uncompromisable values that have characterized the best of the Indian civilization down the ages.

Amar Chand Joshi deserved the highest honour which his country could confer upon him as a renowned botanist and educationist and as builder of the most modern university campus, the Panjab University, Chandigarh. However, with all the qualities he possessed, he had too much integrity of thought and action to kow-tow to politicians, and thus he had no place in the rat race. He was always cool and calm and never allowed his judgment to be coloured by passions of politics and religion. He was fairminded, and had a sense of justice. That is why he managed to select highly talented people for the professorships which he created. He will be long remembered by his friends and students as a great Indian and as a great son of the Panjab. His memory should be perpetuated by building a suitable memorial in his honour in Panjab University, Chandigarh which he built up from scratch, and also in the Guru Nank University whose development he fostered by his mature advice.

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MORPHOLOGICAL STUDIES IN THE FAMILY CONVOLVULACEAE

II. MORPHOLOGY AND ANATOMY OF THE TUBER OF *IPOMOEA BATATAS* LAMK[1].

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ABSTRACT

The primary root in *Ipomoea batatas* is tetrarch to hexarch. The early secondary growth is normal in fibrous as well as 'would be' fleshy roots. But in the later stages of development the root that is destined to become fleshy shows more of secondary xylem parenchyma.

The tuberisation is caused by the activisation of xylem parenchyma cells and the cambium cells. The xylem parenchyma cells form a number of 'meristematic' strips which add more and more parenchymatous cells. The starch grains accumulate in the storage cells quite early.

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The author is indebted to Prof. V. Puri, Institute of Advanced Studies, University of Meerut, for suggesting the problem and kind encouragement; Dr Y. S. Murty of the same Institute, for guidance and to the concerned authorities of Meerut College, Meerut, for providing all facilities for the work.

The fleshy roots of *Ipomoea batatas* develop lateral shoot buds when grown in soil. These shoot buds like the lateral roots arise endogenously but from the cortical cells which are 5–6 layers below the epidermis. Their initial cells arise de novo. The sequence of development and their arrangement on the tuber is noteworthy.

INTRODUCTION

Ipomoea batatas is distinguished from other members of the Convolvulaceae the development of fleshy under-ground tubers formed by a peculiar anomalous secondary growth and its anatomical structure. Also, these fleshy tubers, when grown in the soil, develop the lateral shoot buds, like the Irish potato. The morphological nature of these tubers, whether root (Mc Cormick, 1916; Artschwager, 1924; Hogue, 1931) or stem (Tuyihusa, 1914; Kamerling, 1914) has been argued in the past. A perusal of the relevant literature reveals that there are certain lacunae, left here and there, which require a further intensive study to have a better understanding of the problem. The author, on the suggestion of Professor V. Puri took up this problem and tried to fill up the gaps where ever possible.

MATERIAL AND METHODS

The roots and tubers of different thickness were collected from the field and fixed in F. A. A. For the development of the lateral shoot-buds from the tuber, the mature tubers were grown in sandy soil and buds in different stages of development were fixed in F. A. A. Following the customary methods of dehydration and embedding the material was sectioned at 8–15 μ thick. The slides were stained with safranin-fastgreen combination.

OBSERVATIONS

All nodes except five or six towards the apex have the potentialities to develop adventitious roots. Usually two adventitious roots arise from each node out of which one becomes fleshy and the other fibrous. In the later stages of maturation the normal root becomes fibrous and functions as an absorbing organ while the would-be fleshy root becomes fusiform or irregular in size and shape. The lateral roots arising from depressions of the fleshy roots are rudimentary and short lived. The surface of the fleshy roots is rough due to these depressions and the ruptured skin (Fig. 1).

Primary structure and early secondary growth.—The primary structure of the normal root and the would-be fleshy roots is similar. In a transverse section the roots are tetrarch or pentarch with a common metaxylem element in the centre (Fig. 2). The phloem and protoxylem elements are separated by parenchymatous cells. The phloem is poorly developed and encloses a latex canal (Figs. 2, 3). The endodermis is single layered surrounding the single layered pericycle. The cortex is well developed and is enclosed by a well developed epiblema.

The early secondary growth is similar in both the normal and fibrous types of roots. The tissue cut off from the cambium on the inner side in either case mainly matures into thick-walled xylem elements while in a root which would become fleshy, the inner secondary tissue consists of the xylem elements segregated by the patches of parenchymatous cells (Figs. 4–6). The difference between the two becomes more evident as more and more secondary growth takes place (Fig. 7).

Further in a would-be fleshy root starch grains appear early in the parenchymaous cells becomes clear (Fig. 8).

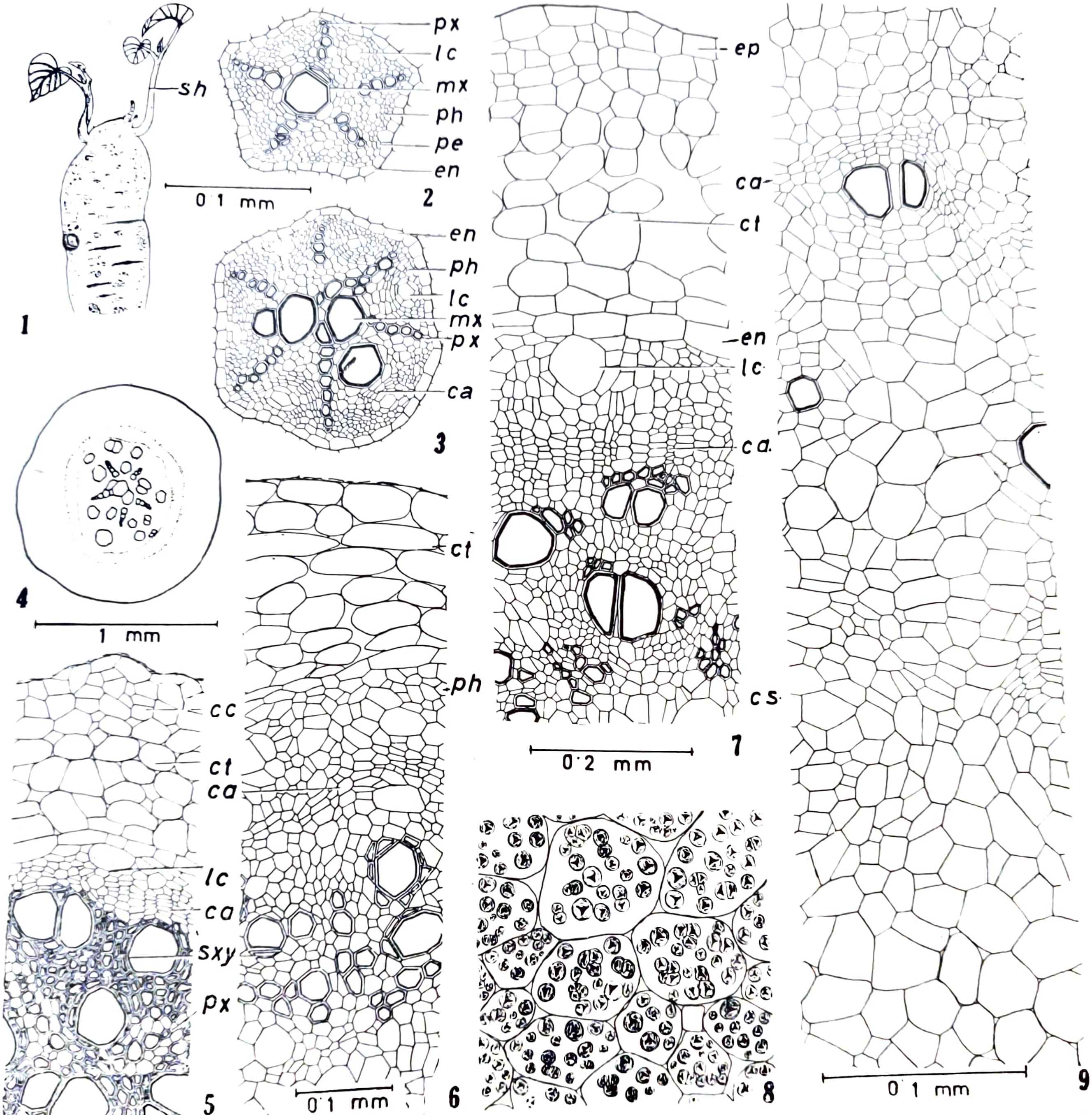
After a considerable amount of secondary tissue is added, the cells just below the epiblema become meristematic and arranged in 2 or 3 layers (Figs. 5, 7). They cut off cells mostly towards the inner side and add to the thickness of the cortex there by rupturing the epiblema.

Tuberisation.—The development of the fleshy root begins in the early stages of the secondary growth. The complete cylinder of the secondary cambium continues its activity up to the last (Fig. 9). The cells which are cut off on the inner side of this cambium differentiate into parenchyma surrounding a few tracheids and vessels. Simultaneously, the parenchymatous cells present around the primary and secondary xylem groups become meristematic and arrange themselves in tangential rows. To start with they are one layer thick but later on form a tangential band of meristematic strips of appreciable width. These cambia or meristematic strips cut parenchymatous cells on either side in greater quantity thereby separating further the xylem groups. In later stages of development more and more such cambial strips are formed independent of the vascular groups already present. Finally each newly formed xylem group or individual vessel or tracheid gets surrounded by a complete or partial ring of meristematic strip which produces new elements of parenchyma in a regular manner. Bulk of the root tissue increases by the activity of a number of such meristematic strips (Fig. 9).

Along, with the activity of these cambia in the centre, the phellogen originating in the sub-epidermal region also keeps pace and helps in increasing the surface area of the root. It cuts more and more cells on the inner side to add tissue to the cortex. Further increase in the surface area of the root is brought about by the tangential enlargement of the cells of the cortex.

Thus a fleshy root of about 3–4 cms, in diameter shows in a transverse section an outer phellogen layer covered with the ruptured epiblema. The phellogen is a 5–7 layered structure consisting of rectangular cells which are tangentially elongated. Inner to the phellogen is a zone of secondary cortex, which consists of large parenchymatous cells which are tangentially elongated and are filled with starch grains. There are present certain latex cells and cells containing crystals of oxalate of calcium. The primary and secondary cortex cannot be demarcated. The secondary phloem is poorly developed and is present in patches having only a few phloem elements. The secondary tissue consists mostly of the parenchymatous cells rich in starch grains, and of a few xylem vessels and tracheids. The peripheral storage cells like the cortical cells are also tangentially elongated with intercellular spaces. The larger vessels and tracheids are mostly surrounded by rings of meristematic strips which owe their origin to the parenchymatous cells of the secondary tissue, cut off by the secondary cambium. At this stage it becomes difficult to mark the position of the primary xylem (Fig. 9).

The starch grains appear quite early in the development of tuberous structure. A root which is about one to two millimetres in diameter shows abundant development of starch grains in parenchymatous cells. They are dis-



FIGS. 1–9. Development of tuber in *Ipomoea batatas*. Fig. 1. Mature tuber with 'sprouts' Fig. 2. T. s. Primary root, stelar region. Fig. 3. T. s. root showing differentiation of cambium. Fig. 4. Outline diagram of the T. s. of normal root. Fig. 5. A portion cellular in T. s. of the normal root. Figs. 6, 7, 9. Portions in T. s. of different sizes of the developing tuber. Fig. 8. Storage cells with starch grains.

ca, cambium; *cc*, cork cambium; *cs*, cambial strip; *ct*, cortex; *en*, endodermis; *ep*, epidermis; *lc*, latex canal; *mx*, metaxylem; *pe*, pericycle; *ph*, phloem; *px*, protoxylem; *sh*, shoot; *sxy*, secondary xylem.

tributed in all the regions of the root. There are as many as 10–15 simple or compound starch grains in each cell (Fig. 8). Besides the starch grains a large number of stellate calcium oualate crystals are also noticed in cortical and secondary parenchymatous cells.

Development of lateral buds.—The lateral structures that develop from roots are either the normal type of lateral roots or the shoot buds. The shoot buds are developed from the fleshy tubers only.

Development of lateral roots is typically angiospermous. A group of three or four cells of the pericycle opposite the protoxylem elements form the lateral root and bud initials (Fig. 10). They elongate radially and become distinct from the rest of the neighbouring cells. These cells undergo periclinal and anticlinal divisions and produce the lateral root primordium (Figs. 11, 12). Side by side the endodermal cells also divide anticlinally to keep pace with the developing primordium, but ultimately it ruptures and the primordium penetrates into the cortical cells. Before the primordium emerges out on the surface of the parent root, the apical meristem, the primary tissue region of the young root axis and the root cap become differentiated (Figs. 13, 14).

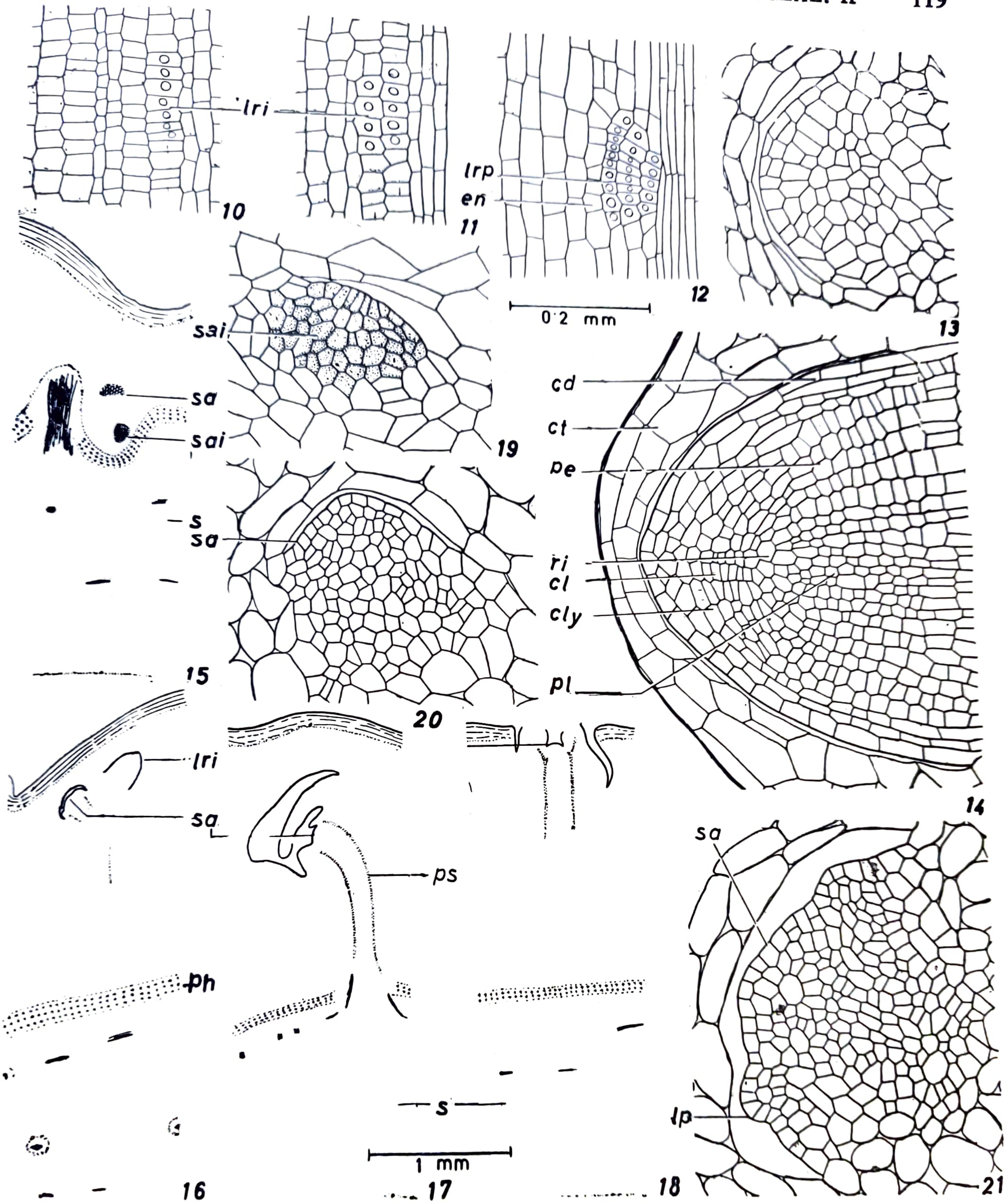
The fleshy roots of *Ipomoea batatas* sprout into shoots when grown in the soil. This character is common in the tubers of certain other plants; but there the dormant buds are already present in depressions as in potato tubers; but in *I. batatas* no such buds have been noticed. It is also interesting to note that the shoots that sprout from the fleshy roots are arranged in longitudinal rows. The number of these rows corresponds to the number of protoxylem groups. The arrangement of these shoots is acropetal, that is the youngest towards the proximal end and the oldest towards the distal end of the fleshy root (Fig. 1). Polarity of the shoot is fixed and does not change even if the roots are sown upside down.

A group of initials differentiates four or five cells below the phellogen in the cortex of the tuber (Figs. 15, 19). These initial cells divide both anticlinally and periclinally and soon organise into a shoot apical meristem (Figs. 16-20). The cells of the cortex surrounding the apex disorganise and a space is formed for the growing apex (Figs. 17, 21). As many as two or three leaves may be differentiated while still in the cortical region. The growing apex bursts out and develops into a normal shoot (Fig. 18). The vascular supply to the shoot is derived from the secondary peripheral xylem tissue (Fig. 17). On the other hand lateral roots receive their supply from the primary xylem. As the fleshy root grows the lateral roots become inactive and their vascular traces lose their connection with the primary xylem.

Discussion

A critical review of the observations recorded above reveals that there are some points that can profitably be discussed at some length. For instance, the tuber, that is structurally a root and functionally a stem in so far as it bears lateral buds, deserves some critical attention; the development and the origin of these buds is interesting in the sense that they arise acropetally in rows of four or five on the tuber.

In the process of tuberisation of the root the cells cut off on the inner side of the cambium are mostly thin walled,



FIGS. 10–21. Lateral Root and shoot bud development. Figs. 10-14. T. s. of the young roots showing different developmental stages of the lateral root. Figs. 15-18. Outline diagrams of mature tuber in T. s. showing developmental stages of lateral shoot buds. Figs. 19-21. Same in the cellular diagrams.

cd, calyptrodermatogen; *cl*, columella; *ct*, cortex; *cly*, calyptrogen; *en*, endodermis; *lp*, leaf primordium; *lri*, lateral root initials; *lrp*, lateral root primordium; *pe*, periblem; *ph*, phloem; *pl*, plerome; *ps*, procambial strand; *ri*, root initial; *s*, storage tissue; *sa*, shoot apex; *sai* shoot apex initial.

parenchymatous and only few cells out of them get thickened to form secondary xylem. These cells later on become meristemtic and form the cambial strips. The bulk of the tuber increases due to the meristematic nature of these strips and the enlargement of the resultant cells.

McCormick (1916) has also reported a similar mode of tuberisation in this species. On the contrary, Artschwager (1924) remarks, "the enlargement of the young roots into fleshy roots is initiated at a very early stage in the development of the root, and always precedes the differentiation of xylem on the inner face of the protoxylerm groups". However, the present investigation does not reveal this activity of parenchymatous cells prior to the differentiation of xylem elements on the inner face of the protoxylem groups.

It is interesting to note that in spite of enormous growth in central cells, there is no crushing or disorganisation of the peripheral cells which is normally seen in roots and stems. In *Ipomoea batatas* such a distortion or crushing of cells is avoided by the development of phallogen which adds new tissue on the inner side thus increasing the surface area of the tuber. Further increase in surface area is aided by the enlargement of the cortical cells of the tuber. These cells enlarge tangentially and show large intercellular spaces. Thus increase in the number of peripheral cells and their enlargement keeps pace with the addition of the tissue in the central region by the numerous meristematic strips.

Artschwager (1924) has also referred to the origin of primary, secondary and tertiary cambia in the process of tuber formation. He has named these cambia on the basis of their sequence of development. But as has been noticed here, the cambial strips inner to the secondary cambium do not have any regular sequence of development and may arise from the secondary tissue. They are active at one time and inactive at another. Therefore, such strips cannot be termed as primary or secondary cambia. However, development of supernumerary secondary and tertiary cambia are known in roots of *Raphanus sativus* (Hayward, 1948) and *Beta vulgaris* (Artschwager, 1926). But in all these cases such cambia are well organised showing a clear sequence in their development either from the pericycle cells or the cortical cells outside the secondary cambium. Such a feature is not met with in *Ipomoea batatas*.

Endogenous origin of shoot bud from the tuber.—Mature tubers of *Ipomoea batatas* when sown in moist, soil develop certain buds which grow into new plants. Such shoot buds have been mentioned earlier by Kamerling (1914) and Mc Cormick (1916) also. It is interesting to note that the development of these buds is acropetal and they are arranged in definite rows corresponding to the protoxylem groups inside the tubers.

Several examples are on record where buds are developed from the roots Begenrick 1887; Irmisch 1957). Recently Bonnett and Torrey (1966) have described the bud formation from the root in *Convolvulus arvensis*. Earlier authors have also recognised the endogenous formation of lateral buds opposite the protoxylem in *Convolvulus arvensis*.

That the lateral organs in case of root develop mostly endogenously, opposite the protoxylem is true in most of the angiosperms, but such a correlation could not be observed here because the protoxylem groups fade away in mature tubers. However, the occurrence of the sprouts in four or five distinct rows does indicate some relationship with the protoxylem groups.

Such sprouts, occurring as undifferentiated and detached meristems, have been described in rhizomes of *Dryopteris aristata* (Wardlaw, 1949, Cutter, 1956); *Osmunda* (Steeves, 1961) and in root cuttings of *Convolvulus arvensis* (Bonnett and Torrey, 1966). But such a situation does not exist in *Ipomoea batatas*. The present observations reveal definitely that the primordia differentiate from the cortical cells of the mature tuber. The young as well as the old mature tubers before sowing do not shcw these undetermined primordia. Rather the inception of these buds might be caused by certain specific physiological conditions which require more intricate physiological and morphological investigations.

Morphological nature of th2 tuber.—A study of the early ontogeny and anatomy of the tuber reveals that it is a part of the root which due to localized activity and for functional adaptation has become swollen. The presence of shoot buds, the lenticels and the shifting of the position of protoxylem in mature tuber divided the opinion of earlier workers. Vanderwakk 1914, (see Growth, 1911) Mc Cormick (1916), Artschwager (1924) and Hogue (1931) believe that it is a root. The stem nature of the tuber has been advocated by Van Haak 1892, (see Growth, 1911) Kamerling (1914) and Tuyihusa (1914). Van Haak (1892) states that it is a typical example of metamorphosed stem, and compares the sweet potato with that of ordinary potato tuber. According to him, "The naked" tubers of sweet potato and Irish potato show many buds surrounded by minute scales. These buds are called the 'eye', and each one can produce a sprout. Kamerling (1914) on the basis of the sprouted shoots and tubers concludes the organ in question as stem in nature. He remarks that a wrong concept has been transplanted throughout the literature due to the mistake of some earlier authors. It may be pointed out that Kamerling (1914) mainly based his arguments on the anatomy of the mature tuber and thus ignored the basic concept of the root structure where the protoxylem is exarch.

Artschwager (1924) and Hogue (1931) on the basis of the anatomy of the tuber have supported that it is a root and not a stem. They studied the transections of the young and old tubers. Hogue (1931) studied the oblique sections also to confirm the position of the protoxylem. The fact that the metaxylem is in the centre proves beyond doubt that the tuber is a root and not a stem. Further as the shoots arise endogenously and not exogenously as they do in stems, the organ has to be interpreted as of root nature.

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TYPE MATERIAL OF GRASSES IN SOME RUSSIAN HERBARIA[1]

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ABSTRACT

In the year 1969, the author had the opportunity of working in several herbaria of U.S.S R. He examined the type material of the family Poaceae deposited in all those herbaria. The paper gives an account of those type specimens which relate to the grass species occurring in India, and whose duplicate sheets have not, so far, been located in any Indian herbarium. About 100 type specimens belonging to 40 genera and 82 species are described

INTRODUCTION

The author had the opportunity of visiting the U. S. S. R. during April to October 1969, under the Scientific and Cultural Exchange Programme of the Government of India and the Academy of Sciences of U. S. S. R. He worked mainly in the herbarium of the Komarov Botanical Institute of the Academy of Sciences of U. S. S. R. at Leningrad, which is the largest herbarium of U. S. S. R. and is one of the largest of the world. It is very rich in Indian material.

He also visited the herbaria at Moscow (in Russian Republic), Tashkent (in Uzbekistan Republic), Dushanbe (in Tajikistan Republic), Tbilisi and Batumy (in Georgian Republic), Yalta and Kiev

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