A T H E S I S.

Studies on

"The Anatomy and Physiology of the Swede Turnip",

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by

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FORE-WORD.

This paper sets on record work carried out by me in the Department of Botany in the University of Glasgow, during the Sessions 1925-26-27, during which time I held the Donaldson Research Scholarship in Biology. The work was to some extent continued in the University of Cambridge to which I went as Carnegie Research Fellow in October, 1927. The data on the Seasonal variations in the Carbohydrate Content have been somewhat amplified and were published as a paper in the "Scottish Journal of Agriculture" in July, 1927. This paper was entitled "The Seasonal Variations in the Carbohydrate Content of Swedes" and stressed rather the practical aspects of the problem - especially with reference to date of ripening and the feeding value. The subject of the localised translocation of Reserve materials which is but lightly touched on in the following pages has been very much extended. Part of the additional work done was carried out with Swedes and the results were incorporated in a paper communicated to the Royal Society of Edinburgh last year. It is hoped that this paper will shortly be in print.

C O N T E N T S.

SECTION 1

INTRODUCTION : NOMENCLATURE.

The systematic position and the original wild condition of the Swede are not well understood. On the other hand there exists on both subjects the greatest possible confusion. Numerous authorities have expressed views sometimes similar, sometimes diametrically opposed, and, in all cases, probably on somewhat tenuous evidence. Unger (U.S. Pat. Off. Rept. 327. 1859) says that the Swede is derived from a species growing wild at the present time in Russia and Siberia and on the Scandinavian Peninsula. From this species it is supposed that there have arisen two distinct races (a) Brassica campestris L. (The Cabbage, Rape and Swede) and (b) B.rapa. (The Common White Turnip). It is not quite clear that this distinction exists so definitely as this writer would suggest. Darwin ("Plants and Animals under Domestication" p. 345) writes "The other cultivated forms of the genus Brassica are descended according to the view adopted by Godron and Metzger (Godron "De l'Espece" tom. 2. p.54, Metzger "Kohlarten" p.10) from two species B.Napus and B.Rapa; but according to other Botanists from three species; while others again strongly suspect that all these forms, both wild and cultivated, ought to be ranked as a single species .... B.Napus has given rise to two large groups namely Swedish Turnips (believed to be of hybrid origin) and Colzas, the seed of which yields oil."

De Candolle, who studied the wild types of cultivated plants at some length especially as regards the systematic position of the cultivated forms seems to have held slightly different opinions at different times regarding the origin and position of the Swede. In his book "Geographie botanique" p.826 there appears this passage "Les auteurs les plus recents s'accordent assez à reunir les B.Rapas et campestris. Quelques-uns doutent qu'un puisse distinguer le B.Napus par les caractères positifs. Quoi qu'il en soit, deux choses seulement nous intèressent et n'offerent pas l'incertitude. (1) l'ancienneté de la culture des raves, naves et de la plupart de leurs modifications (2) le fait qu'on en retrouve les types a l'état sauvage .... L'agriculture des Celtes et des Germains reposait en partie sur ces racines usitées comme lègume ou nourriture des bestiaux (Regnier "Econ. Celt." p.438) Les Grecs et les Romains les cultivaient aussi quoique d'une manière moins generale à cause de la temperature plus elevées des pays qu'ils habitaient (Billert "Flora class." p.170, Fraas "Syn. Flora class" p.122) Le grand nombre de figures et de synonymes à l'epoque de la renaissance montre combien il existait de races de navets en Europe, a la fin du moyen age (D.C. "Syst." 2. p.590) .... La patrie originaire a été regardée comme douteuse (D.C. ibid) probablement à cause de la facilité avec laquelle ces plantes si communes se repandent hors les cultures. Depuis quelques années une exploration plus exacte des pays septentrionaux et orientiaux de l'Europe ne laisse pas de doute. De Ledeboin (Flore.Russ.1. p.217) n'hesite pas à indiquer le B.Rapa (auquel il reunit le B. campestris) spontane dans toute l'entendue de la Russie et de la Siberie et le B.napus dans la Russie temperée, l'Armenie et peut être la Siberia. M. Fries (Summ. Veg. Scand. p.29) admet ces deux éspèces dans la peninsule scandinave comme plantes spontanées la primiere partout, la seconde dans le midi. L'habitation s'etendant de la baltique au Caucase il n'est surprenant que les peuples de centre et du sud-est de l'Europe aient essayé la culture des ces éspèces depuis une epoque reculée peut-être sans communications les uns avec les autres ...."

De Candolle describes the species B. campestris in the same book as follows ;- "Brassica campestris L. (B. campestris et Rapa DC. et B. Napus L.). En traitant plus loin de l'origin des éspèces cultivées je prouverai que la patrie primitive doit avoir été la region entre la Baltique et le Caucase. Je doute qu'elle s'étendit en Ecosse et en Angleterre; mais les methodes ordinaires ne prouvent rien dans le cas actuel à cause de la culture excessivement ancienne. Ainsi, des noms gallois ou irlandais tout a fait celtes ne prouveraient pas l'indigenât. A present l'éspèce est à peine sauvage (Watson Cyb. 1.p.158) et si elle parait l'être on peut soupçonner une series provenant de peids cultives".

Buchman states that in his view both B. Napus and B. campestris are varieties of B. oleracea which may have arisen as a result of cultivation and selection (Treas. Bot.1. 1870)

He asserts in substantiation of his hypothesis that these two varieties are only to be found as a result of cultivation and if they appear to be wild it is as a result of escape from cultivated ground (cf.De Candolle above). Lindley contends that B.campestris has been found apparently wild in Lapland. This point is of special interest with regard to the Italian name of the Swede - Navone di Laponie. It was also found in Spain, the Crimea and Great Britain. In Belgium the turnip in some forms is called the Colsa as it is in Eastern France, Germany and in Switzerland whereas in other countries the name Colza is applied to the Rape (B.Napus). Unger (l.c.) says that the Belgian Colsa is a plant growing wild from the Baltic to the Caucasus and is B.campestris oleifera DC. or B. colsa Lam. De Candolle (Trans.Hort. Soc.Lond.1824) supposes that the Swede is a variety of this species which has developed a root-system rather than an aerial storage system. He gives as an analogous case the Cabbage and the Kohlrabi.

In its original wild condition, according to Sturtevant (Notes on Edible Plants.ed.Hedrick) the Swede is a flattish globular root with a very fine tail and a narrow neck and hard deep yellow flesh. Unfortunately he gives no indication as to where he saw Swedes "in the original wild condition". Apart from anything else this information is rather beside the point unless it is clearly substantiated since there is some evidence (see Sinclair below) that the white-fleshed Swede - a very different type was originally the more commonly grown one.

Buchman (l.c.) by seeding Rape and Common Turnips in mixed rows alleged that he had obtained, presumably by hybridisation, a small percentage of malformed Swedes which were greatly improved by cultivation and subsequent selection. If B. Napus be, as Bentham and others have suggested, a type of B. campestris - then Buchman's experiment may be taken as furnishing corroborative evidence. On the other hand, it is rather improbable that Buchman's idea would receive much support from present-day plant breeders who, in many cases at least, would be inclined to question the validity of the experimental evidence. Don (Hist.Dichl.Pls.1831) classifies the Swede as B.campestris L.var.oleifera sub-var.rutabaga.

As to the antiquity of the culture of the Turnip - especially the Common Turnip there can be little doubt. Columella (Liber.42) tells of the cultivation of both Napus and Rapa as he calls them. They were both grown in Europe especially in Gaul and were used for food for men and for animals. The Napus did not have a swollen root but the Rapa did. Pliny (De.Rer. Nat.) was not so careful to distinguish between the two species and he uses Napus to denote a large number of types. These he describes in the vaguest possible manner. He describes five distinct types :- the Corinthian, that of Cleonaeum, of Liothasium, of Boeticum and the Green. The Corinthian had a large, hard root and grew on the surface of the ground, that is, the root was apparently not buried (?the Kohlrabi). The Napus of Liothasium was very hard. That of Boeticum was sweet, round and not so long as that of Cleonaeum. Under Rapa he describes the broad-bottomed type, the globular and the Nursian. He also speaks of the Nursian Napus being esteemed and also the Napus of Armiternum. This latter he says is of a nature similar to the Rapa. There can be little doubt that in this connection, as in so many others, Pliny confused various types of plants and described, under the same name,plants which were essentially distinct.

Some interesting light is thrown on the antiquity, and popularity in early times, of the turnip by the references which occur in various places regarding the size to which Turnips grew. Pliny (l.c) records a case of a Rapa which was over one hundred pounds weight. Matthiolus (Comment.1558) had heard of Turnips weighing one hundred pounds and had seen those which weighed thirty pounds.

In the Fifteenth Century Turnips were grown as one of the principal field-crops of the Flemings (Booth "Treas.Bot." 1870) Booth holds that the Turnip was introduced into England about 1550. This is not in agreement with a statement cited later in this paper. McIntosh ("Book Gard.1855) tells that in the time of Henry the Eigth Turnips were eaten roasted or the young leaves were used as a salad.The first reference to the Turnip as a field-crop in England is apparently about 1645. Probably it was taken to England rather before this time. Cartier sowed Turnip seed in Canada after his third voyage in 1540 (Pinkerton "Coll.Voy."1812). From this time they are mentioned as being grown in America to a greater or less extent.

In Miller's "Gardener's Dictionary" 1759 there are some interesting notes on the subject of Turnips. "Turneips (that is green-toped) are sown in great plenty in the fields near London not only for the use of the Kitchen but for food for cattle in Winter when there is a scarcity of other Foods: and this way is becoming a great improvement to barren sandy lands especially in Norfolk, where by the Culture of Turneips many persons have doubled the yearly value of their Ground . . . It is not many years since the practice of sowing Turneps for the Feeding of Cattle has been of general Use; how it happened that this improvement should have been neglected in every part of Europe is not easy to determine, since it is very plain that this piece of Husbandry was known to the Ancients . . . And yet this plant was not much cultivated in the fields till of late years nor is the method of cultivating Turneps yet known or at least not practised in some of the distant countries of England at this time".

The Swede Turnip proper, on the other hand, is much less extensively mentioned in literature. Whether this is due to the fact that the Swede was described in such a way as to confuse it with another type, so far as one's interpretation of the description goes, or whether the confusion existed in the minds of the authors, or whether no such plant existed, it is very difficult to say at the present day. As a matter of fact Sinclair, whose papers are referred to and quoted below, definitely suggests by implication that the Swede was a mutant which became known about the middle of the eighteenth Century. He speaks of the tendency of the Swede to degenerate by accidental cross-fertilisation if not carefully grown. The cross-fertility of the Swede, he says, is increased by the fact that it is probably an accidental variety. Of what it was a mutant, however, is a point on which there is no definite information. The fact that the probable ancestor is unknown in no way lessens the possibility of the Swede's having arisen by mutation. Many of the plants commonly cultivated are known to be mutants, though often the ancestral type is doubtful.

The French names for the Swede - Navet de Suede - Chou de Suede - suggest an origin in Sweden while the name Chou Navet jaune certainly refers to the distinctive flesh colour. An American writer in 1835 refers to the plant as Rutabaga, Swedish Turnip or Lapland Turnip.

Apart from the name there is some confusion regarding the classification of the two types of Swedes. The yellow-fleshed and white-fleshed types were usually called Swedes without much distinction being made between them. In point of fact, however, the white-fleshed type is rarely grown at the present time so the distinction is not of much consequence. The French distinguish between the two types Chou navet the white-fleshed, Rutabaga the yellow-fleshed. Sturtevant (l.c.) asserts that the Chou navet-the White fleshed Swede is B. napo-brassica communis DC. and that Rutabaga, the yellow, is B. napo-brassica

Rutabaga DC. In England the White-fleshed was originally called the Turnip-rooted Cabbage and this distinction was made also in America. McMahon (Amer.Gard.Cal.1806) describes the two types under the distinctive names.

It is not desirable to attach too much importance to names but in the case in point the differences in the nomenclature may have considerable significance. If one were to suppose a mutational or Hybrid origin for the Swede it would probably be as well to keep before one's mind the fact that different common names were originally given to the two types viz. The Swedish Turnip and The Turnip-Rooted Cabbage.

The White-fleshed form is described by Bauhin (Prodromus) in 1620 and again in 1623 (Pinax). Ray (Hist.Plant.1686) refers to Bauhin's description and makes no mention of the plant in England although he says it is eaten in Bohemia. Morrison (Hort.Reg.Bles.1669) mentions it as being grown "at the royal Gardens". Vilmorin (Plant.pot. 1883) describes the plant under the names Chou navet and Chou de Lapland. Don (l.c.) mentions the plant as being commonly grown in France but not in England. Sinclair speaks of it as being grown in Scotland at the end of the eighteenth Century (see below).

In the light of the fact, as revealed by the excerpts from literature quoted above, that there is much doubt as to the place of origin and of the systematic position of the Swede no attempt is being made in this paper to express a definite opinion on the matter. To throw as much light on the subject as is possible under the circumstances and to present the facts as fully as possible two lists are here appended. The first is a list of the common names, together with the authority on which they are given (as nearly as possible the original reference is given though this in some cases is somewhat problematical). The second list contains most of the specific names which have been suggested at various times for the Swede together with the authority for each.

COMMON NAMES.

Swedish Turnip	Sinclair (Agric.Scot.)
Rutabaga or Rootabaga	McMahon (l.c.) Miller's Dict.1807 etc.
Navet jaune Navet de Suede Chou de Laponie Chou de Suede	De Candolle (l.c.) 1821.
Chou navet de Suede	Noisette 1829.
Rutabaga	Pirolle 1824.
Rutabaga Russian Turnip	Thorburn 1821.
Navone di Laponie	Don 1831.

An article in an American paper of 1835 describes the plant as Rutabaga, Lapland Turnip and Swedish Turnip. (Sturtevant l.c.)

BOTANICAL NAMES.

From Loudon's "Encyclopaedia of Plants"

B.Campestris L. Field Cabbage.

v. Rutabaga Swedish Turnip.

From Sowerby's "English Bot."

B.campestris	v.oleifera	Colza.
	v.pabularia	
	v.Napo-Brassica	Swedish Turnip (Turnip Rooted Cabbage)

From De Candolle's "Geog.Botan."

B.Campestris = B.campestris et Rapa DC. and B.Napus L.

From Darwin's "Animals and Plants under Domestication."

B.Napus has given rise to Swedish Turnips (believed to be of hybrid origin) and the Colzas."

From "Gentes Herbarum" sect. "The Cultivated Brassicas" by L. H. Bailey.

B.oleracaea	v.Napobrassica L.
B.Napus	v.Napobrassica
B.campestris	v.napo-brassicata.

SECTION 2.

HISTORY OF CULTIVATION.

The cultivation of the Common Turnip as a field crop in Britain is not of very long standing. It appears to have been grown in England as a garden crop from a very early period and Turnips (A.S.Naepas cf. "neeps") are spoken of as well known before the Conquest. It was first cultivated as a field crop in the South-eastern counties of England towards the end of the eighteenth Century by Sir Richard Weston who learned the practice in Holland where he resided as Ambassador of Charles I. It was, however, Lord Charles Townshend of Rainham in Norfolk who about thirty years later first brought into prominence the growing of Turnips as field crops. In spite of his influence, however, their field culture made little progress till the introduction of the system of drill husbandry by Jehro Tull in 1731. By the same time the second Earl of Stair - a noted agriculturist, is said to have grown Turnips in the fields in Scotland. Craig of Arbigland in Dumfriesshire drilled Turnips in his fields in 1745 and in 1764 Dawson, another very progressive farmer, grew one hundred acres drilled in ridges on his farm of Harparton near Kelso (from "Stand.Enclc.Agric."). As is set out below there is some evidence for believing that the Common Turnip was introduced into Scotland about 1740. One might fairly say, therefore, that the Common Turnip, was introduced into Scotland about 1740 and that the Swede followed some forty years later. If this be so, then it is clear that the feeding value and the suitability of this crop must have been immediately realised. Writing just thirty years after the date of the introduction of the Swede Aiton states that the "Rutabaga or Swede Turnips are raised to a great extent in the County of Ayr. The soil best adapted, the preparation, hoeing and weeding are the same as for other Turnips except that the seed should be sown about the first week of June. The yellow-fleshed type is preferred. The White-fleshed have too much shaw and too little nip (cf. the common Scottish word "neep"). They are sometimes sown in the garden and are transplanted to the field after they are out of danger of the fly. This species are not so injured by the fly as are the Common Turnips. They are equally valuable and productive with them; are not so easily hurt by frost and can be preserved much later in the Spring to serve as a green food for cattle after the other kinds are eaten up" (Aiton "Agric.of Ayr, 1811). In the account of the State of Agriculture in Scotland published in 1814 the value of the Swede is stressed even more definitely. "It is an article of farm produce of great importance as it supplies succulent green food of the very best quality which is highly relished by every kind of stock. It is therefore of extraordinary importance to all farmers carrying on the alternate husbandry as it enables them with certainty to unite the summer and winter seasons of feeding - a circumstance which has long remained a desideratum in husbandry".(Sinclair "Agric.in Scot.Vol.I.1814). Sinclair also considered the yellow-fleshed "species or variety of Rutabaga is alone worth cultivation". When Swedes were first introduced into Scotland there was apparently some confusion as to the types of Swedes and many farmers grew the white-fleshed type and were, on account of the fibrous nature of the bulbs, prejudiced against the crop as a whole. Sinclair advocated that the seed should be sown in the second week of May or by the fourth week at the latest. This author also mentions that when the seed had been scarce and dear it had been the custom to plant the seeds in seed-beds and to transplant them thereafter. As seed became plentiful the necessity for this practice was removed and since it tended to delay the development of the plants and entailed a great deal of work it was abandoned. A point which is much stressed is the fact that, bulk for bulk, Swedes are heavier than Turnips. Sinclair says that if a Rutabaga and a White Globe Turnip occupy the same space in water the Swede will be 20% to 25% heavier than the Turnip". So far as I can find Sinclair was the first authority to point out that great care must be taken to keep the seed-mother "at a distance from any other crufiform plants of the same natural order(!) as it is exceedingly apt to degenerate by the influence of their Pollen or fecundating dust to give worthless hybrid or mule varieties of various descriptions". He suggests that the Swede is the more liable to cross-fertilisation since it is itself "a hybrid or accidental variety". Another point he noticed was the the White-fleshed and the Yellow-fleshed Swedes (so-called) are quite different types, "the white-fleshed Rutabaga producing a bright golden yellow flower while that of the true orange-fleshed Rutabaga is of a paler lemon yellow".

As a matter of fact the flower of the white-fleshed is better described as being of a sulphur yellow colour while that of the orange-fleshed type is buff. There is no reasonable doubt that the descriptions in Sinclair are confusing merely because of the difficulty of standardising verbal descriptions of colour.

The same author points out the very interesting fact, viz;- that the Swede has a remarkable faculty of healing a wound in the bulb - a fact which is of some importance practically at the present time with regard to the selection of the most suitable bulbs as Seed-mothers.

It is of interest when considering the extraordinary rapidity with which Swedes established themselves as a crop in this country to notice that on the Continent and, especially in Sweden, where they are supposed to have originated they are not very extensively grown. Incidentally Swede Turnips are very much esteemed in Denmark - being considered more suitable for cattle feeding than Cereals. Vilmorin (Les Plantes potageres 1891) writes "Si en France les rutabagas sont moins en faveur qu'en Angleterre c'est surtout x une affaire de climat. Les étés chauds et secs sont extrèmement contraires à cette plante qui, par centre, supporte bien le froid et prospère surtout dans une atmosphere une peu humide. En Bretagne où les conditions climateriques sont à peu près celles de l'Angleterre le rutabaga est très cultivé et réussit parfaitement . En Angleterre où les rutabagas sont cultivé sur une tres grand eschelle et jouent presque dans las grande culture le même rôle que les betteraves fourraginères chez nous. C'est le Rutabaga à collet rouge

ou

ou violet qui est plus en faveur".

The time of the introduction of the Swede into Scotland is rather a vexed question. The problem is complicated by the fact that the systematic position and the origin of the Swede are, as has been seen, unknown or, at best, are matters which give rise to some little controversy.

Walker (Hebrides Vol. 1) appears to be alone in holding a theory which seems to have a good deal of circumstantial evidence to support it. He suggests that the Swede was first introduced from Germany into England about the middle of the 18th Century under the name of the Turnip-rooted Cabbage and that it was brought from England to Scotland in 1766. About this time, also, he alleges, seed was taken from England to Sweden and the plant was thereafter reintroduced from Sweden into Scotland under the name of the Swedish Turnip or as it was more commonly and more correctly called the Rutabaga ("the Swedish name").

The name Swede certainly suggests that the plant was first introduced from Sweden. Curiously enough this crop is not now grown to any extent in that country so that if it had its origin there the cultivation of the plant has since been abandoned. Even if the Swede as grown in this country were introduced from Sweden, this in no way accounts for the fact that in other countries the names given to the same or very similar plants makes no mention of Sweden. As has before been pointed out the plant in Italy is called the Lapland Turnip - Navone de Laponi, a name which suggests an origin similar to that suggested by the older French name Chou de Lapone. On the other hand another French name was Chou de Suède which brings one back to the conclusion that all that can be gathered from the names is that the plant was probably introduced from the North of Europe.

Sinclair (Husb.of Scot.Vol.1.) writing about the same time as Walker, or just shortly after, says "I am informed that Swedes were first introduced into Scotland anno 1781-82 on the recommendation of Mr. Knox a native of East Lothian who had settled at Gottenberg in Sweden whence he had some seed sent to Dr. Hamilton." Stephens states emphatically that the Swede was introduced from Sweden but that the date was previous to 1780. He adduces the evidence of a Forfarshire farmer Airth who told him that his father had had seed sent him from Sweden by a son who had settled at Gottenburg. Airth himself grew them in 1777 and they had been introduced just previously (Book of the Farm, Vol.1) The seed was sown in seed beds and the young plants were transplanted after they had grown to a fair size, a fact which had already been commented on.

It is extremely difficult to decide as to the ultimate source of the Swede - the more so since, as has already been noticed, the systematic position and relationship is so obscure. So far as the evidence goes there is no authority of any standing who is prepared to commit himself to a statement as to whether or not the Swede is a variety or a definite species. In the absence of any satisfactory evidence in either direction since little cytological or genetical work has been done on the

Swede heretofore - one is inclined to withhold judgment. This much may, however, be said. There are some characters of the Swede , especially the Flower-colour (the flower is of a buff colour peculiar to this plant) and the distinctive foliage mark it off from the other Brassicas more definitely than are many plants which are characterised as species.

THE TURNIP CROP.

The Turnip crop is grown in almost all the temperate parts of the world where prolonged droughts are not of regular occurence. Should drought be a regular feature of the climatic conditions Swedes are replaced by Mangolds or forage crops. The high water-content of the Swede and the Common Turnip make the growing of these crops uneconomical from the point of view of export and these crops are therefore normally grown for use in farming practice nearby or for sale at a neighbouring market. The acreage of Swedes grown for the latter purpose is obviously relatively small. The value of the Swede in agricultural practice is, however, very high and as a food for stock in winter it is especially prized. Some authorities are particularly eulogistic in their remarks on Swedes and suggest that the whole of modern farming practice followed directly on the introduction of this crop.

The acreage under Turnips and Swedes - one cannot obtain data for either of these crops alone - is very large as compared with the total acreage of arable land in this country. This holds for most of the counties in Great Britain. A detailed analysis of the acreage in the different counties is made hereafter. (p. 9).

The Swede crop is so important in most places in this country that it has an established place in most rotations of crops. As has been noted some authorities go so far as to say that the introduction of Turnips and Swedes into general agriculture brought about a complete revolution in agricultural practice (cf."Mod.Encycl.of Agric." Art. on Turnips.) The Swede crop is interpolated between two "white" or cereal crops in most rotations. Two Swede crops are rarely grown on the same land in two successive years. If they be so grown then the addition of large quantities of lime can hardly suffice to keep down the ravages of Finger and Toe Disease, should the causative organism have established itself. The only part of Britain where two crops of Swedes are commonly grown in successive years is the downland of Wiltshire and Hampshire, where the excessive chalkiness of the soil seems to be largely instrumental in preventing the ravages of the disease. The Turnip Crop is considered, by reason of the thick mat of the foliage, to be especially valuable as a "cleaning crop" - although Turnips are hardly so valuable in this respect as Potatoes on account of the expense involved in their cultivation and the fact that they remove a considerable amount of mineral matter from the ground.

The Swede crop grows best on a well-drained loam where the rainfall is somewhere in the region of 25-30 inches a year and there are no prolonged periods of drought. As is discussed more fully in a later section the Swede is a plant which is curiously unfitted to resist drought and quickly shows signs of wilting. At the time of germination the plants are particularly susceptible to adverse weather conditions and many Swede crops have to be resown if the season is not particularly suitable.

A study of the following table, compiled from data set out in the Transactions of the Highland and Agric. Society of Scotland and the Ministry of Agric. Returns for 1926 gives some indication of the relative values of the Swede crop in farming practice in different areas. The figures also indicate very roughly the suitability of specific areas. This is only very rough since Swedes are never grown unless they can be used locally, for the reason set out above.

Table I.

Data for the Season 1925.

County.	Arable Land.	Turnips & Swedes.	Mangolds.
Aberdeen,	585,556	81,405	-
Ayr,	139,515	7,000	223
Berwick,	131,524	20,593	75
Dumfries,	126,349	14,789	138
Fife,	166,547	30,341	11
Roxburgh,	112,209	16,818	32
Stirling,	51,741	3,572	3
Total for Scotland,	3,229,359	395,940	1,117

County.	Arable Land.	Turnips & Swedes.	Mangolds.
Berkshire,	158,869	8,900	5,140
Cambridge,	214,224	6,953	6,668
Isle of Ely,	164,719	33,667	582
Cornwall,	334,553	10,644	8,366
Cumberland,	179,858	25,076	1,144
Devon,	465,865	35,669	25,079
Durham,	151,170	18,403	571
Essex,	476,721	6,870	16,031
Gloucester,	211,294	15,274	5,761
Hampshire,	321,220	27,843	11,273
Hereford,	135,283	10,998	4,650
Huntingdon,	123,702	1,020	3,126
Lancaster,	225,516	6,963	1,750
Lincoln. Holland,	185,622	2,644	5,240
Lincoln. Kesteven,	260,482	19,664	6,824
Lincoln. Lindsey,	539,444	56,762	9,517
Norfolk,	758,315	82,573	52,207
Northumberland,	171,217	25,977	367
Suffolk,	556,925	25,593	25,213
Warwick,	132,488	8,345	6,714
Yorks,	1,116,286	155,257	17,676
Total for England,	10,000,453	759,051	348,314
Total for Wales,	681,600	47,410	10,759

From this table it will be seen that the Northern and

Eastern and to some extent the Western parts of Britain are those in which the Turnip crop is most extensively grown. That this is only an approximation is very obvious since the type of farming must have almost as great an influence on the amount of the crop grown as have the soil or climatic conditions. Turnips, as has been seen, are not grown for export. They have too high a water content to make them economically a suitable commodity for transportation.

The Dry Matter Content of a Swede which is often in this country and regularly in Denmark taken as the criterion of feeding value is not more than one half that of Potatoes or Sugar-Beet and in this country it is customary to substitute about twice as much Swede pulp for any quantity of Sugar Beet pulp. On the other hand, the Danish Authorities have shown that Swede pulp is as suitable as, if not better feeding than, other types - notably cereals while the cropping power of the Swede is immensely superior.

SECTION 3.

The Development of the Plant.

The Turnip belongs to the Natural Order Cruciferae, Group Brassicae and the Swede (B.Rutabaga) and the Common Turnip (B.Rapa) have much in common. Cross-fertilisation takes place freely between the two types though it is not so frequent as is often suggested, by some writers. The Swede as grown under farming conditions is a biennial. The seed is sown in May or June and the fully matured bulbs are available in October or November. If, however, Swedes are allowed to flower in their second year and the seed falls, is self-sown and is able to develop in the same year the plants which develop are usually small and fibrous and are annual in habit. This does not, of course, prove definitely beyond doubt that the ancestral Swede was an annual plant but it certainly suggests that the Swede may have been an "annual" ancestor and that the biennial types have been selected and much improved by careful cultivation. Nevertheless, it is well known, as the result of many observations, that Swedes in cultivation readily tend to bolt if they receive the slightest check during development - more especially in the earlier stages.

The seed of the Swede is roughly 2 mm. in diameter and almost black in colour, being rather larger, and, on the whole, darker than that of the Common Turnip. It is exalbuminous. The embryo proper is relatively small and, in the resting condition, the internal tissues are not particularly well differentiated. The cotyledons are rather large and are so folded that the embryo lies in the folds of the cotyledons - thereby being afforded some little protection. The testa is hard and resistant. Germination takes place after a week or ten days in the ground as a general rule. The cotyledons are fairly large and show in different strains a wide variation in form. They may be flat, curved, or recurved, or have smooth or crenate edges and so on. It is more than possible that this feature may be used in the classification of some of the well defined types in the seeding stage - a point of considerable importance in plant breeding. The cotyledons, the germination being epigean, act secondarily as organs of assimilation. Since the amount of reserve material stored in the cotyledons is very limited the foliage leaves are quickly developed. The first foliage leaf of the Swede is very glaucous, there being a deposit of wax on the surface. This feature distinguishes the Swede at a very early age from the allied races of Turnips etc. in which the first foliage leaf is distinctly pubescent. The tap root is long and thin in the early stages and the hypocotyl - since germination is epigean - is also rather tenuous in the first stages. The first leaves are small but the later leaves which soon begin to appear are much larger, being up to two feet long and more than six inches broad at the widest part of the lamina. The leaves are of a blue green colour. About the second month the swelling of the "bulb" becomes very pronounced. The bulb in the case of the Swede consists morphologically of Stem, Hypocotyl and Root. The various constituent parts are easily recognisable by the fact that the leaf-scars are clearly marked on the stem and lateral roots are developed from the root region. The main lateral roots are developed in two rows in a single plane through the centre of the bulb, being associated in origin with the ends of the diarch protoxylem. An interesting point with reference to the lateral root system is that when Swedes are grown fairly closely together in drills the lateral roots tend to grow out in the region between the drills. When the young plants are so placed that the lateral roots would normally develop in a plane parallel to the drills - that is, towards the plants on either side - they tend on emerging to turn quite sharply at right angles close to the main root. When therefore one pulls up a number of Swedes and does not examine them carefully one is inclined to think that the lateral roots have all developed on the sides nearer the space between the drills.

The protoxylem plate is situated in a plane at right angles to the plane in which lie the petioles of the cotyledons. The food materials elaborated in the leaves are passed down to, and are stored in the bulb. The seasonal variation and the general physiology of the storage mechanism are discussed at some length in a later portion of this paper.

Throughout the whole of the growing season there are developed large numbers of leaves in acropetal succession the older leaves dropping off from time to time. In the Autumn, towards the end of the growing season, the older foliage leaves tend to wither and die and after the incidence of fairly keen frosts the younger leaves of the crown are all that remain. The following table gives some idea of the way in which the total weight of the bulbs and of the leaves varies throughout the year.

Table 2.

Date.	Weight of leaves.	Weight of Bulbs.
9th July	9.5 lbs.	0.9 lbs.
17th Aug.	52.25 "	80.5 "
28th Sept.	46.75 "	140.25 "
30th Oct.	26.5 "	206.0 "
15th Jany.	10.0 "	240.0 "

It will be seen from this table that the leaves are heaviest at the end of August and that they decrease in weight thereafter. These results were obtained in an experiment carried out by Dr. McArthur and the writer in connection with an investigation into the metabolism of Swedes. The weights refer to quantities of 50 bulbs at each sampling.

When the leaves have begun to drop in large numbers the Swedes are normally harvested. They are then considered to be ripe, in common parlance. If they be left in the ground over winter the second growth appears some time in the early spring. The materials stored in the bulb are transported upwards in the plant and a long stem develops. This stem is the stem of the second year and is much branched in some varieties and bears few leaves. Those leaves which are developed are of a type rather different from the leaves of the first year. They are somewhat hastate in shape and resemble bracts more closely than normal leaves. Especially is this so in the case of the leaves associated with the branches on which are borne the racemes of typically Cruciferous flowers. These flowers are fairly large - about ½ an inch across - and of a buff tinge. In this they differ materially from the flowers of the Common Turnip which are smaller and are of a paler suplhur yellow colour, and those of any of the other cultivated Brassicas. Curiously enough, the white-fleshed Swede (so-called) has pale lemon flowers which in all respects but size resemble the flowers of the other cultivated Brassicas. The White-fleshed types were formerly very frequently grown (see above) but are now little valued - the bulbs tending to be very coarse, misshapen and fibrous.

The pollination is entomophilous - the pollen being sticky and not suitable for wind pollination. The pollen and nectar in the flowers encourage the visits of large numbers of bees - both hive and wild. The result is that cross pollination can, at least, take place with great frequency in nearly every case. In this connection it is of interest to notice that the genetical constitution of the commercial Swede varieties is somewhat complex. Swedes differ from Common Turnips in the fact that they are very self-fertile. The attractiveness of the honey and pollen for insects is well illustrated by the fact that so much cross-pollination appears to take place under natural conditions.

Common Turnips, on the other hand, are almost entirely self-sterile and the complexity of their general constitution is even more pronounced - and readily explained. There is a very large field of investigation here which is practically untouched. A paper by Nelson (J.G.1925) is one of the very few which deal with the problem of self-fertility and sterility in the Brassicas. There is some evidence, however, that the degree of sterility is by no means constant but that it varies in different strains. The fruit is a long smooth siliqua containing numerous seeds. At the end of the second season the storage materials in the bulb have all been used up in the formation of the floral parts and, consequently, the plant dies.

The consideration of the second year's growth is rather outwith the scope of this paper which deals more especially with the vegetative phase of the Swede.

Varieties.

The number of varieties of Swedes which are now grown ona larger or smaller scale is very great indeed. Considerable confusion exists regarding the nomenclature of these varieties as is found in the case of most of the crop plants. From some half-dozen varieties which existed at the beginning of the 19th Century there have arisen - by breeding and selection - the many dozens which exist at the present day. The absence of any coordinated effort to examine and classify these numerous varieties with a view to the recognition of synonyms has helped largely to add to the confusion. There, therefore, remains a great deal to be done in an effort to arrange for a more correct and comprehensive nomenclature. In a study of this kind all possible characters would have to be surveyed. Especially would it be necessary to carry out methodical genetical investigations. The types of Swede, as judged by the obvious feature of bulb colour are three (a) the Green Top (b) the Bronze Top and (c) the Purple Top. Generally speaking, the Green Tops are rather late ripening types, the Purple Tops are fairly early, and the Bronze Tops occupy a somewhat intermediate position. It is also held, with some justification, that the Dry Matter Content (expressed as a percentage of the whole bulb) is highest in the Green Tops, intermediate in the Bronze Tops, and lowest in the Purple Tops. (Lauder, S.J.A. Oct.1926). Within broad limits this state of affairs seems to hold viz. the Bronze Tops are intermediate in many of their characters between the Green and the Purple Tops. The impurities of the commercial strains and the differences due to soil and climatic conditions are very pronounced and in any comparison of type these must be taken into consideration.

Since there are so many varieties of Swedes and some variation in the bulb colour and so on it is to be expected that the shape of the bulb is not constant. It is found on examination that there is considerable variation and that the shape varies from the long narrow tankard type to the iso-diametric round.

The following Table sets out in some detail the better known types of Swedes. (Compiled from data contained in "Farm Crops" Vol. 1 and from numerous other sources.)

Table.

Name.	De-velop.	Bulb Colour.	Shape.	Similar Types.
Best of All,	Early	Purple	G.-S.T.	Magnum Bonum, Magnificent, Paragon, etc.
Knockdon,	Early	-S.	S.T.	
Picton,	Early		S.T. - T.	Superlative.
Enterkin	Medium	Grey P.	Round (flat)	Aberdeenshire Prize.
Skirving	Late		G.-S.T.	Springwood Bangholm.
Elephant	Late		Tankard	Monarch,
X.L.All	Late	P. Bronze	G.-S.T.	Up-to-Date, Ne plus Ultra.
Halewood	Late	Bronze	Tankard	Scotia, Great Scot.
Conqueror	Late	G. Bronze	Round	Caledonia, Darlington.
Kinaldie	V. Late	Green	Round	

Footnote ;- G = Globe S.T.= Semi Tankard.

It will be seen from this table that there are quite wide variations in the shape and the appearance of the bulbs - as has already been discussed. Figure 2 represents diagrammatically some of the more definite types of shape that are found. For the anatomical and physiological studies on the Swede a description of which constitute the next section of this paper a type was chosen which breeds fairly true as compared with other commercial strains and which was thought to be an intermediate type on various grounds e.g. in the period of development and bulb colour and shape. This was "Scotia" which was also used for the same reasons in the study of the seasonal variation in the Carbohydrate Content.

SECTION 4.

External Vegetative Characters.

The Swede, as has been pointed out, is a biennial plant. In the first year the plant develops a crown of Leaves, a neck (figs. 3-6) or short stem, and a bulb, a storage organ morphologically somewhat complex. The neck is characteristic of the Swede type and while constantly present differs considerably in different strains and varieties. The impurity of the average commercial strain makes dogmatising on the score of varietal characters dangerous but some types are characterised normally by the possession of an elongated neck. The Green Top variety "Kinaldie" is commonly possessed of a neck up to a foot in length. The Purple Top variety "Picton", on the other hand, has a neck just sufficiently developed to be recognised. The Bulb or storage organ of the Swede has definitely marked leaf-scars on the upper half. The scars tend to be more highly developed in the region of the neck - showing that the upper portion of the bulb consists essentially of an altered stem structure. The lower portion of the bulb is furnished with rootlets, the main lateral roots being developed in two rows in a plane passing through the centre of the bulb - the protoxylem areas. The main lateral roots and the tap root bear fibrous roots which function as absorbing organs. A point of some interest regarding the direction of growth of the main lateral roots has already been referred to. (p.3 Sect.3).

Between the portions of the bulb which are formed, respectively, of altered stem and of hypertrophied root there is a region of much altered hypocotyl. This region is recognisable in external view by the fact that there are neither leaf-scars nor rootlets developed on it. In this connection, lest there be any misunderstanding, it should be added that adventitious roots do develop from the base of the neck if that part be treated as a cutting.

The tap root proper, as distinct from the swollen region of the root, is not always very well developed and is furnished with large numbers of small fibrous roots which arise directly from it or from the two rows of lateral roots which have been noticed as so characteristic of the Swede.

The leaves of the Swede are numerous, being developed on a short stem and having a divergence of 5-13ths. The leaves are grouped together to form a crown during the first year of growth - the period of the elongation of the stem being at the commencement of the second season when a long many branched stem is sent up. On this stem are borne the numerous buff flowers and, subsequently, the seeds in siliquas.

A point which may be mentioned in connection with the external appearance of the leaf is that there are found, on occasion, in certain strains of Swedes, quite large spines developed on the lower side of the veins. These spines, or more correctly multicellular trichomes, are not highly lignified but are fairly stout. What their function may be is somewhat of a mystery since they are few in number and limited in distribution, both with reference to a single leaf, and to the varieties on which they are found.

The Structure of the Leaf.

As has already been noted the leaf of the Swede is of considerable size. The lamina is large and of a somewhat irregular outline. The petiole is massive - as would be expected from a consideration of the size of the lamina. Below the lamina proper there are developed on either side of the petiole hastate folioles which practically join up the lamina and stipules. The petiole in transverse section is triangular in outline, tending to be rather expanded laterally at the basal region. There are traces of stipular outgrowths in this region. The general appearance of the transverse section of the petiole of a normal foliage leaf at different parts is shown in the accompanying diagram (Fig. 7). The number of the bundles seen in transverse section varies with the position from which the section is cut. There are some larger bundles which apparently run from the base of the petiole right up to the lamina. From these larger bundles smaller bundles are sent off. These smaller bundles run through the parenchymatous ground-mass of the petiole for a shorter or longer distance and then they rejoin the bundle from which they were originally sent off. The cells of the ground tissue of the petiole are parenchymatous and are relatively large. The cells in the region immediately underlying the epidermis, however, and those surrounding the bundles tend to be collenchymatous. The epidermis is covered with a very definite cuticle. The epidermis here and there is perforated by stomata. The cells of the hypodermal layers contain a few chloroplasts, the numbers being, however, distinctly limited. The colour of the petiole is for this reason of a somewhat pale green, the paleness of the colour being rather intensified by the deposit of wax which invests the outside. In many of the cells of the petiolar ground-tissues are to be found crystals of calcium oxalate.

The anatomy of the xylem and phloem of the petiolar bundles does not present anything of special interest. The phloem area is not very large, the cambium is composed of a few layers of cells, and the xylem is fairly well developed. The collenchymatous bundle sheath which invests the Vascular Bundle is normally of considerable size.

The point of interest which emerges from a study of the anatomy of the petiolar bundles is that the bundles are compound. Three or more sets of vascular tracts are associated together within a common bundle sheath. The component bundles are separated from each other by groups of cells with thickened cellulose walls. The general appearance of the compound bundle is well illustrated in the diagram (fig. 9). It will be seen that in the case of the larger group five large bundles and two smaller are in close juxtaposition. In the case of small groups three bundles are in association.

The xylem is composed of fairly wide and of narrow vessels with reticulately thickened walls associated with some few tracheidal elements and xylem parenchyma. The amount of cambial activity which takes place within each bundle is not very great and the bundles are rather small compared with the considerable size of the petiolar ground mass.

As may be noticed in the accompanying diagrams the Epidermis of both the upper and the lower sides of the large expanded lamina of the leaf are similar in structure and the component cells are of nearly the same size. The cells of the lower epidermis have on the whole more tortous walls. The upper and lower surfaces of the leaf are both furnished with stomata the structure of which presents no points of special interest.

There is a waxy layer over the whole surface of the lamina both above and below and occasionally it was found that a plug of wax had apparently occluded the pore of some of the stomata. This was not of so regular an occurence as to justify the conclusion that it was a mechanism primarily intended to prevent excessive transpiration, although obviously it tended to reduce the water loss.

As regards the number of stomata present, it was found that these on the lower surface were more numerous than those on the upper surface - the normal state of affairs in mesophytes. As to the actual number of stomata on each surface there was considerable variation. The age of the leaf seemed to be the main factor in determining the number of stomata present. Other factors were the position on the lamina at which the count was made and the position of the leaf on the plant.

The density of the stomata was very much greater in the region of the mesophyll, the epidermis on the vascular bundles having comparatively few. Numerous counts were made of the stomatal numbers of various leaves. The results obtained are contained in the following table. It will be seen from this table that it is very difficult to decide as to what relationship, if any, there exists between the numbers of stomata on the two sides of a leaf. There seems to be not the slightest approach to any proportionality between the numbers on the two surfaces except that the number on the abaxial side is always much the larger.

Table 4.

Type of Leaf.	Stomata/sq.mm. Upper Surf.	Stomata/sq.mm. Under Surf.
Small, Juvenile leaf	190-210	300-320
" "	170-180	270-330
" "	210-230	310-320
Large, Light green leaf	90-110	130-150
" "	80-100	170
Large, Dark green leaf	95-100	170-180
" "	100	170
Very large leaf	36-60	90-100
Small, Juvenile shade leaf l.green	120-210	240
" " d.	190-210	330-380
Large dark green leaf	65-90	200-220
light	70-80	150-210
light	120-130	210

It will be seen from this table that the small juvenile leaves have the greatest density of stomata on both the adaxial and abaxial surfaces. The reason for this appears to be that the stomata are initiated while the leaf is still in a distinctly immature condition and the subsequent development of the leaf is largely brought about by the increase in size of the component cells and not by an increase in the actual number of these cells.

The size of the leaf obviously varies with age. The younger the leaf the smaller it will be, other things being equal. This state of affairs holds for most of the features of the leaves. In fig. 8 it will be seen that the difference between the two leaves, a large and a small specimen from the same plant, is one of magnitude rather than of type. That is to say that the margin of the older leaf is exactly similar to that of the younger leaf except that the parts of the second are on a smaller scale. From another figure it will be noticed that the component cells of the mesophylls of a large and small leaf are very similar in outline and in arrangement the subsequent development being largely, but not entirely, one of extension rather than of meristematic activity or displacement.

With reference to the cellular construction of the mesophyll it is of interest to note that the anatomical structure is not pronouncedly of a xerophytic nature, but on the contrary is rather of the opposite type. The palisade tissue is so ill-defined in the case of the mesophyll of the

Swede leaf that one would almost be justified in describing the leaf structure as isobilateral (cf. Artschwager, l. c.) There are slight differences in the upper and lower epidermis and in the spongy and palisade layers of the mesophyll though in this case they are not so pronounced as in a great many other plants considered as being typical mesophytes.

The fact that the palisade tissue of the mesophyll of this plant is normally very ill-defined and in some cases is not developed at all when taken in conjunction with the presence of hydathodes on the leaves - a matter to be discussed later - is of interest as regards the probable origin of the Swede. There seems to be a feeling general among Botanists not, as is true, often stated in so many words but rather implied, that the Swede was developed in some way from a xerophytic - possibly maritime-ancestor. In the light of the facts set out above in the first section of this paper it is obvious that one cannot dogmatise on this point. One reason, probably, why the idea of a xerophytic ancestor is suggested is that there is a waxy covering on the leaves of the Swede, which might be construed as an adaptation to xerophytic conditions. Be that as it may, there can be no doubt that, even if the original ancestor of the Swede were a xerophyte, the result of cultivation has been to produce a plant curiously unfitted to resist xerophytic conditions or even moderately unfavourable conditions of any kind. An interesting case of the apparent inability of the plants to resist slightly abnormal conditions may be observed in any field of Swedes during the Summer. The phenomenon is more obvious, from the very nature of the case, in the East of Scotland and in parts of England. It may be seen, on many occasions, that on a warm Summer day, especially when there is a drying wind, the leaves of the Swedes in a field tend to lose water to such an extent that they become quite flaccid and lie almost flat on the ground. In the evening however they recover very rapidly and in the early morning, when the air is usually rather humid, the Hydathodes on the leaves are found to be excreting water very freely. Along with this phenomenon must be placed the facts that the mesophyll tends to be composed of spongy cells and that the stomata have simple guard cells and show no adaptations which might be effective in preventing or controlling the egress of water vapour.

To sum up the evidence adduced above, the anatomical construction of the leaf with its spongy mesophyll cell arrangement, the not too highly developed cuticle and the possession of a large number of hydathodes does suggest a habitat where the water supply did not constitute a problem difficult of solution.

The hydathodes of the Swede are developed in large numbers on the margins of the leaves. At each point on the margin of the leaves which are deeply serrated there is developed a hydathode. That these hydathodes do function very freely under suitable circumstances has already been seen with regard to their behaviour on summer mornings. On these occasions drops of water are formed at the points on the margins. The hydathodes are apparently not of a secretory type but are rather of the nature of the water pores found in the leaves of many other plants, notably Hydrangea and Fuchsia. The exudation of water can be easily induced at any time by covering the plant with a bell-jar - thereby surrounding the leaves with a saturated atmosphere. The vascular connections of the region round the hydathodes is traced out in fig.9

The Structure of the Bulb.

It has already been noticed that the storage organ of the Swede is morphologically a complex structure. The reserve food-material is laid down in a swollen Stem-Hypocotyl-Root system. This point is well illustrated in some of the figures and plates. The Swede bulbs illustrated in figures 3-5 were put upright into aqueous solutions of Eosin with the end of the tap root removed. The eosin solution passed up the xylem strands, especially along those in the region just internal to the cambium and those in the centre of the bulb. These are stained red and show the arrangement of the strands very clearly. The main storage region is, as may be seen, the xylem parenchyma of the hypocotyl and that of the upper portions of the tap root. The lower portion of the bulb tapers gently until it passes into the tap-root proper while the upper portion of the bulb, being altered stem, has a well marked pith.

In the exalbuminous seed the cotyledons are of considerable size and are folded closely round the young embryo proper.

The tissues of the embryo are not very clearly defined before germination. On germination the rapid growth of the hypocotyledonary region raises the cotyledons above ground at an early stage. These unfold and function as photosynthetic organs for the first fortnight or so of the plant's life. The stele at this time consists essentially of protoxylem and protophloem groups. The cortex at this stage is relatively large in extent and occupies a considerable area of the cross-section. The relative areas of the stele and the total area of the transverse section of the middle of the developing bulb are set out in the table below. The ratios are expressed $\frac{R}{r}$, where R is the radius of the whole section and r the radius of the area bounded first by the endodermis later by the cambium.

Table 5.

Stage of Develop.	Diameter of Bulb	$\frac{R}{r}$
A.	1.5 mm.	40
B.	2.0 "	25
C.	4.0 "	15
D.	1.0 cm.	3
E.	20.0 "	1.5
F.	60.0 "	1.2

From the figures contained in the above table it will be seen that the rate of the growth of the xylem area, associated with the development of the plant and the elaboration of reserve food material in the leaves is much greater proportionally than is that of the total transverse section. In this way the development of a large storage xylem area the Swede differs fundamentally from the Sugar Beet and many other plants in which there are developed in the cortical ground-tissue a fairly large number of secondary cambia. In the case of the Swede the cambium which is initiated at the time of the development of the first foliage leaf remains as the only cambium developed in the life of the plant.

In the young bulb the distinction of the component parts is clearly seen. In the region of the root there is a diarch protoxylem plate with two protophloem groups and a considerable area of conjunctive parenchyma. The pericycle - a single layer of cells as a rule - and the Endodermis are clearly defined. The Endodermis is characterised by the facts that it is composed of very large cells and that the cells are furnished with broad Casparian strips at a very early stage.

As the hypocotyledonary region is approached the middle cells of the plate of protoxylem are less lignified until there is a region, as the stem region is approached, where there are definitely collateral bundles of protoxylem and protophloem and a small central pith.

The development of the stele in the bulb is illustrated, as regards the region just below the hypocotyl, at least, in the camera lucida drawings A, B, and C of figure 13. In them it will be seen that the number of tracheae and tracheids cut off by cambial activity is relatively small and that the major portion of the xylem tissue is composed of elements of a parenchymatous nature. The phloem also is somewhat poorly developed as indeed it is throughout the life of the bulb. This fact is of some interest as regards the possible physiological aspects of the functions of the phloem and xylem in the case of this plant. (figs. 13,14)

Figure represents the appearance of the phloem when the diameter of the bulb is of the order of 0.5 cms. In the case of the Swede the cotyledons act as photosynthetic organs from the very earliest stage and so there is no period, after germination, at which the store of reserve material is depleted without some additions being made to it. For this reason largely, the carbohydrates and other substances metabolised in the first foliage leaves are passed down to the region of the hypocotyl and the tissues of the young bulb are rapidly developed. Storage takes place in the parenchymatous cells of the xylem and in this instance the activity of the cambial divisions is not sufficiently great to cope with the need for large numbers of these parenchymatous cells. The cells themselves under these circumstances are capable of quite active division so that the number of cells originally cut off by cambial activity is rapidly increased by the secondary divisions of the growing cells. This phenomenon is not uncommon in many plants which develop swollen storage organs and in the Swede apparently this characteristic has made unnecessary the development of numbers of concentric cambial rings. The appearance of the lignified elements surrounded by the living parenchymatous cells which store the reserve food material and which have the power of dividing freely if necessary is illustrated in the figure 11.

The development of the Stele in the Swede bulb has been treated in some detail. It has been shown that there is a great deal of growth in this region as the result of cambial activity and of the secondary division of the parenchymatous cells. This division is most marked in the case of the storage cells of the hypertrophied xylem but it is also to be found to some considerable extent in the case of the component cells of the other stelar tissues. The pericycle cells usually divide as do the cells of the conjunctive parenchyma of the stele. On the other hand the Endodermal cells do not divide nor do those of the cortical tissues.

The cortex is composed in the early stages of a large number of very large cells. As growth continues they increase rapidly in size. When the hypocotyl elongates considerably, as it does at an early age to bring the cotyledons above the surface of the ground, the cortical cells become very elongated. Since, however, they cannot extent indefinitely to admit of the continued growth of the plant in thickness the whole of the primary cortex is ultimately exfoliated. (cf. J.A.R. 33 p.168). For this reason, also, it follows that the endodermis which is so conspicuous a feature of the young bulb becomes of little importance. In the end the bulk of the parenchyma outside the cambium proper is formed by the activity of a secondarily initiated cambium.

The formation of this "secondary cortex" has been described for the case of the Sugar-Beet by Artschwager. (J.A.R.33 p.168) It appears that the formation in the case of the Swede is very similar. His description is as follows - "The periderm of the Beet always develops from cells of the pericycle. Its formation is initiated when the seedling has about five pairs of leaves, that is, at a time when the supernumary cambiums are forming and the primary cortex is being sloughed off and since this process takes place first in the root zone the periderm develops acropetally extending gradually to the hypocotyl. Periderm development begins with the conversion of the cells of the pericycle by tangential divisions into a band of meristematic tissue which constitutes the phellogen or cork cambium. From the phellogen are formed, by reciprocal divisions, cork cells outside and phelloderm cells inside. The number of phelloderm cells is however smaller than the number of cork cells since these are constantly being sloughed off and must be replaced. On the whole the periderm forms a thin covering from five to eight cels wide. The individual cork cells have the form of a parallel piped with a five or six sided base. The height is less than the diameter of the bases thus giving the cells a flattened appearance. The walls of the periderm cells are thin and suberized except the middle lamella which is lignified."

This description would fit equally well for the Swede, except for the fact that in this case there is only one vascular cambium.

There are considerable differences in the various types of Swede but in many cases the corky layer on the outside of the bulb withers at more or less regular intervals and as a result there is a somewhat scaly appearance on the outside of the bulb.

The plates which show the sections of the mature bulbs present some features of more than passing interest. The bulbs before the sections were cut had the end of the tap-root removed and were placed upright with the cut end of the root in an aqueous solution of Eosin. In this way the Eosin was allowed to travel up the plant along the xylem vessels. As a result of this treatment the strands of lignified vessels in the xylem are clearly defined and show up against the yellowish background of the parenchymatous tissue of the ground-mass of the xylem. It will be seen that in the cross section there are definite zones of tissues. On the outside there is a layer of suberised cells - the Cork. Internal to this there is a band of fairly regularly arranged cells of the "secondary cortex." Thereafter there is a narrow strip of cells - the phloem-which in the case of the Swede is on microscopic examination found to be rather ill-defined with relatively few sieve-tubes and a large amount of phloem parenchyma. The xylem, which lies internal to the phloem band and which is separated from it by the narrow cambium ring, is the most obvious and the largest in extent of the component tissues of the bulb. The fact that the lignified xylem elements are so clearly marked out from the others by reason of their red colour after the above treatment makes obvious the relatively small amount of this lignified tissue present-a concomitant of the storage function which is so important a factor in this case. There is a feature of the passage of the stain in this plant which is dealt more in detail in the next section. It will be noticed that the strain has passed in the strands of vessels towards the protoxylem area and those just below the cambium. The large intermediate area has also lignified vessels in it but these are not stained,

A particularly obvious feature of the protoxylem is its diarch structure. In every case examined was this found to be constant. As a result of this the main lateral roots develop in two rows in the plane of the protoxylem plate. This point is clearly indicated in the two plates 3. + 4. In one case it may be seen that the lateral roots extend outwards from the centre line in the plane of the section. In the second instance the section was cut in a plane at right angles and does not therefore expose the lateral roots in longitudinal view but only in cross section.

The bulb develops very rapidly in the case of the Swede and in the short growing season of the first year - usually from May till October all the materials which are to be utilised in the development of the stem and floral axis are synthesised and laid down. The leaves of the crown drop off periodically and the younger leaves develop and replace them. The scars of the leaves which have dropped off are a feature of the external appearance of the neck of the Swede.

SECTION 5.

Studies in the metabolism.

In this, the third and last section of this paper, it is proposed to deal with some aspects of the study of the development of the Swede which have a definite physiological bearing and which may be applied in the elaboration of general physiological principles.

The first point which impresses the observer is the remarkable rapidity with which the plants grow. Whereas in the case of many plants one finds the development of the adult proceeding very slowly - it may be over a long period of years - in the case of the Swede the whole process of the manufacture and storage of reserve materials takes place in the first season of growth. The second season is devoted to the development of the inflorescence and the small amount of chlorophyllaceous tissue which is present in the stems and floral bracts is obviously quite inadequate to supply anything like the amount of material which is required for the building up of a large number of floral parts and seeds. The number of fruits which are developed and the quite considerable amount of reserve material which is contained in the cotyledons of the embryos make necessary an abundant supply of available food-material during the second season of the plant's growth. Whatever the ancestral type of the Swede was, and there is some doubt as to the wild type from which it originated, cultivation has resulted in the increase of the amount of reserve material in the storage organ so that the necessity for photosynthesis in the second season is practically removed.

The fact that Swedes are grown for food and that much stress is put on the amount of vegetative growth which takes place has rather obscured the fact that Swedes are almost certainly the biennial descendants of an annual plant. It would appear that the purpose of the early growers was to select strains which tended to be biennial in habit. Considerable economic importance attaches to this observation since there is a tendency, under certain conditions, for Swedes to "revert" or, at least, to develop abnormally and flower in their first season. The writer has had the opportunity of examining some of these plants and their selfed progeny of the first generation. These plants were found to the number of about 10% in a field of Green Top Swedes and were characterised by the early development of a thick branched stem and large numbers of flowers of a Swede type. The flowers appeared at the end of the first season's growth in the case of the rogues but in the case of the L1 generation few plants grew to a large size and only one flowered at the end of the season before the onset of frost killed the flower buds which were developing in the others. The L1 generation plants were very like the parental type as regards external morphology and there was little evidence of any segregation of types. The phenomenon of "bolting" is not uncommon in Swedes under ordinary conditions if there have been late frosts or similar disturbing factors in the early summer but bolting of this particular kind has not been fully studied. At the present there are two distinct theories on the matter (1) that the bolters are the progeny of an accidental cross with some other Cruciferous plant and (2) that they are reversions.

The specific cause of the abnormal development of the Swede in some circumstances does not seem to be a suitable subject for fuller discussion at this point and is not strictly germane to the thesis. It is well, however, to bear in mind the fact that in considering the growth and development of the Swede one is dealing with a plant which is growing under conditions which probably do not admit of its carrying out its life cycle, in a normal fashion. It is not suggested that the cultivation of the Swede or of any other plant has given rise to a number of new factors but the fact that cultivation does play so important a role in stressing, as it were, some features of its development may have some effect on the growth.

Studies in Swede growth.

The most obvious method of studying plant growth is by measuring the weight of the plants. That this method is of only limited value is quite clear on even cursory consideration. For example, there is no certainty that increase in weight may not be due mainly or even wholly to the inbibition of water without any corresponding increase in the amount of plant substance. This consideration naturally leads to the question of the criterion of growth a subject on which there is a considerable literature (see papers by Kidd West and Briggs and others). To attempt to deal in any way with this problem would be out of place in this paper and for the present attention will be paid to the fresh weight of the crop at various stages.

The Swedes from which the data were obtained are of the commercial strain "Scotia" a Bronze Top Semi Tankard variety which breeds comparatively true to type and which is characterised by the possession of numerous intermediate qualities as compared with many commercial strains. This variety was selected because of (a) its comparative purity (b) its intermediate growth period - it ripens as an early main crop and (c) its shape which, being also intermediate, is very suitable as being intermediate between the almost spherical globes and the somewhat elongated tankards.

The plants were grown at the experimental farm of the West of Scotland Agricultural College in connection with an experiment in phosphatic manurial treatment carried out by Prof. McArthur of the College. The writer was associated with Prof. McArthur in this work and the data given below were obtained in this connection.

The Swedes were grown in two large plots and samples of 50 plants were taken at random on each of the days specified. The roots were cleaned and washed and then the bulbs and the tops were weighed separately. For the purposes of analysis each of the bulbs was quartered in a longitudinal direction and a slice was taken from a quarter of each bulb so that a fairly representative sample was obtained. This material was weighed and then air-dried for 24 hours. Subsequently the pulp was dried in an electric oven at 80° C until the difference in weight between two successive weighings was slight. Occasion to refer to this procedure arises subsequently in this paper but for the present it may be assumed that this method gives a rough idea of the Dry Matter Content of the bulbs.

As has already been noted there were two sets of plants. In one case the plants were treated with a phosphatic manure which the other plot did not have but for the study of the fresh weight curves the data may be considered as of two separate experiments and the form of the curves obtained are for the present of more importance than the absolute values indicated by them.

In the earlier part of the experiment it was felt to be desirable that samples be taken at fortnightly intervals but as the experiment progressed it was found to be impracticable to adhere to this procedure and in the end sampling was carried out at intervals of a month.

The details of the fresh weight in pounds of the lots of fifty Swedes from each of the two plots are given below.

Table 6.

Date.	Plot A. Weight of Bulbs.	Plot A. Weight of Tops.	Plot A. Weight of Total	Plot B. Weight of Bulbs.	Plot B. Weight of Tops.	Plot B. Weight of Total.
25th June	0.0178	0.496	0.518	0.0098	0.273	0.2828
9th July	0.912	8.616	9.528	9.578	5.168	5.76
23rd July	10.125	31.25	41.675	4.825	16.125	20.75
17th Aug.	80.5	52.25	132.75	65.25	52.5	117.75
31st Aug.	100.75	48.75	149.5	81.75	53.75	135.5
14th Sept	122.5	46.75	169.25	115.0	54.5	169.5
28th Sept	140.25	46.25	186.5	126.75	46.5	173.25
30th Oct.	206.0	26.25	232.25	176.75	34.5	211.25
4th Dec.	249.0	13.5	262.5	209.0	11.0	220.0
13th Jan.	240.0	10.0	250.0	213.25	9.0	222.25
12th Feb.	235.75	11.75	247.5	202.25	9.5	211.75
12th Mar.	224.75	14.75	239.5	206.5	14.25	220.25
30th Apr.	188.25	25.0	213.25	158.0	23.0	181.0

There are some very interesting points which arise from the study of these data. From a consideration of the figures of the total weight of the bulbs it is clear that there is a very great increase in the amount of material in the first period (i.e. between the time of planting and the 25th June). This large increase in weight has been noticed by numerous writers (cf. above) for various types of plants and it is obvious that the Swede is a plant in which the photosynthetic activity is effective at a very early stage in the lifecycle and in which there is a large amount of material metabolised in the early stages. The weight of the embryo is obviously very small and the weighing of germinating seeds is a somewhat tedious process. The total weight of fifty embryonic plants may however be taken as neglible especially when it is borne in mind that during the first stages of germination the amount of material lost by respiration must be relatively large.

Starting, therefore, from very small quantities of material it is found that at the end of the first period of growth there has been an increase in weight of 0.5 pound in one case and of .25 pound in the other. For the purposes of this present discussion it is proposed to consider the data for plot A. The actual increase is expressed as a fraction $\frac{\text{Weight at end of period}}{\text{Weight at beginning of period}}$. For the first period this value must be fairly large. In the second period the ratio is of the order of 20, in the second period of 45 and in the fourth period of 3.5. In the subsequent three periods the increase is much less marked and the ratio falls to the value of approximately 1.2. In the eighth and ninth periods when on general grounds it might have been concluded that the growing season was almost over the ratio $\frac{W_2}{M_1}$ has almost the same value as in the previous stages. Allowance has to be made in this case for the fact that each of these periods, unlike the previous ones, is a month and not a fortnight. There is no indication that the Autumn of the season in which the swedes were grown was particularly mild and congenial and the probability is that the increase in fresh weight does not mean a considerable increase in carbohydrate materials but is more probably an index of the increased absorption of water. This point is more clearly illustrated by the data contained in the subsequent tables (Tables 7, 8). The general conclusions which may be drawn from the study of these figures for the fresh weight is, therefore, that in the early stages the curve of the Weight plotted against time is very steep in gradient but that as growth continues the curve tends to turn over and to have a much lower gradient. At the beginning of the second season, as might be expected , the curve tends to turn downwards and the ratio $\frac{W\,2}{W\,1}$ has a value of less than 1.0. Since the materials for the development of the large floral parts come primarily from the reserve storage in the bulb this decrease in weight is readily understood. The general appearance of the curve of the fresh weight is seen in the accompanying graph (see below).

A study of the figures in the first two columns of Table 6 is of interest. The increase in total fresh weight in the first period is largely associated with a considerable increase in the fresh weight of the leaves and it would appear that at first the products of metabolism are used up largely in the making of foliage parts and that the amount of material available for storage purposes is slight. This suggests that at an early stage the curve of the increase is closely similar to the curve of Increase by compound Interest, in other words, the material as synthesised is laid down in the form of photosynthetic tissue which immediately adds to the total amount. Soon, however, as may readily be seen, the weight of the bulb proper increases very greatly while the increase in the leaf falls off and, in fact, the total weight of the leaves is actually decreased by reason of the withering of the oldest and first formed leaves. At this stage therefore the Compound Interest Law can in no wise be applied. This seems to have been ignored by many investigators in studying growth curves although it should be obvious enough on merely general grounds. While the products of metabolism are being used in increasing the photosynthetic mechanism the Law may well be expected to hold and if it did not some justification for comment would arise. On the other hand,as soon as, and in so far, as any of the products of photosynthesis are laid down as reserve storage material the rate of increase will tend to fall off by the simple energetics of enzyme action, the end products being accumulated and tending to encourage the reverse process. On these grounds, therefore, there is no valid reason for expecting that the Compound Interest Law should hold and no reason for expecting that the growth curve should fit the formula for Increase by Compound Interest.

One other point emerges from the study of these figures viz. that the increases noted in the 8th and 9th periods of growth are due to a considerable increase in the weight of the bulbs the weight of the leaves having decreased very much indeed. This confirms definitely the idea that the increase in total weight is due to an increase in water content at the latter part of the growing season. Incidentally, at this period, Starch, which was a prominent constituent of the storage material of the bulbs in the earlier stages, tended to disappear about the beginning of October and it may be that the hydrolysis of this Starch, by increasing the concentration of the sugars in the cells of the bulb, increases the osmotic pressure. This increased osmotic pressure is neutralised by the imbibition of water in large quantities. There is no exact evidence on this point but this hypothesis would certainly fit the observed facts. This presence of Starch in the tissues of the bulb is significant. More especially is it so since the reserve Carbohydrate in the Swede is in the form of Hexose sugars apparently almost equal quantities of a dextro - and a laevo-rotatory sugar. This point it is hoped will be dealt with more fully in the near future.

There is apparently little published work on the subject of the growth of the Swede contained in botanical literature. In Germany a good deal of work has been done on the Sugar Beet and in this country on not a little on the agricultural side of Swede culture. In these experiments dealing with the Swede as a fodder crop emphasis has been laid especially on the final weight of the crops grown under controlled conditions particularly as regards manurial treatment. There is one paper of interest on the Swede which was published recently in a Danish Journal by Axel Pederson. The features noted below are taken from his appended English Summary.

"The Root of the Mangel, Swede and Turnip consists ontogentically of root hypocotyl and epicotyl or root, neck and crown. The proportion of the three parts varies much from one type to another and to a certain degree within the same strain (commercial?) It is to some extent characteristic for one type.

The growth of the root, hypocotyl and epicotyl by which the mature root is formed is partly in thickness and partly in length. The growth in length with which this paper deals is secondary, intercalary and involves the feature that the root, when growth is considerable, grows out of the ground. The length of the overground part of the root corresponds approximately to the growth in elngth of the whole root.

The limits between root and hypocotyl and between hypocotyl and epicotyl can with good approximation be determined throughout the whole period of growth from the young seedling to the mature root. On the surface of the root the limits can be determined by means of the lateral rootlets and the leaf scars: inside the root by means of the vascular bundles of the lateral rootlets and the first leaves.

The rate of the growth in length was examined by measuring the increase in length at intervals of 10 or 11 days from the 10th July to the 23rd Oct.

The rate of intercalary growth follows the usual curve of Growth (sic). It is slow at first, it increases to a maximum in the middle of the grand period of growth diminishes then, first at a rapid rate and later slower until it ceases altogether. The whole course is symmetrical about the point where growth is at its maximum. It follows from this that the course can be expressed with good approximation by Robertson's Curve for Growth. (This last point holds if the previous statement is correct but up to the present it has been difficult to correlate the data obtained in growth experiments with the Curves of Autocatylitic Reactions.)

The Dry Matter Content was ascertained in the four parts A, B, C, and D separately. The percentage of Dry Matter is lowest in the central parts B and C increasing towards the ends. In the examined types of Brassica it was found to be rather below the greatest diameter.

(This last point might be compared with the findings recorded hereafter. It would appear that the distribution of Dry Matter is as would be expected. From an anatomical point of view there is every reason for supposing that the portion of the bulb which has most sugar is the central and hypocotyledonary region. On the other hand, the regions where there is most fibre per unit of weight are probably the root proper and the base of the stem.)

The Increase in Total Carbohydrate and the Carbohydrate Metabolism.

It has been seen that in the Swede there is a great increase in the weight of the crop from the time of germination to the time of "ripeness" and that the curve of weight, plotted against time, has the general appearance of the curve for Autocatalysis without necessarily - and perhaps of necessity not - fitting it exactly. The fresh weight of the crop however accurately measured and whatever precautions be taken to prevent any error in sampling is little indication of the photosynthetic activity of the plants in that the amount of water present is hardly likely to be constant. This factor - the water content of the tissues - is probably the one which in the case of the Swede bulb is the most variable. It has already been shown that the resonse of the plant to excess or deficiency of water is rapid and that at one part of the day it is possible to have the active secretion of water from the hydathodes while at another the leaves may be completely flaccid. This flaccidity and excessive absorbtion of water must have an effect on the water-content of the bulbs - a point which is being at present investigated. A method of avoiding this difficulty readily suggests itself viz. the Method of estimating the Dry Matter Content of the Bulbs. The Dry Matter Content was determined by carefully drying slices from each of the fifty bulbs in the samples, first at low temperatures and then at 88° Cent. - drying at this temperature being continued till the weights at two successive weighings did not differ more than 0.5 mm. The Dry Matter of the whole sample was then calculated, as a percentage of the total weight and as the absolute weight of Dry Matter present in the fifty Bulbs.

This method is so simple, as regards the Chemical technique and so obvious that it is not surprising that it has suggested itself as a possible method of assessing the relative value of the bulbs of different strains. The assessing of the relative values of different strains has of late years become of considerable interest and of economic importance since efforts are now being made to improve the types of Swedes grown. In a paper (Scot. Journ. Agric. July 1927) I have endeavoured to deal with the matter of the feeding value of Swedes in so far as it effects the plant breeder. For the present the Dry Matter data afford some interesting points for consideration. The amounts of Dry Matter, expressed as a percentage of the Total weight and as an Absolute amount present in Fifty Swedes ("Scotia") grown as before indicated, are given in the following table.

Table 7.

Date.	Percentage of D.M. in Bulb.	Total D.M. in Fifty Bulbs.
25th June	19.0%	.0034 lbs.
9th July	8.9	.081
23rd July	12.0	1.23
17th Aug.	10.9	8.82
31st Aug.	10.7	10.76
14th Sept.	11.3	13.85
28th Sept.	11.4	15.99
30th Oct.	10.2	21.63
4th Dec.	10.0	24.8
13th Jan.	9.2	22.01
12th Feb.	9.0	21.2
12th Mar.	8.4	19.3
30th April	8.4	15.8

The figures in the above table suggest some interesting possibilities. The curve of the figures in column three is the normal type which one would expect on the basis of the previous study of the fresh weight of the bulbs except in some minor details. These details become more obvious when the percentage of Dry Matter is considered (col. 2). The first value may well be considered as being of the order of 80% and there is evidence therefore that during the first period of growth there is considerable intake of water and a consequent increase in the weight of the bulb not associated with an increase in the amount of reserve materials or of the cell-substances proper. This continues through the second period and the amount of material added in the form of cell-substance during these two periods is smaller, as compared with the increase in actual weight, than at any other period in the life of the bulb during the first season. To put the matter on a numerical basis - it has been found that the ratio $\frac{W' n}{W' n-1}$ varies throughout the season of growth and had different values at different periods of the life-cycle. The ratio

$$\frac{\text{Dry Matter Content at end of period}}{\text{at end of period}} \quad \text{or} \quad \frac{W'' n}{W'' n-1}$$

varies in the manner shown in the appended table. In the first period the value ~~is-approxim~~ of the expression is of the order of x, In the second period the value is approximately 30, in the third 15, in the fourth 7 in the fifth 1.25 and so on.

The ratio of the fresh bulb weight $\frac{W^{*} n}{W^{*} n-1}$ is also variable and has differing values throughout the season. The value of the expression is in the first period of the order of y, in the second of 50 in the third of 11, in the fourth of 8 and so on. The values are given in the first column of the table below.

Table 8.

Period	$\frac{W' n}{W' n-1}$	$\frac{W'' n}{W'' n-1}$
1	x	y
2	50	25
3	11	15
4	8	7
5	1.25	1.25
6	1.2	1.3
7	1.2	1.2
8	1.5	1.5
9	1.2	1.2
10	1.0	0.9
11	0.9	0.9
12	0.9	0.9
13	0.8	0.8

It can be seen from this table that in the initial stages of growth the increase in weight is not correlated with a corresponding increase in the amount of Dry Matter present in the plants but is probably due to the intake of a large amount of water. On the other hand, the second stage of growth is apparently characterised by a large increase in the Dry Matter Content where the increase in fresh weight is of the order of 11 while the Dry Matter increase is 15. Thereafter the curves of the two ratios are within the reasonable limits of experimental error, coincident. The experimental error involved in this work is necessarily very large and no more can be deduced from these results than the broad lines along which development progresses - more detailed hypotheses would require the carrying out of elaborate experiments on a wide scale.. The possibilities suggested by such results as are here presented are very numerous and it is hoped that many of them will be dealt with in the near future while some are being explored at the present time.

Changes in the Carbohydrate Content of Swedes

The variation in the Carbohydrate Content of Swedes was thought to present an interesting problem. Since it appears that the main feeding value of a Swede is associated with the Total Sugar content it is clear that a knowledge of the changes which take place in the amounts is of some economic value.

In a biennial such as the Swede the reserve material increases in amount to a maximum at the end of the first year's growth. As a result of the growth in the second season the reserve material is used up in the formation of floral parts.

The work to be detailed below was carried out with a view to finding the changes which take place both in the percentage amount of sugar present in the Bulb and the Total Carbohydrate Content. The varietal peculiarities of the various types is very great in the matter of the Carbohydrate content and attention was paid to a strain of an "early main-crop" type.

A plot of "Scotia" swedes was set apart for the purposes of the investigation. "Scotia" was selected because this variety, as has been seen, shows a fair degree of uniformity; hence the samples taken were reasonably typical of the crop at any given time. The seeds were sown on 18th May in rows 27 inches apart and the young plants were "singled" to 9 inches. Fifty swedes were taken at each sampling. Samples were taken at intervals of a fortnight at first, but subsequently the intervals between two samplings was rather longer. The swedes were washed and allowed to dry, after which the necks and leaves were removed and the "bulbs" weighed. The weights of the samples at different times are shown in Table 1.

After the bulbs had been weighed they were quartered by two radial longitudinal cuts at right angles. Slices were taken from these "quarters" so as to give a uniform and typical sample, care being taken that all the quarters were equally represented. It was borne in mind that there are different amounts of dry matter in different parts of a swede bulb (see Sansome, Jour. of Agric. Science, Jan. 1926). Further, I myself have established the fact that carbohydrates are stored in greater quantity in the south-facing portions of the bulb. The slices so obtained were weighed and dried, first at a low temperature for a short time and then at 80° C., until the difference between two successive weighings was slight.

The dried "flesh" was ground to a powder and thoroughly mixed. Small quantities - about 3 grams - of this powder were boiled with 200 c.cs. of 2 per cent. hydrochloric acid. In this process any complex sugars present are hydrolised, i.e. are converted into simple sugars, and hemicelluloses and other readily hydrolisable polysaccharides are also converted into simple sugars. A certain amount of starch was present in the tissues of the bulb during spring and summer and up to the beginning of October. This carbohydrate was, however, practically absent from then onwards. "Carbohydrate" as used hereafter in the present paper must therefore be understood to include not only the simple reducing sugars, but also any Fehling-reducing substances produced as a result of the treatment of the dried pulp with dilute acid. It corresponds to the "readily soluble mater" of Fruwirth ("Handl der landwirt. Pflanzenzurch.") A priori, this might be supposed to correspond roughly to the material digestible by herbivorous animals - which includes more than the simple sugars - but this is one of the points which can be settled only by means of feeding experiments combined with detailed chemical analysis. The percentage of carbohydrate present on the various dates is shown in Table III.

Table 9.

Table showing the percentage of carbohydrate present at different stages in the development of the crop.

Date.	Percentage of carbohydrate.
Aug. 17th	4.2 per cent.
" 31st	5.1 " "
Sept. 14th	6.8 " "
" 28th	6.6 " "
Oct. 30th	Sample over-dried.
Dec. 4th	5.9 per cent.
Jan. 15th	5.1 " "
Feb. 12th	4.9 " "

The advantage of not only taking similar samples but also weighing each sample before analysis is that one can calculate the actual amounts of dry matter and of carbohydrate present in the crop at different periods, and can from these figures indicate the relative values of the crop at different times in its growth. Table IV shows the actual amount, in lbs., of dry matter and of carbohydrate respectively present in 50 swedes at different stages in their development.

Table 10.

Date.		Amount of dry matter.	Amount of carbohydrate.
Aug.	17th	8.8 lbs.	3.4 lbs.
"	31st	10.8 "	5.1 "
Sept.	14th	13.8 "	8.3 "
"	28th	15.9 "	9.2 "
Oct.	20th	-	-
Dec.	4th	24.9 "	14.6"
Jan.	15th	23.2 "	12.3 "
Feb.	12th	21.3 "	11.5 "

It will be seen from the figures in Table IV that the actual amounts of dry matter and of carbohydrate present in the Swede bulbs are greatest in both cases at the beginning of December, and that they tend to diminish during December and January. This result was borne out by parallel sets of figures obtained for bulbs of the same variety of swede which were grown under slightly different cultural conditions (see above).

Conclusions. A consideration of the figures contained in Table I leads one to the conclusion that as far as the actual weight of the crop is concerned the longer swedes of the "Scotia" type are left in the ground the better, at least up to about the middle of December or so.

A comparison of the figures in Table I with those in Table IV shows that for Swedes of this type bulbs of the greatest feeding value - assuming that the feeding value is indicated by the amount of carbohydrate present - would be obtained if the crop were harvested about the beginning of December. If the crop be left in the ground after that time the amounts both of dry matter and of carbohydrate tend to diminish very rapidly. Naturally, these conclusions apply only to swedes of the "Scotia" type; "early" swedes, e.g. of the "Superlative" "~~Scotia~~"type, probably contain the greatest amount of carbohydrate and of dry matter at an earlier date. It must also be borne in mind that the results summarised in this paper apply to a particular season and to particular conditions of cultivation.

Another point of considerable practical interest arises out of a consideration of the figures in Tables II and III. From these it will be seen that from the point of view of "quality" - as judged by the percentage either of dry matter or of carbohydrate content - the swedes were of better "quality" at the middle or end of September than they were at the beginning of December. In other words 100 swedes contained approximately 18 lbs. of carbohydrate at the middle of September and 28 lbs. of carbohydrate at the beginning of December; 100 lbs. of swede pulp, on the other hand, contained about 6.8 lbs. of carbohydrate at the middle of September but only 5.9 lbs. of carbohydrate at the beginning of December.

Furthermore, it will be seen that there is a definite scientific basis for the practical growers' contention that the "Scotia" type of swede matures relatively late in the year. The weight of the bulbs continued to increase, in this instance, up to the middle of December. The percentage of dry matter, on the other hand, fell steadily from the middle of September onwards, and the percentage of carbohydrate began to diminish a fortnight or so earlier. The final two months of "growth" of the bulbs thus consisted essentially in an active absorption of water.

S U M M A R Y.

The difficulty of discovering the ancestor of the Swede Turnip is first stressed and the early literature examined to find if any of the references give a clue to the possible source. The Common Turnip has been known and cultivated from the earliest times but the Swede appears to have come into cultivation in Britain in the middle of the eighteenth century. Writers who have discussed the introduction of the Swede have, however, rather complicated, than simplified the problem by reason of the fact that the nomenclature has been most confused-especially as regards the botanical name for this plant. There is little doubt that the introduction of the Swede into farming practices had a great influence on the agriculture of this country and it is, therefore, the more remarkable that it is possible to find, at this time, no direct reference to its appearance. Sinclair, one of the most critical observers, suggests that it is a mutant - "an accidental variety" and he wrote only a few years after its introduction. Lists of the Common Names and of the Botanical Names are here given, together with the source so far as it is possible. These give some idea of the complicity of the problem of discovering the ultimate origin of the plant.

In the next Section the History of cultivation is mainly considered. A study was made of the literature dealing with the agricultural practice of a century and a half ago. The modern practice is also discussed to illustrate the changes in

cultivation that have taken place in the last few decades. The climatic and geographic factors are discussed thereafter, and the average acreage under Swede in the various districts in Britain tabulated.

The Third section is devoted to a description of the development of the plant, the increase in fresh weight of the leaves and of the bulbs and kindred problems. The extraordinary confusion which exists in the classification of the different varieties in this as in most of the agricultural crops is emphasized and an effort is made to classify some of the main types of Swede commonly grown. The number of so-called varieties increases enormously from time to time by reason of the lack of any standards for classification. The whole situation is rendered more difficult by our almost complete ignorance of the genetical aspects of the problem and the inheritance of even the more obvious characters. It is abundantly clear that this problem is one which requires immediate and detailed consideration.

The morphological characters of the whole plant, leaves, seed,neck, and bulb are described fairly fully. The development and distribution of Stomata on the two sides of the leaf, at different stages, the occasional presence of large spines on the midrib and the distribution of the hydathodes are all discussed. The formation of an elaborate storage organ by the hypertrophy of the xylem of a stem-hypocotyl-root system is dealt with. In this connection attention is paid to the development of the stele from the stage with a single protoxylem plate, and the consequent development of the rows of lateral roots is noticed. In no other plant, possibly, does such a large storage organ develop in so short a time by the activity of a single ~~x~~vascular cambium and this is probably associated with the ~~trad~~ tendency of the parenchymatous cells of the xylem to divide secondarily more or less irregularly.

The last section is devoted to a study of the metabolism of the Swede. The work of Pederson, and others on growth curves is touched on. Thereafter the variation in the Carbohydrate Content throughout the season is examined and the data tabulated.

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Frequent reference was made to the standard textbooks (eg. Haberlundt, Strasburger etc.) but it was not thought necessary to detail these in this list.

Fig. I.

Photograph of Swede Turnips in the middle of the second season showing the "bulb", stems, inflorescence etc. (X 1/10 approx.)

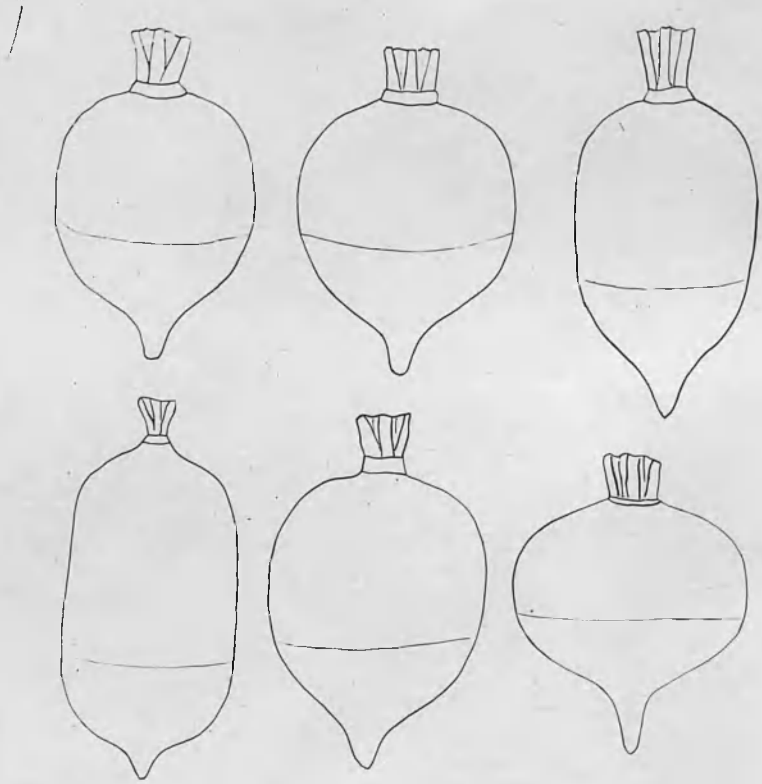


Fig. 2. Outline drawings of Swede bulbs showing the varieties of shape - Globe, Round, Tankard and intermediate types.

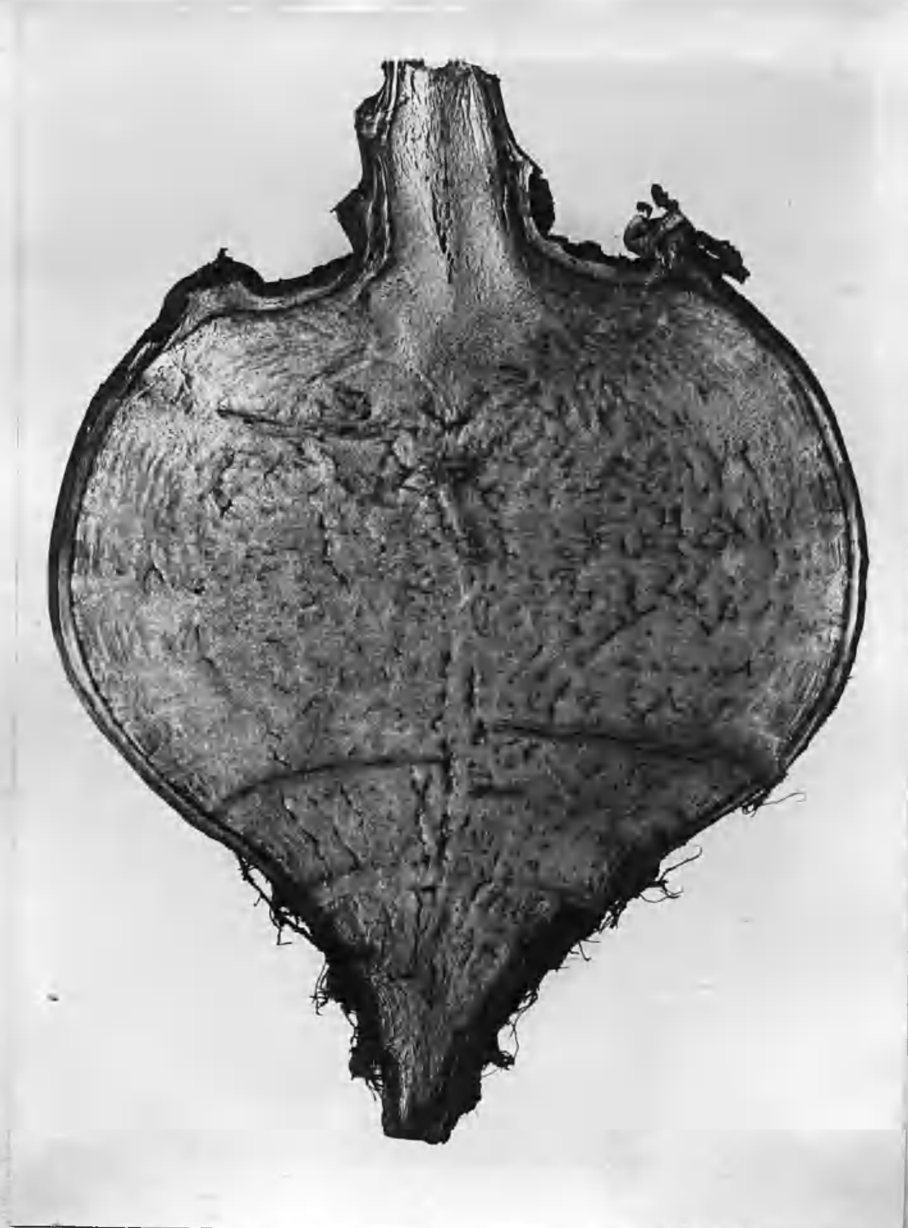


Fig. 3. Photograph of Swede "bulb" cut in plane of main lateral roots - the vascular tissue being stained in Eosin. The pith region in the neck is clearly seen. (X $\frac{1}{2}$).

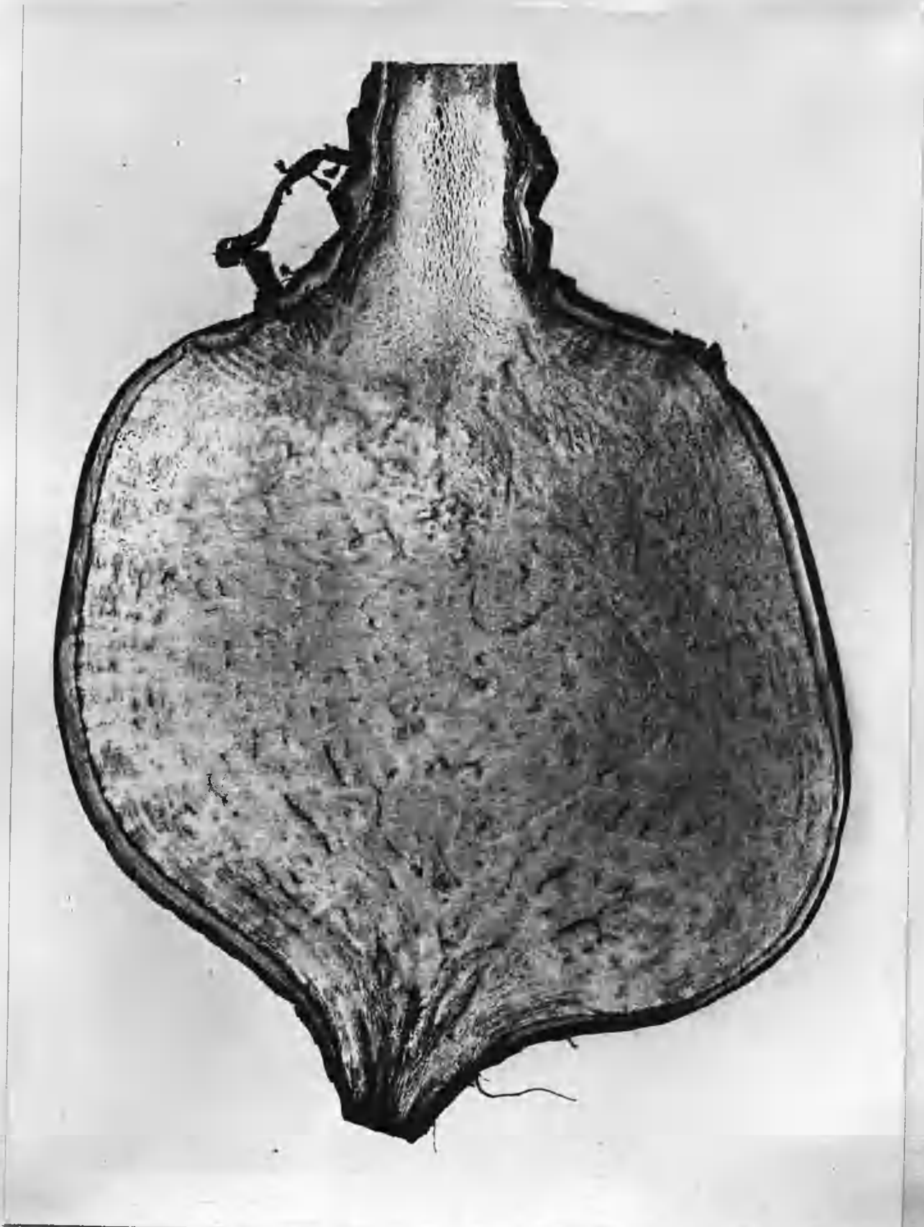
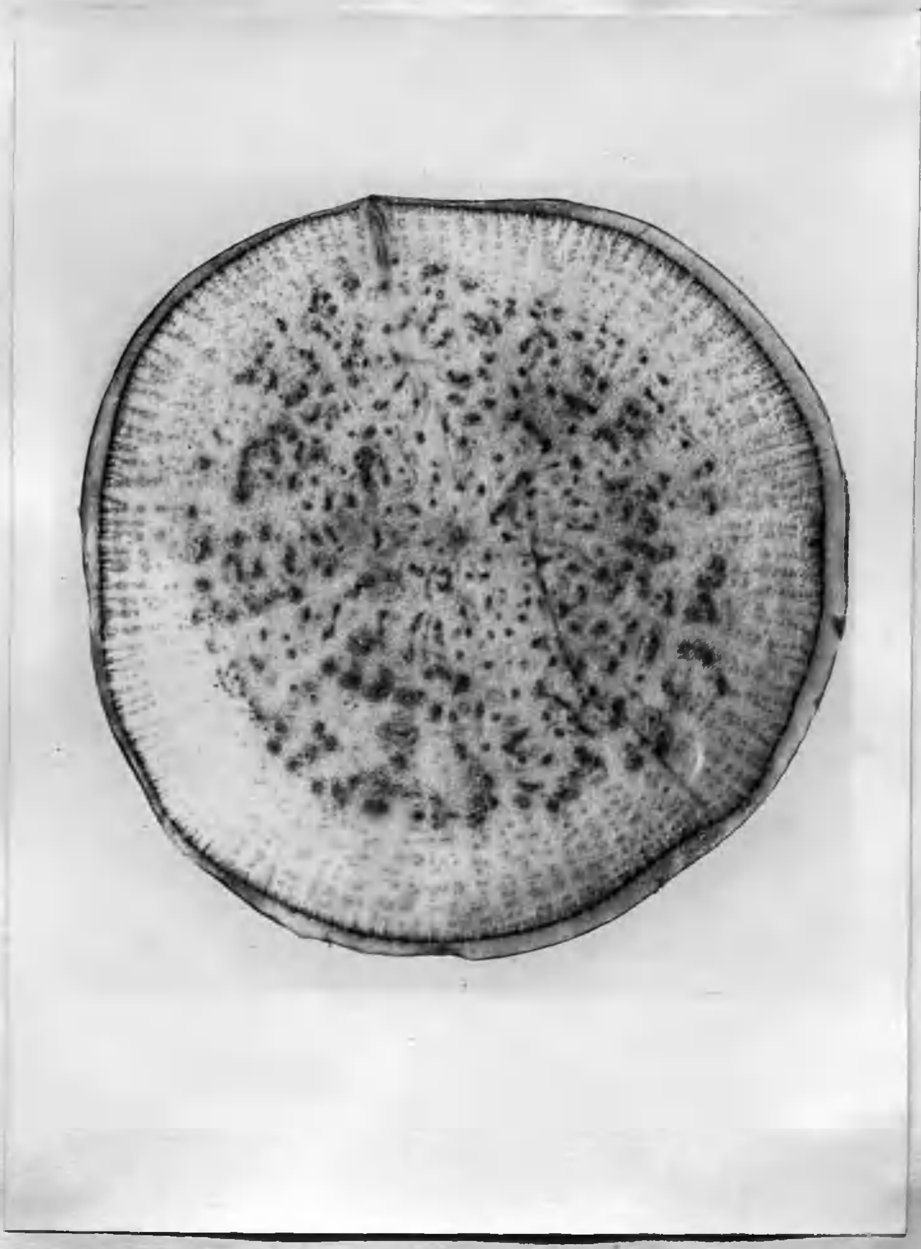
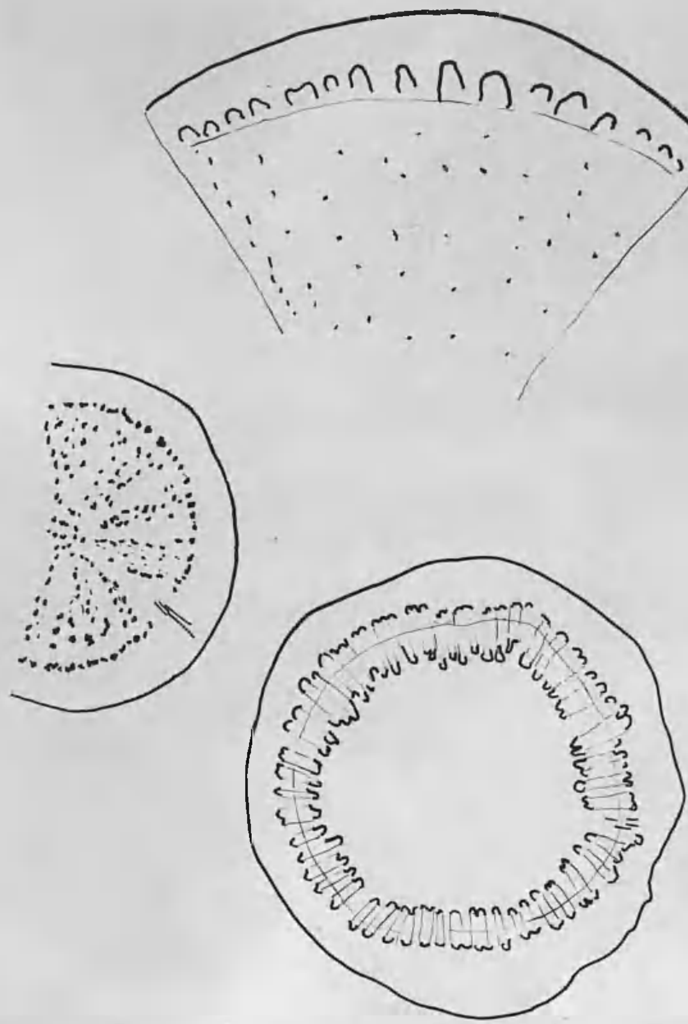


Fig. 4. Photograph of Swede "bulb" cut in plane at right angles to the main lateral roots. (X $\frac{1}{2}$). (Treated with eosin).



<u>Fig. 5</u>. Photograph of Swede "bulb" cut transversely to show the groups of lignified tissue in the xylem.

(Treated with Eosin) (X ½).



<u>Fig. 6</u>. Diagram showing the occurence of vascular tissue in (a) the root. (b) the bulb. and (c) the neck.
(various magnifications).

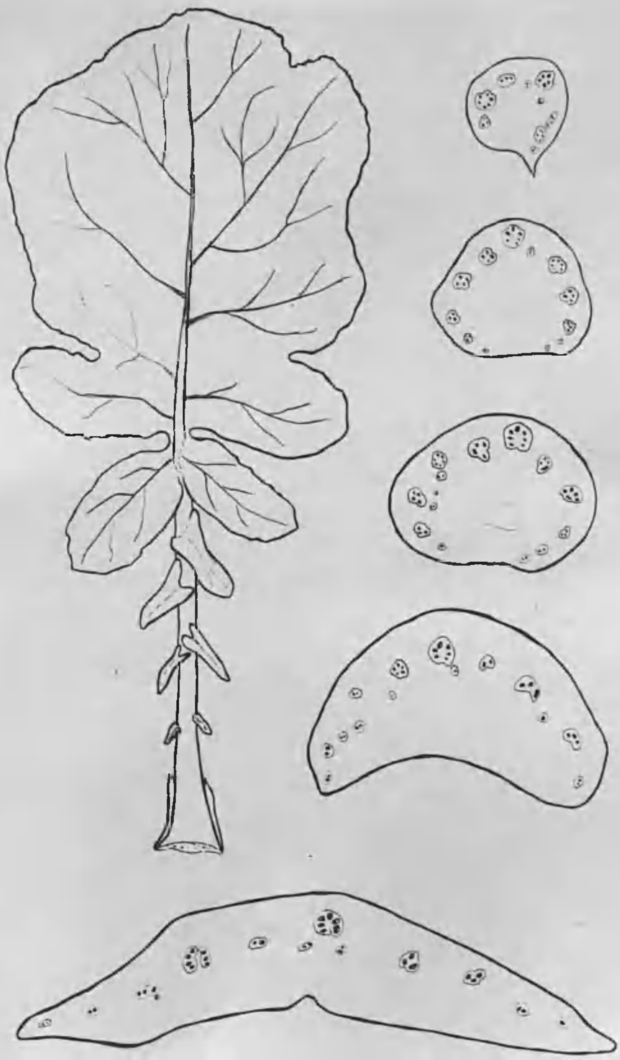


Fig. 7. Diagram of leaf ($\frac{1}{5}$ nat. size) showing lamina petiole and folioles, and of sections of the petiole at various parts. (X 2).

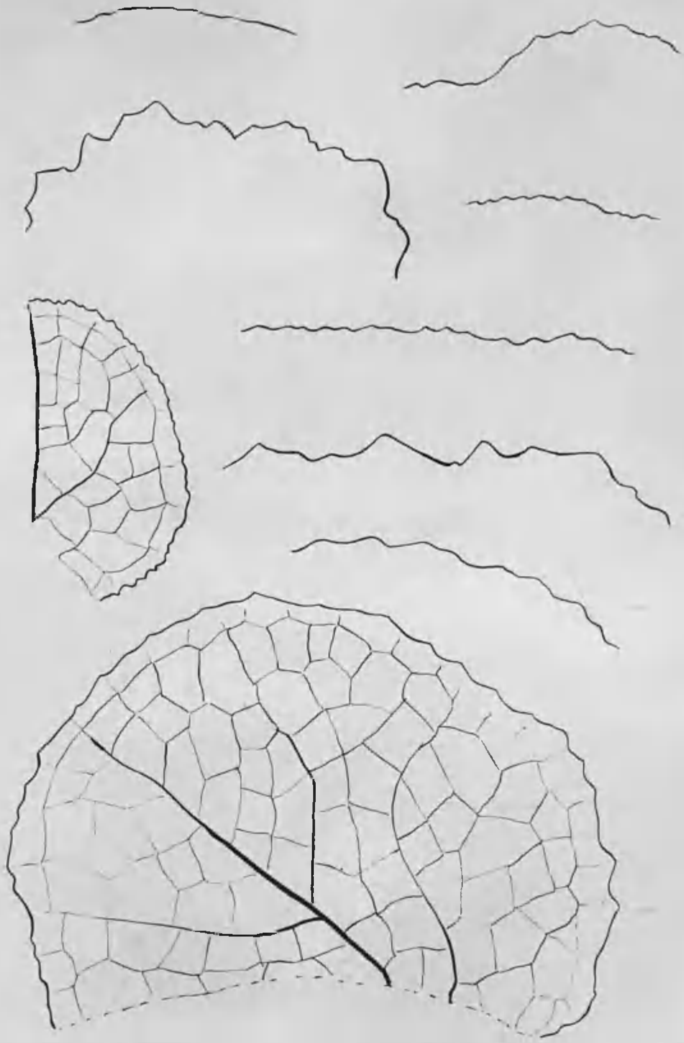


Fig. 8. Diagram illustrating (a) the various types of leaf margin found, and (b) the similarity between the margins of two leaves of same plant.

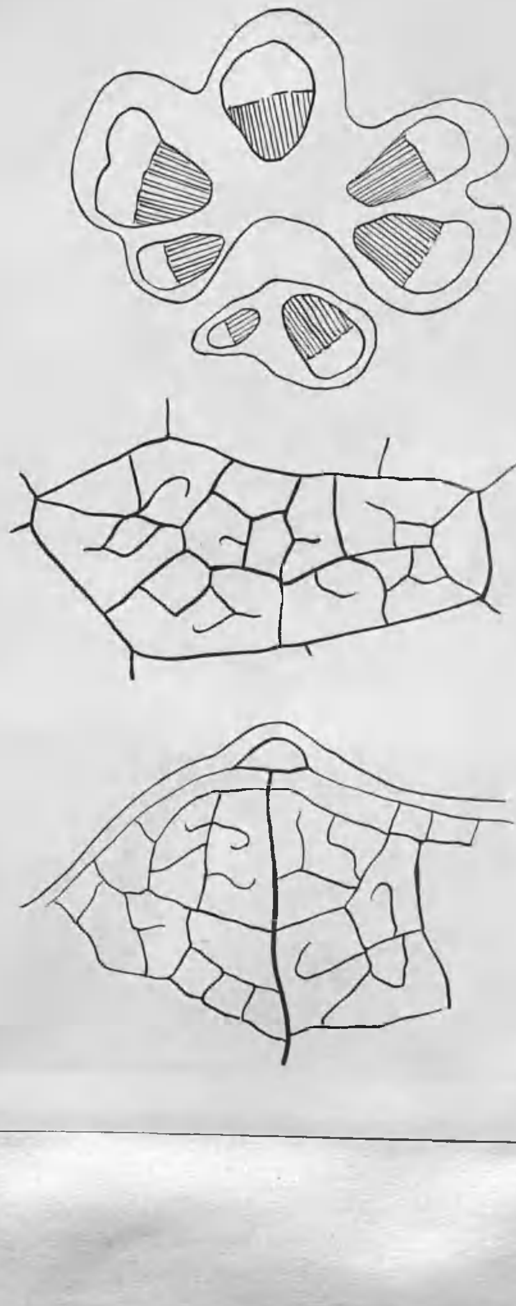
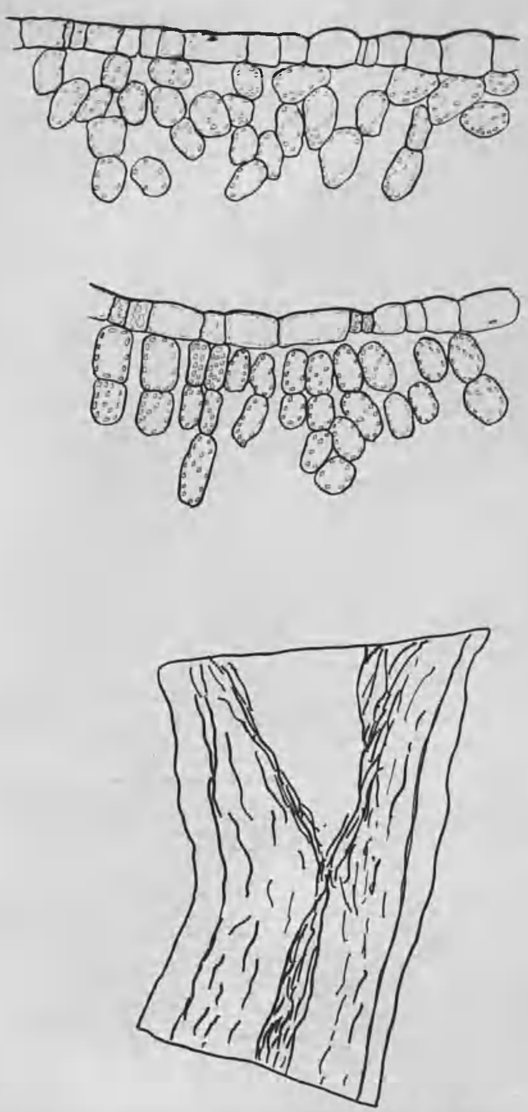


Fig. 9. Diagram of (a) single vascular bundle in petiole showing the "compound" type. (b) portion of vascular reticulum on the leaf lamina and (c) the vascular connections of a hydathode. (X 45).



<u>Fig. 10</u>. (a) Portion of T.S. of lamina of a young leaf on (1) the abaxial (2) the adaxial side. (X 250)

(b) Long. Section through the "neck" of a young "bulb".

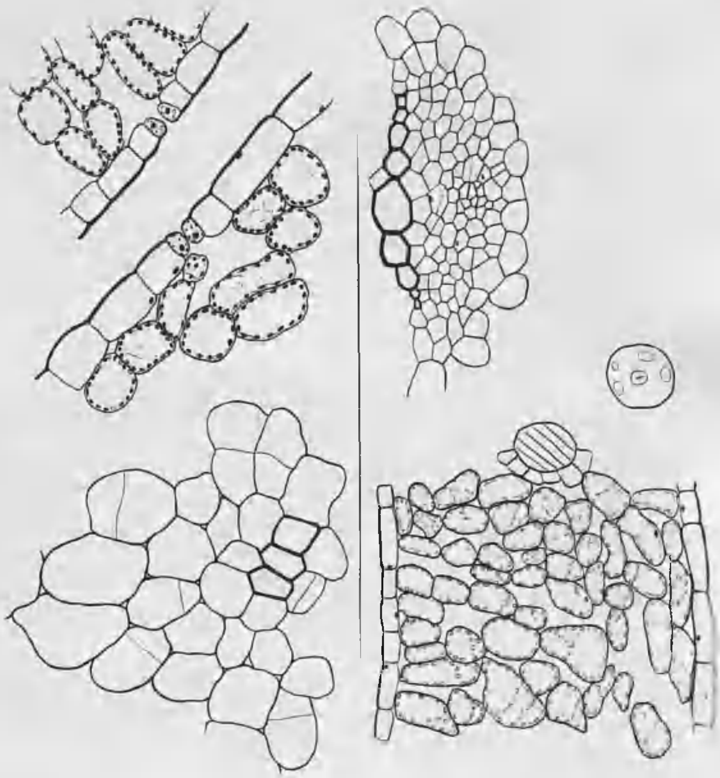


Fig. 11.

Diagram representing -

(a) The upper and lower epidermis of the Lamina in T. S.

(b) The protoxylem plate of a young Swede "bulb".

(c) The lamina in T.S. - showing the feeble development of the palisade tissues, and

(d) A group of lignified cells in the xylem area of a maturing Swede - showing the secondary cell division which takes place in the parenchyma cells.

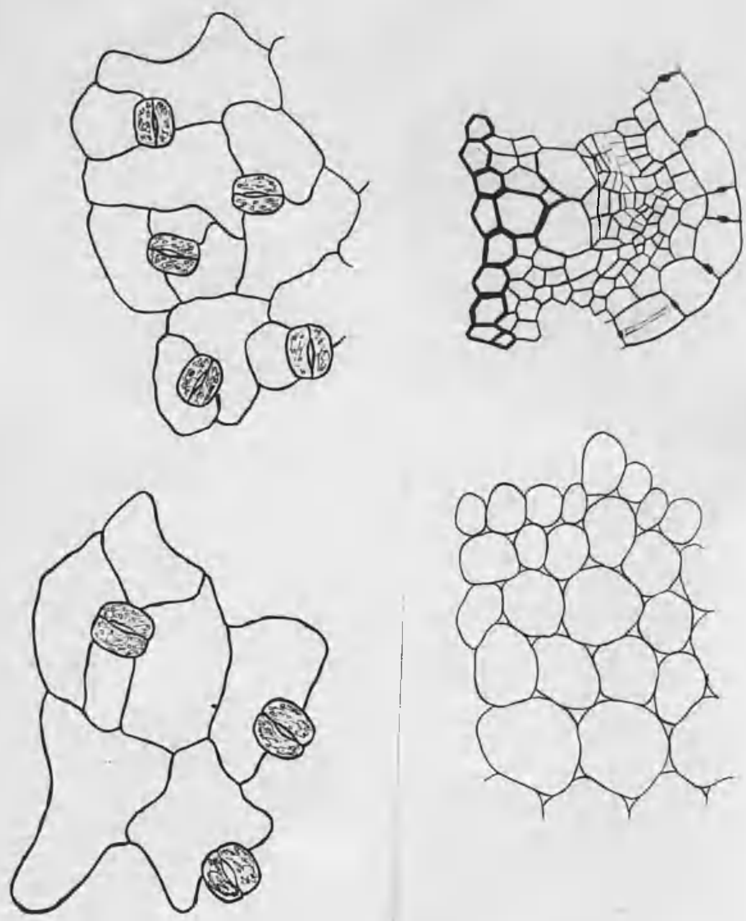
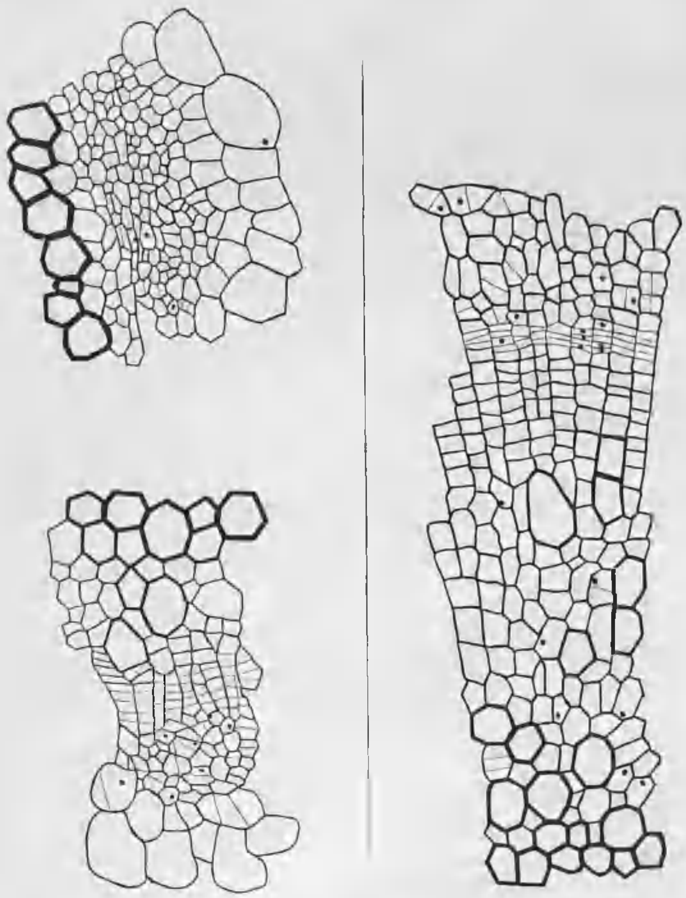


Fig. 12. Diagram showing -

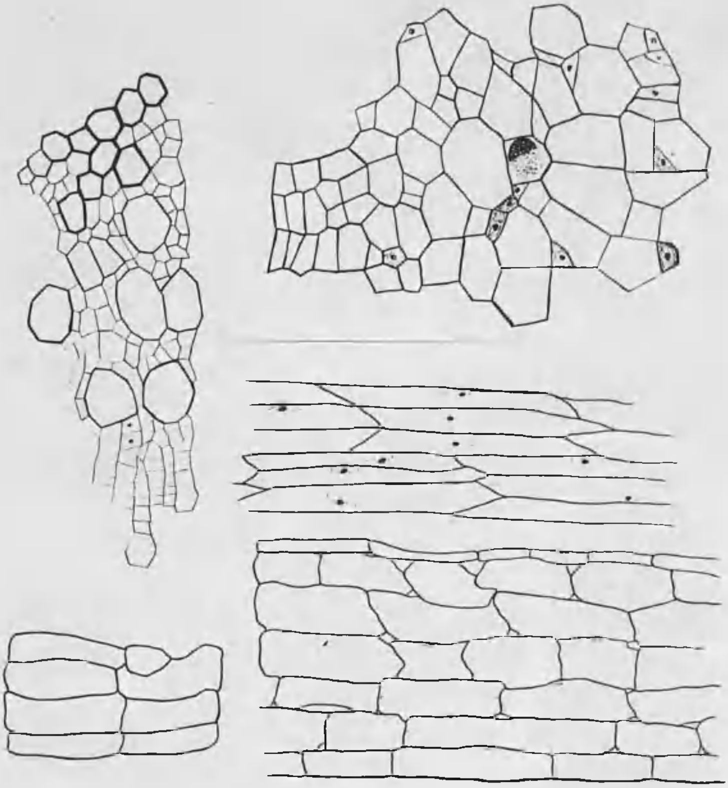
(a) The upper (1) and lower (2) epidermis of the lamina. (x 300)

(b) The well marked Casparian Strip on the Endodermal cells of of the young Stele. (x 350)

(c) The part of the primary cortex of the young Swede "bulb". (x 350)



<u>Fig. 13</u>. Diagrams representing the development of the Stele of a Swede "bulb". (continued on Fig. 13). (x 250)



<u>Fig. 14</u>. Diagrams representing ;-

(a) The stele of a developing bulb. (see fig. 13).

(b) The phloem of the above stage (much enlarged).

(c) The ~~R~~ Cambium of the same stage in Tang. Section.

(d) The Cortex in Tang. Section.

(e) The Endodermis in Tang. Section. (x 400)

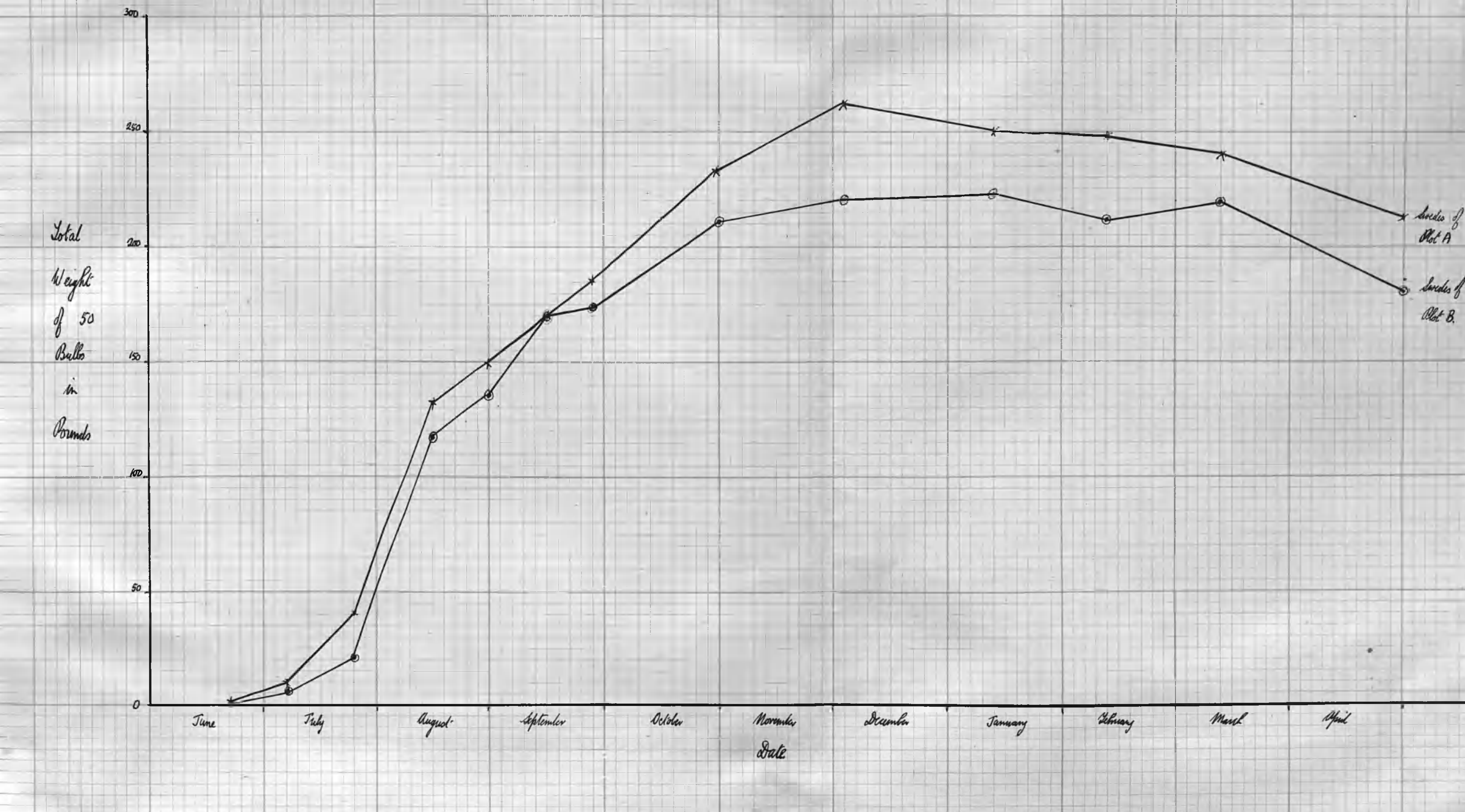
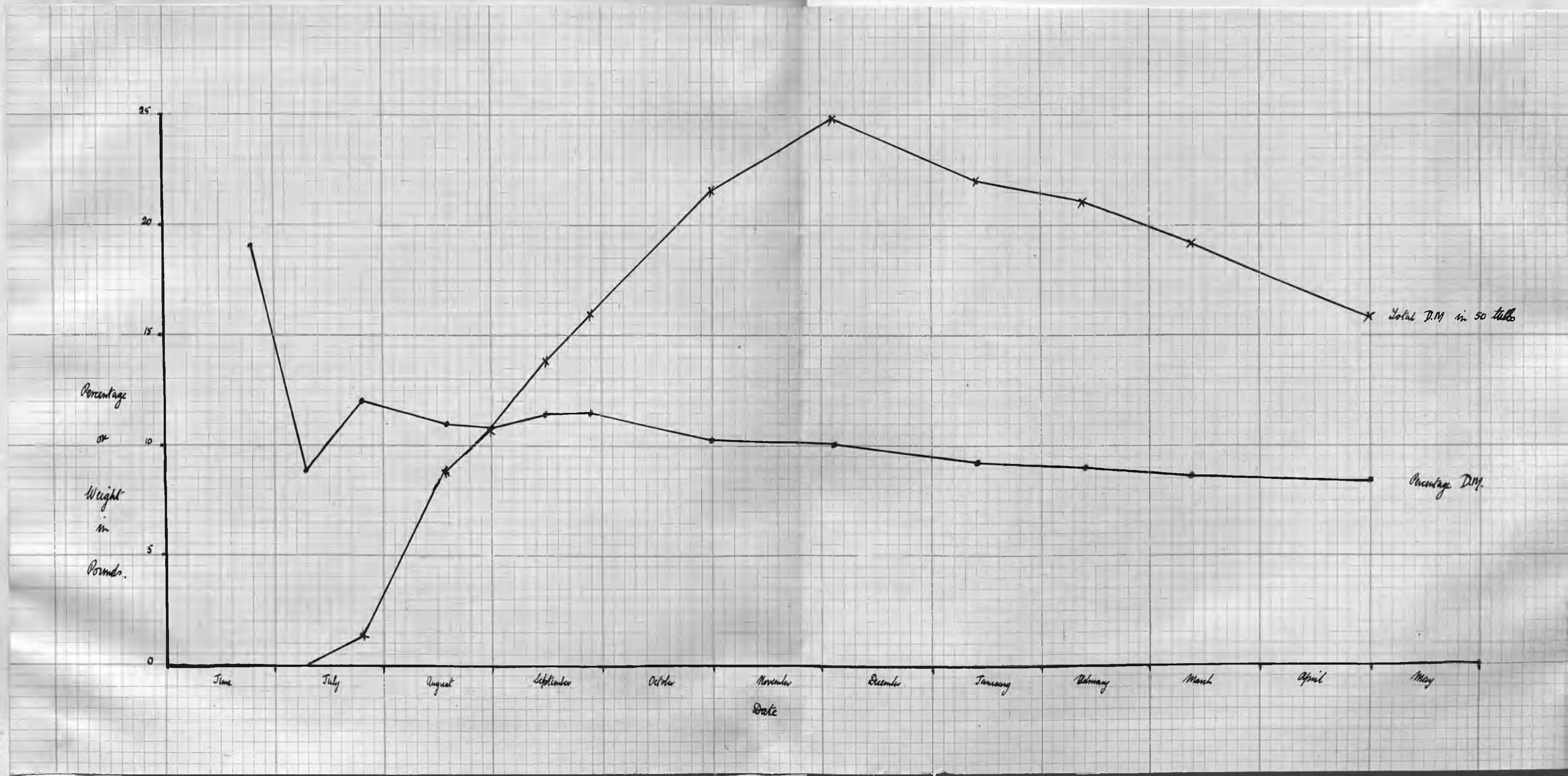


Fig. 15.

Graph of Fresh Weight of Swede Plants.

(see Table 6)



<u>Fig. 16</u>. Graph of Percentage and Total Amounts of Dry Matter in 50 bulbs. (see Table 7).

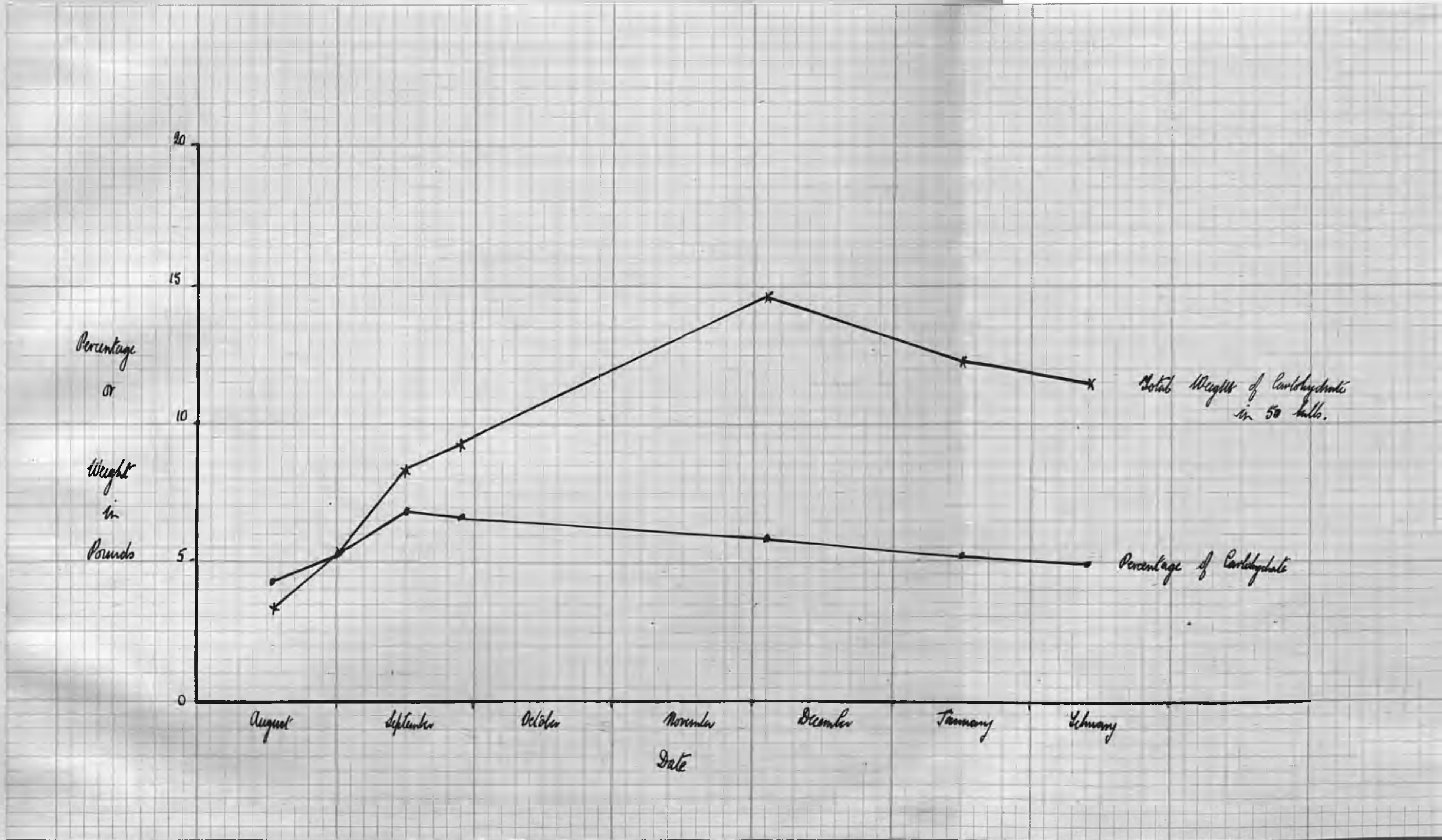


Fig. 17.

Graph of Percentage and Total Amounts of Carbohydrates present in 50 bulbs at different stages.

(see tables 9 and 10).