same year, as

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a result of a cross, Elephant × Victoria, Messrs Sutton & Sons placed another of Clark's productions on the market, viz., Ninetyfold. In addition to the above, Clark raised Early Market and other varieties.

Robert Fenn.—Most of the varieties produced by Fenn were introduced by Messrs Sutton & Sons. They include Fiftyfold, Reading Russet, Rector of Woodstock, Early Regent, International Kidney and Bountiful. The first two are still grown, and International Kidney is still the mainstay of the Jersey early potato trade. Fiftyfold, Early Regent and Reading Russet had for their parents Bountiful and Late Rose.¹ Fenn used American varieties freely in his crosses, the first of which was made in 1857.

Archibald Findlay.—Probably no individual has placed so many potatoes on the market as this breeder. He is responsible for the following varieties, viz.: Bruce, Up-to-Date, British Queen, Jeannie Deans, Evergood, Royal Kidney, Northern Star, Majestic, Katie Glover, Di Vernon and Catriona. Apart from these, however, there are a number of other lesser known varieties which stand to his credit, e.g., Mairsland Queen, Farmer's Glory, Ruby Queen, Conquest, Eightyfold, Gold Reef, Diamond Reef, K. of K., etc. Findlay began his hybridising experiments, at first for amusement, in 1877. At the beginning he contented himself with ordinary horticultural varieties for prize-taking. Apparently in all his varieties there is some Victoria "blood," for we find him stating to the Glasgow Discussion Society in 1905: "Individually, for breeding purposes, I would not give a farthing for any potato if I could not trace its descent from the Victoria on the male or female side." According to himself, his first real success was the Bruce, which, he informs us, was the result of cross-fertilising the Late Rose with the Victoria. It is decidedly curious how Clark's Magnum Bonum and Findlay's Bruce are so similar, both in form and reaction to diseases, that the names are classed as synonymous in official publications. It is highly probable, however, that the Bruce has been out of cultivation for a considerable time, and that the official coupling of the

¹ R. N. Salaman, Potato Varieties, 1926.
two names has had its origin in an examination of two samples of Magnum Bonum. Undoubtedly the greatest success of all was Up-to-Date, the result of a cross between Victoria and a seedling of the Old Blue Don. This variety is probably the best all-round potato ever put before the public, and it is still extensively grown in Britain, America, and the Continent.

In Britain the variety, Up-to-Date, has been widely cultivated under other names. It largely supplanted Magnum Bonum. The date of its introduction to the British market is 1893. In the following year, another variety of great merit appeared, viz., British Queen, which was derived from the same "plum" as Up-to-Date. These two successes, but especially the former, paved the way to the period of the great potato "boom" in the first few years of the present century. For a single tuber of Eldorado a price of £100 was paid, and the breeder was offered £200,000 for the complete stocks of this variety. Much excitement was caused also by the appearance of such varieties as Northern Star (1902) which was sold at £25 per tuber. Royal Kidney appeared in 1901. Majestic was placed on the market about 1911. This variety, along with K. of K., was stated by the breeder to be a cross between a wild species of Solanum and one of his own hybrids, probably British Queen. Before leaving the productions of Mr Findlay a word or two may be written about Jeannie Deans, which was placed on the market in 1890. Regarding it, Mr Findlay states: "In 1890, I was able to offer Jeannie Deans and Early Beauty out of what I may call a double Scoto-American cross—first cross Beauty of Hebron and Victoria: second cross, seedling of and natural seedling out of the old Scottish Blue Don." It is remarkable that here again the variety is similar in appearance to one of Clark's, viz., Sutton's Abundance, and the two names are classed as synonymous in the official publications. This may be merely a coincidence, and the explanation the same as that offered for the Bruce.

Nicol, Arbroath.—Nicol's claim to attention rests on the fact that he produced the Scotch Champion, which is still largely grown in the Highlands and in Ireland. Champion,
according to Findlay,\(^1\) was a natural seedling of Victoria. It would appear that the variety is grown extensively in Malta. It was placed on the market in 1879.

Charles Sharpe, Sleaford, Lincs.—Mr Sharpe introduced Sharpe's Victor and Sharpe's Express, the former in 1891 and the latter sometime before 1901. The parentages of these varieties are not known.

Wm. Sim, Greenmyre, and Gourdas, Fyvie, Aberdeenshire.—The Duke of York potato, raised by this breeder, has become extensively cultivated, not only in England but on the Continent. It was, according to Fisher, the result of a cross between Early Primrose and King Kidney, being introduced in 1891 by Daniels Bros. It is the principal early potato of Holland, where it is named “Schotsche Muis” or “Erstelingen.” In the Rhineland it is known as “Erstling.”

E. Sadler, Bentlaw, near Cheltenham.—Mr Sadler was the raiser of the variety, May Queen, which was put on the market by Messrs Sutton & Sons in 1900. The parentage of this variety is not known.

F. Butler of Scotter, Lincs.—To Mr Butler must be ascribed the credit of first recognising the merits of the variety, King Edward. This variety, the parentage of which is unknown, was raised by a gardener in Northumberland who called it “Fellside Hero.” Ultimately it was brought to Mr Butler's notice and he put it on the market in 1902. The variety is extensively cultivated in Britain and is grown also in Germany, where, in Westphalia, it is known as “Bunte Molle.” Butler also introduced King George V. in 1911.

F. Brown, Peasiehill Farm, near Arbroath.—As in the cases of Nicol and Sim, this breeder's reputation rests on one variety only, viz., Golden Wonder, which appeared in 1906. In all respects it is similar to Clark's Maincrop, with the exception that the tuber skin is russet. Brown certainly deserves credit for selecting the variety, but it is to be presumed that it is just a russet variation of the former.

Dr J. H. Wilson, St Andrews.—Dr Wilson\(^2\) produced and placed on the market a number of varieties. His great

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\(^1\) A. Findlay, The Potato, its History and Culture, 1905.

object was to obtain blight-resistant forms, and for this purpose he utilised some of the wild species of Solanum in his crossings. None of his varieties has, however, become very popular. The most prominent are Rector, Bishop and Templar. Rector was the result of a cross between an unidentified red variety and Maincrop. The parents of Bishop were Up-to-Date and Rector. Bishop was raised from seed in 1906. Templar, which was raised in the same year, was produced by crossing Rector with Myatt’s Kidney.

D. McKelvie, Lamlash, Arran.—Mr McKelvie is undoubtedly our best known present-day breeder. He has already produced a number of varieties of outstanding merit, including Arran Chief, Arran Victory, Arran Comrade, Arran Rose, etc. However, his work is not yet finished, and several of his most recent seedlings show promise of developing into high-class commercial varieties. Mr McKelvie commenced potato raising in 1907, when he received several packets of seed from F. W. Keay, Ox Barn Farm, Merry Hill, Wolverhampton. From this seed Arran Chief and Ally were raised. The pedigree of Arran Chief is indefinite, but the pollen parent was Flourball, which variety Mr McKelvie subsequently utilised much in crossing. Arran Chief was introduced in the autumn of 1911. The Ally was first named Arran Treasurer, but owing to its very bad table quality Mr McKelvie himself did not introduce it. In the spring of 1914, the stock of this variety was shared with several merchants, including Messrs J. R. Poad, W. J. Reid, J. Donald, T. Mosson and J. Bettinson, who named it Ally, and introduced it. Arran Comrade was also raised from seed supplied by Keay, but its pedigree is obscure. It was raised in the spring of 1912, along with Arran Rose, and introduced in the spring of 1918. Arran Victory also was raised in 1912 and introduced in 1918. It was grown from a seed taken from a “plum” of an unknown variety. Arran Consul, introduced 1924, was the result of a cross made by Mr McKelvie between Flourball and President.

Messrs Farish.—Tinwald Perfection, which was placed on the market in 1916, was raised by Mr W. B. Farish,
Dumfries, who had previously introduced Lochar in 1909. Rhoderick Dhu was raised by Mr S. T. Farish, Todhillmuir, Lockerbie, and was marketed for the first time in 1920. The parentages of Messrs Farish's varieties are not known, some mixing having apparently occurred at seedling time.

A. Mair, Meikle Holm, Lockerbie, and A. W. McAlister, Dumfries.—These two names will ever be associated with the potato, Great Scot, which, because of its immunity to wart disease is probably the best introduction since Up-to-Date. Great Scot was raised from seed supplied by Mr Ezra Miles to Mr Mair, who sowed it. Mr A. W. McAlister assisted Mr Mair in selecting what he thought to be the best seedling. Mr Miles states that the seed from which Great Scot was obtained was the result of crossing either Schultz Lupitz or Imperator with Champion. It was placed on the market in 1909.

Messrs Dobbie & Co., Edinburgh, and Mr Henry, Cornhill, Banff.—To Messrs Dobbie must be ascribed the credit of putting Kerr's Pink on the market. The variety was raised by Mr Henry, and its merits were first recognised by Mr Kerr of Banff, from whom the above firm purchased it. It was first introduced in 1915, but it had been in Messrs. Dobbie's hands for the two previous years. Its immunity to wart disease and its general merits have won for it an outstanding place amongst potato varieties. Messrs Dobbie deserve great credit for their early recognition of the merits of this variety, which are only now acknowledged by the public. Official statistics show that its popularity is on the increase. The parentage of Kerr's Pink is obscure. It is stated to be a cross between Lord Rosebery and Crofter.

Continental Introductions of Note.¹

1. Präsident Krüger (President).—This variety was produced by Cimbal, Germany, as the result of a cross between Daber and Erste von Frömsdorf. It was placed on the market in 1900 and had a considerable vogue. The appearance of wart disease, however, had much to do with

¹ Dr K. Snell, Kartoffelsorten, 1925.
its waning popularity. General is a white-flowered variation of President.

2. Juli (Immune Ashleaf) was raised by Paulsen in Germany. Its parents were Josef Regault and Pflückmaus. It has been in commerce since 1891 and very largely owes its popularity to its immunity from wart disease and its earliness.

A number of older breeders have been omitted from this discussion because their varieties are not considered to be of such importance as to justify their inclusion. Some present-day workers have also been excluded, perhaps wrongly, as it is difficult to obtain a correct perspective of current productions.
PART II

BOTANICAL
CHAPTER III

THE SYSTEMATIC POSITION OF THE POTATO AND NOTES ON SOME WILD SPECIES OF TUBER-BEARING SOLANUMS

The potato belongs to the natural order Solanaceae and in consequence is related to the following well-known plants, viz.: Solanum nigrum, (nightshade), Solanum melogena (eggplant), Solanum lycopersicum (tomato), Nicotiana tabacum (tobacco), Atropa belladonna (deadly nightshade), and Hyoscyamus niger (common henbane). The Solanaceae include many species in the tropical and warmer parts of the globe, but in the northern regions they are represented by a few stragglers from southern latitudes. The genus Solanum is one of the largest in the vegetable kingdom. About 900 names stand in botanical books as species; and Bentham and Hooker estimate that probably 700 of these are really distinct. According to Baker only six of these are tuber-bearing species, viz., (a) S. tuberosum, (b) S. maglia, Schlecht, (c) S. Commersonii, Dunal, (d) S. Cardiophyllum, Lindley, (e) S. Jamesii, Torrey and (f) S. Oxycaipum, Schiede. Baker's observations, however, were limited to the material available in 1884. Since that date other works on the subject have been published by numerous writers, including Sutton in England, and Wittmack and Bitter in Germany. At present there are about forty recognised tuber-bearing species of the Solanum. These are to be found only in South and Middle America up to South-west U.S.A., and they have so many points of resemblance that a common ancestor is to be presumed. Wittmack classifies the tuber-
bearing species with pinnate leaves into four groups according to the forms of the sepal tip and corolla, viz:—

A. With long-pointed sepal tips and five-cornered wheel-like corolla. To this group belong *Solanum tuberosum* and *S. maglia*.

B. With short, rounded, triangular sepal tips and five-cornered wheel-like corolla. Here are found *S. fernandestianum*, *S. bridgesii* and *S. etuberosum*, Lindley.

C. With long sepal tips and star-like corolla, *i.e.*, approaching the polypetalous condition. Only a few species belong to this group, *e.g.* *S. janesii*.

D. With short, rounded, triangular sepal tips and star-like corolla as in "C." In this category, amongst others, are placed *S. commersonii*, *S. chacoëse*, and *S. cardiophyllum*.

According to Wittmack, those species with the wheel-like corolla are native to West S. America, from the Andes to the coast in Chili, Peru, Bolivia and Colombia, although a few are found farther east. On the other hand, the species with the star-shaped corolla are distributed more in the East, in Argentine, Paraguay, Uruguay and South Brazil. In Mexico, however, both forms appear.

The wild forms have, in general, smaller haulms and tubers than the cultivated potato. With the exception of the *S. etuberosum* described by Sutton, those species which produce seed are characterised by the fact that plants raised from such seed exhibit no variation whatever from the parents. Seedlings, however, of the cultivated potato differ widely from each other, generally showing extensive variation in foliage, colour of tubers and habit of growth. The wild forms produce long stolons on which new foliage shoots frequently arise some distance from the mother plant, a characteristic not found in *S. tuberosum*. Sutton states that the pollen grains of the wild species with which he worked were of one particular shape, namely, oval or elliptical, whereas the pollen grains of the cultivated potato
were very irregular in form and size. The three most interesting wild species are *S. maglia*, *S. commersonii* and *S. etuberosum*.


This species was, according to Baker, first clearly characterised by Schlechtendahl in his *Hortus Halensis*. Grown for upwards of twenty years at Kew, side by side with *S. tuberosum*, it maintained its individuality. It is native to Chili and the following are Baker's notes on it: "Root-stock bearing copious large tubers. Stems stout, erect, flexuose, much branched, 1 to 2 ft. long, slightly hairy, strongly winged on the angles. Leaves pseudo-stipulate, 6 to 9 in. long, including the 1½ to 2 in. petiole; large leaflets 5 to 7, ovate, acute, thinly pilose, 2 to 3 in. long, the side ones stalked and unequally cordate at the base, lowest pair of leaflets much dwarfed, interspersed small ones few or none. Flowers in copious compound long-peduncled cymes; pedicels downy, under 1 inch long, articulated about the middle. Calyx ¼ to ½ in. long, hispid, teeth deltoid-cuspidate longer than the tube. Corolla white, subrotate ⅓ to 1 in. diameter; segments deltoid, ¼ in. long and broad; anthers ⅓ in. long, bright yellow, filament very short. Style clavate, twice as long as the stamens. Fruit not seen."

*S. maglia* grows in the neighbourhood of the coast and is the same species as that obtained by Darwin in the Chonos Archipelago.


This species is described by Baker—whose observations were drawn from herbarium specimens—as follows: "Stems dwarfed and more slender than in the ordinary *S. tuberosum*, the root stock bearing copious large tubers. Leaves sometimes, but not always, pseudo-stipulate, 5 to 6 in. long when fully developed, with a naked petiole 1 to 1½ in. long; 5 to 9 oblong acute or often obtuse thin leaflets, the terminal ones much the longest, the lowest pair much dwarfed; the rachis entirely without any small leaflets interspersed amongst the large ones. Flowers in lax compound terminal
cymes, just as in *S. tuberosum* and *S. maglia*; pedicels long or short, articulated about the middle. Calyx \( \frac{1}{6} \) to \( \frac{1}{3} \) in. long; teeth deltoid or lanceolate-deltoid, as long as the tube. Corolla \( \frac{1}{6} \) to \( \frac{1}{3} \) in. long, pale lilac or white, the lanceolate-deltoid segments quite as long as the tube; anthers orange-yellow, longer than the corolla-tube. Style always distinctly exserted beyond the anthers. Berry not seen."

According to Sutton the jessamine scent of the flowers is very noticeable. The berry is heart-shaped. This species grows wild in Uruguay.


This species is described by Lindley: "This curious plant is a hardy perennial, native of Chili, whence it was obtained some years since by the Horticultural Society. It bears rich clusters of purple blossoms, with a golden yellow centre, from July to October, and is easily multiplied by dividing its stout rooting underground stems. Although extremely similar to the potato in appearance, yet its larger and more compact flowers, and its want of power of producing tubers, render it a proper plant for a flower garden."

Baker considers *S. etuberosum* as likely to be a variety of *S. tuberosum*, marked by its want of tubers, its sub-glabrous leaves and calyx, its short unpointed calyx segments and very large bright-coloured corolla.

The *S. etuberosum* described by Sutton were obtained from the Royal Botanic Gardens, Edinburgh, and may not be the same as that described by Lindley. Berthault has named Sutton's plant *S. edinense*. According to Bitter, *S. edinense* is probably a hybrid produced by the crossing of the ordinary potato with one of the wild species. As described by Sutton, the plant has the elliptical pollen grains of the wild types and possesses tubers. The seedlings derived from it differ greatly, as is found with *S. tuberosum*. Sutton considers this plant as the probable parent form of the cultivated potato.

The interest that these wild species have for us is twofold. In the first place, the question arises as to whether or not they themselves may be useful economic plants. Experience
has shown, however, that even after a prolonged period of domestication, the tubers, although sensibly increasing in size with favourable conditions, do not, under any circumstances, reach such dimensions as would render them serious competitors of the cultivated potato. In the second place, it is desirable to know if these wild types can be utilised to advantage in breeding and improving the present commercial potato by virtue of their alleged disease-resisting power. The wild species would certainly appear to be more resistant to blight (*Phytophthora infestans*) than *S. tuberosum*, but as far as the writer is aware there exists no definite evidence indicating that these species are more susceptible or more resistant to other diseases than the common potato. Up to the present the main effort of potato raisers, who have used the wild species for hybridising, has been directed toward the securing of blight-resisting types. The bearing that these species have on the production of new types will be discussed further in the section dealing with potato breeding.
CHAPTER IV

THE POTATO PLANT

The potato seed varies from oval to round in form and its dimensions vary slightly according to the variety, although different sizes are to be found in a single potato berry. On an average, however, the greatest length is about 2 mm. and width 1.5 mm. The seed may retain its vitality for a considerable time, there being definite records of germination after eleven years. When sown under suitable conditions it grows readily and produces a seedling with a definite tap-root and two or even three ovate cotyledons. The plumule develops rapidly into a stem with leaves, and from the axils of the cotyledons spring shoots which are geotropic in nature, i.e., they grow downwards. When these shoots or stolons have found their way into the soil and developed more or less horizontally for some distance, their tips begin to enlarge and give rise to tubers, owing to the storage of reserve foods, principally starch. Other stolons may arise from the axils of the foliage leaves above the cotyledons.

A plant derived from a "seed" tuber has no cotyledons; it begins from an eye or bud on the tuber and its structure can be seen in a sett taken from the sprouting boxes before planting. The only essential difference between the seedling plant and that grown from a tuber is to be found in the root system; otherwise the two plants may be considered identical.

The Root System.

The root system of a plant grown from a true seed begins as a tap-root with numerous branches; other roots—adventitious roots—may arise from the stem, especially from the part at the base which is more or less covered with soil. In plants grown from tubers all roots are adventitious: the
tubers themselves do not normally bear roots, although these have been induced to form on tuber callus growths. Adventitious roots usually arise in groups of three or four at the nodes of the stem bases or on the stolons. The root system of the potato is distributed mainly in the upper layers of the soil, but individual roots may penetrate deeply.

The Shoot System.

The shoot system consists of all the above-ground parts, the tubers and the stolons.

Aerial Stem.

The above-ground stem of the potato is herbaceous and erect in the early stages of growth, but later it becomes more spreading. It has its origin from the plumule in seedling plants or from the sprout in plants grown from tubers. The thin-walled cells of the pith can be recognised readily in the centre of a cross section. In the lower parts of the stem the pith generally breaks down, leaving a hollow; the nodes, however, are always solid. The vascular cylinder of the young stem consists of isolated groups of bundles corresponding chiefly to the angles of the stem, but in older tissue they unite to form a closed cylinder round the pith. The vascular cylinder thus formed is the principal track for the conveyance of water and food material; it can be traced continuously from the root or sett into each leaf and stolon, and through the heel end into each tuber. The cortex of the stem consists partly of thin-walled and partly of thicker-walled cells. Below the epidermis the colouring matter of the stem is to be found in one or two layers of cells; the colour is green if these cells contain chlorophyll alone; in coloured stems the chlorophyll is partly obscured by a pigment dissolved in the cell sap. The epidermis, or outermost layer of cells, is always more or less pubescent.

The stem is normally triangular in cross section, except at the nodes, where it is round. At each angle of the triangle the margins are drawn out to form wings (Fig. 2, p. 61); these wings originate in pairs at the base of each leaf and
are decurrent unequally on the stem, one extending for one internode, the other for two. The portion of the stem covered with soil has no wings, is round in cross section and is normally solid.

**THE LEAF.**

The first leaves formed by a seedling are entire, but from about the fourth leaf onwards they become compound and irregularly pinnate, opposite pairs of large leaflets alternating with smaller ones (secondary leaflets). The first leaves of a plant grown from a tuber are also entire. The leaves are arranged on the stem in a spiral, which is usually to the left up the plant, although right spirals are found frequently. The midrib of the leaf is semi-circular in cross section; the flat portion, or upper surface, is densely pubescent, whereas the convex portion, or lower side, is only slightly pubescent. At its junction with the stem it encircles the latter for nearly one-third of the circumference. Two stipule-like growths are to be found at the base of all normal leaves; these are somewhat half-moon shaped and encircle the stem. The venation of the leaf is netted; from a strongly-developed midrib lateral branches arise which subdivide freely, forming a dense network. Young potato leaflets are thickly covered with hairs, some of which are long and straight, others being shorter and glandular. The straight hairs, which are more numerous on the under than the upper surface, are one or several-celled; the glandular hairs have a spherical head, usually four-celled, borne on a short pedicel. The mature leaflet has relatively fewer hairs and these arise in greatest density on the midrib and lateral veins. Stomata, or pores, are found on both surfaces, but they are more abundant on the lower.

**THE FLORAL PARTS.**

The inflorescence is a cyme. The flower stalk, although always lateral, sometimes seems to occupy a central position, having become stronger than the growing point of the stem, which it pushes aside.

There are five partially united sepals, the outer surfaces
of which are always more or less hairy. The petals are also united and are tubular with five lobes. Fine hairs occur on the under surface of the petal tips and extend downwards along the ribs referred to below. Radiating from the centre of the flower are five yellow-green rays or ribs, consisting mainly of vascular bundles. There are five stamens which alternate with the corolla lobes and are attached to the tube. The stamens have orange anthers. These are larger than the filaments, and until maturity they form a close column round the style. Each anther has two lobes, and each lobe consists of two pollen sacs which open by means of a single pore situated at the apex. The pollen grains vary in form from round to elliptical. There are two completely fused carpels, forming a two-celled ovary with a single style and bi-lobed stigma. The ovary is superior and the placentation axile. When the stigma is receptive a sticky fluid is exuded on its surface. The potato "plum," "seed ball" or "apple" is a berry, round, two-celled and many-seeded.

THE TUBER AND STOLON.

Shortly after the potato haulm appears above ground, stolons develop in the axils of the scale leaves on the underground portion of the stem. These stolons lengthen for several internodes and ultimately swell at their tips to form tubers. The tubers and stolons, being modified stems, present a typical stem structure, the tissues having undergone the same process of development as those of the stems. The change from stolon to tuber is quite abrupt. In the young tuber extensive cell division takes place in the pith and much less in the outer cortical region, hence the vascular tissue in passing from stolon to tuber bulges outward and is to be found not far from the skin; later growth in size results from active division of cells lying between the cortex and the pith, divided into two unequal parts by the narrow vascular ring; these become the chief starch-containing cells. On cutting a mature tuber it is easy to recognise the vascular cylinder which lies roughly about one-eighth inch below the skin. This cylinder encloses a
large amount of storage tissue, then the pith, while externally there are more storage cells and the cortex. In the young stolon the cortex occupies a large area compared with the organ as a whole, but in the later development of the tuber the cortex adds little new tissue and "hardly more than doubles the number of rows of cells in the radial extent." ¹ While the tuber is expanding, fine strands of vascular bundles are formed amongst the pith and storage cells; the bundle can be clearly traced entering the heel end of the

Fig. 1.—Left: Radial Section of Stolon Tip (x 6), and Right: Mature Tuber (½ nat. size), showing Homology of Tissues. (After Artschwager.)

tuber from the stolon and sending branches into each eye, or bud, produced by the tuber. As this vascular cylinder is the part mainly concerned in distributing the sap which afterwards gives rise to starch, its amount is about the same in a stolon as in a tuber, but in the latter it forms an open meshwork rather than a closed cylinder. The pith forms the central part of the tuber and it is broadest near the middle; it gives off lateral branches which communicate with the eyes and it terminates with the apical eye. The entire tuber is covered with a corky skin, from six to ten

cells deep; this skin is pitted with lenticels (breathing pores) which have developed underneath the stomata of the young stolon tip and under certain conditions these become quite visible as white dots owing to a proliferation of their tissue.

Morphologically, the tuber is a shortened, thickened stem with scale leaves, and in the axils of these leaves lie the eyes. Each eye is a collection of buds lying more or less in a depression. The number of buds in each eye may be greater, but three is the usual figure. Actually the eye is a lateral branch with undeveloped internodes. Thus it will be seen that the tuber is a branched shoot system and not a simple shoot. The spiral of the eyes is towards the left from heel to rose end, but occasionally right spirals are found. At the rose end, or apex of the tuber, the eyes are more crowded than at the heel or stolon end.

The Sprout.

Normally, ripe tubers do not sprout before a certain time has elapsed. According to Denny¹ the dormancy of tubers can be overcome by treatment with certain chemicals, e.g. by soaking the tubers in a 0.3 to 0.4 per cent. solution of ethylene chlorhydrin for one hour. The minimum temperature for sprouting is about 8° or 10° C. The cause of the resting and the processes which go on during that period are imperfectly understood, but when sprouting begins diastase and other enzymes are formed and the starch is converted into sugar, being transferred to the growing sprout where it is used in the formation of new tissue. The eyes do not develop equally; the most vigorous is the apical one. As with the dormancy period, however, Denny has shown that treatment with a 1-per cent. solution of thiourea for one hour destroys the dominance of the apical eye and allows all eyes on the tuber to grow equally vigorously.

It is well known that the length of the sprout and the development of colour on it are influenced by light and moisture; in darkness long etiolated sprouts are found on

which the colour, if present, is very faint and confined mainly to the lenticels. In diffuse light the sprouts do not grow to the same extent and the colouring is much more marked, being partly green and partly red or blue: the green is due to the formation of chlorophyll with which the cells underneath the colourless epidermis are filled; the colouring matter is dissolved in the sap of the cells immediately underlying the epidermis. Chlorophyll is also present in the coloured portions, but its presence is often obscured by the pigment. Even in the green parts pigment is present in small quantities, although it is absent from the light green portions. The root points on the sprouts are generally colourless. All sprouts are more or less pubescent.
CHAPTER V

THE CLASSIFICATION OF VARIETIES OF THE POTATO

A THOROUGH knowledge of potato varieties is essential for breeder, pathologist, grower and merchant alike. All must know what the peculiarities of any variety are; whether it resists or is susceptible to disease; whether it keeps well or badly; what conditions of soil and climate are most favourable to its growth; and what demands are made upon it by the public. But information on these points is not enough. All persons handling potatoes should be able to identify the different varieties and to detect impurities in stocks. Potato varieties can be placed in groups by the use of sound systematic classifications. Absolute identification, however, cannot be accomplished without reference to characters incapable of being systematised. It is proposed, therefore, in the first place, to discuss some classifications in detail, and, in the second, to describe varietal types and characters of use for absolute identification.

If one seeks to trace the history of any variety, it will be found that all the stocks have had a common origin in one plant. This plant was derived from a seed produced by the normal sexual process and subsequent propagation has been carried out vegetatively. The seed itself may have been the product of cross-fertilisation between two varieties, or it may have had its origin in self-fertilisation. It is true that variations occur occasionally in the potato, e.g. the red tuber variation of King Edward, but there has been—so far as the writer is aware—no authenticated occurrence of vegetative variation in the potato where the variant has had qualities which marked it as a greatly superior type to that from which it arose. Even with a variation, however, the ultimate origin is a true seed. It is the vegetative reproduction which retains the varietal features constant from season to season,
as, rightly regarded, all units of a particular variety are portions of the same plant. Except for occasional variations and mutations, a variety remains constant when multiplied vegetatively; true seed, on the other hand, produces normally a multitude of types differing both in form and in growth from the parent or parents.

Historical.

A description has been given in a previous chapter of the probable ways in which the potato was introduced into this country. It is not known if the original stock consisted of one or of several varieties. All available evidence, however, favours the latter view.

"It is known that, at the time of the conquest of Peru, more than one variety of the potato was being grown by the natives; and that then, as in many sections of South America to-day, the potato was very largely reproduced from the true seed, rather than from tubers. It is the exception, rather than the rule to-day, to find the Indian in the Andean region growing but one variety in his potato plot; the chances are strongly in favour of his having a dozen or more different varieties (seedlings) intermingled with one another."  

Since the introduction of the potato into Europe and North America, descriptions of varieties and attempts at classifications of these have appeared from time to time.

The plants originally described by Clusius and Bauhin do not seem to have been identical. Each, however, gave rise to seedlings, some with white and others with purple flowers. At a very early stage in the development of the potato, two types were recognised, viz., the white tuber and the red tuber. At the beginning, progress in differentiation was slow, and in 1752 Miller 2 records "... the common potato of which there are two varieties; one having a red root and a purple flower, and the other a white root and a white flower; but as these are accidental varieties, I shall not make them different." Soon after this, the separation of varieties appears to become more detailed, and in 1757 Maxwell 3

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described the following seven varieties, the names of which indicate a rudimentary classification; (a) the long red; (b) the round red; (c) the long white; (d) the round white; (e) the blue; (f) the leather coat; and (g) one maturing a month before the ordinary types. As is to be expected, however, in all the earlier descriptions and classifications the tuber is the part of the plant which receives most attention. Nevertheless, in Maxwell’s descriptions is found the germ of what was later to become the primary differentiating feature of all classifications, viz., maturity. In 1770 Varley described nine varieties in detail, enumerating features such as peculiarities of tuber, maturity, cropping capacity and cooking quality. In describing “The Early-Wise Potato,” he states that apart from tuber characters, the variety is ready for use two months before others, and that it produces a small top but no blossom. Here is the first attempt—so far as the author can trace—at a complete description of a potato variety. Somerville, in 1795, classified the best varieties of his day as follows:

<table>
<thead>
<tr>
<th>Early Potatoes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dwarf Early, Round and Kidney.</td>
</tr>
<tr>
<td>2. Royal, or Cumberland Early.</td>
</tr>
<tr>
<td>Late</td>
</tr>
<tr>
<td>1. Large White Kidney.</td>
</tr>
<tr>
<td>2. Killimanca or Icanie.</td>
</tr>
<tr>
<td>5. Winter Long, with great number of eyes.</td>
</tr>
<tr>
<td>For Cattle</td>
</tr>
<tr>
<td>1. Ox-Noble or Cluster Potato.</td>
</tr>
<tr>
<td>2. Yam, or Surinam Potato.</td>
</tr>
</tbody>
</table>

Descriptions are given of these varieties, particularly of the tuber characters, but Somerville draws attention to differences of maturity in the late group and thus lays the foundation for another division, viz., mid-season varieties. In the *Gardeners' and Botanists' Dictionary* (1807) forty-three different kinds are described, attention being paid to tuber characters, maturity, cropping power and quality.

The first serious attempt at systematic work was that published in 1819 by Putsche. Putsche opened his discussion by enumerating eleven different characters which had been used in previous efforts at classification. However, his experience led him to conclude that as these characters were inconstant, groupings based on maturity would be more satisfactory. In consequence, he placed German varieties into two large groups, early and late. All those which matured before the end of August were placed in the early group and those maturing after August in the late group. He made no attempt at further classification and contented himself with a fairly complete description of every variety. Altogether, he described thirty-three varieties, including ten earlies, and his descriptions were illustrated by a coloured plate of a typical tuber of each variety. Special importance was assigned to the tuber, but use was also made of the following points:

**Stems.**—Height; branching; colour; condition of wings and nodes.

**Leaves.**—Number; size; colour of midrib.

**Leaflets.**—Shape; colour; surface; secondaries.

**Inflorescence.**—Length of flower stalk; peculiarities of sepals; colour of flower.

In the same year as Putsche's work was published, a classification of British varieties appeared in *The Cyclopaedia or Universal Dictionary of Arts, Science and Literature*, edited by A. Rees, D.D., F.R.S. In this classification varieties were grouped as early and late, twenty-three varieties being included in the former and twenty-six in the latter group. Louden, in his *Encyclopaedia of Gardening*,

1 Dr C. W. E. Putsche, *Versuch einer Monographie der Kartoffel*, 1819.
published in 1824, distinguished varieties by the following characters: (a) earliness; (b) lateness; and (c) form, size, colour and quality of tubers. He made the following distinctions:—

1. Form of Tuber:—Round, oblong and kidney.
2. Size:—Small and large.
3. Colour:—White, red and purple.
4. Quality:—Watery, waxy and mealy.

About 1831, Charles Lawson of Edinburgh, enumerated seventy-three varieties, of which twenty-one were early, forty-four late and eight medium. Thirty-three of these were white; fifteen red; eleven purple; three black; four pink; one buff; four white and pink; one pink and red; and one white and purple. Five years later, Lawson published his Agriculturists’ Manual in which is given what is undoubtedly the most exact and painstaking of all the early British systematic works on the potato. Lawson grouped his potatoes in seven large classes, four of which were devoted to garden varieties and three to field varieties, viz.:—

“Class I.—Earliest garden sorts adapted for forcing on account of their dwarf growth.

“Class II.—Earliest garden potatoes not so well adapted for forcing as the preceding on account of their taller habit of growth.

“Class III.—Second early garden potatoes.

“Class IV.—Early Field Potatoes, the leaves and stems of which (under ordinary circumstances) are decayed by the time when they are usually taken up and the tubers of which are then fit for use.

“Class V.—Late Field Potatoes, the foliage of which in ordinary seasons does not decay until injured by frost and the tubers of which generally require to be kept for some time before being fit for using to the greatest advantage.

“Class VI.—Large, Late, Prolific sorts more particularly adapted for feeding cattle.

“Class VII.—Late Unprolific curious Garden sorts.”
Seventeen subsections appear according to tuber characters, and each variety is described under the following headings: 
(a) Height of stem; (b) habit of growth; (c) foliage; (d) flower; (e) shape of tuber; (f) colour and peculiarities of skin; (g) fold of increase; (h) general remarks; quality, health, etc.

Another British classification appeared in the *Gardeners’ Magazine*, 25th February 1882, in which there is a catalogue of four hundred varieties, presumably prepared by the Editor, Shirley Hibberd, or at least compiled under his supervision. In this classification the following points are used to differentiate varieties:—(a) class of tuber (round or kidney); (b) colour of tuber; (c) size of tuber; (d) quality; (e) productiveness; (f) relative growth; and (g) height and season.

The next stage in systematic work marks a distinct advance. Vilmorin\(^1\) published first in 1882 and again in 1886 and 1902, the results of many years’ observations of a very complete collection of potato varieties. These varieties were grouped into twelve classes in 1886, and these twelve classes were subdivided into thirty sections. In 1902 only nine classes appeared, viz.:—

1. Yellow, round.  
2. ” oblong.  
3. ” long.  
4. Flesh-coloured, oblong.  
5. Rose or red, round.  
6. ” ” oblong.  
7. ” ” long.  
8. Violet coloured.  

These nine classes were further subdivided into forty sections. Vilmorin’s classification was very elaborate. The outstanding feature was the use for the first time of the sprout colour.

Sprout colour, as a differentiating character, is not found in the descriptions of potatoes at Chiswick in 1896 which appeared in the *Journal of the Royal Horticultural Society*, 1896-97, and in which emphasis is laid on the following points:—(a) maturity (very early, early, second early and late); (b) shape and colour of tuber; (c) height of haulm (tall, moderate or short).

Present-Day Classifications.

German.—The principal present-day German classification is that of Dr K. Snell.¹ Snell groups German varieties into four large classes by maturity, viz.: Early, Medium Early, Medium Late and Late. Each of these groups is subdivided into sections by floral characters and foliage types, a standard being fixed for each section and illustrations being given. Tuber characters are almost entirely disregarded. However, tubers receive separate treatment and are grouped into two large classes, viz.: (a) Early; (b) Medium Late and Late. These tuber groups are further subdivided by reference to such essential features as shape, colour of skin and flesh, cooking quality, etc. A key is given for the identification of German varieties, and the author describes 248 German, 33 Dutch and 24 Scots varieties, and 12 groups of American varieties, the essential features of each receiving treatment under the following headings: Stem, Flower, Tuber, Maturity.

American.—The standard American classification is that of Stuart.² In this classification American potatoes are placed in eleven groups, and the principal characteristics of each group are described under the following headings, viz.: (a) Tuber; (b) Sprouts; and (c) Flowers. Coloured plates and illustrations are added.

British.—A great stimulus was given to systematic work on the potato in Britain by the spread of wart disease and by the discovery that some varieties were immune to that disease. This fact was first brought to the notice of the Ministry of Agriculture and Fisheries by Mr G. C. Gough, one of the Ministry's Inspectors. The segregation of commercial varieties into immune and susceptible categories was carried out by Malthouse at Harper Adams College, and later by Mr John Snell at Ormskirk. A classified list of immune varieties was issued in leaflet form by the Ministry of Agriculture in 1919. In this publication

¹ Dr K. Snell, *Die Kartoffelsorten*, 1925.
varieties are grouped as Early, Second Early and Maincrop. Each variety is described under the following headings: (a) Description of tubers; (b) Colour of sprout; (c) Haulm and Foliage; and (d) Flowers. Synonymous nomenclature is also dealt with, twenty-four different names appearing under the common heading, "Abundance." In "The Ormskirk Potato Trials," Annual Report, 1919, a similar classification is given for immune varieties, and susceptible varieties are described under (a) Maturity, (b) Tubers and (c) Flowers. In a leaflet published by the Board of Agriculture for Scotland, a revised edition of which appeared in 1920, immune and susceptible varieties are grouped into four classes, Early, Second Early, Early Maincrop and Late. For each variety are described the sprout colour, the characteristics of the tuber (including the colour of the flesh), and the flower. More elaborate descriptions appeared in an article in the Scottish Journal of Agriculture, January 1920. Similar but more comprehensive articles appeared in July 1921 and in July 1923.

The most useful existing classification, judged from the standpoint of the relegation of varieties into groups in which the essential features are apparent, is to be found in the Key to Potato Trials and Collections at East Craigs and Philpstoun, 1926, published by the Board of Agriculture for Scotland. In this classification, potato varieties are grouped into four Maturity classes: First Early, Second Early, Early Maincrop and Late Maincrop. The classes are all treated similarly: two groups are formed by sprout differences, viz.: (a) pink and faint pink, and (b) blue. Each group is divided into three sections according as the tuber skin is white or yellow, coloured or parti-coloured. The sections are further split into subsections by the tuber shape. Flower colour constitutes the next reference character, varieties being classed as non-flowering, flower white and flower purple. The colour of the tuber-flesh is used as a final means of separation. For purposes of lucidity a diagrammatic representation is presented, showing the stages gone through in placing in its correct category, an early, round, blue variety with white flowers and white tuber-flesh.
CLASSIFICATION OF VARIETIES

FIRST EARLY

Sprouts, Pink  Sprouts, Blue

Skin, White  Skin, Coloured

Tuber:—Kidney
  (long oval)  Kidney
  (Pear shaped)

  Flower:—White  Purple  Non-flowering

  Tuber-flesh:—White  Pale Yellow  Yellow

The foregoing classifications represent successive developments in systematic work on the potato. The more constant characters have been gradually adopted for the main groupings, the less constant being omitted or used only for subsidiary groupings. There can be no absolute key for the determination of potato varieties: new types with different combinations of characters are continually appearing on the market, while chance seedlings and “rogues” frequently find their way into old stocks. The most that can be done is the construction of distinct groups into which all types must fall. Tubers, regarded by themselves, are susceptible of a finer grouping than is given above, and a classification of these will be found elsewhere in which the tubers of common commercial varieties are arranged in a systematic order.
CHAPTER VI
INTERVARIETAL DIFFERENCES IN THE POTATO

I. Foliage.

POTATO varieties have been elaborated through generations of cross-breeding; the seeds of self-set berries of all popular varieties carry many characters in a blended state and give rise to plants which differ amongst themselves and are distinct from the parent. It is not easy to find seedlings which cannot be distinguished from one another; but all conditions prevail, ranging from plants which are widely different to those which are very similar. Differences appear not only in the grosser features, but also in those of detail; moreover, these differences are not confined to form, but extend to physiological and chemical characters, such as maturity, disease resistance and composition. All recognisable differences are useful in distinguishing varieties, but those treated in the following sections will be mainly connected with form. During the growing season it is possible to identify a variety with precision, but during the winter, when tubers alone are available, this can be done only with exceptional varieties.

Foliage.—No hard and fast classification of the above-ground parts of the potato has been attempted, or, indeed, is possible: an endless number of types exists, the number of varying characters is very great, and many of the individual characters have wide ranges of fluctuation. The most that can be done with the foliage is to define certain types and to describe it in such a way that those interested will have less difficulty in identifying the varieties with which they deal and in recognising impurities in crops.

Experience in the field shows that during the summer
INTERVARIETAL DIFFERENCES

months potato foliages are recognised largely by general appearance: it is undoubtedly true that the skilled observer recognises these by headmark, without enumerating details of identification characters. This composite impression is very difficult to define because it is not produced by a few characters but by many, some of which cannot be described adequately in words. However, it would appear that the essential features which form the various combinations are as follows:

1. The Contour of the Foliage.
2. The Relative Height of the Stems.
3. The Number, Branching and Colouring of the Stems.
4. The Size, Number and Set of Leaves.
5. The Distribution, Size, Shape, Number and Colour of the Leaflets.

All the above may be modified by environment—climate, soil and cultivation—but essentially they are hereditary characters and are transmitted by vegetative propagation, *i.e.*, the usual method of propagation in the potato. When we seek to utilise general appearance in grouping varieties, two difficulties are encountered; in the first place, there is the difficulty of fixing standards, and, in the second, it is impossible to eliminate the personal conceptions of the classifier. Thirteen standards have been adopted here, and an attempt has been made to group round each of these standards those varieties which are similar in general appearance of foliage. The salient features of each group are described. Some varieties have not been classed: it is recognised that more groups could have been adopted and perhaps more varieties placed within the individual groups, yet the following grouping of potato foliages by general appearance will materially assist a beginner in the study of potato varieties. The reader will find it very helpful when dealing with new varieties to seek in the first place for resemblances to other varieties whose general appearance has already been grasped and in this way construct fresh groups for himself.
Group 1.—Type: Duke of York.

Salient Features.—Low growing; spreading; stems weak; leaves long, open and drooping; leaflets long and narrow.

Milecross Early. Downie's Early.

Group 2.—Type: British Queen.

Salient Features.—Slightly taller than Group 1; spreading; stems more robust than in Group 1, and branching frequently near ground; basal foliage vigorous; flowering freely.


Group 3.—Type: Up-to-Date.

Salient Features.—Medium to tall; spreading; stems robust and branching near ground; basal foliage vigorous; taller and more vigorous than Group 2.

Up-to-Date. Field-Marshal. Bobbie Burns.  

Group 4.—Type: Sharpe's Express.

Salient Features.—Medium height; upright; very little branching; secondary leaflets numerous and conspicuous.


Group 5.—Type: King Edward.

Salient Features.—Medium to tall; upright; very little branching; leaves drooping; characteristic drooping tops; seldom flowering.

St Malo Kidney. Evergood. Lymm Gray.  
Epicure. Braemar Castle.

Group 6.—Type: Sutton's Abundance.

Salient Features.—Medium to tall; upright; stems robust; little branching; lacking the characteristic tops of Group 5.

(a) With close leaf:—


(b) With fairly open leaf:—

Sefton Wonder. Nithsdale. "Great Scot Rogue" in Kerr's Pink.1  
Arran Chief. Scottish Chief. Cumberland Ideal.

1 See Key to Potato Trials and Reference Collection at East Craigs and Philpston, 1926, Board of Agriculture for Scotland.
INTERVARIETAL DIFFERENCES

Group 7.—Type: Golden Wonder.

Salient Features.—Tall; upright; stems robust; branching when it occurs is mainly apical; leaflets dull, much wrinkled and arched; apical foliage usually more luxuriant than basal foliage.


Group 8.—Type: Keppleston Kidney.

Salient Features.—Tall; upright and very open; stems robust, few and coloured; very little branching; leaf open.

Tawny.

Group 9.—Type: Templar.

Salient Features.—Tall; upright; open; stems very robust; branching when it occurs is mainly apical; leaves more numerous than in Group 8; leaf open, rigid and dull.

White-flowered Rogue in Crusader.¹

Group 10.—Type: Kerr's Pink.

Salient Features.—Very tall; upright; dense and vigorous; stems very robust; stems and midribs of leaves coloured; branching at the tops; foliage compact.

Kerr's Pink. Sir Rufus. Gregor Cups.
Arran Victory. Kerr's Pink Substitute.¹ Shetland.

Group 11.—Type: President.

Salient Features.—Tall; upright; vigorous; stems very robust; leaves rigid and set at acute angle to the stem; secondary leaflets not numerous.

President. General. Marconi. Blue President Rogue.¹
Blue Grey.¹

Group 12.—Type: Champion.

Salient Features.—Tall; spreading; open and vigorous; stems strong but thin; leaf very open; leaflets narrow.

Champion. Orkney Rogue.¹
Up-to-Date Rogue resembling Champion.¹

¹ See Key to Potato Trials and Reference Collection at East Craigs and Philpstown, 1926, Board of Agriculture for Scotland.
Group 13. Type: Rocks.

Salient Features.—Stems weak and tending to droop; leaves and petioles small; leaflets inclined to be arched and corrugated.


Although the above groupings will be found of much assistance in memorising the general appearance of variety foliages, a more intensive study is required before actual identification can be made with certainty, hence differences in the individual characters are set out systematically below. It has been considered necessary to go into much detail, as the principal features of some varieties differ very slightly and reference to detail characters may furnish at times the only conclusive evidence of identity. As a rule, however, the first distinction of a variety will be found in the larger characters, regard for finer points being necessary only when the larger ones offer no help.

Most of the botanical characters of the potato are influenced by environment, but the modifications of any character are normally of about the same degree in different varieties grown under similar conditions. All character differences have therefore a relative value and are important in detecting impurities in the field. However, for the identification of a variety, reliance must be placed primarily on points which have an absolute value. Amongst varieties an individual character has generally a range of variation, starting with a strong and finishing with a weak development; it appears, however, most often in a medium condition, e.g. dark green, medium green and light green foliage.

It is the extremes—the strong and the weak developments—which are of most use in diagnosing varieties.

The Contour.

The contour of the foliage may be said to be spherical when growth is equally vigorous in all directions. Most varieties, however, show a more abundant growth upwards, hence the typical shape becomes more oblong rectangular, this shape being modified to a greater or lesser extent according to the vigour of apical or basal foliage.
The Stem.

Stems differ according to variety in the following characters: height, colour, strength and thickness, frequency, branching, peculiarities of wing, nodes, solidity, pubescence and distribution of the leaves.

(a) Height.—As previously stated, the height of potato stems is associated largely with the date of maturity of the plants. Varieties may be classed as tall, low growing and of medium height. Kerr's Pink, Duke of York and Great Scot respectively are typical of these groups.

(b) Colour.—On occasion the colour of the stem may be of great use in diagnosing varieties. Some varieties have green stems always, e.g. Fortyfold, Marquis of Bute, Lochar and Golden Lass; the great majority of potato varieties, however, have some colour on the stem. This colour is due to a pigment which can produce a range of colours from pale pink to deep purple. Differences exist not only in the intensity of colour but also in its distribution: thus we speak of the stems of British Queen and King George as being reddish-brown at the base; of Champion, Templar and the Dean as mottled purple; of Di Vernon as red purple; of Epicure and Eclipse as tinged pink; and of Arran Chief and Abundance as tinged blue purple, especially at the base. Often the stem is only markedly coloured at the bases of the midribs of leaves, a feature of special consequence in some varieties, e.g. Buchan Beauty. It is noteworthy that all colour is intensified as the season advances, and, as a result, discretion is to be exercised with the age of the plant. There seems to be no doubt that sunlight is favourable to the production of pigment, and that insufficient moisture and want of manuring have the same effect. Varieties with coloured tuber skins have generally coloured stems; there is, however, no correlation between stem and tuber-skin colours; Fortyfold, which has coloured tubers, has green stems, while International Kidney, a white-tuber variety, has very dark-coloured stems.

(c) Strength and Thickness.—Under uniform conditions the strength of potato stems is useful in separating varieties.
Some, such as Immune Ashleaf, have weak stems, and others, such as President and Rhoderick Dhu, have much sturdier stems. In a great measure the strength of a stem is an index of its thickness, yet this is not always the case: Champion, which has thin stems, may be mentioned as a variety with exceedingly strong stems. The thickness of stems, however, may often be used by itself as a varietal identification mark. Catriona and Di Vernon may be confused at times, but a comparison of their respective stems may lead to absolute differentiation, those of Catriona being thicker.

(d) Frequency.—Varieties differ greatly in the number of stems which may develop, some possessing, like Summit, many, and others fewer, e.g. President and Golden Wonder. In general, however, it is only when the varieties under observation are at the opposite ends of the scale of numbers that one may use stem frequency with any assurance.

(e) Branching.—Many varieties, e.g. Arran Comrade, Ally, Lochar and Great Scot do not normally branch above ground. Other varieties have stems which are always branched. Some seem to branch mainly at the apex of the foliage, e.g. Kerr’s Pink, and others nearer the ground level. Basal branching is a distinct feature of Group 3, and to a lesser extent of Group 2.

(f) The Wings.—These may be of great use in diagnosis. Generally, in early varieties, the wings are less conspicuous than in late varieties. In some types they are very much waved (Fig. 2), e.g. Arran Chief; in others they are unwaved (Fig. 3), e.g. Lochar, and in others again an intermediate condition exists, e.g. Great Scot. Where stems are coloured the wings are usually coloured also, but this is not so in every variety, Di Vernon and the Loose Anthered Rogue¹ being examples of the combination—coloured stems and green wings.

(g) The Nodes.—The nodes may be used at times in separating one variety from another. The characters which vary are the colour and size. In most varieties the stem

¹ See Key to Potato Trials and Reference Collections at East Craigs and Philpstoun, 1926, Board of Agriculture for Scotland.
colour, if any, does not pass completely through the nodal tissue, so that the latter is greener than the remainder of the stem. This phenomenon is well illustrated in the variety, Eclipse. There are, however, other varieties, e.g. Arran Victory and International Kidney, in which the nodal tissue is as highly coloured as the internodal tissue. A few varieties are distinguished by having nodes which are swollen, a feature especially prominent in the variety, Summit.

**Fig. 2.—Shoot of a Variety showing Origin of Inflorescence Stalk (D) on side Shoot (B); (A) Main Stem; (C) Waved Wing.**
(h) **Solidity of Stem.**—Reference has already been made to the breaking down of the pith in the internodal tissue of all but the upper parts of the aerial stem. This breaking down leaves the stems hollow, a condition easily determined by making a cross-section between two nodes. All varieties do not possess this characteristic, two, viz., Eclipse and Carisbrook Castle, being peculiar in that their stems remain solid until maturity, when a slight breaking down occurs. The comparative size of the hollow is also useful in distinguishing several varieties.

(i) **The Degree of Pubescence.**—The hairiness of stems is not very helpful in deciding between varieties, most having about the same development of hairs. Nevertheless, on
occasion, it can be used, *e.g.* the stems of Rhoderick Dhu are hairier than those of Arran Chief. Its usefulness, however, is almost entirely limited to diagnosis late in the season, when the remaining foliage parts are dying.

(k) *The Distribution of the Leaves.*—In some varieties the basal internodes are short and there is a crowding of leaves at the bottom of the stems (*cf.* Group 3); other varieties have long basal internodes, the leaves being more numerous at the apex (*cf.* Group 7).

**Leaves.**

The mature leaves of potato varieties differ in the following characters: frequency, size, set on stem, openness, number of primary leaflets, number and position of secondary leaflets, colour of midribs and condition of stipule-like growths.

(a) *Frequency.*—Although it may not be realised always, the frequency of the leaves constitutes a very important diagnostic character. Leaves may be numerous or few; when they are numerous the plant presents a compact appearance, and when they are few an entirely different aspect is produced. It is principally in this feature of compactness that Arran Comrade is distinguished from Great Scot, and Crusader from Golden Wonder.

(b) *Dimensions.*—Leaves may be long or short and broad or narrow. All combinations occur. Up-to-Date, White City and Immune Ashleaf are varieties which have exceptionally long leaves; President, Blue Grey, The Dean and Northern Star are varieties whose leaves are short. The relative length is a more helpful character than the width, yet on occasion the latter may be quite useful, *e.g.* Duke of York may be distinguished from Immune Ashleaf by its narrower leaves.

(c) *Set on Stems.*—This important feature is somewhat difficult to define, as it is composite in nature and includes certain peculiarities of the leaflets. The outstanding characteristic, however, would appear to be the presence of or want of rigidity in the leaf midrib. Where the midrib is rigid (Fig. 3, A) the leaf makes a more or less definite angle
with the stem. In some varieties, *e.g.* President, this angle may be small; in others, *e.g.* Templar, it may be larger. On the other hand, the midrib may not be rigid and may droop (Fig. 4), in which case quite a different appearance is produced. Although rigidity of midrib constitutes the main

![Diagram of leaf](image)

**Fig. 4.**—Leaf of the Variety, Katie Glover, illustrating drooping Type of Leaf; (A) Stipule-like Growths.

feature of the leaf set, the leaflets may contribute a share to the general aspect; the rigidity or want of rigidity of the leaflets may alter considerably the leaf set.

(d) Openness of Leaf.—Fig. 5 and Fig. 6 illustrate what are known as open and close leaves. An open leaf is one in which the leaflets are not crowded and where comparatively large intervals exist between the leaflets. Where opposite conditions prevail the leaf is termed close. Intermediate
types occur, but varieties with open leaves may always be separated from those with close leaves without the slightest difficulty. Abundance, Irish Queen and Miller's Beauty may be distinguished from the other members of Group 6

FIG. 5.—Leaf of the Variety, Champion, showing open Type of Leaf and few Secondary Leaflets. Note absence of Secondary Leaflets on Midrib between Terminal Leaflet and last pair of Primary Leaflets.

by this characteristic. However, even within the close-leaved varieties distinctions may be drawn: some varieties, e.g. Lochar and Sharpe's Express, owe their close leaves to the number of secondary leaflets; in others, e.g. Irish Queen, the characteristic is due more to the overlapping of the primary leaflets.
(e) Number of Primary Leaflets.—Varieties may be grouped as having numerous or few primary leaflets. In the former class are found such varieties as White City, Up-to-Date, Immune Ashleaf and Sharpe’s Express; while in the latter, Myatt’s Ashleaf, Lochar, Ally, President, General and Blue Grey. Marconi and President, two varieties which resemble one another very closely, may be differentiated quite readily by the frequency of the primary leaflets.

FIG. 6.—Leaf of the Variety, Lochar, showing close Type of Leaf and numerous Secondary Leaflets.

(f) Number and Position of Secondary Leaflets.—The number and position of the secondary leaflets are of great importance in many varieties. For example, there are some, such as are found in Group 4, which are conspicuous by the number of secondary leaflets; others, e.g. Arran Consul, on the contrary, possess comparatively few secondaries, and where these do occur they are rudimentary and inconspicuous. Absence of secondaries on the midrib between the terminal leaflet and the last pair of leaflets is characteristic of the varieties, Champion and Ally. The majority of
secondary leaflets are to be found situated between the pairs of primary leaflets on the midrib of the leaf. Some varieties, however, e.g. Rhoderick Dhu, are characterised by development of large secondary leaflets situated immediately at the junction of the petioles of the primary leaflets with the midrib of the leaf. A few, again, e.g. Dargill Early, are outstanding by the frequent formation of secondary leaflets on the petioles of the primary leaflets.

(g) Colour of Midribs.—At times the colour of the midrib is distinctly useful in diagnosing types. Royal Kidney and Evergood are varieties which are easily confused. They can, however, always be separated by the absence of pigment on the midrib of Evergood and its presence, although only to a small extent, on that of Royal Kidney. Many varieties have green midribs, e.g. Ally, Evergood, Witchhill, Duke of York, Lochar, Arran Comrade, Rhoderick Dhu and Great Scot. In other varieties the midribs are coloured—purple in such varieties as Pride of Bute, and red in others, e.g. Ranfurly Red and Kerr's Pink. Frequently the colour is located only at the base of the midrib and the bases of the leaflet petioles. In Rector and Dean these are red, while in Champion, Lord Tennyson and Irish Chieftain they are purple. Faint colouring is developed in some varieties, e.g. Bishop, Majestic and Magnum Bonum. But such a diversity of types exists that space does not permit the inclusion of further detail here. The midrib colour is usually most highly developed in young leaves; faint colour often disappears with age.

(h) Stipule-like Growths.—In the general description of a potato plant it has been stated that two stipule-like growths (Fig. 4, A) occur at the bases of all normal leaves. These are somewhat half-moon shaped and encircle the stem when fully developed. With age they often grow large and leaf-like. The characteristics which are useful in field work are the relative sizes and the presence or absence of hairs on

1 The condition of the hairs on the upper surface of the midrib is also useful; King George may be differentiated from British Queen by the fact that the hairs on the midrib of the former are conspicuously hooked, whereas on the latter they are more or less upright.
the upper surfaces of the stipule-like growths. Kerr's Pink may be distinguished from Gregor Cups, which it resembles closely, especially when affected with mosaic disease, by having large glabrous stipule-like growths, while those of Gregor Cups are small and hairy. Such differences exist between other varieties, but generally these are so different in grosser features that reference to this character is quite unnecessary.

**LEAFLET**

The leaflets manifest some of the same differences as the leaves, the varying characters being: size and shape, colour and condition of surface, the set on midrib, colour of petioles, condition of margin, joining of leaflets, over-lapping of leaflets, and apparent thickness.

(a) *Size and Shape.*—The size of leaflets varies greatly with the environment, but for varieties grown under similar conditions it is a fairly constant character. Some varieties, e.g. America, are noted for their large leaflets, and others, e.g. Northern Star, for their small leaflets. All gradations occur; but with the majority of varieties the shape is much more helpful. The shape is difficult to define and a very important feature of it is the amount and type of tapering: the leaflet tip may be long and drawn out or short. In these descriptions, reference is made only to the shape of the lateral leaflets of full-grown leaves, the terminal being disregarded. A primary difference may be drawn in the way leaflets taper towards the tip; where the tapering begins near the base, the leaflet may be termed lanceolate, e.g. Champion II. (Fig. 7, D): when the tapering is mainly at the tip it may be termed oval, e.g. International Kidney and Sharpe's Victor, (Fig. 7, C): and where the tapering begins about the middle the leaflet may be either approximately round, e.g. British Queen and Lochar (Fig. 7, B), or oval (pointed) Fig. 7, A). By far the most common is the oval (pointed) type. With the exception of the round class, all types may vary in width. It must be understood, moreover, that even on an individual leaf, shapes may differ and that as regards any variety one may speak only of an average type.
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Differences may be seen often in the way the two lobes of the leaflet join the petiole. In general these differences have no significance. It has been observed, however, that in some varieties e.g., Up-to-Date, the upper lobe, or one nearest the apex of the leaf, joins the petiole farther from the midrib than its neighbour; in other varieties, e.g. Tinwald Perfection, the two lobes join in approximately the same position. This distinction is seen best in the two leaflets nearest the terminal, and, although it is a minor one, it is sometimes of considerable value (cf. Figs. 8 and 9).

![Leaf Diagrams]

Fig. 7.—Types of Leaflets.

Dr. Salaman in *Potato Varieties* gives a Leaf Index for most common varieties. This index is arrived at by selecting from healthy plants always the first leaflet, *i.e.*, the one under the terminal leaflet on the left of the midrib, dividing the width by the length and multiplying by 100. If a minimum of twenty leaves be taken, a difference of three units indicates with practical certainty that the varieties are distinct.

(b) Colour and Condition of Surface.—Leaflets may be almost any shade of green, ranging from the light yellow-green of Early Market to the dark green of Magnificent. The colour is an extremely important feature, for although it can be altered by manuring, it has always a relative value. Varieties may be classed as having (1) light, (2) medium and
FIG. 8.—Variety, Tinwald Perfection.

FIG. 9.—Variety, Up-to-Date.

Showing even and uneven junction of Leaflet Lobes with Petiole (A).
FIG. 10.—Crusader Leaves, showing Rise and Fall of Primary Leaflets from the Midrib. ("Arching")
(3) dark-green leaflets. Typical varieties in each group are 
(1) Early Market, Barley Bounty, Sutton’s Early Regent and 
Stirling Castle; (2) Witchhill, Katie Glover and Marquis of 
Bute; and (3) British Queen, International Kidney, Great 
Scot and Magnificent. Occasionally the young leaves are 
a much lighter green than the remainder; such, for instance, 
give rise to the so-called “sulphury tops” of Lochar, Crusader 
and Southesk. The surface of the leaflet may be glossy or 
mat, depending chiefly on the absence or presence of many 
hairs. British Queen, Mona, King George and Evergood 
have glossy leaflets, while Ally, Rhoderick Dhu, Early 
Market and Ben Cruachan have mat leaflets. Some leaflets, 
*e.g.* those of the varieties Crusader, Nonesuch and Rocks, are 
corrugated, *i.e.*, the tissue between the veins is raised much 
above the level of the veins, giving a rough appearance. 
This last condition, however, is the exception, and in most 
varieties it is wanting. A further useful feature of the leaflet 
is the occurrence of the yellow spotting of Aucuba Mosaic. 
Some varieties, *e.g.* Ninetyfold and Fiftyfold, have these 
spots on practically every plant.

(c) *The Set on the Midrib of Leaf.*—The position of the 
leaflet relative to the midrib of the leaf varies considerably. 
Leaflets may be rigid or drooping according to the rigidity 
of the leaflet petiole. Templar, Champion, President, Kerr’s 
Pink and many other varieties have rigid leaflets, while 
Royal Kidney, King Edward, King George, Evergood, etc., 
have drooping leaflets. *Fig. 3, A,* shows typical rigid leaflets 
and *Fig. 4* typical drooping leaflets. In some varieties, *e.g.* 
Great Scot and Arran Victory, it is only the terminal leaflet 
that is markedly drooping. *Fig. 10* illustrates another and 
extremely common type, where the leaflets rise first above 
the level of the midrib and then fall, a condition known as 
“arching” and common in Group 7.

(d) *Colour of Petiole.*—The leaflet petiole may be green 
or it may be coloured. In some varieties the colouring is 
chiefly concentrated at the base of the petiole, but in others, 
and particularly with young leaflets, the colouring may run 
well up the midrib of the leaflet, *e.g.* in Majestic.

(e) *The Condition of the Leaflet Margin.*—The leaflet
may be more or less flat, the margin being normal. However, in many varieties, e.g., Lochar and Sharpe’s Express, the margin is turned up slightly, giving what is termed a “cupped” appearance. This character is found most frequently on varieties which have cordate leaflets. Fig. 11 illustrates another type of leaflet in which the margin is waved. Such leaflets are found on King Edward, Abundance, Arran Chief, and many other varieties.

(f) *Joined Leaflets.*—Frequently the terminal leaflet is joined with one or both of the nearest pair of lateral leaflets (Fig. 12). This feature is varietal, and is found in Ally, Mein’s Early Round, Wonderful, Nonesuch and King Edward. “Webbing,” or the union of the petiole of one of the last pair of leaflets with the midrib, is common, but of little consequence, in a few varieties, e.g., Early Pink Champion.
(g) Overlapping of Leaflets.—It has been mentioned previously that the overlapping of leaflets is one of the factors in producing close leaves. It frequently happens, however, that the overlapping is confined to the last pair of leaflets which project forward and overlap the terminal. This may occur even in open leaves and may be seen in Up-to-Date, Puritan and Witchhill.

(h) Thickness.—Owing to a very slight downward curvature of the leaflet margins some leaflets appear thicker than others. Apart from that, however, there are distinct
differences in the relative thickness of leaflets, some, such as those of Evergood, being much thicker than those found on other varieties, e.g. Magnum Bonum.

THE ORIGIN OF THE INFLORESCENCE STALK.

The origin of the inflorescence stalk is of some importance in differentiating types. In some varieties, e.g. Duke of York, the inflorescence stalk is borne in the axil formed by a leaf and a main stem (Fig. 3); in other varieties, e.g. Witchhill, it is terminal on a side shoot and appears to arise on the midrib of a leaf (Fig. 2). Most varieties show both types in approximately equal numbers.

SPECIAL NOTES ON FOLIAGE IDENTIFICATION.

Disease, Injury and Variations.

The effects of certain potato diseases frequently modify the normal foliage characteristics and render identification extremely difficult. A few, such as blight, destroy the foliage and render identification impossible; others, such as the virus diseases (i.e., Leaf Roll, Mosaic, Crinkle, etc.), while not destroying the foliage, obliterate to a large extent the typical appearances of the leaves. On the other hand, in plants affected with virus diseases, the floral parts, although reduced in frequency by mosaic, retain their typical morphological features, and the tubers, although reduced in size, retain their varietal characteristics.

Leaf Roll and Blackleg, especially in the early stages of the latter, impart a certain rigidity to the plant and cause upward rolling of the leaflet. Similar manifestations may be seen in plants which have been injured; it is practically impossible at times to differentiate an injured King George plant from a normal British Queen plant, unless the exciting cause has been noticed. With diseases of the mosaic type there is a mottling of the leaf; crinkle produces a downward curling of the leaf tips; while dwarfing, differing in degree, unevenness of the leaflet surface and marginal waviness are accompanying characters of most virus diseases. It must be
noted, however, that the effects of virus diseases are not the same on every variety, and that in consequence the student must know how these particular diseases manifest themselves in each variety. It may be stated, for example, that although diseases of the mosaic type usually cause marginal waviness, some varieties, *e.g.* Ben Cruachan, which show marginal waviness on healthy plants, may partly lose this character when attacked by such diseases.

Variations and mutations are known to occur on most domestic plants, and the potato is no exception. A description of these is given in Chapter XII. Fortunately, mutations would appear to be rare. Nevertheless, there are two types of variations which are of common occurrence, *viz.*, Bolters and Wildings. These variations, however, may be readily recognised in any variety once the characteristic features of the types have been grasped.
CHAPTER VII

INTERVARIETAL DIFFERENCES IN THE POTATO

II. — The Floral Parts of the Potato.

There is a widespread impression that the flowering of cultivated potatoes is not general, but it should be recorded that, with one exception, all potato plants which have been examined during the various phases of growth have developed flowers or at least produced rudimentary flower-buds. The exception occurs in the case of true Wildings on which floral parts are seldom observed.

(A) Morphology of the Flowers and Fruit.

(a) Peduncles and Pedicels (Inflorescence and Flower Stalks). — Potato flowers occur in cymose inflorescences (cf. Fig. 13). In some varieties, however, the main branches of the inflorescence are shortened to such an extent as to impart a simple umbel appearance (Fig. 14). This type is found on Arran Rose, Dunvegan and Immune Ashleaf, and is known as a contracted cyme. The peduncles and pedicels vary in length and colouring with the variety, e.g. in Up-to-Date and British Queen they are long and fairly dark coloured, while in Royal Kidney and Arran Chief they are short and lighter in colour. There is a tendency on the part of some varieties to form leafy bracts on the inflorescence stalks, these being found in large numbers very frequently in the varieties, Dominion, Maud Meg, Edgecote Purple and others. Often, owing to a proliferation of buds, the whole floral structure is malformed and confused, a characteristic which is specially common in Findlay's varieties, Katie Glover and Celt. The density and distribution of hairs on the inflorescence stalks are also varietal features. Quite
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visible on the upper half of the pedicels is a distinct ring of corky tissue which indicates the point from which the flower or fruit falls. The varying colour of this ring is sometimes a useful identification mark, e.g. Beauty of Bute may be distinguished from John Bull, which it closely resembles, by the presence of colour in the cork layer of the former and its absence in that of the latter.

(b) Calyx (Sepals).—There are normally five sepals, united at the base, their tips remaining free. Irregularity in number of sepals appears in some varieties, e.g. in May Queen. Sepals may be uniformly coloured, as in Fortyfold.

Fig. 13.—Typical Inflorescence of the Potato: (1) Immature Flower; (2) and (3) Mature Flowers; (4) Old Flower; and (5) Leafy Bracts.
and Kcay's Champion, where they are green, and in Di Vernon and Myatt's Ashleaf, where they are brownish-purple. Frequently, however, the basal portion is green and the tips brownish, e.g. Golden Wonder and Royal Kidney. The reverse condition occurs in such varieties as Ninetyfold and K. of K. A characteristic of great diagnostic value is the length of the sepal tips: the majority of varieties have short tips, hence the long tips of Witchhill, Arran Victory and other varieties are useful for identifying these. All sepals are hairy on the outer surfaces and the condition of these hairs is often useful for identification; they may be long or short, numerous or few, adpressed or outstanding: in the variety, Keppleston Kidney, the hairs are infrequent and lie closely on to the sepals; on the other hand, in the variety, Utility, the hairs are long, numerous and spread out. Kerr's Pink Substitute differs, amongst other things, from Kerr's Pink by its having upstanding hairs, those of Kerr's Pink being more adpressed. The comparison should be made with full-grown sepals; in some varieties the outstanding condition of the hairs is not visible during the early stages of growth.

(c) **Corolla (Petals).**—Normally, the corolla consists of five united petals and shows five tips. A departure from five has been observed in May Queen, Yam, Balmoral Castle and some other varieties in which up to ten tips have been counted. Double corollas are characteristic of others, e.g. Blackheart. The size of the flower may vary on an individual plant, but some varieties, such as British Queen, may be described as large-flowered, while others, such as Dean and Rhoderick Dhu, are small-flowered. The size of the flower varies from \( \frac{3}{4} \) inch to 2 inches in diameter. The petals are not so completely united in some varieties as in

![Fig. 14.—Potato Inflorescence, showing contracted Cyme Type.](image-url)
others, with the result that the flower may assume at times a star-like appearance, e.g. in The Massie; indeed, a variation of Up-to-Date shows the polypetalous condition. The colour of the flower is of great value in identification because it is almost constant for each variety. The petals may be self-coloured or parti-coloured, but potato flowers are classed as white, greenish-white or purple. Purple, the predominating colour, might be regarded as being due to the presence of a red and a blue cell sap, and, according to the proportions, the tint may be more blue or more red. Pure red and pure blue flowers do not appear to occur. The colouring may vary in shade and tone on the different parts of the same flower: the tissue adjacent to the vascular bundles in the centre of the flower is usually deeper coloured than the remainder, and red frequently enters more into its composition. The outer part of the petals lying between the tips is also frequently deep coloured. Generally, coloured flowers have white tips, but in some varieties, e.g. Up-to-Date, this characteristic is absent. With age the colour of the flower fades, but within a variety the changes are uniform; the red seems to fade more rapidly than the blue, with the result that slightly withered purple flowers may actually appear blue. Varieties are sometimes coloured only on the lower surface of the petals, e.g. Shamrock, Flourball, Dean and occasionally Majestic; and others again are characterised by the high development of pigment at the very base of the corolla tube, e.g. Dean (A. Dean) and Rector. It is impossible to describe in words the various shades and tones which appear in a flower: the most convenient method of arriving at a satisfactory standard is by using a colour-chart. The comparison is made with the colour of the petals—but not the heart of the flower—when full maturity is reached. A correlation appears to exist between the flower colours and those of the sprouts of the tubers. Varieties with pink sprouts show the colour as red-purple in the flower, or they may be white; blue sprouts are followed by blue or blue-purple flowers, or white. The white flowers may be regarded as albinos, the colour element being absent, and occur in both groups. On the other hand, there are some varieties, e.g.
Golden Wonder, which may be described as "border-line varieties" and in which the flower colour fluctuates between red- and blue-purple. While the flower colour is an extremely useful identification mark, it must not be regarded as infallible; variation in the colour of the potato flower occurs occasionally. Thus, white flowers have been found in the following varieties: Up-to-Date, Field-Marshal, President and Golden Wonder. Occasionally an inflorescence is met in which white and coloured flowers exist together, and very rarely individual coloured flowers may have a white sector. Again, General, a white-flowering variety, occasionally produces red-purple flowers.

(d) The Androecium (Stamens).—The stamens are normally arranged in a symmetrical column surrounding the pistil, but in most old flowers they assume a loose appearance. Some varieties, however, such as Crusader, are characterised by loose but normal stamens in the younger flowers. Other varieties appear incapable of forming normal stamens, these generally remaining small, yellowish and twisted, e.g. King Edward, Ally and Arran Chief. The normal colour of anthers is orange-yellow. Yellow or greenish-yellow anthers are found in some varieties and in others at times a reddish tinge is exhibited, e.g. Rector. Stamens sometimes become pistillate, forming a rudimentary ovary with ovules and stigmatic surface, but as yet no ripe seeds have been found or induced in these, e.g. Champion and Celt. The colour of the anther is in general varietal, but exceptional plants occur commonly in many varieties in which a departure from the normal is found. In some varieties which have coloured tubers the line of dehiscence of the anther is coloured.

(e) Gynoecium.—(1) The Stigma is usually bilobed, but not infrequently numerous lobes occur, as in May Queen. Normal stigmas are green but sometimes they are black, especially when immature, e.g. Burnhead Rogue.

(2) The Style is erect and light green coloured; in some

1 Observations made by the writer during season 1927 determined a further correlation in the potato, viz., whenever pigment appears in the cork cells of the tuber, the flower is coloured; with white flowers, tuber pigment, if present, is always entirely in the cortex.
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varieties it may be twisted, *e.g.* King Edward, while in at least one variety—Buchan Beauty—it has a purple-coloured ring at a point almost coincident with the apices of the stamens. Some varieties, *e.g.* Bishop, Boor, Dargil Gem, Abundance and the Colourless Rogue have long styles, these protruding for some distance beyond the tips of the anthers; others, including Up-to-Date, Sharpe's Victor and Buchan Beauty have short styles; and others again have styles of moderate length, *e.g.* Templar and Majestic.

(3) The Ovary.—Multilocular ovaries occur, but these are not characteristic of any variety. Where the tuber skin is coloured, the placenta (*i.e.* the tissue on which the ovules arise) may also be coloured: thus Arran Victory and Edzell Blue have purple placentas, while those of Kerr's Pink and Farish's Pink Champion are red. On the other hand, the placentas of Yam, Pride of Bute and some others are colourless. The shade of colour is also of use: Raeburn's Gregor Cups may be distinguished from Sharpe's Pink Seedling, which it closely resembles, by its more purple placenta.

(f) The Fruit.—The round form of the fruit is stated to differentiate *Solanum tuberosum* (*i.e.* the common potato) from some wild tuber-bearing species of the same genus, *e.g.* *S. commersonii* and *S. demissum*, whose "plums" are heart-shaped. At least one cultivated variety, the Holm Red of Orkney, exhibits the heart-shape form of berry. Such "plums" have also been found on seedling varieties. The size of the fruit varies on an individual plant, but varieties may be grouped into those which produce large and those which produce small fruit normally. The size, however, may depend on the capacity for receiving pollen, *e.g.* one can induce large berries on varieties which produce normally small-sized fruit by using profusion of pollen. Green is the usual colour of the "plum," but different varieties exhibit different shades of green; some varieties show black, red or brown markings on the skin and some are purple. The placenta of the fruit, as of the flower, of some varieties is coloured, a characteristic which is of some importance in identification. As before, the colouring has only been observed in varieties of which the tubers have a coloured skin. The colour varies from
almost a pure pink to a dark purple. Some varieties have the colouring only in the young fruit, e.g. Shamrock and Flourball, and in others only the mature fruits are coloured. The placentas of Edzell Blue, Orkney Blue and Old Long Blue are deep purple; those of Lord Rosebery, Ranfurly Red, Cardinal and Prizetaker are pink or reddish-purple; while some varieties with coloured tubers exhibit no colour, e.g. Pride of Bute. If the calyx be removed from the fruit, normally a buff or yellow-coloured ring can be seen at the point of attachment; in at least one commercial variety—Rector—this ring is red, and in others it is purple. Up to the present, the purple colouring has been found only on seedlings, but there is no reason to assume that it will not at some future date appear on a commercial variety. Its occurrence appears to be associated with blue sprouts. As further varietal characters peculiar to the fruit the following deserve mention: (1) The ease or otherwise with which the "plums" separate themselves from the mother plant: the fruits of Flourball, Majestic and some other varieties fall easily from the inflorescence stalks, while that of Leinster Wonder or of Keppleston Kidney clings with some tenacity to the parent; and (2) the aroma; such fruit as Majestic is seldom, if ever, scented, while that of other varieties, e.g. Myatt's Ashleaf, when fully matured, emits a pleasant odour.

(B) THE PHYSIOLOGY OF THE FLOWERS AND FRUIT.

(a) Flower.—The opening of the flower-bud takes place at the apex and seems to be occasioned by the increasing growth and pressure of the enclosed floral parts. Normally, the petals are the first structures to appear when the buds open, but owing to different relative developments in some varieties, e.g. Rector and Catriona, the stamens and pistil are usually visible before the petals. The colour of the petals commences to develop whenever the bud is about to open; in the immature bud they are greenish. One day, or perhaps two days, after the bud has opened the petals are fully developed and in most varieties are reflexed. On some, however, such as Northern Star, Rhoderick Dhu, Arran Chief and Duke of
York, this characteristic has not been observed. At this
stage the anthers have developed their deepest colour and
occasionally show browning at the tips. The stigma may
now be sticky. Full maturity of the flower is indicated
when the petals lose their reflexed character, the anthers
being then open and the stigma receptive. The pore at
the apex of the stamens is at first round but ultimately
becomes oval, when the walls are deep brown with a white
margin. The condition of full maturity may be maintained
for several days; ultimately, the flower begins to fade and
a brownish colouring appears on the petals, which lose
their elasticity and do not open completely; finally, they
remain closed. The anthers become browner and shrivelled
and a longitudinal slit usually appears on the inner side of
each lobe. As the flower grows older the stigma loses its
glistening appearance. The flowers fall off along with their
upper short flower-stalks. Sometimes the corolla and
stamens fall off first; at other times the corolla remains
attached to the growing fruit for a period after the stigma
and style have been thrown off.

The duration of the flowering period is peculiar to the
variety: data have been collected for several varieties and it
appears from observations made in Edinburgh that individual
plants may remain in flower for periods of from four to eight
weeks, individual inflorescences from two to three weeks, and
individual flowers from six to fourteen days.

The Daily Blooming Period.—A marked difference exists
in the sensitiveness of the flowers of various varieties to
outside influences. Young flowers, however, are always
more sensitive than older ones. Some varieties, e.g. Bishop,
open early in the day; and others, e.g. Northern Star and
Duke of York, open only in full sunshine. There is not
much difference in the times of opening and closing of
flowers of one variety in a particular locality. Temperature
does not appear to exert such an influence over the move-
ments of flowers as does moisture: some varieties, e.g. Arran
Comrade, Up-to-Date and British Queen are very sensitive
to the influence of moisture, others are not so readily affected.
The normal period of closing in the afternoon also varies
with the variety: the flowers of Bishop and some other varieties remain open to a later hour than do those of Arran Comrade and British Queen.

Pollen.—The pollen grains may retain their capacity for germination for several days. In one variety they remained potent for six days in stamens which had been removed from the flower. The amount and viability of pollen seems to be a varietal characteristic. Although self-pollination is normal in this country, the potato flower seems to be adapted to insect visits, indeed, it is recorded that some varieties are at times odoriferous, e.g. Templar.

(b) The Capacity for Flower and Fruit Formation.—Varieties differ in their natural tendency to flower and fruit. Thus, the following varieties flower and "plum" freely, Templar and Majestic; others, e.g. British Queen and Up-to-Date, flower very freely, but do not form fruit naturally; others again flower very seldom and have not been known to bear natural berries, e.g. Great Scot, King Edward, Arran Chief and Northern Star. The formation of flowers is essentially constitutional for the variety. Breeding and artificial selection have resulted in many practically non-flowering varieties being put on the market. The production of fruit in flowering varieties would appear to depend almost entirely on the formation of fertile pollen, as even such varieties as King Edward, Arran Chief and Up-to-Date "plum" when viable pollen is used. During 1923 nine flowers of Up-to-Date, fertilised with pollen of the variety, Pepo, all produced normal berries. In seeking rogues in a field caution must be exercised in judging whether a plant is a rogue or not, especially when the only difference discernible lies in the profusion of flowers; accidents, e.g. injury to the stem by animals, implements or disease may induce a profuse setting of flowers and in all cases the presence or absence of such exciting causes should be looked for. Bolters, because of their increased capacity for flower and fruit bearing, may also be mistaken for rogues. To obviate such errors, those engaged in purifying stocks should familiarise themselves with the other characteristics of the bolter type peculiar to the variety in question.
(c) Environmental Influences on Flower Formation.—
The production of flowers can be influenced to a very great extent by environment. There appears to be a certain optimum condition of soil and atmospheric moisture, of warmth and of light, which is most favourable to the production of flowers; low temperature, too much moisture and too little light appear to be unfavourable, while warmth and plenty of sunshine seem to encourage flower formation. According to one authority, where the overground food supply (CO₂) exceeds the corresponding neutralising underground mineral supply through the roots, the plant is forced to develop organs which can consume carbon quickly, e.g. flowers—a theory which finds support in the fact that, when stems are partially severed, the production of flowers is greater than normal. Despite theoretical considerations, however, the fact remains that a variety may flower freely one year and show comparatively few flowers the next. Cultural conditions also, e.g. hard ground, may increase the tendency to flower.
CHAPTER VIII
INTERVARIETAL DIFFERENCES IN THE POTATO

III.—The Tuber, Sprout and Stolon of the Potato.

A study of the characters of the tuber useful in diagnosis will be facilitated by first discussing differentiating points which are apparent during the growing season only and which disappear at maturity.

Potato breeders in appraising the value of their seedlings have always taken into consideration the proximity of the tubers to the mother plant, hence it is that in very few varieties are tubers formed at a distance from the stems. Nevertheless, there exist amongst varieties differences in the plan of the tuber positions. Generally, early varieties form tubers near the surface; some earlies, however, e.g. Di Vernon, have this peculiarity developed to a very considerable extent, while others, e.g. Eclipse, Witchhill and America, tend to form tubers in tiers and they are thus not so readily exposed. Late varieties differ in their settings, few having tubers very close to the parent; Golden Wonder and Langworthy are types, however, which show a distinct disposition to deep tuber formation; and Templar, Dominion and Irish Chieftain, having comparatively long runners, set tubers at some distance from the mother plant. The development of aerial tubers is characteristic of certain varieties: this phenomenon, known as supertuberation, is frequently due to accident, hence its occurrence may be associated with weakness of some kind in the haulm; it occurs frequently in Edzell Blue.

It has already been mentioned that the eyes of the potato tuber lie in the axils of scale leaves. These scale leaves are coloured in certain white-skinned varieties, the
INTERVARIETAL DIFFERENCES

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colour corresponding to that of the sprout and forming an extraordinarily useful feature in identification work: the scale leaves of May Queen, Conquest, Wilson's Seedling (338/2), Irish Chieftain, Blue Grey ¹ and many other varieties are generally blue, while those of Fiftyfold are pink. It frequently happens in white varieties that the heel end of the tuber develops colour during the growing season, as also does sometimes the rose end. The heel ends of Arran Chief and Abundance are blue, while those of Lymm Gray, Epicure and occasionally King George are pink. Immature tubers with pink rose ends are frequently found in Rhoderick Dhu and King George. The classification of tuber shapes shown on pp. 88-90, has been compiled from a study of mature, well-grown tubers. During the growing season, especially in July and early August, it is not always possible to form an accurate idea of the type, if only small, immature tubers are available for examination.

The characters of the tuber which persist after maturity and which are useful in diagnosis are: (1) shape; (2) colour and condition of skin; (3) position and depth of eyes; (4) colour and consistency of the flesh; (5) type of second growth; (6) microscopic characters.

Shape—Each variety has its typical tuber shape. Soil conditions, however, may greatly impair the development of this shape, the potato being apt to follow the line of least resistance; the conditions of nutrition have also some influence: nitrogenous manures tend to increase the length of tubers, while phosphatic and potassic manures and much moisture appear to increase the thickness. There is in consequence no rigidity of shape in any variety, and even on one plant several tuber forms may be found. Nevertheless an accurate conception of the general varietal type may often be obtained by the study of a number of large mature tubers. Except in spherical varieties each tuber has normally an upper and a lower surface. The upper surface practically always possesses more eyes than the lower and in most cases it is rounder than the latter. The true shape

¹ See Miscellaneous Publications, No. 3, Board of Agriculture for Scotland.
Classification of the Tubers of some Common Potato Varieties.

I. White Tubers.

<table>
<thead>
<tr>
<th>ROUND</th>
<th>LONG</th>
<th>OVAL</th>
<th>PEAR-SHAPED</th>
<th>OVAL, POINTED</th>
</tr>
</thead>
</table>

**Round (flat):**  
- Epicure  
- America  
- Rocks  
- Bobbie  
- Burns  

**Spherical:**  
- Arran Comrade  
- Great Scot  
- Rhoderick Dhu  
- Southesk  
- Burnhouse Beauty  
- Ally (a)  
- President  
- General Conquest  
- Arran Chief

**Champion:**  
- Templar *  
- Abundance †  
- Evergood *  
- Irish Chief-tain ♣  
- Up-to-Date †  
- Tinwald Perfection †  
- Arran Consul (a) ♣  

**Short:**  
- Witchhill *  
- Royal  
- Kidney †  
- Norna †  
- Magnum  
- Bonum †  
- Majestic (a) †  
- May Queen ♣  
- International Kidney †  

**Long:**  
- Sharpe's Victor *  

**Langworthy †  
- Sharpe's Express †  
- Crusader †  
- Nithsdale *  

**Duke of York (a) †  
- Immune  
- Ashleaf †  
- Myatt's  
- Ashleaf †  
- Dargill Early †  

**Bishop (a) *  
- British Queen ‡  
- King  
- George ‡  
- Puritan ‡  
- Ninety-fold ‡  
- Eclipse (a) †
2.—Red Tubers.

### Round.

<table>
<thead>
<tr>
<th>White Flesh.</th>
<th>Yellow Flesh.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round (flat)</td>
<td>Spherical.</td>
</tr>
<tr>
<td>Kerr’s Pink Flourball</td>
<td>Early Pink Champion</td>
</tr>
<tr>
<td>Reading Russet Shamrock Utility</td>
<td>Gregor Cups Sharpe’s Pink Seedling</td>
</tr>
<tr>
<td>Rector</td>
<td>Arran Rose †</td>
</tr>
<tr>
<td>Lord Rosebery</td>
<td>Ardenil Rose †</td>
</tr>
<tr>
<td>Yam</td>
<td>Crimson Beauty †</td>
</tr>
<tr>
<td>Waverley</td>
<td>Red King</td>
</tr>
<tr>
<td></td>
<td>Edward (a) †</td>
</tr>
<tr>
<td></td>
<td>Mr Bresse *</td>
</tr>
<tr>
<td></td>
<td>Cardinal †</td>
</tr>
<tr>
<td></td>
<td>Early Rose ‡</td>
</tr>
</tbody>
</table>

3.—Purple Tubers.

### Round.

<table>
<thead>
<tr>
<th>White Flesh.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin Dark Purple.</td>
</tr>
<tr>
<td>Edzell Blue</td>
</tr>
<tr>
<td>Arran Victory</td>
</tr>
<tr>
<td>Herd Laddie</td>
</tr>
<tr>
<td>Skin Light Purple.</td>
</tr>
<tr>
<td>Eightyfold</td>
</tr>
</tbody>
</table>

### Long.

<table>
<thead>
<tr>
<th>White Flesh.</th>
<th>Yellow Flesh.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oval.</td>
<td>Pear-Shaped.</td>
</tr>
<tr>
<td>Short.</td>
<td>Oval, Pointed.</td>
</tr>
<tr>
<td>White Flesh.</td>
<td>White Flesh.</td>
</tr>
<tr>
<td>Pride of Buts †</td>
<td>Keppleston Kidney †</td>
</tr>
</tbody>
</table>

**Abbreviations:**
- * Thin tubers.
- † Tubers medium depth.
- ‡ Thick tubers.

Those varieties in italics have blue sprouts; the remainder have pink sprouts. Those varieties marked (a) are rather inconstant in shape.
4.—PARTI-COLOURED TUBERS.
(The Skin may be White and Purple or White and Red.)

<table>
<thead>
<tr>
<th>ROUND.</th>
<th>LONG.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OVAL.</td>
</tr>
<tr>
<td></td>
<td>Short—White Flesh.</td>
</tr>
<tr>
<td></td>
<td>Long—Pale Yellow Flesh.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>White Flesh.</th>
<th>Yellow Flesh.</th>
<th>White Flesh.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Purple Champion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Purple</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Champion</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fortyfold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buchan Beauty</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye Pink</td>
<td>Eye Red</td>
<td></td>
</tr>
<tr>
<td>Lochar</td>
<td>Mein's Early Round</td>
<td></td>
</tr>
<tr>
<td>Northern Star</td>
<td>Beauty of Bute</td>
<td></td>
</tr>
<tr>
<td>Marquis of Bute</td>
<td>John Bull</td>
<td></td>
</tr>
<tr>
<td></td>
<td>K. of K.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Katie Glover</td>
<td></td>
</tr>
<tr>
<td></td>
<td>King Edward</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(a)</td>
<td></td>
</tr>
</tbody>
</table>

5.—RUSSET TUBERS.

<table>
<thead>
<tr>
<th>ROUND.</th>
<th>LONG.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OVAL (Short)—White Flesh.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>White Flesh.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Village Blacksmith</td>
<td>Field-Marsh *</td>
</tr>
<tr>
<td>Brown Rocks</td>
<td></td>
</tr>
</tbody>
</table>

**Abbreviations:** * Tubers medium depth.  
† Thick tubers.  
Those varieties in italics have blue sprouts; the remainder have pink sprouts.  
Those varieties marked (a) are rather inconstant in shape.
is visible when the tuber lies on its lower surface. When thus viewed, the tuber outline may appear round or to have a long axis. In the former case the tuber is round (flat); in the latter, it may be pear-shaped, oval or oval (pointed) according as the largest diameter occurs towards the rose end, about the middle or towards the heel end respectively. In commerce the term "Kidney" is employed to describe pear-shaped and long-oval tubers. Tubers may be thin, thick or of medium depth according to the thickness of the cross-section. Very frequently it is found that the stolon joins the tuber in a depression. When this happens, the tuber is spoken of as having a recessed heel end, a condition prevailing in the following varieties, America, Champion, Rocks, Early Pink Champion, Fortyfold, Buchan Beauty, Gregor Cups and Epicure. The depth of the recess appears to be correlated with the depth of the eyes. Varieties with pear-shaped tubers, seldom show the recess; indeed, these often exhibit the reverse character, namely, pointed heel ends, such as are common in King Edward. Figs. 15, 16 and 17 illustrate tuber types, and the classification on pp. 88-90 gives in tabular form the tuber shape of most common varieties. It must be kept in view that the finer the distinctions the more difficult it is to place the various types, especially if few tubers are available for examination. Generally, however, a variety may be relegated to its position in the larger groups, viz., round, oval, oval (pointed) or pear-shaped. Some long-oval and pear-shaped tubers show slight curving of the main axis, e.g. Sharpe's Express and May Queen.

Colour and Condition of the Skin.—Potato tubers may be coloured, parti-coloured, white or russet.

(a) Coloured Tubers.—The colour of the skin is fully developed only when the plant reaches maturity. The intensity of the colour, however, depends largely on soil conditions: in sandy and peaty soils the colour is usually highly developed, whereas in clay there is marked diminution of the intensity. The colour is at its highest in autumn and with age it fades slightly. The red and blue colouring is due to a pigment dissolved in the cell sap of the periderm and
the peripheral cortex. Distinctions may be drawn within each of the two groups. Thus Eightyfold is not so densely coloured as Edzell Blue, or Arran Rose and Early Pink Champion so deeply as Flourball; the different tones and shades of colour cannot be described in words without reference to a chart, but, with practice, the reader can readily familiarise himself with the various types and the modifications of these consequent on variations in soil. In some varieties, e.g. Rector, the eye tissue is much more highly coloured than the remainder, a characteristic quite useful for identification.

(b) Parti-coloured Tubers.—In parti-coloured tubers the pigment is the same as described above; its distribution, however, is not uniform but localised, some of the skin being white. In most parti-coloured tubers the colour is situated mainly in the region of the eye, e.g. Di Vernon, King Edward, K. of K., Katie Glover, Northern Star, Lochar, Catriona and Beauty of Bute; in other varieties, e.g. The Apple, this condition is reversed, the tissue about the eyes being usually white and the remainder coloured. Finer distinctions can be made in this group than in the previous one, and the basis of these distinctions is the relative amount of colour present. In some types, e.g. Northern Star, Lochar and Marquis of Bute, the pigment develops in the region of the eyes and lenticels, but only faintly, if at all, elsewhere; others, such as Catriona, K. of K., Beauty of Bute and Katie Glover, have more colour, but mostly concentrated about the eyes; in others, again, the colour has a wider distribution, e.g. King Edward, Buchan Beauty and Fortyfold. In the last-mentioned variety the coloured areas exceed the white areas in extent.

Both whole-coloured and parti-coloured varieties are subject to occasional variations; thus Di Vernon, Catriona and Arran Victory have been known to produce white

1 In all coloured and parti-coloured varieties pigment appears in the peripheral cortex. Whole-coloured tubers have generally colourless periderms, but there are exceptions, e.g. Rector and Crimson Beauty. On the other hand, with rare exceptions, colour is always present in the periderms of parti-coloured varieties.
FIG. 15.—Tuber Shapes. A, Oval, Pointed; B, Pear-shaped.

FIG. 16.—Tuber Shapes. A, Round; B, Oval.

FIG. 17.—Long Oval Type of Tuber. (Photo Stuart.)
tubers; King Edward, on the other hand, may give rise to whole-coloured tubers.

(c) White Tubers.—The great majority of commercial varieties have what are known as “white” skins. The term “white” is apt to be misleading, as no variety has an absolutely white skin: it is used commercially to include a wide range of yellow shades. Varieties may be differentiated by the shade of yellow; most yellow-fleshed varieties, especially where the colour is highly developed, have yellow skins, e.g. Duke of York, Myatt’s Ashleaf and Immune Ashleaf; other varieties have pale yellow skins, as, for example, Great Scot; but the greatest number have skins which are even paler than the Great Scot type. Whiteness in tubers is due to the absence of visible pigment in the cork cells. On being exposed to light and air the tubers of many white varieties develop colour, e.g. Epicure, Royal Kidney, Dean, Templar and Norna. This character is especially frequent in bluesprouted varieties and the breeder must often discard seedlings because of it.

(d) Russet Tubers.—Several commercial varieties have russet skins and for that reason are very easily identified. How exactly these types arise is not known, but it is a noteworthy fact that each has its white-skinned homologue.

Tuber skins may be rough or smooth, depending on the thickness of the skin. The following varieties have smooth skins: Lochar, Marquis of Bute, King Edward and Witch-hill; rough-skinned varieties are: Duke of York, Gregor Cups and Ally.

Position and Depth of Eyes.—The eyes are always most concentrated at the apex of the tuber. The majority may be in a cluster on the tuber point or they may be grouped some distance from the point, when they are said to be on the shoulder. The remainder are distributed spirally over the tuber surface, the internodes becoming greater towards the heel end. The basal internodes are usually longer in pear-shaped than in oval (pointed) tubers. In some varieties, e.g. Epicure, King George, British Queen and Early Market, there is a distinct swelling below each eye, “raised eye-
The term employed to describe this condition. The eyebrow itself often affords useful assistance; in Abundance, for example, it is long, while in Arran Comrade it is short. Some varieties, e.g. Great Scot, President and Rhoderick Dhu, may be distinguished from others, such as Ally, by having more numerous eyes. Eyes may be classified as deep, medium and shallow; in the first group are found such varieties as Epicure, Champion, Rocks and Fortyfold; in the second, British Queen, King George, Kerr's Pink, Rhoderick Dhu, and Great Scot; and in the last, Evergood, Templar, King Edward, Witchhill and Duke of York.

**Colour and Consistency of the Flesh.**—As with the skin, the flesh colour is fully developed only in the mature tuber. Varieties are described as having yellow, pale yellow and white flesh; the yellow pigment is elaborated in the leaves and transmitted to the tuber. Duke of York is a good example of the first type, Bishop of the second, and Edzell Blue of the last. Some varieties, especially when immature, are characterised by the frequent development of colour in the region of the vascular cylinder of the tuber. The Blue President Rogue,¹ Herd Laddie and Flourball show this trait fairly constantly. Again, the cut surface of a few types turns rapidly red-brown, a feature of special importance in Majestic, and due probably to enzyme action. The consistency of the flesh is such that some varieties may be called soft- and others hard-fleshed—conditions which may be determined by cutting. Generally earlies have soft flesh and lates hard flesh, but exceptions exist. Comparisons, however, must be made with mature tubers and those free from virus or other diseases. As examples of early varieties, it may be stated that Puritan, Ninetyfold and May Queen have softer flesh than Duke of York, while, amongst lates, Langworthy and Crusader have harder flesh than Majestic or Nithsdale. It should be pointed out that much practice is necessary before one can make even moderately certain decisions in this way.

¹ See *Miscellaneous Publications*, No. 3, Board of Agriculture for Scotland.
Type of Second Growth.—The type of second growth is frequently very helpful in determining varieties, but its occurrence is not general, being dependent on the season, and can therefore be applied only on special occasions. Second growth occurs when plants have commenced to ripen and when growth has been reinduced by altered weather conditions. There are several distinct forms of second growth, viz., cracking, formation of secondary tubers, protrusions from tuber eyes, and prolongation of the tuber axis. Cracking is a distinct feature of Ally and Scottish Chief; the formation of secondary tubers—separated from the primary ones by a length of stolon—occurs in Up-to-Date, Northern Star, Dominion, Pathfinder and Rhoderick Dhu; protrusions from the eyes appear in British Queen, King George and Majestic; and prolongation of the tuber axis is found often in long but seldom in round potatoes, e.g. British Queen, King George, Puritan, Catriona and occasionally in Golden Wonder. The flesh of the prolonged portions of Golden Wonder and Catriona is generally lighter coloured than that of the remaining tuber tissue.

Microscopic Characters.—The ability to produce a large percentage of superior starch grains would appear to be varietal. Johnson and Boyle have compiled a table showing the average size of the largest and medium size grains for many commercial varieties: Shamrock and Great Scot have large average grains, while Royal Kidney has small average grains. It is to be noted, however, that size of grain varies with size of tuber, and tubers must be uniform to make the results comparable. In making such comparisons, also, it must be borne in mind that the largest grains are found generally in the tissue lying immediately adjacent to the vascular cylinder. Artschwager has shown that some American varieties are characterised by having “stone cells.” These are visible when sections through the region of the bud are examined microscopically.

In other varieties such cells are wanting. In this connection nothing definite can be said as yet about British varieties.

Berthault has stated that the number of cells per square millimetre of tuber tissue in any variety is very constant at corresponding levels, and that varieties may be grouped with reference to this character. As with "stone cells," however, accurate investigations on such lines have not been made in this country.

**The Sprout.**

Varieties differ in the periods required before sprouting begins: some, such as Early Pink Champion, May Queen, Duke of York, British Queen, Arran Chief, Rhoderick Dhu and Great Scot sprout quickly, but others, including Arran Consul, Witchhill, Immune Ashleaf, Norna, Tinwald Perfection and Golden Wonder are much slower in sprouting. Apart from the rapidity of development there are distinct differences between varieties in the thickness of the sprouts: Early Pink Champion, Great Scot and America, especially the first mentioned, have thick sprouts; Evergood, King Edward, Majestic and Cardinal have thinner sprouts. Sprout thickness has little diagnostic value, however.

Grown in diffuse light, the colour of the sprout may be:

1. Faint pink, i.e., white or greenish-white with green tips, but generally showing a little pink which increases at the base or at the tip on exposure. The variety is a good example of this class.

2. Pink, generally on a white or greenish-white ground, the colour at the tip being similar to the colour at the base. The greatest number of pink-sprouted varieties are to be found in this group.

3. Blue or blue-purple, when the tip and base are always a shade of blue. Generally the whole sprout becomes coloured. Colour is always most intense at the lenticels.

In the existing schemes for the classifying of potato varieties the fundamental bases are the sprout colour, the maturity and the tuber shape. However, during the growing season there is no sprout to examine, hence it is of importance.

INTERVARIETAL DIFFERENCES

at times to learn how the sprout colour may be inferred from a study of other parts of the plant. The following colour connections have been determined:

1. All plants having blue or blue-purple predominating in the flowers have blue or blue-purple sprouts.
2. All plants having red or red-purple predominating in the flowers have pink sprouts.
3. The colour of the sprout corresponds with the colour, if any, on the tuber itself, including the scale leaves, or on the underground runners.¹

These rules may not always be applicable: some varieties do not flower and others have white flowers; again, many varieties, especially earlies, have stolons on which as yet no colour has been observed. Nevertheless, as guides, they are often useful in the field.

Hairs are to be found on all normal sprouts and these may be used on very rare occasions in separating varieties. Sprouts may be grouped as follows: (1) Hairs frequent, e.g. Duke of York and Arran Comrade; and (2) hairs few, e.g. Great Scot and Arran Chief.

If the sprouted tuber is not planted but retained in the storage house throughout the summer, further varietal differences appear: some varieties develop thickened tuber-like sprouts, while others form long-branched sprouts with small leaves, but having no tendency to thicken.

THE STOLONS.

There exists a great diversity of types of stolons: in Templar and Ben Cruachan they are long, profuse and purple, in Great Scot they are shorter, fewer and white. Generally, early varieties have very short stolons, not exceeding one or two inches in length. There is a correlation between the occurrence of blue or blue-purple on the stolons and blue sprouts.

¹ An apparent exception to this rule is reported as occurring on a “sport” from Arran Victory.
CHAPTER IX

THE MAINTENANCE OF PURE STOCKS OF VARIETIES OF
THE POTATO AND THE ROGUEING OF FIELD CROPS

In the previous sections detailed descriptions have been
given of the characters which vary among potato varieties.
It now remains to give a general indication as to how this
information can be best applied in the field.

The starting point in raising pure stocks consists in the
purchase of good seed, viz., that derived from crops which
have been certified or reported upon officially as having
attained a high standard of purity, or which the buyer knows
by field inspection to be pure. It must not be assumed,
however, that in all such stocks rogueing is unnecessary,
although it is true that the amount of time required for that
purpose is generally considerably less for certified seed than
for seed in respect of which no guarantee has been obtained.

After pure seed has been obtained, the adoption of a few
precautionary measures is essential in order to prevent the
introduction of impurities: the mixing of stocks of a
particular variety with other varieties is nearly always due
to want of necessary precaution at some point in the
handling of the crop or to the mismanagement of the
rotation. Care should be exercised to ensure that there
is no danger of ground-keepers appearing, and, whenever
a short rotation is practised, an endeavour should be made
to plant the field, or portion of the field, with the same
variety on each occasion; indeed, where possible, this should
always be done even in longer rotations. The use of dung
from cattle or pigs fed with unboiled potatoes must be
avoided. It is desirable also to pit each variety on the land
in which it was grown or on land on which potatoes will not
be grown in the near future. Different varieties should not
be put in the same pit, separated only by layers of straw, and where more than one variety is grown on the same field, drills of turnips should separate the varieties, the headrigs also being sown with turnips. The headrigs should never be planted with a different variety from that grown in the field: serious mixing has been known to occur through plants from the inner drill of the headrig becoming mixed with the main crop.

When the seed is boxed and sprouted the first rogueing may be carried out; while the tubers are thus stored, impurities may be eliminated by discarding tubers, the characteristics of which, e.g. colour of sprout, colour of skin and shape, are different from those of the variety to be planted.

In the field not much can be done until the flowering season, as it is only then that the plant reaches its full growth and identity can be readily established. It is, of course, quite possible to rogue before this stage, and it is often of advantage to do so later; indeed it is a good practice to go over potato crops as frequently as the season will allow, as there are few crops which contain no rogues even after they have been purified by the most practised hands. Rogues should be removed immediately they are detected, otherwise they may be missed. An example will make this clear. If a crop of Duke of York (white flower) contains a number of Immune Ashleaf (coloured flower) rogues, the latter should be removed whenever they flower: Immune Ashleaf blooms only for a short period, and it is not easy for a beginner to differentiate between the foliages of Duke of York and Immune Ashleaf when the flowers are wanting. Rogueing should be avoided in wet weather and should not be done against the sun; dull weather gives the best conditions for identification.

The problem presented by each variety must necessarily vary. It is essential in the first place, however, to confirm the identity of the crop itself, reference being made to printed descriptions, if necessary. The points which, either singly or in combination, are of greatest service in the detection of rogues are the larger characters enumerated in
the previous sections, viz., flower, height of foliage, outline of foliage, colour of foliage, rigidity of leaves, openness of leaves, degree of brightness of leaf, shape of leaflet, colour of buds and maturity. Points of detail are of use only for purposes of confirmation or in distinguishing between two varieties which are similar in the larger characters. In proceeding to rogue, therefore, the grower will first eliminate all plants the flowers of which differ in colour from that of the crop. These are obvious rogues. If the variety is non-flowering, all plants bearing flowers must be taken out; if the variety is low-growing, tall plants should be regarded with suspicion; and if the variety has a light green foliage, dark-green plants are almost certain to be rogues. All the larger characters and their combinations should be treated in this way, detail points being used for confirmation. Greater difficulty arises when the cropping variety and the rogue are similar in the larger features; in these circumstances considerable practice is necessary before rogueing can be successfully accomplished. On all occasions, however, where the crop has a coloured tuber, reference to this character should be made whenever doubt exists. Differences in the date of maturity are frequently valuable in rogueing; when an early rogue occurs in a late crop, or vice versa, and when the rogue is not readily distinguishable from the main type, it is often easy to rogue when the haulm of the earlier variety dies. In this way, Up-to-Date may be taken out of Tinwald Perfection.

Tuber characters are of little service in the field when the tubers of the crop and those of the rogues are similar in colour, yet they are often useful for confirming suspicions raised by the appearance of the foliage. Similarly, colour and profusion of stolons are frequently helpful in diagnosis.

Computing the Purity of a Growing Crop.

If the grower wishes to determine the purity of any crop a simple means is at hand: it should be ascertained in the first instance how many yards of drill are necessary to include a hundred plants, after which such distances should be
inspected at various points over the entire field, two drills, \textit{i.e.}, 200 plants, being taken on each occasion. The number of rogues found should be divided by twice the number of counts taken and the percentage of impurities present thus ascertained. It is a good plan to work diagonally across a field, from corner to corner. The number of counts to be taken will, of course, vary with the size of the field, but five should be regarded as a minimum. In making field inspections particular care should be given to probable sites of old potato pits.
PART III

REPRODUCTION AND PROPAGATION
CHAPTER X

POTATO BREEDING AND THE APPLICATION OF GENETICS TO VARIETY RAISING

The production of new varieties of the potato is most readily effected by means of the true seed. However, variations within a variety, propagated vegetatively, do occur from time to time, and these may be isolated. In such a way it is possible, for example, to accumulate stocks of a white-tubered or a red-tubered King Edward; but neither of these variations constitutes a distinct advance in the merits of the variety in question, when all factors, including yield and maturity, are taken into consideration. Nevertheless, the variant character may be at times of such a nature as to enhance the commercial value of the variety, e.g. the selection of russet-skinned tubers—because of their popularity—is of distinct advantage. "Bud sports" have been recorded as occurring in the potato, but from the standpoint of the systematic production of new types their occurrence is too rare. Selections of tubers from high-yielding plants would not seem to be efficacious for the purpose of improving healthy stocks. Thus sexual reproduction affords the only means of progress towards greater yielding capacity, increased disease resistance, hardihood, and general utility of our varieties.

The potato breeder has one great advantage at the start; when he has obtained a new variety there is no further question of fixing its characters; by the vegetative mode of reproduction the seedling plant is carried on year after year without alteration. However, as will be seen, a few difficulties exist which are not easily overcome.

A study of the flower, its bright colour and occasional perfume, would lead one to conclude that the potato is adapted to insect visits. However, whatever the conditions
may have been in its original habitat, there is little natural cross-fertilisation in this country at the present time. Those varieties, therefore, which bear natural fruit do so probably always as the result of self-fertilisation. Plant breeders have caused a number of varieties to appear in which the pollen is sterile, or practically so, as for instance, Up-to-Date, British Queen, King Edward, Arran Chief, Epicure, Great Scot, Duke of York and Golden Wonder. Indeed, most of our best varieties belong to this category. Closely associated—although not invariably, e.g. exceptions are Up-to-Date and British Queen—with the question of sterility of pollen is the phenomenon of diminished flower frequency. There are many desirable types which flower very rarely, and even then are practically always devoid of normal pollen. Conversely, many varieties, which flower profusely and bear viable pollen grains, are far from being desirable parents.

"Selfing" and "Crossing."

The breeder has the choice of two types of seed, namely, that taken from natural berries or that produced by cross-fertilisation. It will be apparent that the second type offers by far the greater scope; by sowing "selfed" seed only, the choice of parents, both as regards quality and quantity, is very limited. Potato varieties have been elaborated through generations of cross breeding; the seed of self-set berries will thus probably carry many characters in a blended condition and will give rise to plants which differ amongst themselves and are distinct from the parent. A high percentage of natural seedlings of the varieties, Abundance, America, Ally, President, Lord Rosebery and Templar are, however, practically indistinguishable from the parent type; on the other hand, other varieties, including Majestic, give rise to seedlings showing great diversity. In the past many popular varieties have been produced from "selfed" seed, e.g. Fluke, Champion, Early Rose, Arran Victory, Puritan, etc., but all authorities are agreed that cross-fertilisation provides the greater amount of material from which to make selections. However, there is no proof at present of the assertion made
by some authorities that the potato is highly sensitive to moderate inbreeding, and that the yield of natural seedlings is in any way less than “crossed” seedlings. A serious disadvantage in the use of “selfed” seed is that faults of the parent are usually very prevalent in the offspring. The plants derived from seed produced by cross-fertilisation sometimes show resemblances to one or both parents, but the isolation of any seedling which possesses all the desirable qualities of the two parents is an extremely difficult matter, although the chances of obtaining it are increased in proportion to the number of seeds sown.

The Object of Breeding.

The aim of the potato breeder is to produce new types of plants which, judged by all standards, are improvements on existing varieties. It will therefore be useful to discuss briefly the points of an ideal variety, keeping in view public prejudices and preferences, which to a considerable extent control the breeder’s work.

(a) Foliage.—Foliage characters should be studied in relation to maturity. Common to all groups there must be sufficient growth to cover the ground and “fill the drill”; marked openness must be avoided, as it allows weeds to grow up readily. Stems should not be too numerous or too thin. It is of great advantage if, other things being equal, the breeder can produce varieties in which the foliages have distinctive appearances which are not readily confused with those of other varieties.

(b) Disease Resistance.—Varieties which show distinct susceptibility to specific diseases are of little value. In Britain, seedlings which are susceptible to wart disease have little chance of success owing to the legislative measures taken to check the spread of that trouble. Generally speaking, all early varieties are susceptible to blight. This is not such a great fault, as if the varieties are lifted early, they will probably escape infection. On principle, however, immunity to wart disease and high resistance to all other diseases must be the aim of every breeder.
(c) **Maturity.**—There is a definite demand by the public for early, mid-season and late varieties, for all of which there are special demands. Individuals in one group should not be compared for yield with members of another; the yield of early varieties, for instance, can scarcely be expected to compare favourably with that of late varieties. The capacity to bulk early is of supreme importance in earlies.

(d) **Tuber.**—(1) **Yield.**—Seedling varieties usually have more numerous tubers in the first year than in succeeding years, when similar growth conditions prevail. Too many tubers are generally associated with a large percentage of small. One of the primary essentials of a good variety is the production of the largest yield per acre of marketable tubers. There must be a preponderance of ware tubers of marketable size and an absence of a large number of seed and chat tubers.

(2) **Shape.**—Amongst present-day varieties there exists a great diversity of shapes, ranging from the fine pear-shaped tuber of Immune Ashleaf to the coarse, round tuber of Champion. At first sight it would appear as if any shape might do, and it has to be remembered that many varieties retain their places on the market in spite of their shapes and not because of them. An ideal shape is that of Up-to-Date, which is flattened oval; however, there can be no radical objection to the pear-shaped type or to the round Great Scot type. The essential feature is that the eyes should not be too deep. Elongated and ungainly-shaped tubers are never popular.

(3) **Colour of Skin.**—Under present conditions, deep colouring is to be avoided: such tubers are not popular with the consumer and they are difficult to lift in late autumn; moreover, diseased tubers are not so readily eliminated from coloured as from white varieties. On the other hand, russet tubers are popular, as also are some with distinct markings, such as King Edward. Pink is not so objectionable as purple. Varieties should have therefore white, yellow or russet skins.

(4) **Colour of Flesh.**—In Britain white-fleshed varieties are in demand, although no exception is taken to a light
lemon colour. Yellow-fleshed varieties, except in the case of earlies, are unsaleable in this country. Any varieties which have a tendency to form streaks of red or blue in the flesh should not be regarded with favour. The flesh should be firm.

(5) Second Growth.—Whether in the form of secondary tubers, runners or protrusions from the eyes, cracking or supertuberation, second growth is undesirable, and varieties showing such tendencies to a marked degree should be discarded.

(6) Cooking Quality.—The mature tuber should possess all these characters which go to make up good quality. This can be estimated by a direct test. At the present stage, there is not sufficient information regarding the actual composition of tubers to enable determinations to be made by chemical analyses.

(7) Keeping Quality.—Keeping quality is usually associated with maturity: earlies do not keep so well as lates, but on the other hand, their function is to serve the early market and, in consequence, this point need not be too seriously regarded. All late varieties, however, do not keep equally well. Tubers should not be prone to become diseased in the pits, and too early sprouting with the consequent depletion of food stored in the tuber is undesirable.

(8) Position of Tubers.—The favourite potatoes have generally the tubers bunched together at the base of the haulm, and varieties, e.g. Templar, with long runners are not popular. A well-bunched group of tubers facilitates digging at harvest and is better adapted to earthing up.

Heredity in the Potato.

Having acquired a clear conception of the points of an ideal variety, the next step is to search for means of producing new seedlings which most nearly approach this ideal. It is necessary therefore to study shortly the results of experience in breeding and the definitely established facts concerning the nature of inheritance in the potato.

Pure Lines.—Theoretically, it should be possible to obtain by continued self-fertilisation varieties which are
pure (homozygous) and which will breed true to type. Such varieties, when obtained, would be distinctly useful in building up new combinations of characters. Self sterility, however, is a disturbing factor, and it is not easy to obtain desirable characters and fertility in the same seedling. Nevertheless, this is a phase of potato breeding which has been largely neglected and which still offers a definite and promising field of work. On the other hand, this system takes time for its completion, it being estimated that five generations of inbreeding are necessary before anything approaching a pure state can be attained. The breeder desires quicker results.

Correlated Characters.—A critical examination of the characters transmitted from parents to offspring seems to indicate that these characters are not always inherited as independent units, but that there are fairly definite associations of them which are practically always inherited together, so that if one member of a group is found the others may be expected. A knowledge of these correlated characters is necessarily preliminary to further investigations regarding heredity in the potato. It must be kept in view, however, that these apparently associated characters may be merely different manifestations of the same thing. Observations of the haulm indicate that height of foliage is intimately connected with maturity; earlies are for the most part low-growing; lates, on the other hand, are tall, while mid-season varieties occupy an intermediate position. Blight resistance would seem to be associated with maturity, earlies being susceptible and lates comparatively resistant. Long runners are also connected with late maturity. Within the various maturity groups there seems to be a definite connection between the number of stems on the plant and the number of tubers produced; the more numerous the stems—especially when these are thin—the more numerous the tubers, which, however, become smaller with the greater frequency.

Hard tuber flesh is associated with good keeping quality, blight resistance and cooking quality; soft flesh, on the other hand, is correlated with opposite characters. The greater the proportion of cortex to pith in the tuber, the
greater the content of dry matter, crude fibre and starch.\textsuperscript{1} Deep eyes have not been found on pear-shaped tubers, and are mostly confined to round varieties. The recess at the heel end of the tuber is also a feature of shape, being usually found only on round varieties and its depth appearing to be correlated with the depth of the eyes.

The conception that the setting of natural berries is correlated with low yields has not been scientifically established and a recent work\textsuperscript{2} seems to show that in most tested varieties the cutting of flowers, instead of increasing the yield, actually decreases it.

The observations of Snell\textsuperscript{3} have established a definite connection between sprout and flower colours, pink sprouts being associated with white and red-purple flowers, and blue sprouts with white or blue-purple flowers. White sprouts (\textit{i.e.} very faint pink) are correlated with white flowers and colourless stems. It cannot be said, however, that these facts are of significance to the breeder. Apparently, the development of pigment throughout the plant cannot be dissociated from the sprout colour. Müller\textsuperscript{4} has further indicated that the development of streaks of colour in the flesh of the tuber is also connected with the sprout colour; where the sprout is white such streaks never appear. Again, it has been observed that the appearance of pigment on the skin of white tubers when these are exposed to light depends on the degree of the sprout colour. As this is a very undesirable trait, seedling varieties should be tested for it at an early stage.

\textbf{Individual Characters.}—Genetic analyses have been made of various varieties and from these it is evident that the potato is a plant whose characters mendelise. However, the authorities who have carried out experiments on heredity in the potato have worked hitherto with comparatively little material; \textit{in consequence, sweeping assertions}

\begin{flushleft}
\textsuperscript{1} C. Fruwirth, \textit{Handbuch der landwirtschaftlichen Pflanzenzüchtung}.
\textsuperscript{2} Dr K. Snell, \textit{Blütenbildung und Ertrag bei der Kartoffel}, 1923.
\textsuperscript{3} Dr K. Snell, \textit{Kartoffelsorten}, 1925.
\textsuperscript{4} K. O. Müller, \textit{Zur Kenntnis der Factoren der Anthozyanbildung bei der Kartoffel}.
\end{flushleft}
or assumptions cannot be made and the best that can be done is to indicate the characters which so far appear to be inherited in a more or less regular fashion.

Salaman\(^1\) has found the undernoted characters to behave as described:

1. **Tuber Shape.**—The tuber shape has been found to depend essentially on a pair of factors, which, in reference to the relative length of the tuber axis, may be called "long" or "short." According to this hypothesis a variety may be pure (homozygous) round, pure (homozygous) long, and impure (heterozygous) long. The rounds breed true to type and are recessive when crossed. Oval and oval (pointed) varieties are hybrids.

2. **Tuber Colour.**—The red skin is due to the presence of two factors. The purple skinned are genetically "reds" with an additional purpling factor. These colours may exist in pure or impure states, and, according to the state of purity—which must be ascertained for each variety—the possibility of obtaining whites on selfing or crossing depends.

3. **Stolons.**—It is probable that more than one pair of factors are involved here, but it is certain that long stolons are dominant to short ones.

4. **Tuber Eyes.**—The deep eye is recessive and breeds true; the superficial eye is dominant. The hybrid between "deep" and shallow eyes is more shallow than deep.

5. **Tuber Flesh.**—This is controlled apparently by a single pair of factors. Deep yellow is dominant, white recessive, and pale yellow the hybrid colour.

6. **Immunity to Wart Disease.**—Immunity is dominant to susceptibility; though this dominance may be inhibited by other factors.

There are 4 types of immunes—

1. Pure immunes.
2. Immunes giving 15 immunes to 1 susceptible on selfing.
3. " 3 " 1 "
4. " 9 " 7 "

\(^1\) Dr R. N. Salaman, *Potato Varieties*, 1926.
Susceptibility may be due to one or other of the following causes:—

1. The absence of all immune factors.
2. The absence of a factor, which acts as a complement to the immune factor.
3. The presence of an inhibitor of the immunity factor.

7. Cropping Capacity.—The forces which control cropping capacity are not definitely known, but it is undoubtedly unwise to use poor croppers as parents.

Maturity.—It is a matter of experience that early varieties give rise to more early types in their seedlings than do late varieties. But the genetic behaviour of maturity is not simple. Müller has demonstrated that so far as average maturity and range of variation go, the seedlings of a cross are intermediate in character between the selfed-seedlings of the two parents. These facts are most readily explained by Nilsson-Ehle's conception of Multiple Factors. According to this theory, it should be possible by crossing judiciously the seedlings of the first generation to obtain seedlings in the second generation which, in respect of maturity, would surpass the original parents' offspring both in a positive and negative direction, that is to say they may be either later than the latest of these offspring, or earlier than the earliest. This possibility has a most important bearing on the production of early varieties, and investigations on these lines are pregnant with great possibilities. Earliness is not a recessive character: the range of variation amongst the seedlings of an early variety is greater than that for later maturing varieties; it may be stated, in addition, that a theory of dominance cannot explain the inheritance of maturity, as intermediates are the rule.

The behaviour of the various characters on crossing cannot be predicted with any certainty unless the genetic composition of the parents has been previously ascertained. The following tables indicate how some characters have

been found to behave in cross-fertilisation. It must be remembered, however, that these statements are based on limited observations:

<table>
<thead>
<tr>
<th>TABLE I.</th>
<th>TABLE II.</th>
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<tbody>
<tr>
<td><strong>Parent Characters</strong></td>
<td><strong>According to Author.</strong></td>
</tr>
<tr>
<td>1. Immune—Immune</td>
<td>Immune.</td>
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<tr>
<td>(Wart disease)</td>
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<tr>
<td>2. Susceptible—Susceptible</td>
<td>Susceptible.</td>
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<td>(Wart disease)</td>
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<td>(Wart disease)</td>
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<td>(Wart disease)</td>
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<td>7. Early—Late</td>
<td>Late.</td>
</tr>
<tr>
<td>(Wart disease)</td>
<td></td>
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<tr>
<td>9. Long stolons—Short stolons</td>
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</tbody>
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*dominating is not used here in the Mendelian sense.

A study of the above tables will enable the reader to realise that in order to have the greatest chances of securing a good seedling, an attempt must be made to avoid utilising parents showing faulty characters which dominate in the offspring, otherwise the probabilities of obtaining desirable combinations are remote. On the other hand, faulty characters, if not dominant, may be disregarded to some extent, if the parents possess good qualities. Thus, objection need not be taken to round tubers, deep eyes, susceptibility to wart disease or early maturity in one parent.

Collins¹ has discussed the tuber pattern of King Edward

—a very desirable type, because of the ease in identification—and has arrived at the conclusion that it may be assumed that the parti-coloured pattern depends on a definite factor and it exists in the variety in a heterozygous condition and that, if it could be obtained in a homozygous state, it would breed true. Further, it would behave as a dominant to the recessive white state and be recessive to full colour.

Varieties differ greatly in their reaction to diseases; up to the present, however, and with the exception of wart disease, very little is known about the genetic behaviour of susceptibility and resistance to diseases. It seems reasonable to assume that such characters in parents will find expression in their progeny and that therefore disease susceptibility is undesirable in both parents and only tolerable in one when there are compensating advantages.

It is not possible to obtain amongst present commercial varieties parents possessing all the virtues, or, indeed, many virtues in a combined state, but it is to be remarked that the breeder is by no means limited in his selection of parents to ordinary varieties; he may and should utilise meritorious seedlings for crossing with one another or with standard varieties.

Use of Wild Species.—Attempts have been made by certain breeders to evolve blight (Phytophthora) resistant types by crossing other species of tuber-bearing Solanums with varieties of the cultivated potato. None of these has met with great success; the haulms of the wild species are certainly blight resistant, but no recorded observations indicate the reaction of these species to other important diseases, e.g. virus diseases. While the amount of work done in this connection is little, it is clear that in all such matings the wild characters, e.g. poor yield, long runners and late maturity are very prevalent in the offspring. On the other hand, individual varieties of the common potato possess such disease resistance—specific for one or two diseases although not general—as to warrant the assumption that the chances of obtaining a perfect potato are greatest when wild types are excluded.
Technique of Crossing.—The actual method of procedure depends on the parents selected and may be discussed as follows:

1. When the Female Parent does not set Berries naturally.
   —The best time for cross-pollination is when the flower is ripe, i.e., the stigma sticky and receptive; this generally occurs about two days after the flower has opened and while this condition exists the petals are not usually reflexed as in immature flowers. In order to secure pollen an anther should be taken from the male parent when it shows an open pore at the apex, i.e., when it is mature and ready to discharge. The pollen may be gathered on the point of a pocket-knife by running it up one side of the inner face of the anther towards the pore referred to above. The pollen should then be transferred to the stigma. The best conditions for the operation are to be found towards the evening of a quiet day free from rain. Considerable assistance is afforded the potato breeder by the fact that if the anthers are plucked the pollen in them will retain its vitality for several days provided they are suitably stored.

2. Where the Female Parent does form Natural Berries.
   —The procedure here is the same as the above except that the anthers of the female parent must be removed from the opening bud before the pore has developed at the apex of the anther. Great care to avoid injury must be taken during this process. It is not considered necessary in this country to protect flowers from natural cross-fertilisation. However, if the breeder desire to make absolutely certain of freedom of foreign pollen, protection by means of bags may be given.

3. The Fertilisation of Varieties which seldom Flower.
   —A great many of our best varieties bloom very rarely. Various devices, however, can be utilised to induce a freer formation of flowers. The partial severing of the stems is frequently sufficient. In the same way the prevention of tuber formation creates a tendency in the plant to develop floral parts. The use of “bolters” for crossing—because of their more frequent flowers—has been advocated, but so little is known at present regarding these that the breeder would be advised to resort to this method only when others
have failed. Recently Bornemann has advocated the increase of carbon dioxide in the atmosphere surrounding the plant in order to produce flowers.

Diseases are not generally transmitted through the true seed. Nevertheless, it has been suggested that rare cases of transmission of leaf roll by this means are effected. Quanjer, in Holland, has actually demonstrated the transmission of leaf roll and mosaic through the true seed. Diseased plants, therefore, should be avoided as parents.

Treatment of Seed and Seedlings.

The flowers which have been fertilised should be marked, and the resultant berries allowed to remain on the plant as long as possible, but they should be gathered before there is any danger of falling. Seed should be expressed from the berries on to paper several weeks after harvesting.

The seed may be sown in March under glass in a good sandy mould, preferably in boxes. When the young plants are sufficiently well grown, say 4 in. high, they may be transplanted into pots and subsequently planted in the open early in June. Before the final transplanting takes place the young plants should be hardened, by being placed outside for varying periods during the day. The seedlings may be grown in 27-in. drills with $1\frac{1}{2}$ to 2 ft. between the plants.

Virus Diseases in the Seedling Stage.

At present some breeders grow seedlings under cages in order to avoid infection by the above diseases, which are transmitted to the potato by aphids and other insects. There is, of course, no objection to this or to the growing of seedlings in the open at high altitudes or in places where there is no danger of infection. Indeed, at present these would seem to be the only methods of raising stocks free from foliage diseases. However, in the opinion of the

1 Bornemann, Kohlensaure und Pflanzenwachstum, 1920.
writer, exposure to infection is not necessarily a fault in breeding, especially if the breeder desires to produce varieties which are highly resistant to these degenerative diseases or “tolerant” to them. It may be stated, therefore, that if seedlings are not actually grown in an infectious plot, or if they are “caged,” tests should be made to ascertain the degree of susceptibility.

Discarding Seedlings.

Discarding may begin at any moment when undesirable features manifest themselves. Notes on the foliage, maturity and incidence of diseases should be made during the first growing season, while at lifting special attention should be given to the length of runners. The yield during the first year, especially if early varieties are sought, is of minor value, as also is the number of tubers to the plant. Each year the seedlings should be grown in their maturity groups and tested against standard varieties, further discards being made by the application of the principles already discussed. It should always be kept in view that although a perfect potato—combining all the virtues and possessing no faults—may never be raised, any advance on the merits of existing varieties is in itself a great achievement.
CHAPTER XI
THE VEGETATIVE PROPAGATION OF THE POTATO

The potato is generally propagated by means of the tuber. The plants which arise from the true seed and those from tubers differ essentially in their root systems, but the only persistent vegetative portion of each is the tuber. The tuber is a shortened, thickened shoot system, hence its use corresponds to that of cuttings in trees and shrubs; all plants of a variety represent continuous growths of an original parent produced from the true seed. When the tuber is planted, one or several eyes grow, so that the haulm may consist of a greater or lesser number of branched or unbranched stems. Stolons may be formed on each stem and tubers on each stolon. These tubers reach full maturity when the haulms die and they are lifted in autumn or earlier, depending on the variety. Winter storage may be carried out in pits or in houses and the sorting out of tubers into the various grades, viz., ware, seed and chats, usually takes place at times suitable to market conditions. The mode of dressing is familiar to all: the tubers are passed over riddles which differ in size of mesh. Tubers must be planted in the year subsequent to that in which they were lifted, although it is possible to retain them in storage with full vitality for two seasons, provided the temperature is suitably adjusted.

The tuber is the means of propagating the potato from year to year; during the growing season, however, plants may be multiplied in various ways.

When a tuber begins to sprout only the principal buds of one or of a few eyes grow. If these are removed, the side buds will start and if these in turn are broken off, the eye tissue will continue to send out new growths. A tuber kept in moist sand during the growing months may have its
sprouts removed every two to three weeks. Advantage has been taken of this faculty of the potato tuber for producing new growth to increase greatly the number of plants in expensive seedlings. However, as time goes on, such growths cease to be formed and in their places the tuber sends out short stolons from the eyes, at the ends of which small tubers are formed. This phenomenon, known as "little potato," is due to the removal of relatively more water than dry matter from the tuber through the lost sprouts. Eye tissue is not the only part of a tuber which possesses the capacity of giving rise to new growth; if a tuber is cut longitudinally into two portions in spring, and if these are retained in moist sand, callus tissue forms on the cut surface, principally over the vascular bundle or on the area enclosed by it. On the other hand, in transverse sections, callus growths are formed only on that surface which is directed away from the rose end. In October, or perhaps not until the succeeding spring, the callus tissue may send out shoots which are capable of developing into plants. The shoot of a potato plant would not appear to have the power of developing a callus. Nevertheless the apex of a shoot, if cut and planted under favourable conditions, soon develops roots and grows vigorously. It was by means of cutting such as these, that potatoes were propagated in some parts of Germany during the war when seed was scarce. Appel⁠¹ has described a method of propagation by shoot cuttings. In the first place, the tubers should be allowed to sprout in a warm room, the temperature of which is about 10° to 15° C. When the sprouts are several centimetres long and show rings of roots at their bases, they are cut off along with a small piece of the mother tuber. A similar procedure is observed in respect of all the eyes. Care must be taken to ensure that the room is not too dry, otherwise the later sprouts will be weak. The sprouts with the adherent portion of tuber may be collected and retained for some time in an atmosphere which is not too dry. When the collection is complete, the sprouts are planted out in boxes. At a temperature of 15° C. they develop rapidly and root formation

¹ Prof. Dr O. Appel, *Die Pflanzkartoffel*, 1920.
FIG. 18.-Shoot developing from Callus Growth on Tuber. (Photo Snell.)

FIG. 19.-Tobacco Shoot grafted on a Potato Stock. (Photo Snell.)
proceeds vigorously. As soon as a number of leaves is formed, the shoot is cut in such a way as to retain about two or three leaves on the bottom portion of the plant. The top portion is used as a cutting and is planted in a good warm bed and moist atmosphere. This process may be continued several times and after preliminary hardening by a reduction of temperature, all the cuttings may be planted out in the open. In this way over twenty plants may be taken from one tuber.

Stolons may be used for propagation during the vegetative season. In some of the wild species the stolons appear above the ground in the form of shoots and these may be detached from the parent. Such a phenomenon has been observed in some varieties of *S. tuberosum*, but it has no apparent economic importance.

Although callus growth has not been found on the cut surface of the stem, grafts may be readily effected on the potato. These grafts may be accomplished in the following manner. The stock plant when it reaches a height of 10 to 15 cm. is cut over and a vertical V-shaped cavity made on the cut surface. This cut should extend at least 1 cm. down the stem. The scion is also cut and its basal end shaped to fit into the above cavity. The junction of the two pieces is then tied with suitable material and the plant kept for several days under glass in moist conditions and well supplied with light, to facilitate the growing together of stock and scion. In two to three weeks the plant may be taken into the open. This operation can be carried out not only with different varieties of the potato, but also with other Solanaceous plants, e.g. tobacco, tomato and nightshade. Wherever the potato constitutes the stock, tubers are formed on the plants; on the other hand, where the potato is the scion, no tubers are formed. However, instead of tuber formation there is a good development of the floral parts—a phenomenon which may be utilised by breeders with varieties which do not flower normally. Supertuberation, however, has been observed where the potato is grafted on to the stocks of other species. When a potato is scion on a tobacco stock, yellowing of the potato leaf margins occurs.
owing apparently to some disturbance of nutrition. Grafting has been used a great deal in recent years in the study of various diseases and reference to it will be made later.

Attempts have been made at various times to produce tuber grafts. The usual procedure has been to tie together the freshly-cut sections of tubers belonging to different varieties. In this way it is possible at times to produce organic union. Atanasoff\(^1\) has been successful in transmitting disease by this method. The old idea was that the mingling of the two saps would produce something new. In reality each section gives rise to a plant true to type for the variety to which it belongs. Later it was thought that in some way the eye tissues would unite. All such attempts to produce new types, however, have failed, as indeed was to be expected, the practice having no scientific foundation.

Periclinal chimæras are possible in the potato, but it is doubtful if there would be any advantage in these: in the first place, they are very difficult of attainment and inconstant in their features; and, secondly, at present there would not seem to be any hope of obtaining an advance either in yielding capacity or disease resistance by the construction of a new type in this fashion.

\(^1\) D. Atanasoff, *Stipple-streak Disease of the Potato*, 1922.
CHAPTER XII

VARIATION IN THE POTATO

Periodically in the history of the potato, controversy has centred round the question of the occurrence, or non-occurrence, of mutations in this plant. As the difficulties involved are for the most part those of definition, it will be well, at the outset, to obtain a clear conception of the meanings of the various terms used by accepted authorities.

The universality of variation is acknowledged. Babcock and Clausen in *Genetics in Relation to Agriculture* recognise three types of variation according to heritability:

"Character differences either represent something specific in the germ or they are merely the effect of external stimuli upon the individual soma. In the first case they are inherited, although they will not reappear necessarily in all later generations or in all the progeny. In the second case they will not be inherited. This is a fundamental distinction and may well serve as our primary basis of classification. According to heritability, variations are either germinal or somatic. Under germinal variations we recognise two sub-classes, combinations and mutations. Purely somatic variations will be referred to hereafter as modifications.

"Modifications are non-heritable differences between the individuals of a race caused by the unequal influence of different environmental factors. Such variations frequently approximate continuity, and, when studied statistically, display the normal variability curve . . .

"Combinations are heritable differences between individuals of a race or between the offspring of a pair of parents caused by segregation and recombination of hereditary units. They also frequently display the normal variability curve.

"Mutations are heritable differences between parents and offspring which do not depend upon segregation and recombination."

Somatic modifications arise, as stated above, from environmental causes and they are merely transient; they leave no impression whatsoever on the germ plasm. Examples of
such modifications are found in plants grown on dry and on moist land or at high and at low elevations. Germinal variations differ from somatic modifications in that the characters involved are passed on to the offspring. Examples of combinations and segregations are seen in the various types of seedlings produced from self-fertilised potato seed. The term, mutation, on the other hand, implies a discontinuous germinal change, i.e., the occurrence of something entirely new. Mutations may occur in any meristematic tissue as well as in the germ cells of plants. According to Babcock and Clausen, mutations may be grouped into two classes, viz., (a) deviations in the number of chromosomes, and (b) alterations in genetic "factors." Of these, the latter is the more common. An example of a mutation is found in the sudden appearance of a coloured flower in a homozygous white-flowering plant.

However, the above three categories of variations are not always to be recognised and separated by appearances. The type can be established definitely only by careful breeding experiments. The difficulty of defining any variation in the potato will be apparent at once: potato varieties are all heterozygous, and it is therefore impossible to identify a mutation in a variety of unknown history.

The potato, like most horticultural plants, is subject to chlorosis, variegation and marginal variegation of the leaves, and to fasciation. The real nature of these phenomena is not understood, and, as they are not of any economic importance, it is not proposed to discuss them.

The most commonly occurring variations in the potato are those of colour. Colour differences occur in the tuber and in the flower. These differences are transmitted by vegetative propagation with occasional reversion to the normal. Colour changes have been observed in the following tubers:

1. Catriona (splashed to white).
2. Di Vernon
3. Great Scot (white to russet).
4. King Edward (splashed red to splashed purple).
5. King Edward (splashed to red or white).
6. Katie Glover (splashed to red or white).
7. Langworthy (white to russet).
8. Golden Wonder (russet to white).
9. Yam (russet-red to russet).
10. Arran Victory (purple to splashed purple).
11. Arran Victory (white to splashed purple).
12. Up-to-Date (white to russet).

Somatic heterogeneity of colour exists in the original tubers of Nos. 1, 2, 5 and 6, and a possible explanation of these variations is to be found by regarding the normal tuber as a natural chimæra and the variants as produced by the separation of the differently coloured tissues. It is difficult to concede the status of mutation to russet variations. There has been no authenticated occasion, so far as the author is aware, when a russet seedling of the Golden Wonder tuber type has been derived from a true seed. So far as is known, all russet varieties have arisen by vegetative variation and in the numerous seedlings obtained by crossing ordinary varieties with Field-Marshal and Golden Wonder (both russets), not one has had a russet tuber. The change of red to purple in No. 4 is most readily explained by assuming a mutation, although some authorities might regard it as due to vegetative segregation. Careful breeding and an analysis of the genetic constitution of the normal plant would be necessary preliminaries before any statement could be made.

Colour changes have been observed in the following flowers:

General (white to red-purple).
Golden Wonder (blue-purple to white).
Field-Marshal (red-purple to white and parti-colour).
Tinwald Perfection (red-purple to white).
Up-to-Date (red-purple to white).

Most authorities would regard these variations as examples of mutations. Here again, however, breeding experiments are necessary, and it might be that the above
are the results of vegetative segregation. Mutations involving more than one character appear to be of rare occurrence. Mr. D. McKelvie, Lamlash, reports one in Arran Victory. Here the mutant not only differs from the normal in colour of tuber skin but also in the essential features of the foliage. Salaman has analysed Mr McKelvie’s Arran Victory variations by breeding, and concludes that these are real mutations. There is no doubt that mutations may occur in the potato. The great difficulty, however, lies in finding them, and, because of the heterozygous nature of all varieties, in proving that they are mutations. Mutations need not be limited to one character, e.g. flowers: it is quite possible for any individual potato plant to mutate in such a way that general habit, leaf form, flower colour, tuber colour and tuber shape may be affected.

The conditions known as “bolting” and “wilding” have greatly occupied the attention of agriculturists for some time, these degenerative variations of habit being extremely detrimental to the commercial value of stocks. Bolters and wildings are recognisable as the varietal type and they are found in many varieties. The differences which they exhibit from the varietal type are essentially the same for all varieties. There is no evidence to show that they are the result of disease, and grafting experiments by the author have failed to demonstrate that the conditions can be transmitted by organic union, e.g. by foliage or tuber grafts. Dorst¹ considers that bolters are mutations. It should be remarked, however, that a plant is only a bolter by comparison, and, as each potato seed of a heterozygous variety may give rise to a new type, there would be great difficulty in proving that they are mutations unless the variety in which the phenomena are found is known to be homozygous for foliage type. The primary feature of all wildings is the presence of only very rudimentary floral parts or the total absence of these. This being so, no breeding experiments are possible with wildings. It has been suggested that

the "bolting" and "wilding" conditions may be due to alterations of chromosome numbers.

**Bolters.**—A bolter differs from the true varietal type in its greater height, later maturity, coarser tubers and greater capacity for flower bearing. Normally, bolters cannot be distinguished from typical plants until the stage of full growth is reached. In some normally non-fruiting varieties, e.g. Ally, the bolter frequently bears berries. Generally, the primary leaflets of bolters are smaller and more pubescent than those of the normal plant and the stems often develop more colour. Bolters have been found in the following varieties: Ally, British Queen, Epicure, Eclipse, Evergood, Duke of York, Great Scot, King Edward, King George, Up-to-Date and Witchhill. Dorst reports having found a plant with two normal stems and one bolter stem. Bolters are not so susceptible to late blight (*Phytophthora infestans*) as normal plants. The bolter condition is perpetuated by vegetative propagation.

**Wildings.**—Wildings differ from the normal type in the following features: (1) In consequence of the production of a large number of thin stems the plant presents a closer appearance; (2) associated with these numerous stems are numerous stolons, each of which bears an undersized tuber; (3) the wilding leaf is shorter, the number of primary leaflets is fewer, and these have a more rounded contour than is normal to the variety; (4) the floral parts are either extremely rudimentary or entirely absent; and (5) the wilding is not so tall as the normal. The maturity of normal and wilding plants is similar. Wildings have been found in the following varieties: Abundance, Arran Chief, Golden Wonder, Field-Marshall, King Edward, Great Scot, Langworthy Kerr's Pink, King George, Up-to-Date, Majestic, etc. Occasionally plants with both normal and wilding stems are found, and in these the normal stems always bear floral parts. The presence of wildings in a stock seriously diminishes its yield of ware tubers. In consequence of the small size of tubers produced, wildings tend to increase rapidly in stocks. The wilding condition is apparently perpetuated by all the tubers of a plant which has become affected.
From time to time doubts have been expressed about the identity of wildings and bolters, and it has been stated that they do not arise from the variety from which they are presumed to be derived. The characteristics of the foliage of bolters and wildings are essentially the same as the normal type and differences exist in detail only. So far as the present evidence goes, all wildings and bolters react to wart disease in the same manner as the normal plant; the sprout colours are the same; and in the varieties, King Edward (tuber: splashed pink) and Golden Wonder (tuber: russet), the characteristic colour of the tubers is found in the abnormal types. The clearest proof of all, however, is to be had in intermediate types when the normal stems and foliage may be identified without question. These intermediate types have been found both in the “wilding” and “bolting” conditions.

There are other variations in foliage type which may be classed in the same category as wildings and bolters, at least until there is evidence that they are caused by disease. One of these occurs fairly freely. It is characterised by the formation of peculiar leaves and floral parts: the leaves, especially the apical ones, are almost entire, and at the apex of each shoot there is usually only one large, abnormal bud, which rarely opens into flower. The inflorescence stalk is extremely short. This type of variation has been found in Up-to-Date, Herd Laddie, Kerr's Pink and Witchhill. In the first two of these, normal and abnormal shoots have been found on the same plants.

The variations of the potato which have most significance to the grower are wildings and bolters. These ought to be rigorously rogued from stocks. To the breeder, geneticist and selectionist all variations and mutations are of interest, as they may furnish scientific information of value or be the starting points for the development of varieties of economic importance.
CHAPTER XIII
QUALITY IN SEED POTATOES
Theoretical Considerations.

There is no fact concerning potato culture which is better known than that stocks of a variety may differ markedly in productive power. On the one hand, it is maintained that conditions of culture may increase vigour, and, on the other, that irretrievable falling-off in yielding capacity results from growth in certain environments. An examination of the evidence shows that whereas increased vigour of a healthy, normal stock grown under its present optimum conditions is a theoretical possibility which requires demonstration, the expression is used commercially always in a comparative sense, normal stocks being regarded as vigorous and others as lacking vigour in various degrees. In consequence, the investigations into the quality of seed concern mainly those influences which are detrimental to cropping power.

In the literature on the subject, many terms have been used to describe the decline of productive power in the potato; “running-out,” “degeneration,” “deterioration” and “falling-off” are a few which occur frequently. It is noteworthy that these expressions have as their common criterion a diminution in the yield of tubers and that the causes of the phenomenon are not indicated. It is of fundamental importance therefore to inquire into the various ways by which the vigour of a potato plant might deteriorate, either temporarily or permanently.

The earliest explanation of this phenomenon was that degeneration was synonymous with senility. However, it was not long before a second theory was put forward, namely, that diseases were the causal agents. Controversy ranged
itself about these two view-points for more than a century. Recent work on virus diseases has led many authorities to believe that deterioration is due entirely to specific diseases, notably leaf roll, mosaic and crinkle. "Abbau" is the term applied to deterioration of the potato in Germany; at its best, however, the conception is a vague one, and until recently little has been done to disentangle the ideas it includes. The above explanations do not exhaust all that have been offered to account for the falling-off in yield of potato plants, and in the following section the various theories will be dealt with separately, viz.: (1) degeneration of the constitution; (2) senility; (3) mutations and variations; (4) effects of environment; (5) over-ripeness of seed; (6) diseases.

Degeneration of the Constitution.—The word "degeneration" is frequently applied in biological literature; it is not, however, easy to find a definition of the term. A progressive, if gradual, permanent decline in the capacity of the plant for vegetative growth, adaptability to environment, and resistance to disease would appear to be included in the conception. Moreover, degeneration of the constitution must be produced by inward changes and not caused by the introduction into the plant of foreign elements. If the other causes of failing vigour, enumerated above, are excluded, then the nature of the trouble must be sought for in the body protoplasm. Such changes may appear to be brought about by bud sporting. Sporting, however, rightly belongs to the realm of mutations, besides which the progressive element is lacking from sports. Inbreeding also cannot be regarded as the cause, as any diminished vitality thus induced is explained by segregation. An examination of the facts shows that the occasions on which one might justifiably talk of true degeneration must be few, if, indeed, they ever occur in the potato.

Senility.—A comprehensive survey of this subject has been made by Salaman,¹ who records that the first authority to adopt the point of view that the potato ages with repeated

 vegetative propagation was Parmentier (1786). Ageing presupposes that the vegetative plant has a certain period beyond which its vital force is insufficient to maintain life.

The idea probably had its origin in a misinterpretation of the term, individual. The first implication of that term is physical unity. If portions of a plant are removed and grown separately, each is subject to the modifying influences of the environment, but the influence of the parent plant is removed. It is thus a question if one may speak any longer of an individual. Apart from the above, the boundary between sexual and asexual reproduction is not quite so sharp as is generally supposed: there occur in nature intermediate processes, e.g. parthenogenesis. Theoretical considerations aside, however, the assumption has no foundation in fact: many of our oldest cultivated plants are asexually propagated; some of the best varieties of apples and pears are three and four hundred years old; the vine and the date-palm are reproduced vegetatively; and the banana is always an asexually propagated plant. The agriculturist need only consider the vitality of couch grass in order to be convinced of the flimsy nature of the theory. If senility were the cause of deterioration in potato stocks, then every plant of a variety would show signs of decay simultaneously. This, however, never happens: loss of vitality is always local in its occurrence.

Magnum Bonum has gone out of cultivation in this country because of its degenerate symptoms. Yet in Sweden this variety is widely grown, although it has been in cultivation for more than fifty years. In 1921, 6000 wagons of seed potatoes were sent from Scotland to Austria. Many varieties were included in the consignment, and in 1923 it was reported that these varieties, with the exception of Up-to-Date, were being gradually given up owing to want of cropping power; yet the same varieties retain their full vigour in this country. The symptoms of "degeneration" may appear in a variety at any age, even seedlings in their first year may become degenerate, and it is apparent that the causes of the trouble are not to be found in senility.
Mutations and Variations.—The occurrence of mutations in the potato is not questioned. "Factor mutations," e.g., the sudden change of flower colour in plants homozygous for flower colour, are probably as common in the potato as they are in most plants. Here, however, only those sports which affect the yielding capacity come into consideration. It is quite conceivable that a tuber of a variety might mutate in such a way that its vegetative successors would manifest degenerate symptoms. The progressive element would, however, be again absent. In practice such occurrences must be rare, as other explanations are usually to be found for the sudden decline in yielding capacity of individual plants. On the other hand, certain variations in growth, which do not appear to be mutations, do have a marked effect on the productivity of the plant. Such, for instance, are wildings and bolters.

Effects of Environment.—The occurrence of deterioration in potato stocks is generally local, hence the causes are more likely to be found outwith than within the plant. The influence of environment—climate, soil and cultivation—has not received much attention in potato literature.

The modifying influences of environment are not doubted; extreme cases are seen in the different growth types induced by alpine and lowland climates, and in the alterations of form produced by dry and moist surroundings. The effects of environment differ only in degree. Every plant has limits of adaptability, and it is within these limits that environments have their influence. Should these limits not be sufficiently wide to allow the plant to adapt itself, then growth is impossible. On the other hand, although there is a definite range of circumstances under which a plant will grow, it is certain that optimum conditions exist. Moreover, optimum conditions for the plant need not always correspond to optimum conditions for yield. The ultimate result of growing a plant in a given set of conditions is that sooner or later an equilibrium is established between the environment and the plant growth. By the nature of things the process is reversible, and if the equilibrium be disturbed, the plant will immediately endeavour to accommodate itself to
the altered circumstances. It must be understood that
environment can cause no permanent change, and that
although from a commercial point of view the plant may be
adversely affected, no deterioration of the constitution has
taken place. This point is of fundamental importance, as
it implies an alteration on the removal of the causes.
Vegetatively propagated plants pass on their inherited
characters unchanged to their offspring, and in consequence
each successive generation is similarly affected by the same
environment. The study of modifications due to environ-
ment in the potato is rendered extremely difficult by the
absence of data: the results of carefully-conducted experi-
ments are wanting. There is no doubt that environment
affects the composition of tubers; up to the present, however,
no investigations have been carried out to determine what
connection exists between composition of the tuber and
subsequent yield. Experiments at Craibstone¹ seem to
indicate that there is some loss in vigour in potato stocks
grown in warmer and drier regions than that at Aberdeen—
a loss which, however, is only temporary, and from which
recovery may be made by the removal of such stocks to
the north.

Northern seed is generally accepted as more productive
than that grown in the south, the difference being ascribed
to the immaturity of the northern seed—a statement which
cannot stand close examination: in Scotland all but very
early and very late crops are lifted when mature. However,
it is possible that in Scotland the cooler nights in September
and October are a climatic factor which may induce better
ripened seed than is obtained in England. Considering the
adaptability of all plants, it is not to be presumed that the
influence of any particular environment on the potato will
persist for many seasons after the removal of the plants to
another environment; indeed, it is not to be supposed that
the effects would extend beyond the succeeding generation.
All varieties do not suit all environments equally well, some

¹ W. J. Profeit and W. M. Findlay, "Some Factors affecting the
Value of Potatoes for Seed Purposes," Scot. Journ. of Agriculture,
January 1923.
being more adapted to particular conditions than others; it may be further concluded therefore that should an environment factor exist, which seems likely, its effects will differ with the variety.

Over-Ripeness of Seed.—A potato tuber may be regarded as mature when the deposition of starch within it is finished, when the skin has reached its final thickness, and when connection with the parent is destroyed by natural decay of the stolon. Immature tubers are still capable of further growth while attached to the parent plant, their skin is always thin and they are not easily detached from the stolons. The opinion is widely held that maturity or immaturity of the tubers at the time of lifting has an important bearing on the capacity of the seed for producing large crops and that ripe or over-ripe seed is less vigorous than immature seed. If the crop is lifted after the haulms have turned yellow and ripe in the south of England, the tubers used for seed in the following year give usually poorer yields than are produced by seed taken from a similar crop lifted earlier. Many experiments conducted not only in Britain but also in the colonies and on the Continent supply data which indicate quite clearly that under certain circumstances immature seed is to be preferred to mature seed. On the other hand, investigations at Craibstone have shown that, under the conditions prevailing in the north of Scotland, no advantage is to be gained by the use of immature seed. The protagonists of immature seed aver that for the production of good seed the proper water and nitrogen contents of the tubers are obtained just before the haulms show the first signs of ripening. The evidence in favour of unripe seed is so strong that one cannot lightly disregard it. Recent work on virus diseases has shown that with most of these, not all the tubers of primarily infected plants carry the troubles into the succeeding year. This is especially true when the plants are lifted in an immature state. Apart from that, however, a crop lifted in an immature state is not exposed so long to disease infection as is one which is allowed to ripen completely. The matter therefore resolves itself more into the correct interpretation of the results than a controversy.
over their reality; in England and in the south generally virus diseases are widespread, while in Scotland, especially in the north, they are not so prevalent, hence from the standpoint of freedom from disease, much more is to be expected from the use of immature seed in the south than in the north. It may be stated quite definitely therefore that the one important advantage of using immature seed is its comparative freedom from disease and that mature seed is only less productive when diseases are prevalent. All available evidence points to the immature seed being the less vigorous when diseases are absent.

**Diseases**—Periodic outbreaks of disease on a large scale have caused authorities to assume from time to time that degeneration of potato stocks is merely symptomatic of a pathological condition. Although at the present time deterioration of stocks is mostly ascribed to the effects of virus diseases, it is nowhere suggested that seed tubers may not be seriously influenced by other troubles, e.g. brown scab, corky scab, skin spot, late blight, blackleg, dry rot, wart disease, physical injury, etc. That these conditions may cause missing and diminished yielding capacity no one doubts. Their effects are, however, not of a permanent nature, as are those of virus diseases, which, when once infection has been thoroughly accomplished, are passed on to successive vegetative generations without dilution or possible hope of recovery. Many authorities in England, Holland and America, consider that deterioration in the potato is due entirely to virus diseases.

The evil and permanent effects of virus diseases are well known. It must not be forgotten, however, that the real nature of these troubles has yet to be found and that all authorities are not agreed that the causal agents are living organisms. That so many investigators should ascribe all deterioration to disease is not curious; by far the greatest amount of deterioration in potato plants is due to virus diseases. There can be no doubt, however, about the possibility of mutations and the reality of such degenerative variations in growth as wildings and bolters, which seriously influence the value of stocks.
So far as can be determined at present, the facts concerning the deterioration of potato plants may be summarised as follows:

1. Virus diseases cause permanent deterioration of potato plants.
2. Environment affects the rate of spread, or the virulence, of these diseases, making some places favourable and some unfavourable for growing seed potatoes.
3. The practice of changing seed is explained mainly on these grounds.
4. It is probable that some places exert a favourable effect on the seed potatoes they produce apart from the influence of virus diseases.
5. Other diseases (which are not invariably or regularly carried by all the tubers of a diseased plant) may lead to reduced vigour or yield, as may also bad storage; but the weakness so caused is temporary.
6. Such phenomena as bolters and wildings cause permanent deterioration of potato stocks.

**Practical Considerations.**

The nature of deterioration in individual plants has been discussed and it now remains to be considered, how, keeping these principles in view, stocks of a variety differ in productive power. The value of potato stocks may be assessed by (1) purity and freedom from bolters and wildings; (2) freedom from diseases, pests and injuries; (3) origin.

**Purity and Freedom from Bolters and Wildings.—**

An original stock is presumably pure, though oversight on the part of the raiser may give rise to a certain amount of impurity: the stocks of the varieties, Majestic, Ally, Crusader and others contained rogues when they were first placed on the market. However, impurity generally arises from commercial handling, either from ground-keepers in the land or by the mixing of seed stocks. The purity of a stock is important, not only as it affects the
marketable value of stocks, but also because of the influence impurities have on yield and disease susceptibility. In Scotland there exists a scheme for the inspection of potato varieties; certificates and reports are issued by the Board of Agriculture for Scotland, the various grades being 99.5 per cent., 97 per cent., and less than 97 per cent. of purity. All consignments of potatoes sold for seed purposes under a specific variety name must—according to the Seeds Act, 1920—be true to that variety to the extent of 97 per cent. of the quantity sold. Potato seed containing rogues in excess of 3 per cent. by number, must be described as "mixed seed." It will be evident therefore that the planter has at his disposal a ready means of obtaining seed which is comparatively pure. Many stocks, however, are not submitted for inspection, and the buyer can be confident that these are right only if he has a sound knowledge of the features of the varieties in question. When seed is purchased, a statement should always be obtained from the seller of the percentage of wildings present in the crop from which the seed came; wildings increase rapidly in potato stocks and reduce their commercial value. With the exception of crops in respect of which stock seed certificates are issued, cognisance of bolters is not taken in official reports at present. The buyer therefore must satisfy himself by visiting the growing crop or by dealing with a reliable merchant, that these variations are not likely to occur frequently in succeeding growth.

Freedom from Diseases, Pests and Injuries.—The troubles which are detrimental to potato seed may be grouped as follows:—

A. Those which are visible on the tuber surface, e.g. late blight, brown scab, corky scab, skin spot, dry rot, blackleg,wart disease, rhizoctonia, streak in some varieties, and eelworm injury.

B. Those which are visible on making a section of the tuber, e.g. sprain, blackleg and blackheart.

1 Blackleg may not be identified always on the tuber, and field inspection is necessary to determine its total absence.
C. Those which are not visible externally or on making a section of the tuber, e.g. leaf roll, mosaic, crinkle, streak and also the physiological disturbances caused by bad storage.

In this country there does not exist a system of certification of freedom from disease of potato stocks, except for wart disease. However, in the recently introduced Stock Seed Scheme of the Board of Agriculture for Scotland, the prevalence of foliage and other diseases is taken into account before certificates are issued. Much progress in the certification of healthy stocks, however, still remains to be made.

Origin.—It has been shown in the previous section that the environment of itself leaves no permanent effect on the potato plant and that its presumed temporary effects on vigour have not been proved. However, as environment controls the distribution of many diseases, especially those of the virus type, the place of origin of a seed stock is of considerable importance. This is specially true when no information is available concerning the health of a stock. It will be shown later also that virus diseases cannot always be identified during the growing season, as masking of the symptoms may take place and the stock may appear unaffected. Of the factors involved, climate, soil and cultivation, climate is undoubtedly the most important, and the time-honoured practice of selecting seed from stocks grown in northern, late, or exposed districts owes its justification mainly to climatic conditions. However, apart from the general freedom from virus diseases of the districts mentioned there are smaller areas within the larger districts where unhealthy seed is produced.

In conclusion therefore it may be stated that provided seed is pure, free, or comparatively free, from bolters and wildings, and free, or substantially free, from all visible diseases and pests and from physical injuries, its value depends almost entirely on the presence or absence of virus diseases. The distribution of these diseases is largely dependent on environment, hence the importance of the
place of origin. Practical experience has shown that seed from northern, exposed or late districts is on the average comparatively free from virus diseases and is therefore preferable to southern seed. An additional safeguard in selecting such seed, however, would be an inspection of the crop from which the seed is to be taken, or the obtaining of a guarantee that the parent crop was substantially free from disease. Seed should not be obtained from districts in which disease is known to be widespread.

That environment has an effect—apart from that on the distribution of diseases—is not yet definitely established, but it seems clear that in the absence of disease the soil type on which the seed was grown cannot have any great influence on the vigour of stocks, and hence it does not merit weighty consideration in the selection of seed.

The above deals with value of seed from the view-point of a purchaser. As virus diseases appear so important, however, the grower will be interested to know how healthy stocks free, or comparatively free, from virus diseases may be built up and maintained. Measures for the attainment of these objects are discussed in Chapter XIX., in which the degeneration diseases of the potato are described.
CHAPTER XIV

FURTHER FACTORS INFLUENCING THE PRODUCTIVITY OF POTATO STOCKS

We have seen that the yielding power of potato stocks is chiefly affected by purity and disease. Although these are the main factors to be considered, they are by no means the only points which should be borne in mind; there still remain to be solved questions of a more local character. It is desirable to know, for instance, the advantages and disadvantages of large and small seed, of cut and whole seed, and of sprouted and unsprouted seed. The student will recognise that these are matters over which the grower has absolute control; having selected on general principles the crop from which the seed is to be taken, he must now decide what type of seed is to be used.

Large and Small Seed.

It has been indicated already that when a crop of potatoes is being prepared for the market, the ware tubers are separated from the seed by means of a riddle varying from $1\frac{1}{2}$ to 2 in. in mesh. "Chats" are removed by the use of a smaller riddle. The seed tubers thus obtained weigh approximately 2 to 3 oz. It will be apparent that in general seed-size tubers are too small to be economically employed for domestic purposes. If, therefore, there is no disadvantage in planting such setts, their economic value is considerably enhanced. A potato tuber grown in sterile sand and watered with pure water will produce shoots which, however, cease their activities and die long before the tuber is exhausted; it is clear that the nutriment stored in the tuber is by no means sufficient to satisfy the requirements of the plant; on the other hand, if a smaller tuber be planted
in similar sand, but watered with a culture solution, luxuriant growth will result. It may be concluded in consequence that the growth is not entirely dependent on the size of seed, and that this is a matter which must be considered along with conditions of cultivation. Under uniform conditions and with equal spacing of the seed, it has been found that the yield per acre increases up to a point with increased weight of seed. The experiments at Craibstone and those of Salaman all indicate that normally the greatest net returns are obtained by the use of medium whole tubers, i.e., those weighing about 2 oz. It must be remembered, however, that in order to ascertain what size of seed will give the maximum net yield per acre under given conditions, many points must be considered: the conditions of cultivation are of primary importance; doubtless there are also distinct differences amongst the various varieties; earlies, for instance, because of their short period of growth, are more dependent on the seed tuber than are lates, with their longer vegetative period; the climate, in determining the duration of the vegetative period, must have its effect; the health of the stock will have its influence; while the spacing of the plants in the drill is also of considerable importance. On the other hand, it has been clearly established that the use of normal seed—2 to 3 oz.—is amply justified, and that the planting of larger or smaller setts is called for only under special circumstances. Small setts do not give the plants such a good start as the larger ones, and there is no doubt that in times of drought large setts have a distinct advantage in that they provide a convenient source of water. It is not commonly known that the sett generally increases in size after planting. This increase is due to the absorption of water from the soil mainly through the lenticels, and it is brought about chiefly by the increased cell sap concentration, due to the conversion

2 R. N. Salaman, Journ. of Agricultural Science, April 1922 and October 1923.
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of starch into sugar when growth begins. It has been determined in experiments at Craibstone that plants from medium-sized setts mature earlier than do those from either small setts or large cut setts. There exists also, as a rule, an inverse ratio between the size of seed and the percentage of heavy ware in the resultant crop, the larger the seed the greater the proportion of seed-size tubers and the less that of ware, a fact probably to be correlated with increased stem numbers and of some importance to seed growers. In this respect cut seed appears to behave in the same way as whole seed of similar weight.

It has been suggested that the present method of making seed results in a deterioration of stocks; the idea underlying this assumption is that the continued selection of small tubers must be coincident with the selection from degenerate plants. There is a great deal to be said for the idea in relation to unhealthy stocks or those containing many wildings; with healthy, normal stocks, however, no such deterioration has been found. Craibstone experiments indicate quite clearly that there is no falling off in yield in progressive years because of the continued use of medium setts.

Cut and Whole Seed.

The cutting of potato seed was much more common many years ago than it is at present. Nevertheless the rise of prices during the war and the spread of wart disease, with the consequent introduction of new and expensive varieties, have to some extent revived the practice. Under certain conditions the supply of seed-size tubers may be insufficient, and resort must be had to the cutting of ware tubers. It is desirable therefore to know how potatoes react to cutting. When a tuber is cut a large wound surface is exposed. The sequence of events during the healing of this cut surface has been studied by Priestley and Woffenden

and Priestley and Johnston. The findings of these writers may be summarised as follows:

1. The first process in the healing of the tuber is the deposit of a fatty suberin layer in the tissues at the cut surface.

2. If the cut surface is exposed in a moist atmosphere the layer is continuous; if, on the other hand, the surface is exposed in a dry atmosphere, especially in sunlight, the layer may not be continuous.

3. This layer forms within twelve to forty-eight hours. Later, cork is formed below this suberin deposit as the result of cell division in an actively dividing layer, the cork phellogen.

4. The activity of the cork phellogen may be estimated roughly by the number of layers of cork produced. Comparative data show that Majestic, King Edward and Bishop are particularly deficient in this important activity connected with the healing of wounds.

These facts have considerable significance in relation to the practice of cutting. If the original suberin layer is patchy—as will be the case if the cut tubers have been exposed to dry air and sunlight—the subsequent cork will also be irregular, with the result that various organisms may enter through the breaks in the natural protective layer. These organisms may cause the tuber to "miss" or may so reduce the food available for the growing plant that weak development may result. This latter effect will be most pronounced if the plant growth is slow, i.e., when the invading organisms have longer time to deprive the growing plant of food stored in the mother tuber. A series of experiments conducted by Priestley and Johnson has demonstrated that seed cut and exposed to the sun and drying air invariably gives poorer results than seed cut but kept in a warm, damp place.

In many quarters liming has been tried to assist in the

protection of the cut surface. So far as the healing of wounds is concerned, the practice would appear to be without justification. Priestley and Woffenden say in this connection:

“The final conclusion of a large amount of experiment upon this subject is that, under the conditions existing in practice, the procedure of liming, either with slaked or unslaked lime, has no practical value, and that provided the tubers are not cut in sunlight or left in too dry an atmosphere, a day or two’s delay before planting is a more effective method of protection against disease.”

On the other hand, other experimenters have found liming to be of considerable value, especially when the cut tubers have to be kept for some time after cutting. Under such circumstances, it is advisable to dust the cut surfaces with ground quicklime and then to spread the seed out thinly on a floor.

Potato tubers may be cut in different ways. If the tuber is to be divided into two parts only, the cutting is generally accomplished by making a longitudinal section from rose to heel end; on the other hand, if the tuber is sufficiently large, transverse or diagonal sections in addition may be made. Each cut sett must contain at least one eye. The value of such setts, however, would appear to be more dependent on their size than on the number of eyes they possess. An examination of some experiments made to determine the value of eyes taken from different parts of one healthy tuber, reveals the fact that there exists no consistency in the results, hence it may be concluded that there is no particular portion of a healthy tuber which is more suited for seed purposes than the remainder. Basal ends, however, have always been regarded with suspicion in this country. Salaman is probably correct when he states that the difference in yield trials between apical and basal ends may be accounted for by the dominance of the apical sprouts; if the tuber be cut sufficiently early this dominance will

be destroyed, equally strong sprouts will develop on both portions and the capacity for yielding of both will be similar. A critical study of the literature on the value of cut setts leaves the impression that much of the data submitted is very inconclusive. The work of Priestley and his colleagues was not known when many of the tests on this subject were made, hence many poor results obtained from cut seed may be explained by improper care of the seed before it was planted. As previously stated, cut setts produce the same ratio of heavy ware as whole setts of corresponding weight. Further tests are necessary, however, before conclusive statements can be made regarding the relative total yields of cut and whole setts of similar weight; there is no apparent reason, however, why they should differ.

The following points of practical importance emerge from the above discussion:—

1. Potato seed should be cut only when seed-size tubers are unobtainable.
2. Where proper precautions are taken to prevent the entry of organisms into the cut surface, cut seed may be planted with safety.
3. These precautions consist in encouraging the formation of a uniform layer of cork cells by methods already described.
4. The practice of liming would not appear to be of great value provided the above conditions have been attained; however, where the conditions are unfavourable, and particularly where cut seed must be kept for some time after cutting, liming may be practised with success.
5. Particular care must be taken with varieties, e.g. Majestic, which experience has shown are very liable to “miss” when cut.

Sprouted and Unsprouted Seed.

The comparatively high prices paid for potatoes which come on the market in June, July and August stimulated investigations in past times into methods by which crops
could be lifted early in the season. The first step, naturally, was the production of varieties which normally had a short period of growth. As there is with our climate a definite limit to the date of planting, further earliness could be obtained only by commencing vegetative growth before planting, i.e., sprouting. The requisites for sprouting are that the tubers are stored in such a way that they are neither too hot nor too cold and that the shoots grow slowly and firmly from the eyes—a condition which can be obtained only in the presence of a moderate amount of light. Further, the atmosphere in the storehouse must be sufficiently moist to enable not only shoots but also roots to develop to some extent.

The records of experiments conducted with sprouted and unsprouted seed are unanimous in one respect; the sprouted seed always matures earlier. Remy has shown that when crops derived from the two types of seed are compared before maturity, that produced from sprouted seed is always the greater in yield. At maturity, however, the sprouted seed, while generally giving the greater yields, does not always do so, which is natural, as the distribution of the good weather throughout the growing season is bound to have some effect. Sprouting, in addition to its effect on the date of lifting, has the advantage that when it is practised faulty setts may be eliminated at planting time and in consequence "misses" may frequently be avoided. It is also to be presumed that with late varieties and in districts where such varieties are normally checked by frost before full maturity is reached, the sprouting of seed would materially increase the yield.
PART IV

CULTIVATION AND
UTILISATION
CHAPTER XV

THE CULTIVATION OF THE POTATO

In the early days of its cultivation in Europe the potato was grown only in gardens and it received the same treatment as other garden plants. Gradually it became a farm crop, and at first the general method of planting was to dibble the tubers "on the flat." With the improvement of farm implements and machinery, the practice of ridging became general, as it was found that the potato crop gave very satisfactory results under such treatment. Later, when the value of the crop was fully recognised, its position in the rotations became assured in all parts of the country. The cultivation of the potato crop has developed into an art, which, as a result of many years of experiment and practice, has been brought to a high state of perfection.

Suitable Soils.

In Great Britain the potato crop is one which can be grown on practically all kinds of soils, heavy clay and wet undrained lands excepted, but the most suitable soil is light loam or alluvium, such as the red soil of East Lothian and the warp lands of Yorkshire and Lincolnshire. Land particularly suited for early potato production is located mainly near the sea coast where the soil is fairly light and the climate mild. Undoubtedly the best soil for potatoes is one that combines ease of cultivation, richness in plant food and ability to retain moisture and to supply it to the plant during the growing season. Where the climate is moist and abundant organic manures are obtainable, sandy soils may produce very good potato crops. The crop does well also on peaty soils where these have been drained and are easily cultivated, but as a rule the cooking quality of the tubers from such soils is poor.
Place in Rotation.

Normally, the potato crop is taken between two cereal crops, thus ensuring that the cleaning of the land shall be of maximum benefit throughout the rotation. Where circumstances of soil and climate are particularly favourable, as in the early potato areas of Ayrshire, potatoes may be grown year after year on the same land with great success. They are grown frequently after old grass or lea, and highly satisfactory crops may be had under these conditions, whereas cereal crops may "lodge" badly owing to the richness of the land.

Preparation of the Ground.

The objects of cultivation are threefold, viz.: (a) to bring the soil to a fine mould or tilth; (b) to destroy weeds; and (c) to control the supply of soil moisture. The potato is not, as is generally supposed, entirely a surface feeder and its roots may extend to a considerable depth in the soil; in consequence the ground must be tilled as deeply as possible to allow the plant freedom for rapid development. A good tilth is absolutely necessary for the potato, not only because it enables the plant roots to spread and thus to assimilate as much plant food as possible, but also because thereby the plant secures the aeration necessary for its underground parts and the looseness of texture requisite for good tuber formation.

Application of Farmyard Manure.—The question of whether farmyard manure should be applied on the surface and ploughed in during autumn or kept until spring and applied in the drills at planting time, has given rise to much diversity of opinion. The time of application of dung depends mainly on local circumstances and conditions. Should a farmer possess a considerable quantity of manure which has been made after the previous planting season, it may be better to apply it to the stubble land and plough it in than run the risk of loss during winter storage. Again, in autumn the farm staff may have more time available than in spring for applying and spreading manure. On the other hand, it has been found that potatoes respond well to
farmyard manure applied in spring, as the manure is then concentrated under the seed and the developing tubers are enabled to grow with relatively less resistance.

If the grower wishes to apply his farmyard manure to the stubble in autumn, some plan should be adopted whereby its regular distribution can be assured. One efficient and expeditious method is to mark out the ground into squares of five or six yards by means of a ridging plough fitted with a long marker. A heap of manure is placed in the centre of each square, the spreader thus having a clearly defined area in which to scatter each heap, evenness of distribution over the entire field also being secured. In the spring, manure is applied “in the drill” and no difficulty is experienced in obtaining an equable spread.

**Autumn Cultivation.**—When potatoes follow a corn crop, it is advisable to begin cultivation immediately after harvest in order to destroy weeds. The best implement for this operation is the general purpose cultivator fitted with broad paring shares; it should not be worked at a greater depth than 1 or 2 in. below the surface of the soil so that the weeds may be cut off and left lying exposed to the sun. Working the land at this depth produces a fine surface tilth and encourages the germination of weed seeds which may be destroyed later with harrows. The period in which these operations can be carried out effectively is, however, very limited, and speed of working becomes of the greatest importance. Normally, if the land is not too dirty and the autumn weather fairly good, preliminary cleaning and cultivation can be completed before winter.

Whether or not the land is to be manured in autumn, it is advisable to have the soil ploughed as deeply as possible before winter in order to create a deeper root run for the crop and to expose a greater volume of soil to the beneficial influences of weathering and aeration. Depth of ploughing depends, however, to such an extent on the nature of the soil that hard and fast rules cannot be laid down; every farmer must be guided by his experience. When farmyard manure has been applied to the stubble, care must be taken that it is not buried beyond the reach of the plant; it is
advisable therefore first to plough it in lightly, say, to about 4 in., and then to cross plough the land deeply.

Treatment of Old Lea.—Difficulty is experienced in the preparation of a good mould when the crop is taken after a tough old lea, as the turf takes a long time to decompose and is apt to work to the surface during cultivating operations. Various methods of avoiding this difficulty can be adopted. When the soil is fairly deep, double ploughing may be resorted to: two ploughs are required, one operating behind the other; the leading plough skims off the whole of the sod, and the second plough which works at some depth covers this sod with a layer of soil 8 or 9 in. deep. This method unfortunately is very costly in time and labour, and where a large area has to be worked it is not economical. Where the soil is too shallow to allow this, and where economy of time and labour is necessary, the modern digging plough fitted with an efficient skim coulter and the knife tail-piece, instead of the usual presser, will prove an excellent implement for burying the turf. The plough should be set to work at the greatest depth obtainable, thus ensuring a good depth of soil over the turf. An alternative method is the employment of disc-harrows. Incidentally, this is one of the operations of cultivation for which the modern tractor is eminently suited. The turf is first cut by disc-harrowing two or three times in different directions with a sufficiently heavy harrow and then the plough is used to bury the macerated turf. Spring cultivation on such land is better carried out by using the disc-harrows again instead of the ordinary harrows, as the latter are apt to drag unbroken sods to the surface.

Spring Cultivation.—In spring, as planting time approaches, the winter furrow is broken up by the use of harrows and cultivators, and, as a rule, these implements alone can produce the necessary tilth. An excellent though slower method of obtaining a sufficient depth of loose, free soil is to cross-plough the land again before commencing work with the harrows. This method has much to recommend it on moderately heavy soils, particularly in a wet climate where there is the possibility of heavy rains in
January, February and March making the surface of the ground hard and compact.

When a good tilth has been obtained the rows are opened by use of the double mould-board or ridging plough fitted with an adjustable marker which draws lightly the line of the succeeding drill. In cultivation on a large scale two or three rows may be opened at a time by use of a cultivator fitted with double mould-board bodies instead of tines, or by a combined double ridger and manure sower. In drawing the drills straightness and a uniform width are essential, as this permits labour-saving machinery to be used to best advantage in subsequent operations, e.g. during the employment of a two- or three-row grubber. The distance between the drills varies with local circumstances and the requirements of the crop. Recent experiments have demonstrated that under average conditions the lateral spread of potato roots does not usually exceed 14 in. on each side of the plant. This would indicate that to allow for the full development of the underground parts of the plant a good width would be about 28 in. When potatoes are grown for the early market, the growing period of the crop is short, and consequently the plants do not require the maximum amount of space for development. It is usual therefore to have the drills comparatively close, say, from 22 to 24 in. Maincrop varieties, however, are generally allowed to complete their growing period; they require therefore more room and the drills are usually 26 to 28 in. wide.

If dung is applied "in the drill" carting and spreading are carried out immediately prior to planting. Artificial manures should be applied after the dung is spread and just before planting.

**Planting.**—The time of planting depends on the district, the season and the variety to be grown. In Britain it varies from February in the early districts where late frosts are practically absent, to May in the late districts. April, however, is the most suitable time for planting maincrop varieties.

Despite the great improvements made in agricultural machinery in recent times, the method of planting by hand
labour is the commonest in Great Britain. Mechanical planters often cause sprouts to be broken and they are not adapted to take all sizes of tubers; they can be used with success only with unsprouted, uncut, and evenly-dressed seed. In planting a field the labour should be arranged so that the operations of applying the artificial manures, planting, and closing the drills may proceed concurrently and at a uniform rate.

The depth at which the tubers should be set varies with the method of applying the farmyard manure. To protect early planted potatoes from late frosts deep planting is advisable. Once the danger of frost is past the soil surface can readily be brought nearer to them by subsequent operations. The space between the tubers varies considerably, but for maincrop varieties one of 12 to 15 in. is considered ample. For early varieties the setts are planted at a distance of from 9 to 12 in. With sprouted seed planting may be done from boxes. The box normally used holds from 18 to 24 lb. of seed-sized tubers, and can be carried in one hand. After planting, the setts are covered by splitting the drill with the double mould-board ridging plough drawn by two horses; one of the horses walks in the bottom of the last-made drill and the other on the top of the drill next, to be split. The danger of displacing or damaging the setts is thus avoided. On very light land this plough may be drawn by only one horse which walks on the top of the drill.

In order to have a headland of regular width a mark should be made to enable the planters to locate the ends of the drills. A man working a drill plough draws a line with his plough across the ends of the drills at a measured distance from the boundary of the field. The planter then places the first tuber in the row at a distance of 9 or 10 in. from this mark. By this means, also, subsequent cultivations can be carried out without the risk of damage to the end plants by implements.
After-Cultivation.

The potato crop is rightly regarded as the best cleaning crop of the rotation. No other crop on the farm is subjected to more hoeings and harrowings. The process should begin almost as soon as planting is completed and the risk of frosts over. The operations are intended to secure the greatest possible depth of loose mould, the thorough aeration of the soil, to facilitate bacterial action and good tuber formation, the conservation of moisture and the control of weeds. The sequence of operations varies, but as a general rule the first implement to be used is the drill roller. This implement breaks up any clods that may be lying on the drill. When the soil is in a suitable condition, the saddle-back harrow is employed, about two or three weeks after planting, to loosen it and to destroy weeds that have germinated on the drill. After harrowing, a heavy grubbing between the drills with a two-horse hoe is to be recommended as an aid to obtaining plenty of free mould. The ridges should be made up again with the ridging plough drawn by two horses. An opportunity is then afforded to any weed seeds in the loose soil to germinate, when a second harrowing down with the saddle-back harrow should be given. If the young potato shoots are beginning to appear, care must be taken to avoid damaging them. The teeth of the harrow which would pass down the top of the drill may be inverted to prevent their coming into contact with the young shoots. This harrowing lowers the surface of the soil and stimulates growth by giving the young plants access to light and air. Varieties which are prone to too shallow tuber formation should be harrowed down more severely than others.

Should any weeds remain, hoeing by hand may be carried out at this stage if time and labour permit. Every opportunity should be taken to horse-hoe before the potato haulms become too high for horse work. These operations are of particular value in a dry season as they preserve a mulch of loose soil, thus conserving moisture. When the weeds have been well checked a heavy grubber may be used to loosen the soil as deeply as possible. As a rule the side
tines are removed to prevent damage to the developing roots and tubers. The final earthing up with a moulding plough follows and with maincrop varieties this generally takes place in July. This operation should be delayed as long as possible, but naturally it must be performed before the tops have grown so high that they will be damaged by the passage of horses and implements. The ridges should now be well set up to hold the crop and to prevent the exposure of tubers to light.

Spraying.

Spraying is carried out to ward off attacks of blight (*Phytophthora infestans*). The reader is referred to the article dealing with this disease on p. 194 for details concerning the time to spray, the preparation of spray mixtures and the methods of their application.

Harvesting.

The lifting of early varieties may take place at the end of May, in June or in July according to the earliness of the district. This work, beginning long before the tubers are mature or the foliage has ceased to function, is generally done by hand labour, the graip or four-pronged potato fork being used. The tubers, after being graded, are packed into barrels or hampers and dispatched straight to market.

Maincrop varieties are nearly always allowed to remain in the ground until mature, when the foliage has died down and the skins of the tubers hardened. The time of lifting varies with localities, but most crops are lifted and stored between the middle of September and the end of October before the risk of severe frost.

There are three methods which are in general use for the lifting of potatoes.

(a) *Lifting by Digger.*—This method is the one most commonly used where potatoes are grown extensively. The machines vary in type but the principle is usually the same: a broad share is set to cut through the drill just below the level of the tubers, while immediately behind the share is
a set of revolving forks which throw out the soil and tubers to one side. In some machines the action of the forks is an upward and lateral throwing movement, while others are so constructed that the tubers are thrown only laterally. Care must be taken that the share is set neither too high, when the tubers may be cut, nor too low, when the tubers are buried with soil. When properly adjusted the tubers are left on the surface well exposed and not too widely scattered.

(b) Lifting by Plough.—For this method a ridging plough is fitted with prongs instead of ordinary mould-boards. The plough is set to such a depth as to work below the tubers, and it pushes rather than throws them out. Only a small proportion of the tubers are completely exposed by the plough and the gatherers naturally have to work slowly. This method possibly has the advantage of lifting the crop with least damage to the tubers but the difficulty of gathering the whole crop is a decided disadvantage.

(c) Digging by Hand.—This method is now practically confined to the harvesting of early crops and to the lifting of endrigs in maincrop fields. The cost of labour and comparative slowness render it uneconomic except with earlies which command a high price.

After the preliminary gathering of the tubers, the field should be well harrowed to expose any tubers that have been left or covered with soil. Where practicable, it is a good plan to allow the gatherers an interval after the digger has passed down the drill in which to collect the bulk of the tubers, and then to harrow the ground with a single harrow so that any tubers remaining in the soil may be exposed and collected. Sometimes after the lifting plough has been used it may be necessary to go over the ground with the cultivator as well as the harrows in order to bring all the tubers to the surface. Should frost occur between the collection of the harrowings and the lifting of the crop, it is advisable to pit the two lots separately.
Storage.

As the crop is harvested it is secured in pits or clamps, or in sheds. The method of construction of these clamps is practically the same all over the country, the only difference being in point of size. In selecting the site for the clamp it is well to bear in mind that future dressings and removal of tubers may require to be done after wet weather when the ground is very soft, so that proximity to a firm road is a great advantage. The clamp should also be made on the driest part available as the tubers do not keep well under moist conditions. The clamp may be as long as desired, and is generally from 4 to 6 ft. wide. When the ground is dry and well drained the usual custom is to dig out the base of the clamp to a depth of a few inches and thus effect a saving in labour and covering material. The tubers are tipped from the cart on to the clamp bottom and are piled up as high as possible. The first cover given to the tubers is a layer of clean straw, about 6 in. deep. Hard straws, such as wheat and rye are the best for this purpose. This layer covers the sides of the clamp and another layer is laid along the top with the ends bent over the two sides. The straw is then covered with about 3 in. of soil to within a foot of the top of the clamp. The potatoes are protected from frost mainly by the straw; the principal function of the soil covering is to hold the straw in position and to give some protection against rain. An extra thickness of straw is much more beneficial therefore than an extra covering of soil. As the top of the clamp is covered only with straw the escape of moisture, warm air and gases is facilitated. At the time of lifting the tubers are still actively breathing, hence there is generally a rise of temperature immediately after pitting. As the carbon dioxide produced by the breathing increases, the metabolism slows down until at a certain concentration of this gas it practically ceases. The greater part of heating in potato pits is due, however, probably to bacterial action on damaged or dead tubers. Stress is to be laid on the importance of keeping down the temperature of the clamp, and recent experiments indicate that the best storage con-
ditions are secured when the temperature in the early stages does not exceed 40°F, and in the latter stages 36°F.

In a few weeks when respiration is less active the clamp may be finally covered with earth. When completely made the clamp has a uniformly thick covering of soil to the depth of 6 or 8 in. However, it is as well to allow for some slight ventilation, and air shafts in the form of bunches of straw should be pulled up at intervals along the apex of the clamp. In some districts it is the practice to insert at intervals along the top of the clamp ordinary drain tiles filled with straw. These are left in all winter without fear of damage by frost to the tubers. The bottom of the ditch formed round the pit in the process of earthing-up should be below the level of the pit bottom and provision should be made for the escape of the water from it.

In very cold districts where there is a possibility of severe frost affecting the tubers in the clamps, a layer of fresh manure rich in straw may be thrown on to the clamp as a protection.

The use of sheds for storing potatoes is not very general in Great Britain except where large quantities of potatoes are being handled. Most potato merchants make use of sheds and houses for storage of the tubers and in these premises sorting and dressing of the potatoes can be carried out during broken weather. If the tubers are stored in sheds light must be excluded from all potatoes intended for table use, as exposure to light very materially affects their quality. On the other hand, tubers intended for seed purposes rather improve by exposure to light. In many instances potatoes lifted in a dry condition and comparatively free from disease may be piled in heaps from 10 to 14 ft. high in sheds without serious harm resulting, provided that the shed is frost-proof; but should the ground have been wet when the tubers were harvested it is advisable not to pile the potatoes up to a greater height than 6 ft. Adequate ventilation of the shed and of the heap is of supreme importance in maintaining the tubers in a sound and healthy condition.
Storage of Seed Potatoes.

The use of storehouses and sheds is common for seed potatoes as the advantages of sprouting the tubers have become generally recognised. With early varieties it is essential that the seed should be sprouted; with late varieties this is also very desirable provided accommodation be available. Even where it is impracticable to sprout all the seed tubers of the late varieties, it is advisable to have at least a portion sprouted as this is of service to the grower should the season be late. Certain late varieties have more need of sprouting than others, e.g. Golden Wonder, which is a slow sprouter, should, where accommodation is limited, be sprouted in preference to Kerr's Pink, which sprouts readily.

Tubers are sprouted by storing the seed in shallow trays or boxes which are so constructed that they may be placed in tiers to any height desired, the potatoes in each box thus getting a certain amount of light and sufficient ventilation to keep them sound. These conditions conduce to the formation of sturdy green shoots, instead of the long, straggly sprouts which are formed in the dark. Steps must be taken to protect the tubers from frost. The tubers may be boxed at lifting time or during the winter when sorting at the pits is in progress. One of the great advantages of boxing is that the tubers may be examined during adverse weather and any showing symptoms of disease removed. Much trouble in the growing season may also be avoided by removal of the rogue tubers when the sprouts begin to show.

Two types of sprouting boxes are in use. The larger type holds about 25 to 30 lb. of seed and has handles at the ends. This pattern is more useful for the sprouting of the late and maincrop varieties, but as it is cumbersome to handle in the field it is hardly to be recommended. The other type is a box 3 in. deep and 2 ft. long by 1 foot wide made with a bar across the top for convenience of handling. It holds about 18 or 20 lb. of seed-sized tubers.
Grading and Dressing.

The grading of tubers consists of passing them over riddles of various sizes to separate them into three classes, ware, seed and chats. It is usual to separate the ware by passing the tubers over a riddle having a mesh of from \(1\frac{3}{8}\) in. to \(2\frac{1}{2}\) in. while the seed is removed by passing the tubers over another riddle of about \(1\frac{1}{4}\) in. mesh, the chats passing through this riddle.

A modern potato sorting-machine consists of a suitable arrangement of riddles shaking in frames, all grades of tubers being sorted at the same time. While the potatoes are on the moving platform it is the general practice for someone in attendance to remove diseased tubers, injured tubers and foreign material.
CHAPTER XVI

THE MANURING OF POTATO CROPS

With the exception of carbon, all the constituents of the potato plant are derived from the soil; carbon is obtained from carbon dioxide in the atmosphere, and, as it is impracticable at present to improve the yields of field crops by increasing the amount of this gas available to the plant, manuring treats of those plant foods in which soils are normally deficient. Of all the elements in the soil necessary for plant growth, usually only three are not present in sufficient quantities for the production of large crops. These three are nitrogen, phosphorus and potash. It has been found that these plant foods are most profitably applied to the potato in the form of farmyard manure, or other organic manure, supplemented by artificial fertilisers.

Farmyard Manure and Organic Manures.

Farmyard manure is the most general organic manure in use; however, in the neighbourhood of the coast seaweed is a cheap and efficient substitute. Where neither of these is available, resort is usually had to the ploughing in of some green crop, such as rape, mustard, clover or Italian ryegrass. Artificial fertilisers cannot replace organic manures entirely, as the latter have a much wider range of functions to perform: apart from their value as fertilisers, organic manures have far-reaching effects on the physical, chemical and bacterial conditions of the soil.

Artificial Fertilisers.

No other crop receives so much artificial fertiliser or responds so well to it as the potato, which of all our agricultural plants is the most efficient converter of artificial
fertilisers into human food. These artificials may be applied alone when organic manures are not available. In these circumstances double the normal quantities may be given, and it is an advantage to use a greater variety of fertilisers to ensure a steady supply of plant food throughout the season, e.g. part of the nitrogen and phosphate may be given in the form of fish meal or guano, or a mixture of rape cake and steamed bone flour. Under these conditions also potassic fertilisers are of special value. On the other hand, where farmyard manure, or its equivalent, is applied, artificial fertilisers should all be in a very readily available form.

**Nitrogen.**—The function of nitrogen is to promote the vegetative growth of the plant. The effect of deficiency is seen in a general stunting of the plant, while an excess produces a marked increase in the development of foliage which is of a darker green hue than usual. Maturity is considerably delayed by the excessive use of nitrogen. Soils are more often deficient in nitrogen than in the other two elements, as it is constantly being removed from the soil in drainage water. Nitrogenous manures are therefore the most important for the potato and have the most immediate and direct effect. They are the most expensive, but experience has shown that under average conditions they are more likely to increase the yield of potatoes than either potassic or phosphatic manures.

Of the nitrogenous fertilisers available in quantity in Great Britain the commonest is sulphate of ammonia. Potato growers generally use it in preference to nitrate of soda and nitrate of lime. In ordinary circumstances applications of one cwt. per acre of sulphate of ammonia will produce an increase of up to one ton per acre of tubers.

**Phosphates.**—Most soils are deficient in phosphates, hence the necessity of applying some form of phosphatic manure. Two important functions are attributed to phosphates, viz: (1) the stimulation of root development, and (2) the hastening of maturity of the plant. Until quite recently the belief was current that the potato crop should receive a very generous application of phosphates, but recent experiments have demonstrated that phosphatic
manuring under certain conditions may be responsible for only very small increases in yield. This may be due to the early maturity induced by phosphates; a curtailed period of vegetative growth, even although the life processes of the plants may be stimulated by the phosphates, may counteract to some extent the beneficial effects of these manures. The need for extra phosphates is not so general or so pronounced as that for nitrogen and potash, and in many districts the amount of phosphates used is excessive.

For the potato crop, superphosphate is generally accepted as being the most suitable phosphatic fertiliser, as it is readily available to the plant and can be mixed with most other manures. Steamed bone flour and phosphatic guano are also quite suitable for potatoes. Basic slag does not contain phosphates in a sufficiently available form to be useful as a potato manure and it has the further disadvantage of being an alkaline manure.

**Potash.**—Potash is an important fertiliser for plants which produce an abundance of carbohydrates, such as starch, consequently the potato crop is dependent on a good supply of this element. Potash reduces slightly the amount of chlorophyll in the leaf, but despite this reduction the efficiency of the leaves for assimilation is increased. Experiments have proved that potash influences to a marked degree the health and growth of the vegetative parts of the plant. Potash starvation manifests itself in a peculiar coppery colour of the foliage and premature death of the plant. On maturity potash has the opposite effect to phosphates: plants receiving potash are usually late in maturing. Farmyard manure contains a considerable quantity of potash and where such manure is liberally applied, potassic fertilisers may not always produce increased yields. Where the dressing of farmyard manure is not large, or where no farmyard manure is given, the effects of potassic fertilisers are often striking.

Various forms of potash manures are on the market, the principal ones for use with the potato crop being sulphate and muriate of potash. Present evidence leads to the con-
clusion that, as regards cropping, there is little difference between these two manures. The lower grade potassic fertilisers, such as “potash salts” and kainit, are generally less effective and may actually be harmful, and consequently are not to be recommended.

Lighter soils, such as sands, gravels and mosses, are generally markedly deficient in potash, and when potatoes are grown on these types of land it is necessary to apply a more liberal dressing of potassic fertilisers than is required on heavier loams and clays. The potash naturally present in clay soils, however, is not always available in sufficient quantity for the plant; hence even on clay soils the application of potassic manures is advisable.

Influence of Manures on the Quality of the Potato Tuber.—Although, for most farmers, bulk of crop is of first consequence, due consideration should also be given to quality. The ultimate criterion of quality is a cooking test. Available evidence shows that potash has the most marked effect on quality. The problem of quality, however, often becomes obscured when farmyard manure is used for the crop, but there seems to be no doubt that the application of potassic manures, especially sulphate of potash, improves the cooking quality of the potato. In this respect the various potassic manures differ widely: sulphate undoubtedly gives the best quality, while the manures containing chloride are distinctly inferior. Low-grade potash salts and absence of potash both tend to give a sodden, ill-coloured potato. Chemical analysis gives definite figures, and it has been shown that potatoes manured with sulphate contain more dry matter than those grown with chloride. The sulphate therefore yields more food per acre even when it gives no larger crops. Dung counteracts the harmful effects of low-grade potash salts, and when applied alone gives normally quite a good quality potato. Phosphates and lime have little effect on quality.

Manures and Disease.—Unfortunately the potato plant is more subject to serious onslaughts of disease than any other arable crop. As manures may affect the susceptibility or resistance to disease, it is most important to know their action. The most serious potato disease is blight (Phyto-
This disease is favoured by heavy doses of nitrogenous manures, while potash tends to reduce its severity. Healthy growth of potatoes requires a properly balanced relation between the nitrogen and potash available to the plants. Virus diseases are also believed to be favoured by overdoses of nitrogen, the explanation being that the luxuriant foliage growth so produced is more favourable to the multiplication and spread of the insects which transmit these maladies. Growers have long recognised that alkaline manures favour scab, and for this reason lime and basic slag are unsuitable for the crop. When, therefore, an application of lime is necessary it is preferable to allow as long an interval as possible between its application and the growing of the potato crop.

**Suitable Manures for Potatoes**—(1) *Light Soils.*—To render light soils productive the basal dressing of farmyard manure or other organic manure has to be applied on a more generous scale than usual. The amount applied may run from sixteen to twenty or more tons per acre with satisfactory results. In addition to this dressing a supplementary manuring with artificials is necessary. A suitable mixture for light land is 1 to 1½ cwt. of sulphate of ammonia; 3 cwt. of superphosphate; ½ cwt. of steamed bone flour, and 2 cwt. of sulphate of potash per acre.

(2) *Medium and Heavy Soils.*—On these soils there is not such a great need for heavy applications of farmyard manure, ten to eighteen tons per acre being usually sufficient. This dressing may be supplemented by a mixture of 1½ to 2 cwt. of sulphate of ammonia, 4 cwt. of superphosphate, 1½ cwt. sulphate of potash, and ½ cwt. of steamed bone flour.

**Manuring of Early Potatoes.**—Early potatoes are mainly grown on lighter soils near the sea coast, and as these soils are generally very deficient in plant foods, liberal manuring is necessary. Moreover, as a greater price is obtained for early potatoes, much larger quantities of artificials than those normally used may be given with profit. It is not unusual for artificial fertilisers to be applied at the rate of fifteen cwt. per acre with a dressing of dung or seaweed varying from

1 The steamed bone flour is used in both mixtures to retain dryness.
twenty to thirty tons per acre. Early potato crops require a manure containing more nitrogen and less potash than main-crops. As quality is not of so great consequence in earlies, potassic manures containing chloride may be used in place of sulphate of potash. The following mixture is likely to give satisfactory results: 2½ cwt. sulphate of ammonia, 4 cwt. superphosphate, 1½ cwt. muriate of potash per acre. Much heavier dressings may be applied to early potatoes and an additional 50 per cent. of the above mixture would probably give economic results.

The problem presented by each soil varies and the grower must modify the quantities of manures to suit his requirements. Manuring is subordinate to soil and climate; if these are unfavourable no skill in manuring will ensure a profitable yield. Further, manuring will not rectify the results of bad cultivation.
CHAPTER XVII

THE UTILISATION OF THE POTATO

The potato crop in Britain is cultivated almost entirely for human food and the feeding of potatoes to stock is still, as it always has been, merely a means of using up the surplus. A small export trade certainly exists, but it is noteworthy that even in years of abundant crops this trade does not seem to expand. During the war years potato starch mills were established at several places in the United Kingdom, but these had to be closed ultimately owing to the low prices obtained for the starch as a result of foreign competition.

The Composition of the Potato.

On the average the total dry matter amounts to 22 per cent. and the water to 78 per cent. of the tuber. By far the greatest proportion of the dry matter is starch, roughly 70 per cent., or 16 per cent. of the whole tuber. Kellner gives the following as an average analysis of the potato: water, 75 per cent.; crude protein, 2.1 per cent.; crude fat, 0.1 per cent.; nitrogen-free extract, 21 per cent.; crude fibre, 0.7 per cent.; and ash, 1.1 per cent. Of the crude protein only 50 to 60 per cent. is present in the form of pure protein. So far as the mineral content of potatoes goes, Klimmer gives the following as the average contents of 1000 parts of potatoes: ash, 9.5; potash, 6.0; sodium, 0.2; lime, 0.3; magnesia, 0.5; phosphoric acid, 1.2; sulphuric acid, 0.6; silicic acid, 0.2; and chlorine, 0.4. Although varieties may be grouped roughly according to their compositions, especially

1 Dr O. Kellner, "Die Ernährung der landwirtschaftlichen Nutztiere," 1919.
their starch contents, it is clear from the many analyses which have been made that there is no absolute constancy in any variety and that the environment in which the plant was grown has a decided effect on the composition of the tubers. In general, however, the starch varies from 15 to 20 cent. of the tuber weight. All parts of the potato contain a poisonous alkaloid, solanin, and in the tuber this amounts to about 0.01 per cent.

The Potato as Human Food.

In Britain the potato is regarded as a source of carbohydrates, its protein content being ignored. Generally it is consumed not alone, but with other foods rich in proteins, e.g. meat and fish. For table purposes mealy and white-fleshed potatoes are favoured; but this is not a universal preference: on the Continent waxy and yellow-fleshed varieties are often the most popular. Quality for any desired purpose in potatoes grown under identical circumstances varies greatly with the variety, and, although environment may affect cooking quality, as it does composition, there are varieties which, irrespective of environment, are always good cookers and others which are always bad cookers.

Coudon and Bussard have explained what happens to the potato when heat is applied in the process of boiling, steaming or roasting; part of the protein is present as albuminoids which form in each cell a sparse protoplasmic matrix in which the starch grains are embedded; with heat this matrix coagulates and forms a coating round each starch grain. The firmer the coating, the less liable is the tuber to disrupt. The case or otherwise with which a tuber disrupts, however, is more closely related to the total albuminoid substance present than to the quantity of starch. The relation \( \frac{\text{total protein}}{\text{total starch}} \) is useful in determining in what

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manner a potato will disintegrate on cooking: when it is low, disruption will come readily; when it is high, the potato will remain firm. A potato which bursts too soon on cooking therefore is not necessarily one rich in starch; it may be one relatively poor in albuminoids.

An important feature concerning the cooking quality of potatoes is the tendency of some varieties to blacken when cooked. How this phenomenon is caused is not exactly known, but the weakness is very readily detected by a direct test.

For “chipping” potatoes, quality is not such a serious matter; shape is much the most important factor: browning and oil-absorption depend largely on the type and quality of oil used, and particularly on the temperature employed. Flat, elongated potatoes of good medium size are the kind in demand by the chipping trade. Firm potatoes chip better than those which are soft.

A study of the composition of the potato leads to the conclusion that, although it cannot be considered by any means a complete food, it can be regarded as a valuable article of diet when used along with other foods supplying those nutrients in which it is deficient. So far as its vitamin content goes, authorities consider that in the potato the fat soluble vitamin A is very poorly developed, the water soluble vitamin B is present in small quantities in both cooked and raw states, and the anti-scorbutic vitamin C is present in fair quantity in all forms of the potato, except in air-dried preparations.

**The Potato as Food for Live Stock.**

As already stated, starch is the chief constituent of the dry matter of the potato and it is that which forms the bulk of the digested material. Crude protein and fat are present only in small quantities, and 40 per cent., or thereabouts, of the former is in the form of non-protein nitrogenous substances. Of the ash constituents, calcium is specially lacking, so that potatoes are unsuitable for young and growing animals.

Moderate quantities of raw potatoes appear to stimulate
the digestion, and as they have a laxative effect, they are of considerable value when fed with less digestible and constipating foods. They should not, however, be fed with other foods which have an irritating action. Fed in excess they are apt to cause various troubles, amongst which are colic, diarrhoea and even abortion. They have a peculiar acrid taste, and stock at first do not take readily to them. According to Klimmer, immature and sprouted potatoes, even when cooked, have a toxic effect, ascribed by most authorities to the presence of solanin. Potatoes should never be fed in excessive quantities, and sprouts, if present, must always be removed. When fed in somewhat large amounts the best practice is to wash the potatoes, cut them in slices and leach these in water from twelve to twenty-four hours. The water used for this purpose must never be given to stock. Raw potatoes must be added very gradually to a ration, and just as gradually withdrawn when a change is to be made. Cattle are the least sensitive of all farm animals to raw potatoes and horses are the most sensitive. A sufficient quantity of roughages and concentrates must always be fed with raw potatoes.

Cooked or steamed, potatoes have no pronounced flavour; they are non-irritant and much more palatable than raw potatoes, but even in this form they may cause digestive troubles if care is not exercised. Salt is generally added to cooked potatoes in order to make them more palatable. The water which drains away after boiling should not be given to stock. The paramount importance of cleanliness in feeding potatoes cannot be over-emphasised.

Dried Potatoes.—Dried potatoes are not available in quantity to the British farmer, but they are used largely for feeding purposes on the Continent. According to Kellner, they contain, on an average, 12 per cent. water, 7.4 per cent. crude protein, (of which 4.8 per cent. is digestible), 70 per cent. digestible nitrogen-free extract; 2.3 per cent. crude fibre; and 3.9 per cent. ash. They agree excellently with all kinds of animals and are easily digested. 100 lb. dried potatoes have the same value as 350 to 400 lb. raw or cooked potatoes.
Cattle.—Mature animals may be given with profit—comparatively large rations of potatoes, but for young growing animals the proportion in the total ration should not exceed one-third. According to Klimmer, the daily ration for milk cows should not exceed 30 lb. and fattening cattle 50 lb. per head; when fed in small quantities, potatoes may be given raw, crushed and mixed with one-sixth of their weight of chaff; if larger quantities are fed, it is better, according to most authorities, to cook or steam them before feeding. Large unbalanced quantities fed to cows are stated to taint the milk.

Sheep.—Potatoes are not generally fed to sheep in Britain, although they form a common food on the Continent, where wethers and suckling ewes are given up to 2 to 3 lb., and fattening sheep up to 5 lb. per head per day.

Horses.—As with sheep, potatoes are seldom fed to horses in this country. Their weakness as a food for horses lies in the fact that although they give a certain amount of bulk and are suitable for fat production, they lack the strength-giving qualities which are so necessary for draught animals. On the Continent, small quantities, 3 to 5 lb. per head per day, have been found to have a beneficial effect on the general condition. During the second and third year of the horses’ life and for horses at comparative rest, potatoes may be fed with the mere addition of chaffed straw and hay. According to Klimmer, not more than from one-quarter to one-third of the grain ration should be replaced by potatoes. The potatoes should be thoroughly cleaned before using, cut into pieces and leached for twelve to twenty-four hours in water, or, better still, steamed, crushed, and mixed with chaffed straw and crushed oats, a little salt being added. In addition, liberal amounts of good hay should be given. Great care and attention, however, are necessary in feeding potatoes to horses as digestive troubles are easily caused.

Pigs.—Potatoes are fed more successfully to pigs than to any other class of farm animal and they constitute in this country quite an important part of the pig’s diet. They fatten pigs rapidly and economically, but experience has shown that when fed in the raw state they are an unsatis-
factory food: they should always be fed therefore after steaming or cooking. The potato ration must be supplemented with feeding stuffs rich in proteins, for young pigs milk should be given and for older animals bran, oil cakes, etc. Fattening animals may receive up to 12 to 20 lb. and small pigs 1 lb. of potatoes per head per day.

Poultry.—Potatoes have been a common food for poultry on Scottish farms and crofts for generations. They are fed always in the cooked state, mashed and mixed with other suitable foods. Successful poultry keepers do not use more than 25 per cent. of cooked potatoes in a ration for laying stock. For fattening purposes, they are specially useful, particularly with geese, ducks and turkeys. Their value for this last purpose is not always sufficiently recognised.

Other Uses of the Potato.

Except for a few months in the spring, Britain is more or less self-supporting in potatoes, and there is generally a surplus in good years. This surplus creates a difficult problem, as its presence sometimes makes the growing of potatoes unremunerative. It is therefore of interest to inquire into the possibilities of other outlets for the crop. The principal articles which can be manufactured from the potato are alcohol, dried potatoes, potato flour and potato starch, but none of these is produced commercially in this country at the present time. The reason for this is not difficult to find. It is clear that in a country, such as Britain, which has adopted a free-trade policy, these articles, if produced, would have to compete in the world's market. Investigations by competent authorities into the economics of the question have demonstrated that at present the manufacture of these products would be unremunerative in this country, unless supported by some form of trade protection or subsidy. It has been suggested recently, however, that the British sugar beet factories might be able to undertake the slicing and drying of potatoes during

the off-seasons. Whether this would be profitable or practicable, yet remains to be proved.

It would seem that the most effective and natural measures for dealing with a surplus, such as occurs in Britain, would be to increase stock feeding and to institute some form of effective trade organisation with a view to controlling production and to providing means of disposing of the crop.

**Short Notes on the Industrial Products of the Potato.**

**Alcohol.**—Alcohol can be manufactured from all plant substances containing fermentable sugar or starchy material capable of being converted into fermentable sugar. The potato is therefore a very suitable subject. The production of alcohol from potatoes is nowhere so extensively practised as in Germany. About the year 1750 potato distilling started on a small scale in that country; it did not, however, extend greatly until a much later date, and its expansion has been due not so much to cheap and remunerative production as to the German general policy of protection of home industries, in which agriculture is included. Apart from consumption as a beverage, alcohol from potatoes is used for lighting, heating, power, and for chemical and industrial purposes. As only the starch is used in the production of alcohol, the proteins, oils, etc., remain unimpaired, so that the residual pulp is a useful cattle food.

It has been computed that 1 ton of potatoes produces 20 gallons of 95 per cent. alcohol. The process of manufacture is as follows: (1) the potatoes are thoroughly washed and steam cooked; (2) they are then saccharified with green malt and fermented with yeast; and (3) they are finally distilled.

**Dried Potatoes.**—Dried and dehydrated potatoes retain all the ingredients originally present in the tuber with the exception of the water, and they may be kept indefinitely without deterioration. The mode of preparation is simple: the potatoes are washed, sliced or chipped, and finally dried. If they are to be used for human consumption, it is important that discoloration should not take place and special pre-
cautions are necessary; if, on the other hand, they are to be used for stock feeding only, discoloration is of little importance. Dried potatoes contain all the solid matter of the potato, but only one-sixth of the original water, and the finished article weighs only about one-quarter of the potatoes consigned to the factory.

**Potato Flour.**—In the preparation of potato flour the potatoes are first thoroughly cleaned and then cooked by steam. The skins may be included or eliminated, as desired. After cooking, the product is passed on to a flaking machine, which consists of hollow rollers heated internally by steam. The thin deposit which forms on these rollers is thus thoroughly dried and is scraped off automatically in the form of flakes. Finally, the flakes are milled into a flour. The flour is used in the making of proprietary food-stuffs, *e.g.* soup powders, or it may be used with wheat flour in the baking of bread.

**Potato Starch.**—Potato starch is a fine, white, glistening powder, consisting mainly of unchanged starch grains. It is used mostly in connection with the textile industry, for sizing yarns and finishing purposes; but it is also used in the manufacture of glucose, dextrine and gums, in the laundry industry, in various food preparations, such as custard powders, and in bread making.

The process of manufacture is simple: the tubers are first cleaned and reduced to a fine state by milling machines; the starch is then extracted by water, purified by many washings, dried at a low temperature to prevent the conversion of starch into dextrine, and finally milled to a fine flour. Naturally, potatoes rich in starch are preferred for the purpose, but the size of the starch grain is also a factor of some consequence, as the process of extraction depends to some extent on the size and weight of the individual grains. Apart from that, however, the larger the grain, the better the quality of starch.

The pulp left after the starch is extracted contains 10 to 20 per cent. of the total starch originally in the potato, the nitrogenous substances, cellulose and ash, and, when dried, forms a suitable food for cattle.
Starch Derivatives—Dextrine.—Dextrine is used mainly in the textile industries, in dressing and finishing fabrics, and in the stationery industry for envelope gumming. It is produced by the action of heat and dilute hydrochloric acid on prepared starch.

Glucose.—Glucose is used in the manufacture of confectionery and preserves, in fruit bottling and in the distilling, brewery and textile industries. It is manufactured by the action of steam and acid on starch.
PART V

DISEASES, PESTS AND INJURY
CHAPTER XVIII

POTATO DISEASES

General.

The diseases about to be described do not exhaust the list of those which attack the potato. They have been selected because of their relative importance in the British Isles. Many other diseases attack the potato, but these have not been considered sufficiently serious or widespread to warrant their inclusion in this work. Concerning the importance of the diseases dealt with, it may be stated that Blight holds the first place, bringing about, as it does in certain years, wholesale destruction of the potato crop; second in importance are the virus diseases which cause the degeneration of potato stocks; Wart disease, because of the existence of immune varieties, is not so serious as either of the above; and the remaining diseases vary in importance. The prevalence and incidence of potato diseases vary with the season and the locality in which the crop is grown.

Varieties differ in their relative resistance to practically all diseases. It is not known of what the power of resistance consists, but it seems to be specific for each disease and not general: varieties differing markedly in their susceptibility to such diseases as Blight and Black-leg may be equally susceptible to or immune from Wart disease. It is probable also that resistance to certain diseases by any variety is not a constant character. With Wart disease, resistance in some varieties amounts to actual immunity, although recent experiments show that immunity does not depend—so far as this disease goes—on a capacity to keep the invader out, but
rather to some faculty, probably physiological, which renders
the host cells unsuitable for the development of the parasite.

In quite a different category is the phenomenon of
tolerance of certain varieties to virus diseases. Here the
causal agent does gain entry into the tissue of the host,
but, although it appears to develop within its host, no
significant damage is done.
CHAPTER XIX

THE DEGENERATION DISEASES OF THE POTATO

Reports on epidemics of "Curl" have appeared periodically in the history of the potato. The term, however, seems to have been applied for a long time rather loosely to that group of diseases of which Leaf Roll, Mosaic, Crinkle and Streak are members. It is only within recent times that successful efforts have been made to separate the individual diseases included in the group, although, as early as 1819, it was recognised by Putsche in Germany that "Curl" was passed on by a plant to its vegetative successors. But although the detrimental effects of "Curl" were realised long ago, little was understood about its nature. Leaf Roll was the first of the diseases in the group to be identified. In 1905 a widespread diminution in the vigour and yield of the potato crop in West Germany took place. This attracted the attention of scientists and led to the recognition of the cause. Mosaic was the next to be isolated, being noted by Quanjer in Holland in 1908 and described by him in 1913; Crinkle was described by Murphy in 1920, and Streak by Orton in 1913. The above four diseases constitute the main types but they by no means exhaust the list: several other types have been described by American and European writers, and, doubtless, more exist. It is, however, on Mosaic, Leaf Roll, Crinkle and Streak that by far the greatest amount of investigation has been carried out and concerning which exact information is available.

General.—The cause of these diseases is unknown. They exist not only in the potato, but also in many other plants. Tobacco Mosaic was the first to be studied and at the beginning that disease was regarded as due to bacteria. This idea, however, was ultimately given up and most
authorities now consider that these diseases are not caused by fungi, bacteria or ordinary micro-organisms. An important feature of them all is that they can be transmitted by means of the juice of affected plants. If the juice be passed through filters the pores of which are small enough to keep back all ordinary micro-organisms, it has been determined that the filtrate still remains infective. Nevertheless, recent investigations have demonstrated that filters with very minute pores can prevent the passing of the virus and thus give a non-infective filtrate. This suggests that the virus may be corpuscular in nature, and there are reasons for thinking that these diseases may be caused by organisms, normal in respect of development and reproduction, but of ultramicroscopic size.

Virus diseases have much in common. A characteristic feature of all is their persistence in vegetative propagation; when once diseases of this type gain entry into a plant, all its stock is apparently permanently and incurably affected. An exception exists in late season infections, when the virus may not have had time to reach the tubers. It would appear from the experiments of Quanjer and Murphy that occasional transmission by means of the true seed also occurs, but as the exception and not the rule. The symptoms of virus diseases vary with the variety, environment and the age of the plant. This fact is of fundamental importance, as it means that detailed descriptions of symptoms without reference to variety and environment, do not permit of accurate identification and may be misleading. In varying degrees, there is always a reduction in the yield of tubers of affected plants and a dwarfed condition of the haulm. In all the degeneration diseases of the potato infection can pass from one plant to another whenever organic union takes place, as in grafting. The infection of Mosaic, Crinkle and Streak can also be transferred by expressing fresh juice from the leaves and shoots of affected plants and applying it to the bruised surface of healthy leaves. Transmission by means of tuber grafts has been demonstrated for all diseases of the Mosaic type but not always for Leaf Roll. It has been ascertained beyond doubt that, with the exception of Aucuba Mosaic and
Streak, these diseases are spread in the field by greenfly. Capsid bugs and Jassid flies have been shown by Murphy to be carriers of Leaf Roll and it is not without the bounds of possibility that other insects and animal pests may be agents in the spread of these diseases. The virus of Leaf Roll, Mosaic and Streak can also be transmitted by aphids from sprouts of diseased tubers to sprouts of healthy tubers. There is no proof, however, that virus can live a separate existence in the soil. All available evidence seems to show that common arable and hedgerow weeds do not act as carriers of these diseases.

Definition of Terms.—The vast amount of work which has been carried out recently on virus diseases has resulted in the evolution of somewhat distinct technique and terminology. The former has been more or less standardised, but not so the latter, and it becomes necessary therefore to define the terms to be used, more especially as a large number of illustrations of these diseases has little or no diagnostic value.

Crinkling is an abnormal unevenness of the leaf surface in which the depressions are chiefly along the veins.

Curling\(^1\) is an abnormal bending of the leaf blade downward along the main vein.

Puckering is a marked unevenness of the leaf surface.

Rolling\(^1\) is an upward curving of the sides of each leaflet with the midrib at the bottom of the trough.

Ruffling\(^1\) is an abnormal unevenness of the leaf-blade surface caused by ridges that develop or become more pronounced with passage from the midrib to the lateral margins, resulting in waviness of the margin.

Wrinkling\(^1\) is an abnormal unevenness of the leaf-blade surface due to depressions and prominences not arranged in any uniform manner.

Leaf Roll.—The symptoms of Leaf Roll are more constant than those of other virus diseases, there being less modification by environment, variety and age of plant. There are two stages of the disease, primary and secondary. The primary stage occurs during the season in which infection has taken place. Newly-infected plants sometimes show no symptoms of disease; but other plants develop a peculiar rolling and

colouring of their upper leaves and then progressively of the lower ones. Plants affected with primary Leaf Roll generally suffer little or no reduction in yield, but the succeeding vegetative generation shows the secondary form of the disease, except on rare occasions when in late season infections the disease has not had time to reach the tubers. The secondary phase, being persistent, is the more common and more obvious. The appearance of affected plants is very typical. "The tips and margins of the lower leaflets are rolled upwards and inwards on the midribs into the shape of a spoon, and later almost into the shape of a funnel. All the leaves except the lower ones may be normal, and frequently not even all the latter are involved. In other cases, the upper leaflets may show considerable rolling, particularly as the season advances. The thickening and rolling of the lowest leaflets are constant throughout the season, and constitute the one invariable external symptom of the disease. The rolled leaflets are distinctly harsh, brittle and crisp, and feel leathery owing to their being thicker than is normal. As the disease progresses the tips of the rolled leaflets become yellow, and later brown, while red or purple areas may develop on the lower, and also sometimes on the upper leaflets. The exposed lower surfaces of the rolled leaflets frequently present a silvery or purplish appearance. In many cases the leaves become more or less erect, and the whole plant is generally reduced in vigour and height. On account of the abnormal rigidity and partial drying out, a rattling sound may be produced when a rolled leaflet is brushed with the hand."¹ The rolling of the leaflets in plants suffering from secondary infection does not become apparent until the plants have been above ground for some time. The yield of tubers is considerably reduced and the whole plant tends to be dwarfed. On the other hand, Leaf Roll does not cause premature ripening except in extreme cases. A characteristic of Leaf Roll is phloem necrosis or death of the food-conducting tissue, which follows the accumulation of starch in the leaflets. The starch manu-

FIG. 20.—Potato Leaf Roll in Variety, Up-to-Date, showing typical symptoms.

FIG. 22.—Streak, Leaf of the Variety, President, showing typical primary symptoms.

FIG. 21.—Crinkle. Left: Plant of Variety, Irish Chieftain, showing typical symptoms. Right: Healthy Plant of same Variety.

(Photos: Reproduced by kind permission of the Department of Lands and Agriculture, Ireland.)
factured during the day disappears from healthy leaflets during the night. This is not so in plants affected with Leaf Roll, and diagnosis may therefore be confirmed by the presence of starch in the leaflets in the early morning. Such determinations may be made by an iodine test. Frequently the old sett of an affected plant does not decay, but this phenomenon is not of any value in diagnosis, as it may be produced by other causes.

There is no progressive degeneration with this disease, and affected plants fluctuate about the same level of growth from year to year. No variety is known to be immune to Leaf Roll, but there is a number of varieties the stocks of which are less severely affected than others. In Scotland the stocks of Templar, Epicure, King Edward and Great Scot are fairly free from Leaf Roll, while stocks of British Queen, Up-to-Date, Katie Glover and Lochar are sometimes badly affected. Stocks of Majestic, Duke of York, Kerr’s Pink and Witchhill appear to be affected frequently but never very severely.

Mosaic.—In Scotland Mosaic disease is much more prevalent than Leaf Roll. The symptoms of Mosaic are not so clearly defined as those of Leaf Roll, and there is generally greater difficulty in diagnosis: variety and environment have a much greater influence on the symptoms of Mosaic than on those of Leaf Roll. The following description, however, indicates the essential features.

The leaves are irregularly mottled with light spots and their surface is generally puckered or crinkled. The mottling is most clearly discernible on a dull day or when an affected leaf is held in the shade. White paper held under the leaf helps to throw the mottling into relief. The leaflets are usually ruffled, but they do not become curled downward at their edges or tips. Affected plants are not so vigorous as healthy plants; the maturity of affected plants is generally earlier, and the capacity for flowering less than in healthy plants. In all severe forms the yield of affected plants is substantially reduced. A fundamental fact concerning Mosaic is that its symptoms differ markedly with the variety. Some authorities consider that Mosaic begins as a rule with mild
mottling of the foliage, and the severer symptoms such as puckering, crinkling and dwarfing are due to the intensification of the disease within the plant. However, most workers on potato virus diseases now consider that there is no foundation for this assumption and that the different types of Mosaic are separate diseases, which means that, in the absence of infection by other types, the symptoms will remain fairly constant from year to year.

It has been found that the mottling of diseases of the Mosaic type can be considerably modified by environment and the age of the plant. Typical mottled foliage may be found throughout the entire season when the climate is cool and damp, but when warmer and drier conditions prevail, the mottling, although evident in the early season, may become less marked or even disappear later in the season. In Great Britain, however, the crinkling of the foliage would always appear to remain. Of the factors involved in this phenomenon air temperature seems to be the most important: light, soil moisture and soil temperature have little effect on the foliage symptoms.\(^1\) It has been ascertained in the U.S.A. and Canada that if a tuber from a plant affected with Mosaic is cut into four parts and these four parts sent to widely different districts, the appearance of the resultant plants at the four centres is not identical: there may be a marked increase in the severity of the symptoms, or, on the other hand, there may be a suppression of the symptoms. This suppression or masking of the symptoms of mild Mosaic is greater at high temperatures than with other types of Mosaic.\(^2\) A further complication is the possibility that certain varieties ("tolerant" varieties) may carry Mosaic diseases always in a masked condition irrespective of environment. Under these circumstances the presence of the disease may be verified only by infection experiments.

In common with all other virus diseases of the potato,


\(^2\) Ibid.
the tuber progeny of an affected plant all carry Mosaic. As with Leaf Roll, however, there is an exception in plants which are infected late in the season, when some of the tubers or some of the eyes may escape infection and give rise to healthy plants. It would appear to be possible, therefore, to raise healthy stock from primarily diseased plants, provided the tubers are lifted soon after infection. There is no phloem necrosis with Mosaic, and the only method of precise identification in varieties whose symptoms are not known is infection experiments. As with Leaf Roll, the parent sett of affected plants sometimes remains undecayed in the soil. So far as is known, there is no British variety which is immune, comprehensive infection experiments not having been made. Under Scottish conditions, however, some varieties appear to have healthier stocks than others: Great Scot, Epicure and Sharpe’s Express are very free from Mosaic; Up-to-Date, King Edward, Arran Comrade, Abundance and King George are only moderately affected; while stocks of Tinwald Perfection, Majestic, Langworthy (including Golden Wonder), Irish Chieftain, Arran Chief and Immune Ashleaf are frequently severely affected.

**Crinkle.**—Crinkle would not appear to be so widespread in Scotland as either Leaf Roll or Mosaic, but as here again the symptoms vary with the variety, it is possible that much of what has been termed Mosaic is in reality Crinkle. The disease appears to be the same as the Rugose Mosaic of Schultz and Folsom in the U.S.A. “It somewhat resembles Mosaic in its general symptoms. The leaves are very diffusely mottled, but more distinctly puckered than in the case of Mosaic, and they curve downwards characteristically at the tip and margin. The veins on the lower sides of the leaves may show dry brown streaks, and a similar discolouration may develop in minute, isolated spots on the leaf-blades. The lower leaves drop prematurely, and the plant withers and dries up before its time. The plant is notably dwarfed, chlorotic and bronzed, and the tissues are brittle. It appears that streaking may occur in the stem in this disease also, but this is a feature which requires further study. Yield and
vigour are very materially reduced."¹ The most marked symptom is the downward curling of the margins and tips of the leaflets.

There is no evidence available at present concerning the susceptibility or resistance of the various varieties to Crinkle in this country, or of the distribution of Crinkle in present-day stocks in Britain.

**Streak or Stipple Streak.**—Some of the symptoms of Streak resemble those of Crinkle, but authoritative workers consider that this is a specific disease. Some hold that there are several forms of Streak, but as the manifestations of the disease are known to vary greatly in the different varieties, dogmatism on this point is premature. "The most characteristic appearance is presented on newly infected plants, namely, the development of a few small angular dark spots on a leaf-blade, which rapidly elongate when they touch a vein and run down through the latter into the leaf-stalk and stem in the form of a deep-seated dark streak. The spotted leaves rapidly shrivel up and fall off. In the next generation, the plants are extremely dwarfed, with brittle brown-stained stems, and small, downward-curling, puckered leaves, the lowest of which drop off. The curious brown 'blisters' described by Atanasoff as characteristic of the disease have occurred on all the tubers of a 'President' plant in which Streak had been isolated, and up to the present on no other tubers of this, or any other variety, or in the case of another disease so far as a careful examination shows."²

In the tuber blisters, which have been found by Atanasoff on other varieties, there is no evidence of the presence of fungous or bacterial parasites, so that the association of this injury with Streak may be provisionally accepted. The blisters begin as small, brown, conical protuberances, which later expand, collapse and leave depressions. However, it is undoubtedly true that some varieties affected by

Streak do not show these blisters. Schultz and Folsom report streaks and spots on the corollas of affected plants as symptoms of this disease on some varieties. In certain varieties also secondarily-affected plants are very seldom able to exhaust their seed tubers, which remain hard and watery. The tubers from secondarily-affected plants are sometimes very small and incapable of development. In such varieties, therefore, the disease is rapidly self-extirminating. On the other hand, Atanasoff has shown that other varieties may always carry the disease in a masked condition without showing any detrimental effects. These varieties may be active agents in spreading the disease.

Transmission by aphids in the field has not yet been demonstrated for Streak, but aphids may carry it from diseased sprouts to healthy sprouts. Leaf inoculations, tuber grafts and foliage grafts are all successful in transmitting the disease.

Owing to the want of information concerning the symptoms of Streak in the various varieties, it is impossible to state how prevalent the disease is in this country. It is possible that the disease has significance only for a few varieties, and that the importance accorded to it in Holland has been due to the work there being confined in the main to the extremely susceptible variety, Duke of York, which is the principal early variety of that country.

**Combinations of the Foregoing Diseases.**—That combinations of the foregoing diseases exist is not doubted: artificial combinations have been made by various workers, and plants affected both with Leaf Roll and with Mosaic are not uncommon in this country. Moreover, it appears quite probable that several of the types of severe Mosaic, and what in past times has been known as "Curly Dwarf" are combinations of these diseases. In all essential respects, these complexes will act in the same way as the simple diseases and be transmitted in the same way in the field; it does not follow, however, that the symptoms of these combinations can be distinguished always from those of the simple diseases. It has been found also that aphids may sometimes transmit
the diseases separately, but more often in combination. Tuber grafts do not always transmit Leaf Roll, hence diseases of the Mosaic type may be separated from Leaf Roll in combinations of these diseases. Diseases existing in the combined state may be identified by taking advantage of the different rates of diffusion of the diseases from an affected scion to the foliage of a healthy stock. Speaking generally, the symptoms of combined diseases are not so readily masked by high temperatures as are the simple diseases.1

Related Diseases.

Aucuba Mosaic.—The conspicuous yellow spotting sometimes seen on potato foliage is distinct from Mosaic, and from the resemblance of the affected foliage to that of the Aucuba japonica it has been called Aucuba Mosaic. This disease is not a serious one in Britain, and the only known symptom consists of bright yellow patches, more or less round, on the leaflets. Recent research would indicate that there is a possibility of there being more than one type of Aucuba Mosaic. The disease is transmissible by organic grafts, and the tubers of affected plants perpetuate the condition. In Britain there does not seem to be any natural spread, and neither in the field nor in the laboratory has transmission by aphids been demonstrated. The stocks of some varieties, e.g. Ninetyfold and Fiftyfold, are badly infected. The disease can be eliminated from stocks by removing affected plants during summer.

Apparently Related Diseases.

Marginal Leaf-Rolling Mosaic.—This disease appears to have significance for certain varieties and possibly also certain countries; it has been little studied, but, as with all virus diseases, no organism has been found associated with it and the condition is transmitted by seed tubers. “This differs from true Leaf Roll, in that there is no phloem necrosis.

DEGENERATION DISEASES OF POTATO

and only the margins curl upwards. The upturned margins are markedly chlorotic, and mottling is present on the remainder of the leaflet. Crinkling occurs on the variety Arran Chief. Among British varieties the disease has been noted only on three, namely, Arran Chief, Katie Glover and Catriona, but it is of widespread occurrence in stocks of the two former. In Arran Chief and Catriona, the symptoms differ from those of ordinary Mosaic in the same varieties, in respect that plants of Arran Chief and Catriona with ordinary Mosaic do not show the upward curling of the margins of the leaflets. In Katie Glover ordinary Leaf Roll and ordinary Mosaic have been observed. The symptoms of each are quite different from the symptoms of marginal Leaf Roll on the same variety. All the leaves on the plant may be affected, and the effect on the yield is very serious. The disease is transmitted through the tubers, but it has not been noted to spread to other varieties grown in close proximity. No information is available regarding transmission by insects or otherwise, or regarding varietal immunity. The marginal leaf-rolling Mosaic here described does not appear to be identical either with marginal Leaf Roll (Quanjer), for which no Mosaic symptoms were noted, or with Leaf-rolling Mosaic (Schultz and Folsom) in which the leaflets are figured as rolling on their midribs.”

The Control of Virus Diseases.

Reference has been made already in Chapter XIII. to the fact that virus diseases are the principal agents in bringing about the deterioration of potato stocks.

Theoretically, the control of these diseases is simple, and consists of obtaining in the first place healthy stocks and then maintaining them in that condition or of growing “tolerant” varieties, i.e., varieties which, although infected with disease, suffer little in consequence. On the practical side there are many difficulties.

A. The Production of Virus-Free Seed.—In order to raise crops which are absolutely healthy, the starting-point

must necessarily be the selection of disease-free plants; thereafter the stock must be grown where there is no danger of infection. The selection of healthy plants would seem a simple matter, but it is by no means so, and to ensure absolute health it is necessary to leave the initial selection to a competent specialist, who alone is qualified by his technical knowledge to express judgment.

The average grower, however, may be satisfied with something less than a 100 per cent healthy stock, provided he can maintain it comparatively healthy. Superior grade stocks, as already noticed, and so far as Britain is concerned, are those grown in northern latitudes, and particularly those certified by official departments as suitable for stock seed.

B. The Maintenance of Stocks, Free, or Comparatively Free, from Virus Diseases.—Having obtained healthy or comparatively healthy seed, the grower is now confronted with the problem of maintaining the health of the stock. The measures to be taken to attain that end differ according to whether absolute health or comparative health is desired.

To maintain absolute health, virus-free stocks must be grown in isolation from all diseased potatoes or potatoes whose state of health is not known. The greater the isolation, the more certain will be the results.

On a large scale, and in many of our arable districts, it is often impossible to obtain complete isolation. The following steps, however, if adopted, will be found to delay very much the spread of virus diseases, if not to prevent it entirely.

(1) The seed stock should, where possible, be grown for seed alone and separate from the ware stock.

(2) The seed stock should be planted as far distant as possible from other stocks, and in fields where ground-keepers are not likely to appear. Diseased ground-keepers act as sources of infection.

(3) Seed stocks should be grown in the highest and most exposed parts of the farm, compatible with economic cultivation, as it is there that transmitting insects are least numerous.
(4) Seed stocks should be rogued several times throughout the season and diseased plants with their immediate neighbours should be removed.

C. The Growing of "Tolerant" Varieties.—The question of "tolerance" in potato varieties has been investigated by Murphy and McKay. It has been found that some varieties may be quite severely infected with virus diseases but show little or no outward symptoms and suffer no appreciable reduction in yield as a consequence. The solution of the virus problem may be found in the growing of such varieties. Our present state of knowledge in this matter is meagre, and one of the complications is that varieties may "tolerate" one disease but not another. As the above authors have pointed out, those varieties which have the widest range of "toleration" have the greatest chance of long and successful lives.

CHAPTER XX

BLIGHT

(Phytophthora infestans (Mont., De By.)

BLIGHT is the best known and most destructive of all potato diseases; it is widely distributed and appears in every country where the crop is grown extensively. When the disease first came to Europe is not known, but it is certainly curious that, whereas the potato was first introduced towards the end of the sixteenth century, the disease does not seem to have attracted much attention before the first quarter of the nineteenth century. It is considered that this may have had something to do with the change from sailing ships to steamships: the Blight fungus cannot withstand a prolonged high temperature and the reduction of time spent in torrid zones by the steamship may have enabled the organism to survive a journey impossible under previous conditions. At all events, Phytophthora infestans is believed to have originated in South America.

The disease seems to have spread rapidly in the British Isles, and in the year 1846 it was so virulent that it caused a complete failure of the crop in Ireland and western Scotland, and consequent famine to the inhabitants of the former country. Since then it has been prevalent more or less every year, varying in intensity with the season.

Description of the Disease.

Normally Blight first appears as dark brown or black spots, of varying sizes and shapes, on the leaf; it may, however, particularly with certain varieties, first manifest itself as clearly defined and similarly discoloured lengths of young stem. Round the margins of diseased areas,
particularly on the under surface of the leaf, a whitish mould may be seen. Under favourable circumstances, the disease will spread rapidly over the entire foliage and stems, causing the premature death of the plant. The date of the first appearance of the disease is determined by many factors, amongst which are weather, district and variety. Diseased foliage emits an unpleasant, fetid smell.

Tubers do not normally show infection until the disease has been on the foliage for some time; when it appears, however, it may be recognised by the presence of rusty patches just visible through the skin; these are much more evident when the skin is removed. The time which elapses between the actual infection and the appearance of the disease has been variously estimated: usually it should not be more than three weeks. *Phytophthora infestans* alone causes a dry rot, but normally, owing to the invasion of other organisms, a wet rot sets in.

**The Fungus.**—The organism consists of fungus threads (mycelium) and reproductive bodies. The reproductive bodies are spores (conidia) and resting spores (oospores). Up to the present, however, resting spores have been found under artificial conditions only, and so far they have not been induced to germinate. It has been shown that the fungus may lead a saprophytic life in the soil, given favourable conditions and the presence of organic matter; but it is still doubtful whether either in the form of a mycelium or of resting spores it does remain alive for any considerable time in the soil, to say nothing of surviving the winter in our climate.

**How Infection is Spread.**

During the growing season when the symptoms are evident on foliage, the disease is spread by spores (conidia) which in a bad year are almost ubiquitous in potato growing districts. These spores are carried mainly by the wind from diseased to healthy plants. Tubers become infected by spores which are liberated from the leaf and washed down through the soil; there is no spread of the disease in storage, and tubers which show disease after lifting have carried with them into
storage either incipient centres of infection or fungus spores which have subsequently germinated and entered their tissues.

How the disease originates afresh each year is not completely known. The current beliefs may be stated as follows: (1) diseased tubers when planted may give rise to plants and amongst these diseased shoots may appear; (2) diseased tubers which have been discarded from the pits may give rise to diseased shoots, or, if trodden on and broken, produce spores on the bruised surfaces; and (3) resting spores may germinate and produce fungus threads and spores.

Factors Favouring the Spread of the Disease.—During the growing season the disease is greatly favoured by wet, muggy weather; dry conditions seem to be unfavourable. Murphy and McKay \(^1\) have emphasised the paramount importance of Blight infection of the tubers at the time of digging and have demonstrated that the greatest amount of infection takes place when crops are lifted while the disease is still on the foliage; less infection occurs when the foliage is dead or has been removed before lifting. According to these authors, the danger of infection is considerably increased when tubers are bruised in any way at lifting; also, under Irish conditions, a soil may remain infective for at least two weeks after the removal of the foliage, hence lifting within this period is much more likely to result in severe infections than lifting after its expiry. It has been shown that the fungus spores are mainly concentrated in the top layer of soil, a fact which supports the practice of "earthing up" potatoes well. It has been suggested that manuring may affect the incidence of Blight, and that too much nitrogenous manuring leads to increased infection. Recently, de Bruyn \(^2\) has shown that the degree of infection also depends upon the degree of development of the plant, and that at a certain stage a plant is more susceptible than at all other stages.

\(^1\) P. A. Murphy and R. McKay, "Further Experiments on the Sources and Development of Blight Infection of Potato Tubers," *Journ. Dept. of Lands and Agric.*, vol. xxv., i.

\(^2\) De Bruyn, *Tijdschrift over Plantenziektien*, January 1926.
FIG. 23.—Potato Leaf affected with Blight (Phytophthora infestans)
(Photograph by Stuart.)

FIG. 24.—Potato Tubers affected with Blight (Phytophthora infestans)
(Photograph by Stuart.)
Control.

(1) In districts where Blight is common, blight-resisting varieties should be grown. A note is given in the Appendix of the relative resistance of common varieties. (Descriptions of Commercial Varieties.)

(2) Spraying is often very effective. The accumulated evidence of many years indicates that over an average of years spraying pays in Great Britain.

(3) Cultural operations, such as “earthing up” well, the removal of haulms before lifting and the delaying of lifting for some time after the plants are dead, all assist in reducing the ravages of the disease.

Notes on Spraying.

(1) There are two common spray fluids, Bordeaux Mixture and Burgundy Mixture. Both are efficient fungicides.

(2) The Ministry of Agriculture and Fisheries in Sectional Volume No. 3 give the following instructions for the preparation of these solutions:—

"Instructions for making Burgundy Mixture.—The mixture should be carefully made, otherwise injury to the foliage may result. It is essential that all the soluble copper be precipitated by the addition of sufficient soda. Whilst adding the soda to the solution of copper sulphate the mixture must be vigorously stirred. The precipitate formed by the mingling of these two substances should be flocculent and should remain in suspension for a considerable time.

"The method of making Burgundy mixture is as follows:—

"For spraying one-third of an acre (say 50 rods).

"(1) Dissolve 4 lb. of sulphate of copper in five gallons of water in a barrel (iron or zinc vessels must not be used) capable of holding 40 gallons, then make up to 35 gallons.

"(2) Dissolve in another vessel in five gallons of water 5 lb. of washing soda (previously broken up into small pieces if necessary).

"(3) When the soda is completely dissolved, add (2) to (1), stirring vigorously meanwhile.

"N.B.—(Both copper sulphate and soda should be of fully 98 per cent. purity).
"Where smaller areas are to be sprayed, barrels, capable of holding 10 gallons may be used; in that case, the quantities of copper sulphate and soda given above should be reduced each to one-quarter, namely, 1 lb. of sulphate of copper and 1/4 lb. of washing soda.

"Burgundy mixture should be bright blue in colour, and should not settle for a considerable time. Experience has shown that the precipitate remains longer in suspension and adheres better to the foliage when the mixture is made up in the above manner than when the soda is added to a concentrated solution of copper sulphate. The fungicide should be used in a fresh state, and in no case should it be applied more than ten hours after it has been made.

"Both copper sulphate and washing soda dissolve slowly in cold water. The preparation of the solutions may be hastened by dissolving the copper sulphate and soda each in a gallon or so of hot water and making up the quantities indicated above by the addition of cold water; but before the solutions are mixed with one another they should be allowed to become cold. In order to save time, the copper sulphate and soda may each be dissolved beforehand, but after the one is added to the other the mixture should be used at once.

"Sulphate of copper is poisonous, therefore the vessels in which the copper compounds have been prepared should not be used for the preparation of food.

"The above formula gives what is known as 1 per cent. Burgundy mixture, i.e., 1 per cent. of copper sulphate is used in its preparation. The use of Burgundy mixture of double this strength, i.e., 2 per cent., is sometimes advocated, but results indicate that there is little to be gained by the application of the stronger fluid. The Irish Department of Agriculture has for a number of years carried out trials as to the relative merits of 1 and 2 per cent. Burgundy mixture. For the five years 1911 to 1915 the average yield per acre sprayed with the 1 per cent. mixture was 12.24 tons as against 12.25 with the 2 per cent. strength, the weights of healthy tubers being respectively 11.72 and 11.84 tons. In some years the 1 per cent. mixture gave better results than the other. Although the average yield during the five years was fractionally better when the 2 per cent. mixture was used, there is not sufficient difference to justify the use of the stronger fluid especially since copper sulphate is now so much more expensive than formerly. In particularly wet districts, however, it may be advisable to use the 2 per cent. mixture. During 1917 good results were generally obtained with the weaker solution.

"Instructions for making Bordeaux Mixture.—This mixture should be made up in the following proportions:—

<table>
<thead>
<tr>
<th>Copper Sulphate</th>
<th>4 lb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quicklime (freshly burnt lumps)</td>
<td>2 lb.</td>
</tr>
<tr>
<td>Water</td>
<td>40 gallons.</td>
</tr>
</tbody>
</table>
"The copper sulphate should be dissolved in 35 gallons of water in a barrel. The lime should be placed in a separate vessel and slaked slowly. This is best done by adding only the amount of water which the lime can absorb. After the lime is thoroughly slaked, more water should be added gradually, stirring all the time, to make up to five gallons. It should then be strained through a fine sieve and added to the solution of sulphate of copper, the contents of the barrel being vigorously stirred during the mixing. The above formula is for a 1 per cent. Bordeaux mixture, and to make the stronger, 2 per cent. solution, double the quantities of copper sulphate and lime are required to the same amount of water. There is, however, little to choose, as regards fungicidal power, between a 1 and a 2 per cent. mixture."

(3) **Dry Spraying.**—This method is not so convenient or satisfactory as wet spraying. It consists of dusting the foliage with a prepared powder containing copper salts. To be effective it must be done when the leaves are wet with dew.

(4) **The Date of Spraying.**—The date when spraying should take place varies with the season and district. It should be done if possible before disease appears, but it is not too late when disease has just begun. Preferably the actual operation should be carried out in early morning or evening and not when the sun is hot. A second spraying should be given, if possible, usually about three weeks after the first, and a third later should it be deemed expedient. Spraying should not be carried out in very wet weather, and if heavy rain falls after spraying and washes the spray off another application should be given.

(5) No matter in what form the spray is given, great care should be exercised to see that the leaf surface, particularly the lower surface, receives a thorough coating of the material.
CHAPTER XXI

WART DISEASE

(Synchytrium endobioticum (Schilb.) Percival).

Historical.

The first description of Wart disease appeared in 1896 from the pen of K. Schilbersky, who received diseased tubers from Trentschin in Upper Hungary, now incorporated in Czecho-Slovakia. The characteristic growths caused by the organism are so pronounced that as this is the first authentic record of the disease there can be no doubt that it is of comparatively recent origin, nearly 150 years having elapsed after the introduction of the potato into general cultivation before any mention of the disease was made. For a similar reason, some regard must be given to early but unwritten accounts of its occurrence. It is reported to have appeared at Haddington as far back as 1876, a statement which should be accepted with reserve, as at the present day there is record of few outbreaks in that neighbourhood. It may always remain doubtful if the disease had its origin in the region of its first discovery; if the origin must be attributed elsewhere; or whether several unconnected seats of original infection are in question. While complete tests of all species of the Solanum found in South America have not yet been made, it is interesting to note that Wart disease has not been known to occur on this continent, which is the natural home of the potato, either on potatoes (S. tuberosum) or on native species of the Solanum, which have been specially tested. The original host plants of Synchytrium endobioticum are not known; the disease has never been found in nature on any plant but the potato, although in pot experiments it was found on S. nigrum and S. dulcamara. S. jamesii,
S. commersonii and S. chacoense also have been found susceptible to the disease. Some varieties of the tomato are susceptible, but all other solanaceous species tested have hitherto remained immune. The possibility of the organism attacking non-solanaceous plants has been investigated, but no indication has been found that such extension of the host range takes place.

The earliest definite record of the presence of Wart disease in Britain appears to be 1898. It is a curious coincidence that one of the first accounts of its appearance in this country is that published by A. Sutton (1898), who stated that he received an affected potato from Dumfries. The diseased tuber was said to have originated from Hungarian potatoes imported into England through Birkenhead. It was once commonly believed in Cheshire that the disease was introduced by cattle boats arriving at Birkenhead. McDougall, in the Transactions of the Highland and Agricultural Society, 1903, states that the disease was first brought to his notice in 1899 amongst potatoes from Cheshire. M. C. Potter described the disease in 1902, while W. Carruthe in the Journal of the Royal Agricultural Society, England, 1902, also gave a description of the disease, adding that it was known in England for some years prior to that date.

In considering the spread of the disease in England it must always be kept in mind that some varieties are immune. It is possible that it did not spread much until the beginning of this century because of the varieties grown: Victoria, Regent, Champion, Magnum Bonum, Maincrop, Abundance, and Bruce were all extensively cultivated before the introduction of Up-to-Date (1893) and British Queen (1894); of the former varieties, only one is known to be non-immune, viz., Magnum Bonum. The introduction of Up-to-Date, British Queen, King Edward, President and Arran Chief, all of which are susceptible to Wart disease, has been partly responsible for the rapid spread of the disease, although the disorganisation of the potato industry during the war years has also been a cause of considerable importance. The map on page 202 shows places scheduled as “infected areas” in
FIG. 25.—Map showing Distribution of Wart Disease in Great Britain and Ireland.
the British Isles at the present time. It must be understood, however, that isolated outbreaks of the disease are outside these marked areas, which represent only districts in which the disease is most prevalent. There are no reports to hand of the occurrence of Wart in the following countries: Spain, Portugal, Soviet Russia, Italy, Greece, Finland, South Africa, South America, Australia and New Zealand; Hungary, as now delimited, appears to be free. The disease has not occurred in Malta nor in the Channel Islands.

Description of the Disease.

In the early stages of the disease the young warts may easily be seen in the eyes of the tubers. These increase in size and ultimately appear as irregular excrescences, which frequently run together, forming large masses of diseased tissue. The size of Warts is dependent on the stage of the development of the tuber when infection takes place. Should this be very early, it is often quite impossible to find any resemblance to a tuber at all; if, on the other hand, the infection takes place later in the season, the Warts may be very small indeed.

The attacks of the organism are not confined to the eye tissue of the tuber; the abnormal growths may be found on the leaves and buds of the stem near the ground level. Affected leaves become much distorted and fleshy. Warts have not been recorded on the roots or on the tubers apart from the eyes.

The Warts are at first white, but as they become old they begin to turn black and form a putrid mass from which brown liquid exudes.

Life-History of Fungus.—The fungus has no mycelium. It lives in the cells just beneath the skin and stimulates these into active sub-division, resulting in the production of the characteristic Warts. There are two distinct ways in which the parasite reproduces itself, viz., by a summer spore-case or sorus and by a resting spore-case. On the decay of diseased tubers, the resting spore-cases pass into the soil. In the spring these germinate and give rise to
numerous motile bodies, called zoospores, some of which find their way to fresh potato tubers. These zoospores undergo some change and enlargement within the host cells and finally give rise to the summer spore-cases or sori, which consist of comparatively thin-walled cases, each containing five thin-walled sporangia. These sporangia ultimately absorb water and enlarge, rupturing the soral envelope and the host cell wall and setting free new zoospores which have been formed in their interior. These zoospores may repeat the process, but they may behave as gametes and fuse. The zygote resulting from the gamete fusion enters an epidermal cell and there develops into a resting spore-case. The resting spore-cases are unusually large. They occur in profusion just beneath the skin, and can be seen with a pocket lens as brown specks if the warts are examined before they become too old. The exact length of time that these resting spore-cases retain their vitality is not known, but well-authenticated cases have occurred in which the disease has reappeared after an interval of ten years. There are three distinct ways in which the organism might persist in the soil, viz.:—

(1) By the resting spore-cases, only a few of which may germinate each year;

(2) By the organism living on a hitherto unrecognised alternate host; or

(3) The organism living saprophytically in the soil in an amœboid condition, and, by repeated encystments tiding over many winter periods.

Method of Spreading.—There is no doubt that the principal means of distributing the disease is potato seed. Even when an immune variety is planted the infection can be carried in earth attached to the tubers. Second in importance is the use of infected manure. Exact experiments are not to hand with regard to cattle, but dung from rabbits and pigs fed on warty material still contains spore-cases capable of producing the disease. Town's refuse, which includes potato skins or material from infected soil, is a common source, and the frequent
FIG. 26.—Wart Disease. Tuber badly attacked and commencing to decompose.

FIG. 27.—Wart Disease. Tuber of Arran Chief, showing the Disease.
(Photos: Reproduced by kind permission of the Ministry of Agriculture and Fisheries, London.)
practice of many householders of throwing rubbish, etc., over garden walls into adjacent fields spread, infection. Implements, cart wheels, birds and drainage water may also be regarded as carriers. It is a noteworthy fact that most field cases have their location near a gate, i.e., the site of potato pits and where traffic is most frequent. The transference of disease from ploughmen's gardens to farm fields has been reported frequently.

Control.

Seed ought to be obtained from disease-free sources and the use of dung suspected of being infected should be avoided, as also should the use of town's refuse in districts where the disease is known to exist.

The only satisfactory method at present of raising disease-free crops on infected land is the planting of immune seed. The reaction of varieties to Wart disease may be determined by a field test, when the plants are grown in infected soil, or by laboratory tests, of which there are several, and which are much quicker. The question as to whether immunity is absolute or relative has been much discussed. It may be stated that on no occasion has Wart appeared in the field on varieties approved by the Agricultural Departments of this country as immune. The occurrence of such phenomena as "wildings" and "bolters" does not affect this statement, as in all cases these follow the true varietal type as regards immunity. All investigated reports of immunity "breaking down" have had their origin in the use of impure seed. Many susceptible varieties are found as rogues in immune stocks and are morphologically so similar to the immune variety in which they occur, that only an expert can with certainty detect them (e.g.: Up-to-Date in Tinwald Perfection, British Queen in King George).

The nature of immunity is not known. The investigations of Kohler have shown that there is no correlation between the hydrogen-ion concentration of the cell sap and

1 E. Kohler, Arbeiten aus der Biologischen Reichsanstalt für Land und Forstwirtschaft, vol. xi., p. 4.
immunity or between the solanin content of the growing parts and immunity.¹

Although in this country a sharp dividing line is drawn between immunes and susceptibles, all gradations appear. Further, there are differences in the times of attacks on various varieties. Some appear capable of resisting these for a time, e.g. King Edward, while others take the disease very early, e.g. Up-to-Date. A disease-free crop can be raised from infected ground in nearly all cases where early varieties are grown and lifted early.

Soil Sterilisation.

Some authorities are of the opinion that in the course of time the organism may adapt itself to immune varieties and that the use of such varieties solves only the immediate problem. Serious attention has therefore been given to the question of soil sterilisation. Successes have been claimed for formalin, formalin combined with steam pressure, and for other methods. However, the cost of such treatment would render its use uneconomical on a large scale. Recently it was considered that sulphur, thoroughly incorporated with the soil, would destroy the organism; the results of experiments so far have been unsatisfactory.

State Control.

So virulent is the disease that practically every country, in which potatoes are grown extensively, has adopted measures to prevent its introduction and spread.

In Britain notification of all outbreaks is compulsory and the planting of non-immune varieties on infected ground is forbidden. Except under authority, the sale or purchase or use for planting on clean land of potatoes grown on land to which the provisions of the Wart Disease Orders apply is also prohibited. In Scotland it is an offence for any person to plant, or cause or permit to be planted except under

¹ Roach (Ann. Appl. Biol., May 1927) has shown that immunity is not caused by any compound which is able to traverse the plant, and that it is likely to be a property of the protoplasm.
licence, any non-immune potatoes in any holding not exceeding half an acre or in any private garden.

Export of potatoes from Scotland into England is regulated by the "Wart Disease of Potatoes Order of 1923." Export to Ireland of potatoes grown in Scotland or England is prohibited unless the importer has obtained the necessary licence authorising their entry and unless the consignment is accompanied by a declaration by the sender giving prescribed particulars. The individual foreign countries have regulations which in some cases forbid the entry of potatoes from Britain, and in others stipulate conditions which must be complied with before entry may be secured.
CHAPTER XXII

BLACKLEG

(Bacillus atrosepticus, van Hall.)

BLACKLEG is a disease with a very wide distribution: its presence has been verified in every potato-growing country of consequence. It is caused by a bacillus, and although the causative organisms have received different names in the various countries, recent research indicates that they are all very much alike and must be regarded as very closely allied, if not actually identical. Experiments have demonstrated that the bacillus can be parasitic on a number of other hosts besides the potato, but it has not been observed on these other hosts in nature. Although the disease was accurately described only in the early years of the present century, there seems to be no doubt that it is a very old one.

Description of the Disease.

As the name implies, the primary characteristic is an inky blackening of the stems, usually at the ground level. However, this condition is not the first indication of the disease, which is one of the earliest to manifest itself in the potato, affected plants being noticeable in the field as early as the middle of June. Diseased plants continue to appear throughout the entire season; these are small and readily recognisable, even at a distance, by their pale green or yellow foliage. The upper leaves generally remain small, stiff and erect, and the margins of the leaflets are usually rolled inwards. If diseased stalks be pulled, it will be observed that they come away very easily; in some plants all the stems become affected, but in others only one or two.
FIG. 28.—Blackleg of Potatoes: attacked Stem and Diseased Tubers.

(Reproduced by kind permission of the Ministry of Agriculture and Fisheries, London.)
The parts most seriously damaged are the outer or cortical tissues and the pith: in affected stems the former will be found to be soft and decayed or perhaps entirely rotted and the latter to be blackened or destroyed. Sometimes the destruction of the pith extends upwards for a considerable distance. The old sett always rots completely. Another symptom of Blackleg is the darkening of the vascular bundles: when affected stems are cut transversely, three brown spots—the main vascular bundles—will be observed; the colour is caused by the bacteria and in severely affected plants it may extend to the apex of the shoot. When examined microscopically, these bundles will be found to be full of bacteria.

If the disease develops very early in the season, no new tubers of any size will be formed, but where the progress is slower, new tubers will be formed and a certain number of these may be affected. Diseased tubers are generally soft and discoloured, especially at the heel end, and the flesh is brown, ultimately becoming wet and rotten. In severe attacks, practically all the tubers decay in the ground, but often the disease does not advance so rapidly and the tubers remain sound for a time.

**Economic Importance.**—The losses resulting from Blackleg vary with the season and the variety; crops with 20 per cent. infection have been reported, and, although this is an exceptional figure, there is no doubt that the aggregate loss in a normal year is considerable, while, in wet seasons and with particular varieties, it may be very great. The disease, however, is not epidemic in nature, as is ordinary potato blight. The damage done is not restricted to the growing plant: in the pit, infection and rotting of healthy tubers may be caused by the decomposition of diseased tubers; another frequent trouble with Blackleg is the sudden decomposition and destruction of tubers in transit, e.g. on rail or steamer.

**Relation to Environment.**—As a rule, plants affected with Blackleg are scattered irregularly over the field. There appears, however, to be a direct relation between environment and the number of diseased plants: the number of
these is likely to be greater during a cold, wet season than a warm, dry one, and there are usually more diseased plants in the lower poorly-drained spots than in the upper and drier parts of a field.

Spread of the Disease.

The principal means of spreading this disease is by affected seed: seed may be so slightly infected as to appear quite healthy, but when used it may produce diseased plants. It has not been proved that direct infection of tubers from the soil takes place in this country, and recent work indicates that in Maine, U.S.A., the bacillus does not live over the winter in the soil itself, although it may do so in tubers left in the soil. Tubers may become infected in storage through contact with diseased material, and the cutting of tubers without disinfection may lead to further spread, if diseased tubers are included amongst those cut.

Although the above are the only ways in which the spread of infection has been demonstrated, it has been observed that seedlings, which have never been in contact with other varieties, may show Blackleg infection. This occurrence can be explained only on the basis that other modes of spread exist. Stem infections, through wounds and stomata, by blown dust, have been suggested, and it is thought that soil insects may carry the organism. Indeed, it has been shown by Leach that the seed-corn maggot (*Phorbia fusiceps*, Zett) is not only instrumental in conveying infection, but also a host in which the Blackleg organism may hibernate.

Susceptibility of Varieties.—Most of the investigators who have studied Blackleg have noted varietal differences in resistance to the disease: differences have also been noted in the resistance of different parts of the plant: varieties may have susceptible tubers and resistant stems, and vice versa. In Scotland, stocks of the following varieties are

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frequently highly infected with Blackleg:—British Queen, Eclipse, Kerr's Pink, Rhoderick Dhu, Arran Comrade, Great Scot and Arran Consul.

Control.

(1) Only sound seed, obtained from crops free from Blackleg or which have been rogued for Blackleg, should be used.
(2) Crops should be rogued for Blackleg and the rogueing should be repeated throughout the growing season.
(3) Pits should be kept dry and well ventilated.
CHAPTER XXIII

COMMON SCAB

COMMON SCAB has long been one of the most widespread of potato diseases. It was recorded as early as 1825, but in spite of this, it was not until a comparatively recent date that it was seriously studied; indeed, for a very long time the impression was abroad—an impression which still persists in some quarters—that it was not a disease at all but merely a mechanical injury due to gritty particles in the soil. It has been clearly demonstrated, however, that no matter how gritty a soil may be, if it be thoroughly sterilised it cannot produce scabby tubers. The disease is now known to be caused by a fungus belonging to the group, Actinomycetes. Several species of the fungus may attack the potato, and these are to be found in all cultivated soils.

Description of the Disease.

The disease first manifests itself as brown spots on the skin of the tuber. These increase in size, but for a time the skin remains intact. The tissue immediately underlying the skin becomes brown and pulpy. At this stage a greyish-white mould may be seen on the surface of these spots, but this disappears when the tuber is exposed to light. After a certain time the skin ruptures, leaving a shallow depression; very quickly, however, the base and edges become thickened with layers of cork. Scabs vary considerably both in general appearance and in dimensions. Frequently, owing to abundant cork formation, they stand out above the general level of the skin, but often the shallow depression is never raised to the surface. Intermediate types also occur; indeed, it is an intermediate type which appears to be the most common in Britain, being only slightly raised and having a series of concentric and wrinkled layers of
cork, arranged round a central cone or depression. Frequently, scabs coalesce and give the tuber a very unsightly appearance. Millard and Burr\(^1\) have demonstrated that the various types of potato Scab are dependent on the infecting Actinomyces species; the variety of the potato may modify the type, but cannot materially change it. The disease does not spread once tuber growth has ceased.

**Economic Importance.**—Common Scab is not generally a serious trouble, the damage being limited to the superficial tissues of the tuber, yet it may be very severe at times and even the tuber eyes may be attacked and killed. Tubers with scab are unsightly and require deep peeling; consequently their market value is lowered. Moreover, affected tubers are much more likely to be attacked by other organisms than those with sound skins.

**Relation to Environment.**—Common Scab occurs more frequently in light than in heavy soils, and dry seasons favour it more than wet seasons. It is found mainly in land which is more or less alkaline and it is encouraged by liming and inhibited by acidity. Absence of organic matter in the soil would also appear to be favourable to the attacking of tubers by the organism, as healthy tubers may be raised on infected soil to which certain vegetable matter has been added. The explanation of this phenomenon, however, is not yet clear.

**Control.**

(1) Liming and the application of alkaline manures should be avoided on alkaline soils, and acid manures used instead: sulphate of ammonia and superphosphate of lime both counteract alkalinity. A dressing of flowers of sulphur (1 oz. per square yard) may prove beneficial.

(2) Where the soil is poor in organic matter, vegetable refuse should be applied. In farms this can be done by green manuring and in gardens by the application of grass mowings, decayed leaves, spent hops, etc. These should be incorporated with the soil immediately before planting.

Fig. 29.—Common Scab, showing typical appearance of individual Scabs.
(Photo: Reproduced by kind permission of the Department of Lands and Agriculture, Ireland.)

Fig. 30.—Corky Scab, showing open Scabs after liberation of the Spore-balls. The ragged margins of the Scabs are characteristic.
(Photo: Reproduced by kind permission of the Ministry of Agriculture and Fisheries, London.)

Fig. 31.—Corky Scab; Canker form of the Disease, showing the destruction of the flesh of the Tuber.

CHAPTER XXIV

CORKY SCAB

(Spongospora subterranea, Lagerh.)

Corky Scab is found in many countries; apart from the British Isles, it has been identified in many European countries, U.S.A., Canada, Peru and Ecuador. It is highly probable that the organism causing the disease has its native home in South America and that it was introduced into Europe many years ago. In literature it has been known since 1842. Although infection experiments have shown that Spongospora subterranea can be parasitic on other solanaceous species, apart from the potato, no other field crop is known to be attacked by it. The organism is one of a group of fungi, known as “slime fungi,” a group to which the parasite causing “finger and toe” in turnips also belongs.

Description of the Disease.

The disease is found only on the tubers and roots of potato plants. Initially the coryk scab manifests itself on the tuber skin in the form of small conical or roundish elevations. Sometimes they are larger and take the form of distinct pimples. In freshly lifted tubers these swellings are almost white, but they soon become brown. With continued growth the skin ruptures and the reproductive spore-balls of the organism are exposed; these consist of a collection of spores held together in a more or less sponge-like spherical mass. Many of these spore-balls are liberated before the tubers are lifted, and in this way the soil is contaminated. In this form the disease may be differentiated from ordinary scab by the more regular
contour of the scabs and by the fact that round the margins of the scabs the remains of the broken skin may be seen. Unless very old, spore-balls are always found associated with the scabs of this disease and there is a brownish layer of cork below the scab. With ordinary scab, on the other hand, there are no spore-balls and there is only an exceedingly thin layer of cork cells. Microscopic examination, however, is often necessary to distinguish the two complaints.

The disease may exist on the tuber in another form, the canker form, which is specially common on secondary outgrowths; with this type actual destruction of the tuber flesh takes place. The initial stages of the canker form may be mistaken sometimes for Wart disease, and microscopic examination may be necessary to establish identity. Between these two forms all transition types are to be found.

When the roots are attacked, small whitish galls, about the size of a pea, are developed.

**Economic Importance.**—In mild cases the disease consists only of scabbing which, from the standpoint of ware potatoes, is not very serious, as the scabs come off with peeling. There may, however, be a depreciation in the market value of the potatoes. As it may be a source of infection, seed affected with this disease is undesirable. The canker form can sometimes do real damage, especially in gardens and allotments.

**Relation to Environment.**—Corky Scab is most prevalent in the wetter parts of the country; it is widely distributed in Scotland, Ireland, Wales and North England, but in the remainder of the British Isles it seldom causes trouble. The production of the canker form is generally due to a wet, poorly-drained soil. Moist seasons favour the trouble, and, as with ordinary scab, liming stimulates its development.

**Means of Spread and Sources of Infection.**—Corky Scab is perpetuated either by the planting of affected seed or by the planting of healthy tubers in contaminated soil. It is highly probable also that manure from cattle and pigs fed on diseased material may constitute another source of infection.

When the spore-balls are liberated in the soil they may remain dormant for a time; but when conditions are favourable they may germinate and give rise to small motile
"zoospores"; these latter can move through the soil and may infest young tubers. In the present stage of knowledge it is safe to assume that contaminated soil may remain infective for three years at least.

**Control.**

1. Only healthy seed should be planted.
2. Cultural practices calculated to reduce severity of outbreaks should be adopted, viz., drainage and long rotations on infected land.
3. Affected tubers may be disinfected by steeping them for three hours in a weak solution of commercial formalin (½ pint formalin to 15 gallons water).
4. Attempts to reduce the disease by the application of chemical disinfectants to the soil have not been very successful, yet a dressing of flowers of sulphur (2½ ounces per square yard) will materially lessen outbreaks.
CHAPTER XXV

DRY-ROT OF THE POTATO TUBER

(Fusarium caeruleum (Lib.) Sacc.)

DRY-ROT is a very common disease of the potato and the causal organism is probably present in all soils on which potatoes are grown. It has been identified in all parts of the British Isles, in many European countries and in America. It was not, however, until the beginning of the present century that serious attention was paid to it. The disease is essentially one of the tuber.

**Description of the Disease.**

The appearances presented by Dry-rot are quite characteristic. The disease may begin at any external region of the tuber. Affected spots are at first somewhat dark and sunken; later the skin becomes wrinkled and folded irregularly in concentric rings and shrinks considerably; and finally whitish fungus pustules break out through it. When exposed to light these pustules may assume a pinkish colour, but if the outer parts are rubbed away, their bases will always be found to be bluish. At this stage, affected tubers when cut exhibit brown diseased tissue, which is somewhat dry and in which cavities frequently exist. In these cavities the white or bluish mycelium of the organism often grows luxuriantly. Affected tubers lose more and more water and ultimately they are reduced to a hard mass difficult to cut with a knife.

The spores of the fungus which exist in enormous quantities on the pustules above described are sickle-shaped and colourless and consist of several cells. Resting bodies, more or less spherical in shape, are also to be found in the pustules.

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Economic Importance.—The disease is essentially one of early varieties: May Queen, Ninetyfold and Reading Russet are extremely susceptible; Sharpe’s Express and Duke of York suffer severely; Epicure is fairly resistant for an early, and lates do not suffer much. The potato is not equally susceptible to attacks at all times and the disease develops mainly during and after December, being most severe in spring. Losses of 50 per cent. have been recorded. Affected tubers, if planted, generally die and produce no plants, but sometimes they grow and develop small though healthy plants. “Blanking” amongst earlies is often due to Dry-rot.

Sources of Infection.—It is not clear how primary infection arises: it may take place in the soil, or the tuber may carry the fungus spores on its surface into storage. It has been demonstrated, in addition, that the walls of the storehouses may also carry spores, and actual infection has been induced on the cut surfaces of seed tubers exposed in such places. When a stock of seed tubers contains affected members, the disease may be spread by cutting. Wounds would seem to be the principal points of entry, but they are not essential: infection may start at an eye or lenticel.

Control.

(1) First-early varieties are susceptible, hence special pains should be taken at all stages to avoid injury to the tubers of these varieties.

(2) First-early seed potatoes should, if possible, always be stored in boxes and not in pits. Tubers which have been “greened” are less liable to take the disease than those which are not. The storage place should be cool and well ventilated. Diseased tubers should be removed from their boxes whenever they are noticed.

(3) Where the disease is bad, it is advisable to wash the storage boxes and the walls of the storehouse with a 2 per cent. solution of copper sulphate.

(4) Cutting should be avoided when the disease is known to exist.
CHAPTER XXVI

SKIN SPOT

(Oospora pustulans, Owen and Wakef.)

SKIN SPOT is one of the less-known diseases. It is a disease of the tubers and one which develops very largely during storage, a fact which probably accounts for its having been overlooked so long and understood so little. It would appear that the disease was first clearly distinguished in 1904; the causal organism, however, was not accurately determined until 1919.

Description of the Disease.

There is no reason why this disease should be confused with others: its appearance is quite distinct, although it is slightly modified by the variety of potato attacked. In some varieties, especially those with coarse tuber skins, Skin Spot manifests itself in the form of definite pimples, and the skin, which never ruptures, is stretched tightly over the swellings, giving them a shiny appearance. When dry, these pimples are very similar in colour to the skin, but when wet they stand out as dark brown. In varieties which have smoother skins, the spots are seldom raised and consist normally of small and sunken, dark, circular spots with a slightly raised centre, the area being brown or even black. Intermediate types appear and the spots often fuse with one another. The disease is superficial and the affected tissues are sharply defined from the flesh by layers of cork. Varieties differ in their resistance to the disease.

Economic Importance.—The importance of this disease is slight with regard to ware potatoes, as it entails no appreciable waste on peeling. It may, however, when the attack is severe, render the tubers unsightly and somewhat
Fig. 32.—Skin Spot. Affected Arran Chief Tuber.

Fig. 33.—Black Scurf Fungus, showing Scurfy masses of Mycelium on the surface of the Tuber.

(Photos: Reproduced by kind permission of the Ministry of Agriculture and Fisheries, London.)
SKIN SPOT

lessen their market value. With seed potatoes the question is different: the disease is capable of causing considerable damage to the eyes. Sometimes these may be entirely killed and at other times so damaged that the tubers are slow to sprout and produce weakly plants.

Relation to Environment.—Further investigations must be made with this disease: it is not known how and when infection takes place and what conditions of soil, climate and storage favour it. The reports on “Fungus and Allied Diseases of Crops, 1922-24” (Ministry of Agriculture and Fisheries, London), show that Skin Spot is very prevalent in Scottish seed potatoes.

Control.

Owing to the meagre amount of information available concerning this disease, the only advice which can be given at present is to avoid purchasing diseased tubers: if these are planted not only will “misses” arise, but healthy soil will become contaminated.
CHAPTER XXVII

BLACK SCURF OR COLLAR FUNGUS

*(Corticium solani, Bourd. and Galz.)*

The above is a very widely distributed disease and is found in America and most European countries. It exists in two very easily recognisable forms, viz., (1) as Black Scurf on the tubers; and (2) as Collar Fungus at the base of the stems. The former stage has been known since 1859, and the latter since 1891. That both forms belonged to the same fungus, however, was not suggested until 1903.

**Description of the Disease.**

(1) *Black Scurf Stage.*—On the tuber surface the fungus forms resting bodies which are irregular in shape and size and almost black in colour. These bodies are generally scattered over the entire surface of the tuber, but where the tuber has been compressed against some hard obstacle in the soil, such as a stone, they are most common on the compressed area. This form of the fungus does little damage, and the resting bodies may easily be detached from the tuber without leaving a perceptible mark. When tubers are freshly lifted these bodies may appear white, but they ultimately darken. They are connected by thin, brownish fungus threads, which may be seen with the aid of a lens.

(2) *Collar Fungus Stage.*—The brown threads referred to run up the underground parts of the stems and at the ground level produce a whitish, superficial growth at the bases of the potato stalks. This is the fruiting stage, and numerous spores are formed which propagate the disease.

**Economic Importance.**—The damage done to tubers and mature plants is slight. However, the fungus may seriously damage young sprouts in spring and cause "missing" in
crops, especially when the weather is cold, or the sprouts may take some time to come above the surface of the soil.

In the U.S.A. and Germany the disease does not appear to be so harmless, and in these countries it causes reduction of the yield by attacking roots as well as tubers. Drier conditions than those existing in this country seem to favour it.

Control.

Seed seriously affected with the disease should not be planted.
CHAPTER XXVIII

SPRAIN

SPRAIN is a very common complaint, but it is by no means certain that one organism is responsible for all that is normally included in the term. In 1917, Dr S. G. Paine isolated a bacterium from sprained tissue; to this organism was given the name *Pseudomonas solaniolens*¹ and to it the disease was ascribed. Sprain is apparent when affected tubers are cut: the cut surface shows a number of brown areas or reddish, rusty specks or streaks, more or less generally distributed throughout the flesh. These spots are green and translucent at first, but they become brown later. So far as is known, the disease does not increase in storage.

The disease is often severe, and although seed is not much affected by it, it is highly undesirable in ware potatoes. The intensity of outbreaks is closely associated with certain types of soil, light gravelly soil being most prone to produce badly infected stocks. Sprain is most common in dry years.

No certain means of preventing it are known.

¹ D. Atanasoff in a recent paper ("Sprain or Internal Brown Spot of Potatoes," *Phytopathology*, vol. xvi., No. 10) considers that Paine's evidence that this is the causal organism is by no means convincing. Again, Millard (*Nature*, 1927, p. 804) has shown that bacteria which show no resemblance to *P. solaniolens* can produce the disease symptoms.
CHAPTER XXIX

SILVER SCURF

(Spondylocladium atrovirens, Hartz.)

Silver scurf of potatoes is a very common but minor disease. The damage done by the disease is slight and need not be regarded with any concern. The probabilities are that, although it has been recognised in Europe only since 1871, it is a very old disease. In its earliest stages it appears on the tuber in the form of very slightly depressed and discoloured areas, on which are numerous black spots—the fungus resting-bodies—which are just visible to the eye. After affected tubers have been stored for a time, the affected areas become more conspicuous and assume a silvery appearance.
CHAPTER XXX

PINK ROT

(Phytophthora erythroseptica, Pethy.)

This is one of the less-known potato diseases. According to Fungus and Allied Diseases of Crop, 1922-24 (Ministry of Agriculture and Fisheries), it is an extremely serious disease in many parts of Western Ireland. It was first reported in England in 1921 and has been recorded in the following counties: Shropshire, Berkshire, Kent, Hertfordshire, Lancashire and Durham; in Scotland its presence has been verified in Berwickshire and in Midlothian. However, it does not seem to be a serious disease in the British Isles except in Ireland.

The rot begins when the potatoes are in the ground and tubers are almost always attacked first at the heel end, although the organism may begin its depredations elsewhere, gaining entry into the tuber through wounds. Infection occurs from the soil, usually through the stolons, roots and underground stems. To the touch, affected tubers feel somewhat soft and rubbery and the skin above diseased parts is usually discoloured. By far the most characteristic feature of the disease is the series of colour changes which take place on the cut surface of diseased tubers: at first the surface does not exhibit any striking difference from the normal, although the tissue, especially that next the skin, may appear dirty; in a few minutes, however, the surface turns pink; in half an hour this changes to deep salmon-pink; and in a few hours it becomes almost black. Despite this, however, the only certain test of the presence of Pink Rot is the finding of ooospores by microscopic examination. The foliage of affected plants appears unhealthy, especially towards the end of the season, from the beginning of August onwards.
and the leaves become pale green or yellow, the symptoms being those of a wilt.

Resting spores of the fungus are found in the underground stems and in old diseased tubers; these latter contaminate the soil. The disease does not appear to be communicable in the pits, but it is possible that it may be carried by affected seed. The only methods of controlling the disease known at present are the use of clean seed and the adoption of a long rotation, to allow, so far as possible, the fungus to die out in the soil.
CHAPTER XXXI

VERTICILLIUM WILT

(Verticillium albo-atrum, R. and B.)

Verticillium Wilt is a very serious disease in those countries where it occurs freely, but fortunately it does not appear to be common in the British Isles.

The symptoms vary, but superficially the disease resembles Blackleg, except that the blackening of the stems is absent. Affected plants are stunted and the leaves usually discoloured and rolled. If the weather be dry, true wilting will occur and the leaves become flaccid and droop. Affected plants die prematurely. The foliage symptoms are due to a process of desiccation, due to the choking of the wood vessels by the fungus. When affected plants die, the fungus passes from the wood vessels into the neighbouring tissue, assumes a resting condition and becomes black. The disease may be identified by placing small lengths of cut stalks in a moist dish for a few days. The fungus grows out of the ends of these and may be identified under the microscope.

Externally, tubers show no sign of the disease, although most tubers from an infected plant contain the fungus. Usually at the heel end a discoloured ring may be seen in the flesh, but this is not an infallible sign. Diseased tubers give rise to diseased plants and diseased seed is the principal means of spreading the trouble, although a slight spread through the soil has been observed. Exactly how primary infection of healthy plants takes place in the field is not known.

Diseased plants should be “rogued” from affected stocks and burned.
CHAPTER XXXII

SOME ANIMAL PESTS OF THE POTATO

The importance of the animal pests of the potato is not generally realised. This is due largely to the effects of fungous, bacterial and virus diseases being much more evident than the depredations of animals. But the two types of troubles cannot always be dissociated and considered separately: as has been shown already, virus diseases appear to be dependent for their transmission on sucking insects; it is, moreover, quite possible that other animals—at present considered comparatively harmless—are agents in the transmission of important diseases. Animal pests are also of consequence, because by their actions they frequently permit the entry of fungi and bacteria into the plant. Apart from these, however, the direct damage done by animals may be very considerable. It is essential therefore that all who would grow potatoes successfully should have a knowledge of these pests and of means for their control.

Aphids (Greenfly).

The two most important aphids which attack the potato are the green and pink aphid, Macrosiphum solanifolii, and the spinach aphid, Myzus persicae. There are, however, other species, e.g. Myzus pseudosolani, which is usually most abundant on seed potatoes, and Aphis solanina, which restricts its operations to the foliage. An interesting subterranean aphid, Geoica (Tychea) phaseoli of Passerini, has been found on potato roots, but does not appear to be general on the plant. Theobald¹ lists several other aphids

which are casual visitors to the potato but which do not appear to be of any consequence.

**Life-History.**—The general features of the life-history are the same for most aphids, although differences in detail exist. Reproduction may be parthenogenetic (*i.e.* females reproduce without mating) or sexual, and in either case the females may be winged or wingless, oviparous (*i.e.* lay eggs) or viviparous (*i.e.* bring forth active young). Four forms may exist: (1) winged, viviparous female; (2) wingless, viviparous female; (3) oviparous female; and (4) male. The outstanding feature of the life-history of these creatures is their phenomenal fecundity, due not so much to the number of offspring produced by the individual, as to the fact that the young begin to reproduce very soon after birth. The following description gives the details of a simple life-cycle: eggs are laid in the autumn; these hatch in the spring and give rise to wingless, viviparous females, which eight to twenty days later produce young parthenogenetically. These first females are known as the "stem mothers," and they are sometimes much larger than the normal wingless, viviparous females. For a period, successive generations of wingless females are produced parthenogenetically. Amongst the offspring, however, are included a greater or lesser number of winged individuals and at times a few males. Finally, a sexual generation arrives which lays eggs.

* Macrosiphum solanifolii is found on potatoes and roses, and also on many other plants. It passes the winter in two ways, namely, as eggs on roses and as eggs or wingless females on potato tubers and sprouts, and probably on other plants.

* Myzus persicae appears to have a very wide host range, including practically every species excepting conifers and certain other trees. It is common on potatoes, both haulm and tuber, and is to be found on all garden plants. Normally it lays its eggs in autumn on peaches, nectarines, brassicae, potato tubers, and probably other plants. The eggs may hatch as early as January. It is almost cosmopolitan, being recorded in Europe, America, Africa, India and Japan.

**Damage.**—Greenfly occurs on the potato plant mainly on the under sides of the leaflets and on the flowering parts;
FIG. 34.—Potato Leaf (under surface) infested with Aphids.
(Photo Stuart.)
they pierce into the food-conducting tissues and extract the sap; and the insects are abundant on the growing points and on the sprouts. The direct damage done to the potato plant by these pests may be considerable, but it is the indirect damage which is the more important. In 1919 it was found in America\(^1\) that mosaic disease was distributed in the field by aphids, and it was shown by Botjes in Holland (1920) and independently by Schultz and Folsom in America (1921) that aphids transmit the virus of leaf roll; since then it has been established that they are the active disseminators of other diseases of the virus type. It has been demonstrated that they may carry the virus of streak from diseased to healthy sprouts, but field transmission of this disease remains to be determined. It is not known if all the species of aphids which are casual visitors to the potato transmit infection. Aphids are most plentiful in warm climates and sheltered positions. The fact that virus diseases of the potato do not spread rapidly in Northern Scotland and in cool climates generally may be explained by the relative scarcity of these insects. It appears also that the palatability of the potato foliage for the aphids has a direct effect on the intensity of the infestation: varieties not particularly palatable are less prone than others to serious attack. Up to the present, however, little investigation in this direction has been made.

**Control.**—The control of aphids is very difficult. Several natural enemies have been noted, e.g. birds, chalcids, ladybirds, hover-flies, green lacewings, etc. Because of the numerous kinds of plants on which potato aphids feed, it is impossible to control them by attempting to kill their alternative hosts. As with other plants, however, aphids seem to prefer certain potato varieties to others, a fact thought to be explained by the greater palatability of the sap of the former. At present, however, although such preferences have been noted, no variety is sufficiently unpalatable to inhibit the development of these animals to any great extent.

Contact insecticides destroy aphids, but these find economic

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application only on a small scale, such as in the protection of valuable seedlings. In the field the spray invariably fails to reach all greenfly. The best spray is nicotine sulphate, either alone or with black soap; commercial preparations of nicotine sulphate in handy forms are available. In spraying, great importance should be placed on the destruction of the early broods. Tetrachlorethane is a suitable fumigant for use in greenhouses and storage houses, and it can be had in a commercial form as “Westol.” The vapour from commercial carbon bisulphide is also useful for destroying aphids on sprouting tubers. Aphids do not appear to thrive in cold, moist, boisterous weather, hence plantings in neighbourhoods where those conditions prevail are much less prone to severe infestations than are those in more congenial surroundings. Within any farm, the best site to grow potatoes as free as possible from aphids—and therefore plants comparatively free from virus diseases—is the most exposed situation compatible with cultural operations.

**Capsids and Jassids.**

Capsids and jassids have been stated by Murphy to carry the virus of leaf roll and are therefore of some importance, especially as it has not been demonstrated that they do not transmit other virus diseases.¹

Jassids are found almost everywhere—on trees, plants of all kinds and many grasses. They are very active and have the power of leaping. Capsids do not have so many hosts as jassids, but at least two species have been found on the potato. Until further investigations have been made, however, the exact economic importance of these pests must remain unknown, and the control measures recommended for aphids must be depended upon to keep capsids and jassids at bay. In consequence of their barbed mouthpieces and toxic saliva, these animals cause greater disorganisation of the plant cells than do aphids; unlike the latter, however,

¹ Dr K. M. Smith in a recent paper (“Observations on the Insect Carriers of Mosaic Disease of the Potato” (Ann. App. Bio., February 1927) states that he has been unable to secure transmission of mosaic disease by Capsids (*Lygus pabulinus* and *Calocoris bipunctatus*).
they do not always penetrate into the vascular bundles. The leaf punctures of jassids are invariably white.

These insects are far more serious pests in America than in Britain: in America a jassid gives rise to a condition known as "Hopper Burn."

**Wireworms.**

Wireworms are the commonest and the most widely distributed of all our underground agricultural and horticultural pests; they occur practically everywhere; they attack practically every crop, the potato included; but owing to their peculiar life-history their attack is never epidemic.

**Description—Beetle.**—The adult beetles vary in size slightly with the species. They range from half an inch to one-quarter of an inch in length, are elongated, somewhat flattened and of a dull brown colour. The chief offenders belong to the genera *Agriotes* and *Athous*, the larva of each of which feeds on the potato. They derive their name, click-beetles, from their faculty for bending the front part of the body away from the remainder and then straightening it again with a sharp click, a procedure which enables them to jump a short distance vertically and to right themselves when placed on their backs. They possess two pairs of wings, of which the front pair, or "elytra," are hard and serve as a cover for the hind pair, the chief organs of flight.

**Larvæ.**—These are the true wireworms. They are very distinct and easily identified, being about one inch long, rod-like, yellowish-brown or brown in colour, with a very hard skin which is usually highly polished. The head is darker than the remainder and is armed with powerful jaws. Three segments immediately behind the head carry each a pair of legs, the remaining segments being legless, a fact of value in differentiating wireworms from other animals with which they may be confused.

**Pupa.**—The pupa is white in colour. It differs markedly from the larva by being soft and readily injured. Pupæ, however, are not often seen owing to the season during which they are formed.
Eggs.—The size of the egg is characteristic for the species. Those of *Agriotes* are rather more than one-fiftieth of an inch in length and slightly longer than broad; they are milky-white and opaque.

**Life-History.**—Eggs are laid in June and July beneath the surface of the soil. The young larvae emerge about a month later and immediately burrow deeper into the soil. At first they are white and semi-transparent, but as they grow older their colour becomes more and more yellow. To begin with, growth is slow. The feeding habits of very young larvae are not definitely known, but later, amongst other things, they attack the potato tuber. The larva phase ranges from three to five years, according to the food supply. When the larvae are fully grown and ready to pupate, which occurs in the latter part of summer, they burrow down below the surface soil and hollow out a small cell in the ground. In three or four weeks the beetle emerges from the pupa, but it may remain underground until the following spring.

**Damage.**—The potato sett is sometimes riddled and partially exhausted by wireworms, and new tubers may be so affected that they are unsaleable.

**Control.**—Wireworms have many natural enemies, the most important of which are birds. Experience has shown that an attack is most to be feared when grass is broken up, and in the field cultural methods continued throughout the rotation appear to be the best means of control. It is advisable to avoid growing potatoes on old grass land for one or two years after breaking it up, when it is known to be infested with the pest. Great importance is attached to the thorough consolidation of the land throughout the rotation which is attainable only when the turf has been thoroughly broken. A deep, firm, seed-bed will often enable the subsequent crop to withstand wireworm attack. These measures will all assist in reducing the infestation when the potato crop is to be planted. Gas lime, if fairly fresh, applied at the rate of four tons per acre appears to be effective. In gardens the application of soil insecticides is more practicable, and several proprietary compounds are available for the purpose. Naphthalene alone may be used at the
FIG. 35.

1. Click Beetle (Adult Wireworm). *Agriotes lineatus*. (4 times nat. size.)
2. Wireworm Pupa. (4 times nat. size.)
3. *Agriotes* Wireworm (side view). (4 times nat. size.)
4. *Agriotes* Wireworm (upper surface). (4 times nat. size.)
5. *Athous* Wireworm (upper surface). (4 times nat. size.)

(Photograph: Reproduced by kind permission of the Ministry of Agriculture and Fisheries, London.)

[Face p. 234]
rate of one or two oz. per square yard. It is essential, however, that it should be worked into the soil as thoroughly as possible, but even on a small scale it is not a certain cure.

**Colorado Beetle**—(*Leptinotarsa decemlineata*).

The Colorado Beetle does not exist in Britain at present. However, it is a pest which has shown considerable adaptive power, and there is always the danger that it may be introduced. The Ministry of Agriculture and the Board of Agriculture for Scotland have taken steps to prevent, so far as is possible, the entry of this pest into Britain.

The history of the Colorado Beetle shows how adaptive the pest can be and how vigilance is necessary. According to MacDougall, it is possible that originally the pest may have migrated from the north of South America, and there is some evidence of its having given rise to various forms or strains, one of which came to be known in Colorado, where both beetle and grub fed on a wild solanaceous plant, *S. rostratum*. Between 1860 and 1870 the beetle was noted as harmful in the United States of America, and as the frontier of the potato-growing area extended westward, the beetle deserted its original host and settled on the potato. By 1865 it had crossed the Mississippi; by 1874 it had reached the Atlantic, and, moving north, entered Canada. A temperature of 38°C. limits its southern, and the lower temperatures of Canada its northern, migration. The beetle has been introduced into Europe several times; it entered Germany in 1876 and 1877 and again in 1887, being exterminated on each occasion; it was introduced into Holland in 1877, and into France in 1922, when it was first observed in the neighbourhood of Bordeaux. In spite of all measures, the Colorado Beetle has not yet been exterminated in France. The pest has been known to exist in England and to survive an English winter; it was found in some allotments at Tilbury Docks in August 1901. Drastic measures were at once taken, yet a few adults appeared in 1902. All these, however, were destroyed. A study of the environ-

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ments in which the beetle has lived gives grounds for suspecting that prolonged existence is possible for it in some parts of England. Whether it could survive the more rigorous climate of Scotland is another question.
Description.—"The adult beetle is very easy to recognise. It measures about half an inch in length and about one-third of an inch in breadth. The upper surface of the body is strongly convex. The colour of the beetle is yellow; each wing cover has five longitudinal black lines; the prothorax (the region behind the head) has two elongated black blotches near its middle, and smaller black spots towards each side."

"The larva or grub has a small black head provided with biting jaws; the legs are six in number and black in colour; the colour of the body varies somewhat according to the stage of the larva, from a dull red in the young stage to a paler brick-red or orange-red in the later stage; a double row of black or dark spots runs down each side of the body; the body is soft; and the hind or abdominal part is larger than the rest of the body and is rounded above. The full-grown grub measures just over half an inch."—(MacDougall.)

Life-History.—The adult hibernates in the soil. In the following spring the beetles appear and commence to lay eggs, of which a very large number may be laid by a single female during her short life of three weeks. Eggs are laid in clusters on the undersides of the leaves. The full-grown grubs pupate in the soil, and there may be as many as three generations in the year.

Damage.—Both adults and larvæ are voracious and destructive feeders on the potato, and if no measures are taken to suppress them they may cause immense loss.

Control.—The control is easy, but the means of accomplishing it add greatly to the cost of production of the potato crop. Arsenical sprays are very effective; nevertheless, it is far better economy to spend money in keeping the beetle out of the country than to await its arrival with sprays, however effective these may be.

Eelworms.

Two species of eelworm are known to attack the potato, viz.: (1) a form or race of the Beet Eelworm (Heterodera schachtii), and (2) a form or race of the common Stem Eelworm (Tylenchus dipsaci).
DISEASES, PESTS AND INJURY

Life-History.—There are three readily recognised stages in the life-history of eelworms—egg, larva and adult. Only the adults are visible to the naked eye. Newly-hatched larvæ seek the roots or tubers of the potato, penetrate into them, and finally develop into the adult stage. The females appear capable of producing a large number of eggs. The female beet eelworm is at first spindle-shaped, but later becomes distended with eggs and spherical; its colour varies from yellow to red-brown. The stem eelworm is almost microscopic in size, and is colourless or white, elongated and spindle-shaped. It can lead a free life in the soil for long periods. The beet eelworm (potato race) and the stem eelworm (potato race) seem to have specialised in attacking the potato, and there is no evidence of other races of these species affecting this crop. The beet eelworm attacks the potato roots mainly, while the stem eelworm attacks the tubers. Eelworms which attack the potato seem to be widely spread, having been reported in Europe, America and Australia. It is rather difficult to estimate the damage done by this pest. The beet eelworm seems to be very prevalent in gardens where potatoes are grown year after year, mature females being found in abundance on the rootlets. A great deal of damage does not seem to be done in Scotland, but the parasite has been associated with severe injury in England. The stem eelworm appears to be the direct cause of damage to potato tubers and not, as once was supposed, a secondary parasite which followed other diseases.

Control.—Further research is essential before much can be said on the subject. Should the above tentative suggestion concerning the diet of these eelworms prove correct, then the simplest cure would be to starve the pests by adopting a longer rotation. Diseased seed should not be planted, and care should be taken not to spread the pest by feeding unboiled, diseased tubers to live stock and by the transference of affected soil by implements, etc.

FIG. 37.—Potato attacked by Eelworm (internal appearance).

FIG. 38.—Potato attacked by Eelworm (external appearance).

(Photos: Reproduced by kind permission of the Ministry of Agriculture and Fisheries, London.)
Slugs.

Slugs are not serious pests of the potato in the field, but in gardens and allotments they often succeed in making themselves a nuisance and cause considerable damage. Slugs feed omnivorously and attack all succulent garden produce, including the potato; they also eat decaying vegetation and organic matter, and at times aphids, small earthworms and weakly soil grubs. In the potato, the principal damage is done to the tuber: setts may be so eaten that resultant plants are small; indeed, "misses" are frequent when slugs abound, especially if the seed has been cut. New tubers are eaten greedily by slugs and often only an empty shell is left.

Slugs move by means of a muscular surface termed the "foot"; they possess two pairs of tentacles and breathe by means of a large pulmonary chamber, and as a means of protection they are able to secrete a copious mass of slime, which can be discharged at least twice in succession.

Slugs are hermaphrodite. Mating takes place early in the morning and egg-laying begins about a fortnight later. The eggs are round to elliptical in shape, and are laid singly or in clusters. The young slugs attain maturity in from three to four months and they may live for two years. During the winter they lie torpid in sheltered places.

Control.—Dry weather appears to be antagonistic to some extent, and slugs are eaten by some birds, such as the duck, thrush, blackbird and rook. The first mentioned is the only domesticated bird to eat them in large numbers. As slugs take advantage of all kinds of refuse for shelter, it is advisable to dig in all crop residues and organic matter as soon as possible. General cleanliness should be maintained. Trapping with sacks and boards is effective in gardens. As a spray to protect the plants from attack, Bordeaux Mixture, applied either dry or wet, is very successful; lime and soot or lime and salt is an effective dry dust; and a mixture of twenty parts of bran and one part of Paris Green, damped and broadcast by hand, is an effective poisonous bait. Slugs may be killed by contact with certain chemicals, such as
alum, aluminium sulphate, salt and quicklime; it is advisable, however, to apply such dressings three or four times at short intervals in the evening as the slime discharge may enable them to escape. A more satisfactory dressing is a mixture of one part of finely-ground copper sulphate with twenty parts of kainit, applied at the rate of three cwt. per acre. The copper sulphate causes paralysis of the slug, thus preventing its crawling away from the poison and rendering the discharge of slime useless. One application of this mixture appears sufficient.

Millipedes.

Millipedes belong to a group of animals related to insects, *Myriapoda*. They are elongated, cylindrical creatures, whose bodies are divided into a large number of rings or segments. There is a pair of legs on each of the first three rings, and two pairs on each of the others. The head is provided with a pair of blunt chewing jaws and the antennae or feelers are quite short. There are several species, but the only one of economic importance is the Julus Worm, which is about half an inch long, slender and creamy-pink in colour, with a row of crimson spots down each side of the body. It lives in the soil and feeds on roots and tubers.

The attack is usually worst in gardens and the damage is seldom considerable, although they may be the forerunners of fungous and bacterial rots.

Control.—A dressing of quicklime is the best method of checking the pest.
CHAPTER XXXIII

LITTLE POTATO, INJURY BY FROST AND HEAT, AND HOLLOW HEART

1. Little Potato (Premature Tuber Formation)

Most potato-growers are familiar with this trouble. It occurs when apparently normal tubers are planted and produce no aerial shoots, but form a number of small tubers clustered round the parent sett. It is most prevalent in early varieties and has been known for a very long time, probably over a century. Serious damage is never caused by Little Potato in this country, but “missing” in early varieties is frequently due to it.

Our knowledge of the nature of the trouble is mainly the result of investigations by Dr Wellensiek, Holland. In a vague way, warm storage has always been associated with Little Potato, but the exact connection was not clear until Wellensiek’s work appeared.

According to Wellensiek, the primary cause of Little Potato is the loss of water by the tuber and the consequent increase in the concentration of the cell sap. The loss of water is principally brought about by the breaking off of sprouts: the percentage of water in a tuber is about 78 per cent., and in the first sprout 90 per cent., hence the removal of sprouts deprives the tuber of relatively more water than dry matter. Oortwijn Botjes,¹ who has also made a study of this problem, agrees with Wellensiek that Little Potato is caused by the removal of sprouts, but he gives a different explanation and considers that the phenomenon is due to loss of albuminoids in which the sprouts are rich. On the other hand, sprout removal and warm storage only create

a predisposition to Little Potato, and the actual trouble does not appear unless the temperature after planting is low; where it is higher and when the ground is moist the condition does not develop. If the predisposition to the condition has not been created, conditions after planting cannot induce it.

Normal development is favoured, and Little Potato is prevented by the use of mature tubers, cold dry storage in light, no removal of the sprouts, and planting in warm, moist conditions.

It is stated that on very rare occasions virus disease may induce a similar complaint.

2. Injury by Frost and Heat.

(a) Frost.—Potato tubers freeze at a temperature of about $-3^\circ$ to $-4^\circ$C. When a tuber is allowed to thaw after having been frozen it becomes moist on the surface, soft and ultimately collapses, the interior becoming a watery pulp. Occasionally only part of a tuber may be frozen and assume the condition just described. On the other hand, if the temperature has not been sufficiently low or prolonged to induce complete freezing, certain inner tissues, particularly vascular tissues, may be injured and appear on the cut surface of the tuber as discoloured strands or areas. The stem end appears to be more susceptible to such injury than the rose end, and, if the tuber be affected at all, an indication of it will usually be found in that region. Varieties differ in the temperatures at which they freeze, but the difference is not very great. Sprouts are not so susceptible to frost injury as are tubers. The accumulation of sugar in potatoes subjected to low temperature is a common phenomenon; it is stated to be due to the reduction of respiration in the tuber.

On account of the necrosis of some of the vascular elements, partially frosted seed gives rise to weakly plants, unless planted under very favourable circumstances.

The effects of frost on the foliage in autumn are familiar to all; late frosts in spring, however, may act variously on the foliage; the young shoots are not always killed, but contortions
and constrictions of the leaflets may develop and even yellow spotting, similar to that found in ancuba mosaic, may be induced. Frosting at an early stage frequently results in the production of bushy plants.

(b) Heat.—When subjected to a temperature of 38° to 48° C. for from 15 to 20 hours, blackening of the interior of the tubers takes place, particularly of the pith. If the treatment be prolonged for 7 to 10 days the blackened areas may partially break down and leave a cavity.

The above phenomenon is known as Blackheart, and is not very common in this country, being found only where tubers have been stored under too warm conditions. The condition is attributed to a deficiency of oxygen: all living cells require oxygen for respiration which increases with rise of temperature; in the absence of a sufficient supply of oxygen some of the pith cells die. The actual blackening is due probably to enzyme action.

Affected tubers do not make good seed. Thorough ventilation and the maintenance of low temperatures prevent Blackheart.

3. Hollow Heart.

This complaint manifests itself in the form of hollows in the centre of tubers. These hollows are not associated with disease and the surrounding tuber flesh is quite healthy. They are irregular in shape and their walls are lined with cork cells, giving them a greyish-brown to dark brown appearance. Conditions which favour a steady and uniform development of the plant seem to lessen the amount of Hollow Heart in a stock, and the origin of the trouble is attributed to rapid growth succeeding a period of slow growth, so that the inner tissues are unable to keep pace with the outer in their development. Moisture, warmth and heavy nitrogenous manuring are said to be predisposing causes.

The condition is not very common in this country, although it is prevalent in some parts of America. It is most frequent in large tubers, but smaller ones are not immune: some varieties are more prone to it than others.
APPENDIX

DESCRIPTIVE NOTES OF SOME COMMON COMMERCIAL VARIETIES

It has not been considered advisable in the following descriptions to give lists of the rogues commonly found in each variety: in field crops the recognition of a plant as a rogue is more important than its identification; in order to identify rogues, moreover, full descriptions are necessary and space does not permit of that here. A complete list of all the rogues occurring in any variety cannot be written; different stocks of a variety may contain different rogues; and any variety, either old or new, is liable to occur as a rogue.

The rogues of most frequent occurrence in any crop are generally plants of standard varieties, e.g. Up-to-Date, Arran Chief, King Edward VII., Early Market, British Queen, Royal Kidney, Champion, Northern Star, Evergood, Sutton's Abundance, Eclipse, President, Epicure and Myatt's Ashleaf. Some well-known varieties, now no longer in commerce, frequently appear, e.g. Magnum Bonum, Lymm Gray, Rocks and John Bull. On the other hand, rogues are often of unknown origin, e.g. "Blue Gray" and "Blue Gloss." Of all the above, the most frequently occurring are Up-to-Date, Arran Chief, Early Market and King Edward VII.

The notes on cropping must be considered along with the maturity of each variety.

The most important features of each variety are given in italics.
ALLY—Mackelvie. Immune.

Maturity.—Early Maincrop.

Tuber.—Round to oval (flat); skin yellow; eyes shallow, saucer-shaped, few, close together, and on the shoulder; flesh white; sprouts faint pink. Second growth takes the form of cracking.

Foliage.—Haulm of medium height, spreading, dark grey green; leaflets long and hairy, with a dull, thick appearance, towards maturity becoming rather glossy; secondary leaflets inconspicuous. Terminal leaflet often joined to one or more laterals.

Flower.—White; anthers generally lemon-coloured and malformed; buds green with a pink tinge.

Remarks.—Cropping: very good; resistant to Blight; cooking quality: poor; bolters occur.

N.B.—The variety Allies must not be confused with Ally. Allies is non-immune and is identical with Northern Star.

ARRAN CHIEF—Mackelvie. Non-immune.

Maturity.—Late Maincrop.

Tuber.—Round (somewhat flat); skin white, with usually a purple spot at the heel during the growing season; eyes medium; flesh white; runners showing a blue-purple coloration; sprouts blue.

Foliage.—Haulm upright and tall, stem mottled blue-purple, stem wing distinctly waved; leaf moderately open, dull and rigid; leaflets medium to dark green, wrinkled; margins waved; terminal leaflet not drooping.

Flower.—White, with green tips, infrequent; anthers malformed and pale; buds distinctly pale green, becoming slightly darker towards maturity and borne on short stalks.

Remarks.—Cropping: very good; rather susceptible to Blight; stocks frequently affected with Mosaic; cooking quality: floury, very good; keeping quality: good.

ARRAN COMRADE—Mackelvie. Immune.

Maturity.—Second Early.

Tuber.—Round (flat); skin white; eyes shallow, on the shoulder; flesh white; sprouts blue.

Foliage.—Haulm of medium height, spreading and compact, with drooping tops, especially towards maturity; leaf fairly open and drooping; leaflet medium to dark green, top leaflets dull and soft; secondary leaflets conspicuous.

Flower.—White, occurring fairly freely; flower stalk very long; buds green, with pink markings.

Remarks.—Cropping: moderate, large proportion of small tubers; highly susceptible to Blight; stocks frequently affected with Leaf Roll.
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ARRAN CONSUL—Mackelvie. Immune.

Maturity.—Early Maincrop.
Tuber.—Oval, oblong; skin white; eyes shallow but deep on large tubers; flesh white; sprouts pink.
Foliage.—Haulm tall and open; stems branching, tinged pink; wings waved at tops; leaf markedly open, long; leaflets medium to dark green with well-marked light-coloured veins, thick with long stalks; secondaries often borne on leaflet stalks.
Flower.—White, very infrequent; buds dark.
Remarks.—Cropping: very good; large proportion of ware; highly resistant to Blight; stocks frequently affected with Leaf Roll and mild Mosaic; susceptible to Blackleg; keeping quality: excellent.

ARRAN VICTORY—Mackelvie. Immune.

Maturity.—Late Maincrop.
Tuber.—Round (somewhat flat); skin blue-purple; eyes medium; eyebrows long; flesh white; sprouts blue.
Foliage.—Haulm upright, tall; stem tinged purple; leaf with purple midrib; leaflets medium to dark green and glossy; terminal leaflet drooping to the perpendicular.
Flower.—Creamy-white; of free occurrence, with long sepals; buds purple, very hairy.
Remarks.—Cropping: very good; resistant to Blight; cooking quality: floury, very good; keeping quality: very good.

BISHOP—Wilson. Immune.

Maturity.—Late Maincrop.
Tuber.—Kidney (pear-shaped), thick; eyes small, shallow and on the point; skin white; flesh yellow; sprouts pink.
Foliage.—Haulm tall, strong, upright and open; stem mottled with dark pink. Leaf rigid, wings wavy at tops; leaflets medium green, large and long, with a touch of pink at the base of the leaflet stalk at the early stages; secondary leaflets large.
Flower.—Profuse; red-purple, tipped white; blossoms borne on long stalks well above the plant; buds dark red-purple; sepals short and narrow, pointed; stigma protruding from the bud; style long; half-opened flowers deep red.
Remarks.—Cropping: moderate; keeping quality: good.


A very large number of so-called varieties of the British Queen type are known. Some of the commoner are: Maid of Auchterarder, McPherson’s Early, Robson, Pioneer, Pioneer Queen, English Beauty.
Maturity.—Second Early.
Tuber.—Oval to oval, pointed; skin white; eyes medium and on point of tuber; eyes on sides of tuber have eyebrows long and raised; flesh white; sprouts pink.

Foliage.—Haulm of medium height, spreading; stems tinged reddish-purple, branching; branches rigid, wings slightly waved at the tops. Leaf open and rigid; leaflet broad, medium to dark green and bright; end pair do not overlap the terminal.

Flower.—Creamy-white, large and profuse; flower stalks bronze coloured; buds dark.

Remarks.—Cropping: very good; very susceptible to Blight; stocks frequently affected with Leaf Roll; susceptible to Blackleg; cooking quality: floury, very good; keeping quality: good.

CATRIONA—A. Findlay. Immune.

The stocks officially tested as Torquil are identical with the stocks officially tested as Catriona.

Maturity.—Second Early.

Tuber.—Kidney (long oval); skin yellow, blue-purple in the eyes and about the eyes; eyes shallow and on the point; flesh soft, white, with a lemon tinge; sprouts blue.

Foliage.—Haulm of medium height, compact, spreading and vigorous; stem branching freely, with occasional colour on tops; wings waved; leaflets medium to dark green, with waved margins, glossy and semi-drooping, the last pair fitting round the terminal; secondary leaflets numerous.

Flower.—Light blue-purple, tipped white, fairly frequent; buds dark.

Remarks.—Cropping: good; susceptible to Blight; stocks frequently affected with Mosaic; two substitutes are known.

CHAMPION—Nicol. Immune.

Maturity.—Late Maincrop.

Tuber.—Round, irregular, distinctly dentated at heel; skin white; often with a blue-purple splash at the heel in the growing season, and other blue-purple markings; eyes very deep; flesh yellow; runners numerous, blue-purple; sprouts blue.

Foliage.—Haulm erect, very tall with bushy habit and a profusion of thin, hard branches which are markedly mottled purple; leaflet open; leaflets dull, narrow, medium to dark green, and rather small; secondaries inconspicuous; leaflet bases tinged blue-purple.

Flower.—Dark blue-purple, distinctly tipped white—frequent; buds dark and profuse; berries occasionally occurring.

Remarks.—Cropping: good; fairly resistant to Blight; stocks practically always affected with Mosaic; cooking quality: very floury, very good; keeping quality: good.
CRUSADER—Wilson. Immune.

Maturity.—Second Early.

Tuber.—Kidney (pear-shaped); skin white; eyes shallow, saucer-shaped, usually on the shoulder, those on the sides with slightly raised eyebrows; flesh white; sprouts faint pink.

Foliage.—Haulm of medium height to tall, upright, robust, compact; wings waved at the top, stems tinged red-purple towards maturity; leaf dark, glossy, arched and markedly wrinkled, fairly close with drooping leaflets, giving leaf a half-closed fist appearance. The last pair of leaflets fits over the terminal leaflet.

Flower.—Red-purple, tipped white; sometimes occurring fairly freely; buds pink with a green base.

Remarks.—Cropping: moderate, high proportion of small tubers; stocks frequently affected with Mosaic; cooking quality: very good; keeping quality: good.

DARGILL EARLY—Gardiner. Immune.

This variety is identical with Boston Kidney and Mitchell’s Advance.

Maturity.—Second Early.

Tuber.—Kidney (pear-shaped); skin pale yellow; eyes shallow, those on the side having raised eyebrows; flesh yellow; sprouts faint pink.

Foliage.—Haulm of medium height to tall, upright, robust, compact; wings waved at the top, stems tinged red-purple towards maturity; leaf dark, glossy, arched and markedly wrinkled, fairly close with drooping leaflets, giving leaf a half-closed fist appearance. The last pair of leaflets fits over the terminal leaflet.

Flower.—Light red-purple, seldom formed; flower stalk short.

Remarks.—Cropping: moderate; susceptible to Blight; stocks practically always affected with Mosaic.

DI VERNON—A. Findlay. Immune.

Maturity.—First Early.

Tuber.—Kidney (long oval); skin yellow, mottled blue-purple, especially at rose end; eyes shallow, blue-purple; flesh white, with tinge of lemon; sprouts blue.

Foliage.—Haulm low, spreading and later becoming prone, with drooping top; stem becoming mottled red-purple; wings slightly waved; leaf open; leaflets thin, drooping; dark green and glossy; the last pair generally overlapping the terminal, limp when ripening; secondary leaflets small and numerous. Towards maturity the margins of the leaflets frequently curl upwards.

Flower.—Blue-purple tipped white; stalk long, tinged purple; buds dark blue-purple.

Remarks.—Cropping: good; susceptible to Blight; stocks frequently affected with Leaf Roll; cooking quality: waxy.
DUKE OF YORK—Midlothian Early (Sim). Non-Immune.

Maturity.—First Early.

Tuber.—Kidney (pear-shaped), thick; skin yellow, rough at maturity; eyes very shallow and on the point; flesh yellow; sprouts faint pink.

Foliage.—Haulms of low to medium height; open and straggling; leaf open and long; leaflets medium green, dull, thick and long.

Flower.—White, seldom formed; anthers pale and malformed; buds with long green tips.

Remarks.—Cropping: good; susceptible to Blight; cooking quality: very good; bolters occur.

ECLIPSE—Sir John Llewelyn (Harris). Non-Immune.

Maturity.—First Early.

Tuber.—Oval to oval, pointed; skin white; eyes shallow and almost on the point; flesh white; sprouts pink.

Foliage.—Haulm of medium height and spreading; stems pink in colour and solid before maturity; wings waved; leaflets broad, small, dull, light to medium green. There is a pink tinge at the base of the leaflet stalks, and on the margins of the leaflets, at an early age.

Flower.—White, infrequent; buds hairy and dark pink with green tips.

Remarks.—Cropping: good; susceptible to Blight and Blackleg; cooking quality: waxy; keeping quality: good; bolters occur frequently.

EDZELL BLUE. Immune.

Maturity.—Second Early.

Tuber.—Round; skin blue-purple; eyes medium to deep, eyebrows distinct; flesh snow-white; sprouts dark blue.

Foliage.—Haulm of low to medium height, upright, spreading later; mottled blue-purple towards maturity. Leaf open and drooping; midrib purple at base and bases of leaflet stalks. Leaflet ashy-green and dull.

Flower.—White, but sometimes with a tinge of light blue-purple; occurring freely; buds dark.

Remarks.—Cropping: very good; cooking quality: floury, very good; keeping quality: very good.

EPICURE—Clark. Non-Immune.

Maturity.—First Early.

Tuber.—Round, irregular; skin white, but turning pink on exposure; eyes deep, ridged, with raised eyebrows; flesh white; sprouts pink.

Foliage.—Haulm upright, rather robust and tall for an early; leaf dark, glossy, drooping; leaflets long and narrow, the last pair having waved margins, and pointing forward to overlap the terminal which droops. The stem develops a pink colour.

Flower.—White, not blooming freely; buds dark, with green tips.

Remarks.—Cropping: excellent; stocks very free from Mosaic and Leaf Roll; keeping quality: good; bolters occur; this variety is more resistant to frost than any other early.

Maturity.—Early Maincrop.

Tuber.—Oval, flat; skin white; eyes shallow, on point; flesh white; sprouts faint pink.

Foliage.—Haulm erect, with drooping tops; leaf open; leaflets narrow, pointed, dark green with a thick, waxy appearance.

Flower.—Light red-purple, very seldom formed; flower buds pink.

Remarks.—Cropping: moderate; resistant to Blight; cooking quality: waxy; keeping quality: very good.

FIELD-MARSHAL—Stratton. Non-Immune.

For description see Up-to-Date.

GOLDEN WONDER—Brown. Immune.

For description see Langworthy.

GREAT SCOT—Mair. Immune.

Maturity.—Early Maincrop.

Tuber.—Round (somewhat flat), heel generally dented; skin pale yellow, but during growing season white at the eyes; eyes shallow to medium, saucer-shaped, and on shoulder of tuber; flesh white; sprouts deep pink.

Foliage.—Haulm tall, upright; leaves fairly open, glossy and dark; leaflets thin, the end leaflet drooping to the perpendicular; stem deep pink at the base, and not branching freely above ground.

Flower.—White, but frequently dropping off unopened, except in bolters, which generally flower; anthers pale; buds dark.

Remarks.—Cropping: excellent; susceptible to Blight; stocks very free from Leaf Roll and Mosaic; cooking quality: good; keeping quality: very good; bolters occur.

IMMUNE ASHLEAF.

This variety is identical with the German variety Juli (Paulsen).

Maturity.—First Early.

Tuber.—Kidney (pear-shaped); skin white, eyes on point of tuber, shallow, those on sides often with raised eyebrows; flesh yellow; sprouts blue; scale leaves sometimes blue.

Foliage.—Haulm of medium height, spreading; stems only slightly tinged purple at maturity; wings not well marked; leaf open, markedly long and spreading; leaflets light to medium green, long, thin and pointed; terminal leaflet sometimes joined to a lateral leaflet or leaflets, especially in older leaves; secondary leaflets project upwards.

Flower.—Light blue-purple; buds dark.

Remarks.—Cropping: good; susceptible to Blight; stocks frequently affected with Mosaic.
IRISH QUEEN—Strain. Immune.

**Maturity.**—Late Maincrop.

**Tuber.**—Round; skin pale yellow, splashed pink, sometimes whole pink; eyes deep; flesh white; sprouts pink.

**Foliage.**—Tall and branching; stem mottled red-purple; wings waved; leaf close; midrib with only a spot of pink at base and bases of leaflet stalks; leaflet medium green, large, and glossy, slightly wrinkled and arched; terminal leaflet droops.

**Flower.**—Red-purple distinctly tipped white, rather infrequent; anthers malformed; buds dark with green bases; flower stalks rather short.

**Remarks.**—Cropping: good; somewhat resistant to Blight; keeping quality: very good.

KATIE GLOVER—A. Findlay. Immune.

**Maturity.**—Second Early.

**Tuber.**—Oval, thick; skin pale yellow, coloured red in the eyes and about the eyes, colour very occasionally absent; eyes shallow, but deep in large tubers; eyebrows distinct; flesh white; sprouts pink.

**Foliage.**—Haulm low to medium height, spreading and bushy, with a regular circular compact appearance; stems branching and numerous, with finely waved wings, developing pink colour towards maturity; leaf moderately open; leaflets light to medium green, thin, soft, with waved margins; veins well marked.

**Flower.**—Not observed; flower buds hairy and pink, but often yellow before dropping off, very numerous, in a cluster, the cluster of buds not occurring on every plant; stalk long, leafy, and pink tinged.

**Remarks.**—Cropping: moderate; very susceptible to Blight; stocks frequently affected with Leaf Roll.

KERR'S PINK—Henry. Immune.

**Maturity.**—Late Maincrop.

**Tuber.**—Round (somewhat flat); skin pink; dented at heel end; eyes usually medium, but sometimes deep; flesh white; sprouts pink.

**Foliage.**—Haulm tall, upright and branching, especially at tops; very vigorous; stem strong, tinged pink; wings distinctly waved; leaf rigid and fairly close; midrib pink; leaflets dull, medium to dark green, large, broad and pointed; secondary leaflets large and often borne on leaflet stalks.

**Flower.**—White and freely formed; anthers pale yellow; buds dark.

**Remarks.**—Cropping: excellent; fairly resistant to Blight; cooking quality: floury, very good; keeping quality: excellent.

Maturity.—Early Maincrop.

Tuber.—Kidney (oval to pear-shaped); skin white, more or less splashed with pink; characteristically smooth on surface; eyes shallow; flesh white; sprouts pink.

Foliage.—Haulm erect, tall, branching, tops crowded; stems with a pink tinge; leaves dark green and glossy; leaflets with waved margins, the younger leaflets on top being very small, narrow, numerous, and twisted forward, the last pair fitting round the terminal.

Flower.—Red-purple, but very seldom formed; buds pink; flower stalks short.

Remarks.—Cropping: good; very susceptible to Blight; cooking quality: good; keeping quality: good; bolters and wildings are of common occurrence.

Red King Edward, Red Kings and Rob Roy are selections from King Edward VII, having tubers almost wholly pink.

KING GEORGE V—Butler. Immune.

Maturity.—Second Early.

Tuber.—Oval to oval, pointed; skin white, occasionally with a touch of pink at the heel and at the rose end; eyes medium, on point of tuber, those on side of tuber with raised eyebrows; flesh white; sprouts pink.

Foliage.—Haulm of medium height, with a drooping appearance; spreading; stems branching, tinged red-purple; stem tops with slightly waved wings; leaf open and drooping; leaflet medium green, soft and dull.

Flower.—White, with anthers sometimes malformed and pale, occurring fairly freely; flower stalks long and bronze coloured; buds dark.

Remarks.—Cropping: very good; susceptible to Blight; stocks frequently affected with Leaf Roll; cooking quality: poor; keeping quality: good.

LANGWORTHY—Niven. Immune.

Maturity.—Late Maincrop.

Tuber.—Kidney (pear-shaped); skin white; eyes shallow, saucer-shaped, with raised eyebrows; flesh white to lemon colour; sprouts blue; scale leaves sometimes blue.

Foliage.—Tall, vigorous, very upright, consisting of a few stout stems, tinged blue-purple near the base; leaflets medium green and markedly wrinkled.

Flower.—Purple, distinctly white tipped and freely formed; bases of the flower buds green.
Remarks.—Cropping: moderate; tuber not often affected with Blight; all stocks affected with Mosaic; cooking quality: excellent; keeping quality: very good; wildings occur.

Golden Wonder (Brown) resembles Langworthy except that the tuber has a russet skin. Langworthy is the old "Maincrop" (Clark). "What's Wanted" is identical with Langworthy.


Maturity.—Late Maincrop.

Tuber.—Round, sometimes with pink dots under the skin; skin white, very delicately pink when immature, with more pink in the eyes and the heel; eyes medium deep, saucer-shaped; flesh white; sprouts pink.

Foliage.—Haulm of medium height to tall and compact; stem branching freely above ground. Leaf rigid, with a distinct crowded appearance; leaflets small, rounded, and dull, with a delicate shade of green, tending to be cupped, exposing the margin of the underside; secondary leaflets numerous and raised above the level of the larger leaflets.

Flower.—White, generally not freely formed; buds green.

Remarks.—Cropping: very good; fairly resistant to Blight; cooking quality: waxy; keeping quality: very good.

MAJESTIC—A. Findlay. Immune.

Maturity.—Early Maincrop.

Tuber.—Kidney (pear-shaped to long oval); skin white; eyes shallow; flesh white; sprouts faint pink; second growth takes the form of cracking.

Foliage.—Haulm of medium height, spreading; less rigid than that of British Queen; leaf and leaflets flat, open and smooth, ashy-green; midribs of young leaves with a pink tinge; leaflets pointed.

Flower.—Creamy-white, profuse; berries occur freely; buds pink.

Remarks.—Cropping: excellent, high percentage of ware; susceptible to Blight; cooking quality: good; keeping quality: good; requires care when cut for seed.

MAY QUEEN—Sadler. Non-Immune.

Maturity.—First Early.

Tuber.—Kidney; skin white; eyes shallow; flesh white and soft; sprouts blue; scale leaves sometimes faint blue.

Foliage.—Haulm of low to medium height, spreading, vigorous; stem slightly tinged purple, with waved wings; leaflet large, dark to medium green, glossy, cupped, with waved margins, the last pair of leaflets fitting round the terminal.

Flower.—Light blue-purple, with large tips of white; occurring frequently; flower parts irregular; flower stalks long; buds purple.

Remarks.—Cropping: very good; susceptible to Blight; stocks frequently affected with Mosaic.
NINETYFOLD—Clark. Non-Immune.

Maturity.—First Early.

Tuber.—Oval, pointed; skin white; eyes on point shallow, eyes on side often with raised eyebrows; flesh white and soft; sprouts pink.

Foliage.—Haulm of low to medium height, spreading; stem slightly tinged pink towards maturity; leaflet medium green; last pair overlap the terminal.

Yellow Aucuba spotting in leaves very common.

Flower.—White (rarely formed), anthers generally pale yellow and malformed; sepals long, with green tips.

Remarks.—Cropping: very good; very susceptible to Blight; stocks frequently affected with Leaf Roll; cooking quality: waxy; keeping quality: not very good.

NORTHERN STAR—A. Findlay. Non-Immune.

Maturity.—Late Maincrop.

Tuber.—Round; skin white, with a small spot of pink in the eyes and the heel, especially during the growing season; eyes medium; flesh white; sprouts pink; second growth runners common.

Foliage.—Haulm tall, upright and compact; stems branching freely; wings slightly waved; stems slightly tinged pink towards maturity; leaf fairly open and rigid, midrib tinged red-purple in younger leaves; leaflets small, pointed, with a dark grey-green appearance.

Flower.—Small, white, with green tips, seldom formed; anthers pale yellow and malformed; flower buds markedly green.

Remarks.—Cropping: good; fairly resistant to Blight; stocks frequently affected with Mosaic; keeping quality: good.

Allies (not Ally), Aeroplanes and Ajax are identical with Northern Star.

PRESIDENT. Non-Immune.

Maturity.—Late Maincrop.

Tuber.—Round (flat); skin white; eyes medium; saucer-shaped; flesh white; sprouts pink.

Foliage.—Habit tall, upright, vigorous; stems branching, slightly tinged pink, wings waved; leaf markedly open and rigid, characteristically composed of five large and two small leaflets; leaflets large, broad, dull light to medium green, slightly wrinkled.

Flower.—Red-purple, distinctly tipped white; freely formed and with a long period of bloom usually continuing well into October; flower stalks long, buds dark; berries freely occurring.

Remarks.—Cropping: good; resistant to Blight; stocks frequently affected with Leaf Roll; keeping quality: good.

General is identical with President, except that the colour of the flower is white.
PURITAN—Non-Immune.

Puritan is identical with the old American variety White Beauty of Hebron.

Maturity.—First Early.

Tuber.—Oval, pointed; skin white; eyes medium, eyebrows long and raised; flesh snow-white and soft; sprouts faint pink.

Foliage.—Haulm of medium height, spreading; stem slightly tinged pink towards maturity; leaf semi-rigid; leaflet medium green and glossy; secondary leaflets very small. The last pair of leaflets overlap the terminal.

Flower.—White, fairly frequent; anthers orange; buds green or dark, with green tips; sepals long.

Remarks.—Cropping: good; very susceptible to Blight; cooking quality: floury.

RHODERICK DHU—S. T. Parish. Immune.

Maturity.—Late Maincrop.

Tuber.—Round (somewhat flat); dented at heel; eyes medium, on the shoulder, close together; skin white; flesh white; sprouts pink.

Foliage.—Haulm very tall, stout, upright, branching, and very vigorous; wings slightly waved; leaves large, close and rigid; leaflets dull medium green and hairy; leaf very crowded, with large secondary leaflets, the pair of secondary leaflets at the base of the last pair of leaflets being very conspicuous.

Flower.—Fairly small, white with green tips, occurring fairly freely; anthers generally pale green and malformed; buds pink.

Remarks.—Cropping: good; fairly resistant to Blight; susceptible to Blackleg; cooking quality: good; keeping quality: very good.

ROYAL KIDNEY—A. Findlay. Queen Mary. Non-Immune.

Maturity.—Second Early.

Tuber.—Kidney (long oval); skin white; eyes shallow, on the point; flesh white; sprouts pink.

Foliage.—Haulm of medium height to tall, upright; midribs of leaves at young stage with a tinge of pink at the base and bases of leaflet stalks; leaflet medium to dark green; top foliage dull and drooping; secondary leaflets not numerous, projecting upwards.

Flower.—Absent, stalks short; buds green at base, dropping readily.

Remarks.—Cropping: moderate; susceptible to Blight.

SHARPE’S EXPRESS—Non-Immune.

Maturity.—First Early.

Tuber.—Kidney (pear-shaped); skin white; eyes on the point small and saucer-shaped, those on the sides having raised eyebrows; flesh white; sprouts pink.
Foliage.—Haulm upright to spreading; leaves long, medium green and bright, with a large number of bright secondary leaflets which give the leaf a crowded appearance; leaflets distinctly pointed forward and overlapping. The last pair of leaflets often twist round the end leaflet, which curls up to fit into them.

Flower.—Red-purple, infrequent; buds with pink markings.

Remarks.—Cropping: good; somewhat resistant to Blight for an early; stocks fairly free from Leaf Roll and Mosaic; keeping quality: good; bolters occur.

SUTTON’S ABUNDANCE—Clark. Immune.

Maturity.—Early Maincrop.

Tuber.—Oval to round, flat; eyes shallow, open and usually on the shoulder; eyebrows long and distinct; flesh white. During the growing season the heel end usually shows a blue-purple coloration. The runners have usually at least a trace of blue-purple, and the second growth runners have always a blue-purple tint; sprouts blue.

Foliage.—Haulm tall, strong, and upright; stem branching and becoming blue-purple tinted; leaf close; leaflets dark green, glossy and overlapping; the secondary leaflets numerous, round and well developed, giving the leaf its close appearance.

Flower.—White and numerous; berries occur occasionally; the buds are dark and the style is long.

Remarks.—Cropping: very good; susceptible to Blight; cooking quality: floury, good; keeping quality: good.

N.B.—There are numerous so-called varieties of the Abundance type. Some of the commoner are Jeannie Deans, Kerr's New White, Culdees Castle, Crofter, Crowner, Provost, Osborne Seedling, Dobbie’s Favourite, Twentieth Century, Secundus, Laing’s Prolific, Admiral, Bloomfield, Balmuir, White Rose, Plotholder, Darlington, Lomond and Just in Time.

TINWALD PERFECTION—W. E. Farish. Immune.

Maturity.—Early Maincrop.

Tuber.—Oval; skin white; eyes shallow; sprouts faint pink.

Foliage.—Haulm spreading; more compact than that of Up-to-Date, which it resembles; leaves drooping; leaflets round, glossy, arched, and slightly wrinkled.

Flower.—Red-purple, generally tipped white, fading very quickly, blooming only moderately freely and for a short period; branches of the flower stalk short and thin; buds pink.

Remarks.—Cropping: fair, large proportion of small tubers; fairly resistant to Blight; stocks affected with Mosaic; keeping quality: good.

Maturity.—Late Maincrop.

Tuber.—Oval; skin white; eyes shallow and on the point of the tuber; flesh white; sprouts faint pink.

Foliage.—Haulm spreading, of medium height to tall; stems branching, tinged pink towards maturity; leaf long, spreading, lower leaves conspicuous, midrib of younger leaves pink tinged at its base and at the bases of the leaflet stalks; leaflet light to medium green, large and dull, end pair markedly overlap the terminal.

Flower.—Light red-purple, gradually lightening in shade towards the tip, but not distinctly white tipped; blooms freely and for a long period; flower stalks fairly long and thick; buds dark.

Remarks.—Cropping: excellent; susceptible to Blight; stocks frequently affected with Leaf Roll; cooking quality: good; keeping quality: good; wildings occur frequently.

There are many so-called varieties of the Up-to-Date type. Some of these are: Dalhousie, Drumwhindle, Dalmeny Beauty, Dobbie's Prolific, Factor, Glamis Beauty and Scottish Triumph.

Note.—Field-Marshal is identical with Up-to-Date, except that the tubers have a russet skin.


Maturity.—First Early.

Tuber.—Kidney (long oval), flat; skin white and smooth; eyes very shallow and on the point; flesh white; sprouts faint pink.

Foliage.—Haulm of low to medium height, spreading and compact; leaflets slightly arched over the midrib of the leaf; leaflets long, medium green, having a characteristic glossy, thin, and slightly wrinkled appearance. Towards maturity the margins of leaflets tend to curl upwards. Second growth is common, giving the haulm a taller appearance.

Flower.—Creamy-white and seldom formed; buds dark with green tips; sepals long.

Remarks.—Cropping: good; very susceptible to Blight; cooking quality: floury, good; bolters occur frequently.
GLOSSARY

Adventitious Roots.—These are found on stems or leaves and are not part of a tap-root system.
Asexual Reproduction.—The formation of an individual without the aid of sex cells.
Callus.—The mass of tissue formed on a wound surface.
Calyx.—Forms outer whorl of the flower; its parts are called sepals.
Cambium.—A layer of cells which provides for increase of thickness of stems and roots.
Chimera.—Produced by the association of tissues from each of two plants after grafting.
Chlorophyll.—The green colouring matter of plants.
Chromosome.—A definite structure composed of chromatin and found only in the nuclei of cells. During cell division the chromatin passes through certain changes which result in the formation of chromosomes.
Conidia.—Asexual reproductive bodies of fungi, produced on special branches of the mycelium filaments.
Cordate.—Heart-shaped.
Corolla.—Forms the whorl next the calyx of the flower; its parts are called petals.
Cross-fertilisation.—The union of male and female reproductive cells produced by different individuals.
Dominant.—In hybridisation, the parental character which persists and shows itself in the first generation. (See Recessive.)
Factor.—The specific substance or substances in the reproductive cell which give rise to a particular unit-character in the organism.
Fertilisation.—The union of male and female reproductive cells.
Gamete.—A male or female reproductive cell.
Heterozygous.—Impure. Individuals are heterozygous in which any given genetic factor has been derived from only one of the uniting gametes. Half of the reproductive cells from such individuals will possess the factor, the other half will lack it.
Homozygous.—Pure. Individuals are homozygous in respect of any character if formed by the union of two gametes similar in that character. Homozygotes produce gametes of only one kind, hence remain true with self-pollination.
Inbreeding.—The mating of closely-related individuals for several generations.

Meristematic Tissue.—Tissues consisting of cells possessing the power of dividing.

Mycelium.—A collection of filaments constituting the vegetative part of a fungus.

Parthenogenesis.—The development of an individual from an unfertilised egg-cell.

Pedicel.—The stalk on which an individual flower is borne.

Peduncle.—The main axis of an inflorescence together with the secondary axes, apart from the pedicels of the flower.

Periclinal Chimæra.—A chimæra in which one of the differing tissues completely encloses the other.

Periderm.—Cork tissue.

Phellogen.—The dividing layer of cells which gives rise to cork tissue.

Pistil.—Forms the inmost whorl of the flower; its parts are called ovary, style and stigma.

Pubescent.—Hairy.

Recessive.—In hybridisation, one of two contrasted characters which remains latent in the first generation. (See Dominant.)

Saprophytic.—Living on decaying organic substances.

Scion.—The shoot grafted on a stock.

Segregation.—The separation of genetic factors at the time of the formation of gametes.

Self-fertilisation.—The union of the sex cells of one individual.

Somatic Segregation.—Segregation during somatic division, i.e., not sexual.

Stamens.—Form the whorl within the corolla of the flower; their parts are called anthers and filaments.

Stock.—The plant on which a graft is made.

Suberin.—A waxy or fatty substance found in cork cells, rendering them impermeable to water.

Superfibration.—The formation of aerial tubers on the stem.

Tap-Root.—The elongated primary root, developing from the radicle of the embryo.

Vascular Tissue.—Tissue which serves for the rapid transference of food in plants, e.g. wood and bast.

Vegetative Propagation.—See Asexual Reproduction.

Vegetative Segregation.—See Somatic Segregation.

Zoospores.—Asexual reproductive bodies of fungi which move by means of hair-like vibrating organs.

Zygote.—The organism produced by the fusion of a male and a female gamete.
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