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Tuberous Seedlings of Borassus flabellifer

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In South India, the state of Tamil Nadu abounds in the palmyra palm (*Borassus flabellifer* L.). Annually a female tree produces 200–300 fruits (drupes) and thrice the number of seeds, since each one bears three pyrenes. The fruits of this palm are of no commercial value except for the edible pulpy endosperm of the tender stage. In older fruits the endosperm becomes horny and dry, due to extensive accumulation of hemicellulose. The pyrenes, each containing a seed, are germinated for the tuberous seedlings, which abound in starch content and form a seasonal delicacy for the villagers, especially the poorer sections of the population. The present account deals with the botanical and unexplored commercial aspects of the seedling.

The fruiting season: The mature fruits are usually harvested from July to September. It is a common practice for the villagers to roast the ripe fruit over open fire and the steaming hot, odoriferous flesh of the yellowish, fibrous mesocarp is eaten as a delicacy. The pyrenes are either discarded or collected and germinated for the tuberous seedlings.

Commercial germination: Large numbers of the drupes are germinated in specially elevated mounds of garden soil, which are usually prepared by dumping excavated earth to a height of 1–1.5 m (Fig. 1). The pyrenes are buried at the top of the mound and covered with humus and dead leaves. Frequent watering is necessary to keep the dump sufficiently moist. The seeds germinate in a period of 45 to 60 days. The embryonal axis that grows out of the pyrene penetrates downwards into the loose soil of the mound and strikes roots. The cotyledonary sheath (the apocole) is responsible for carrying the embryonal axis deep into the soil. The tuberous first juvenile (bladeless) leaf, which accumulates the food materials derived and translocated from the endosperm, forms the tuberous part of the seedling. The food reserves are in the form of starch grains accumulated in large parenchyma cells.

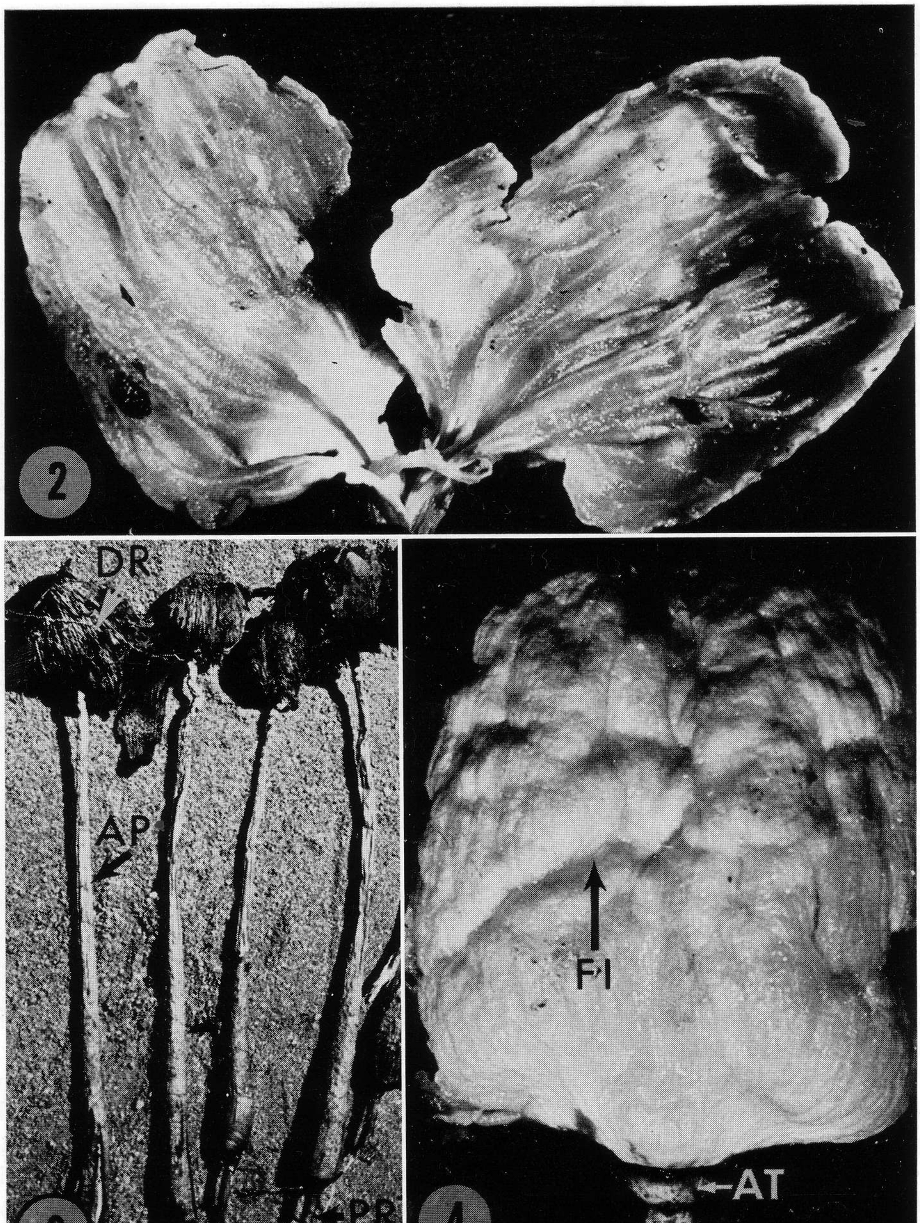
The endosperm: The endosperm of the tender fruit has a jellylike consistency and is delicious to eat. However, it becomes hard and ivorylike (Fig. 5) on maturation due to the excessive thickening of the cell walls (Figs. 12, 13). Most of the thickened wall was found to be composed of hemicellulosic material, by employing the differential extraction and PAS reaction method for cell wall carbohydrates (Jensen, 1962). The deposition of hemicellulose in the endosperm of other palm species, e.g., *Phoenix dactylifera* L. (Netolitzky, 1935) is also known. The cell contents are depleted and the endosperm tissue is devoid of viable nucleus and cytoplasm at maturity (Fig. 12). The endosperm tissue occupies the periphery of the seed leaving a narrow cavity in the center (Fig. 5). The enlarging cotyledonary haustorium converts the hard endosperm into a pulpy mass (Fig. 7).

1. View of 90-day-old heaped up soil mound for raising seedlings. Weed growth and humus help retain moisture.

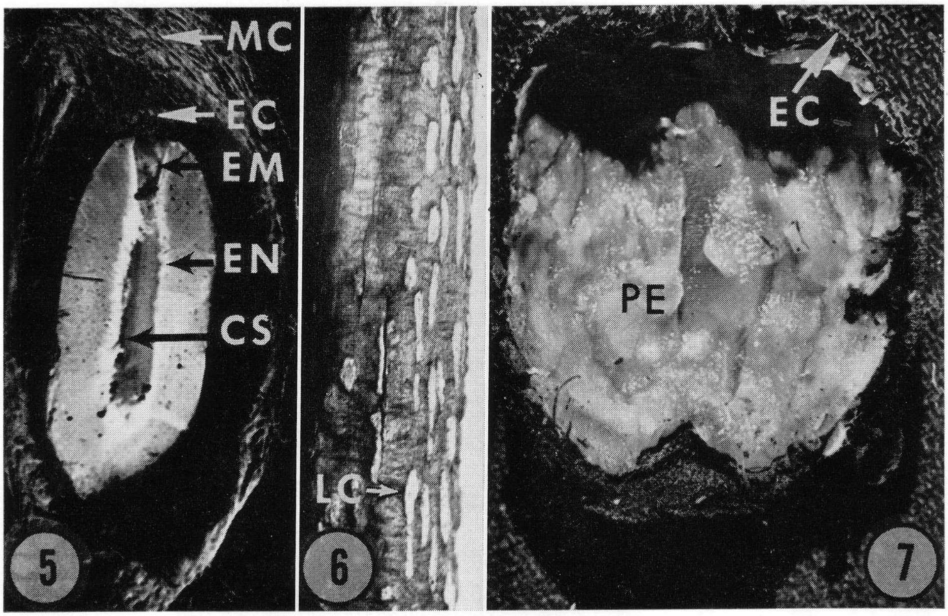
The embryo: The embryo of the mature seed is embedded in the endosperm at the micropylar end. At the time the fruits are shed, the embryo is only a small conical mass of cells (Fig. 5). Internally, it shows a much higher degree of differentiation than would be assumed by the look of it. The cotyledonary portion (Fig. 9) acts as a sucker or haustorium and is the first organ to develop. The moisture reaching the embryo activates the growth of the cotyledon, which begins to enlarge and digest the endosperm. The onset of enlargement in the haustorium is followed by growth in the lower part of the cotyledonary primordium (apocole) as a result of which the embryonal axis pushes out of the pyrene. Further growth results in the axis assuming a knoblike appearance. At this stage it is connected with the haustorium by an isthmuslike region.

The structure of the cotyledon: In the germinating seed the expanding cotyledonary haustorium is thrown into folds on the surface, while its interior becomes spongy and fibrous due to numerous air cavities that develop schizogenously (Figs. 2, 4). The outer surface is marked by ramifying fissures simulating those on the mammalian brain. The creamy-white color of the sucker completes its similarity to the brain. Histologically, the epidermis of the cotyledonary haustorium is differentiated into a secretory layer (Fig. 15) rich in protein as determined by the Mercury-Bromophenol Blue test (Pearse, 1960). This layer is responsible for the secretion of enzymes that break down the hemicelluloses. Internally, a ring of vascular bundles located in the subsurface region (Fig. 15) translocates the absorbed material down the cotyledonary sheath.

The structure of the cotyledonary sheath: The cotyledon can be divided into the haustorium (embedded in the endosperm), the petiole, and the sheath (Fig. 9). The petiole and the sheath in *Borassus* elongate geotropically. Such



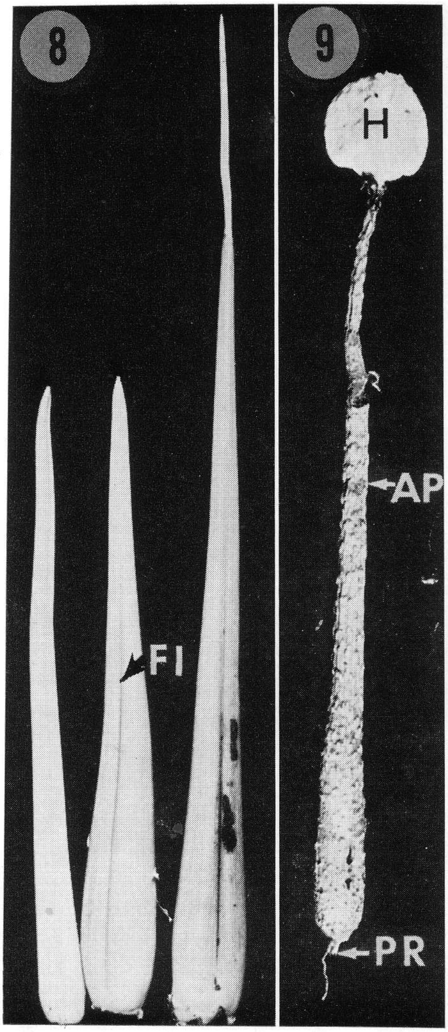
2–4. Germinating pyrenes and haustoria. 2, vertically split cotyledonary haustorium showing the spongy air-filled interior and vascular strands; 3, germinating pyrenes dug out from the mass germination mound; 4, a close view of the fully grown cotyledonary haustorium showing the surface foldings that digest the endosperm. Details: AP, apocole; AT, annular thickenings; DR, pyrene; FI, fissure; PR, primary root.



5–7. Cotyledonary sheath and sections of pyrenes. 5, vertical section of a pyrene showing the endosperm, embryo, and the fibrous layers; 6, lenticel-like openings in the cotyledonary sheath taken from specimens shown in Fig. 3; 7, vertical section of a pyrene showing the endosperm reduced to a pulp by the haustorium of the cotyledon. Details: CS, central cavity; EC, endocarp; EN, endosperm; EM, embryo; LC, lenticel-like opening; MC, mesocarp; PE, pulpy endosperm.

an elongating organ of palm seedlings has been termed apocole by Cook (1939). The apocole in *Borassus* buries the embryonal axis deep (50 cm) below the surface (Fig. 3).

The sheath primordium of the cotyledon, which measures 1 mm in the embryo, exhibits extensive growth and elongation during germination. It forms a bridge between the haustorial organ embedded in the endosperm and the embryonic axis (Figs. 3, 9). Initially the emergence of the axis from the shell through the narrow opening is facilitated by the growth of the apocole. At late stages the narrow passage in the hard shell causes a sort of constriction in the apocole and an annular swelling. Beyond this region the sheath enlarges into a stalklike structure measuring 5 mm across. Along with the process of elongation, the diameter of the tuberous seedling leaf keeps on increasing, especially near the axis (Fig. 8) where it begins to accumulate a large amount of starch grains (Figs. 10, 11). As soon as the elongation of the apocole ceases the tuberous structure attains a thickness of about 2.5 cm (Fig. 3). The apocole itself forms a leathery and protective covering around the tuberous seedling leaf (Fig. 9). At maturity the inner epidermis of the apocole becomes a thin, white, and papery covering while the outer tissue becomes brownish. Numerous lenticel-like structures disposed lengthwise along the outer surface of the seedling impart a broken appearance (Fig. 6). These lenticel-like structures are really fissures in the epidermis through which the underlying parenchyma cells are exposed and pro-

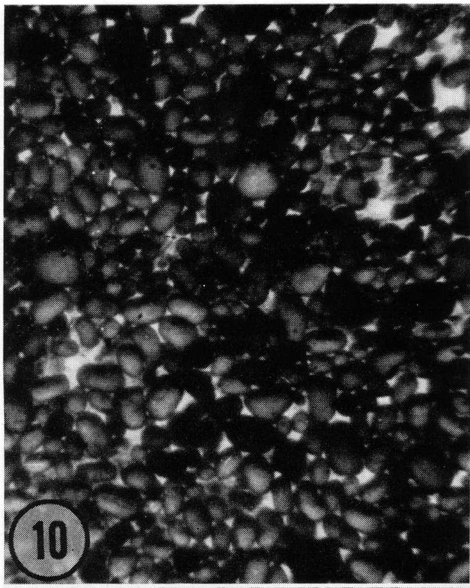


8–9. Seedling and seedling leaves. 8, starch-bearing first tuberous seedling leaves separated from the enclosing cotyledonary sheaths; 9, seedling with haustorium removed from shell. Details: AP, apocole; FI, fissure; H, haustorium; PR, primary root.

ject out. The epidermis becomes ruptured during the course of development and 4–5 layers of corky cells develop in the subdermal zone, imparting a brownish appearance. The interior of the sheath is filled with parenchyma cells loosely packed with large air spaces. A ring of large vascular bundles develops in the peripheral zone of the sheath. These vascular bundles extend into the haustorium and supply the fissures and folds. As mentioned earlier, the inner epidermis of the cotyledonary sheath surrounding the tuberous juvenile leaf remains intact and becomes a white, papery, protective structure. It is composed of compact polygonal cells, many of which accumulate brown contents consisting of tanniniferous compounds (Fig. 14). After the death of the sucker, the sheath usually rots and is lost. Further growth of the seedling leaves is supported by the food materials stored in the tuberous juvenile leaf.

The tuberous first (juvenile) leaf: The activity of the shoot apical meristem results in the initiation of the first bladeless juvenile leaf. Unlike some other palms (e.g., the coconut) the first bladeless juvenile leaf becomes tuberous in *Borassus.* The growth of the tuberous structure is mainly concentrated on the abaxial half which becomes about 50 cell layers thick and its overall shape is an attenuated cone (Fig. 8). This structure is tightly enclosed by the inner epidermis of the cotyledonary sheath. The tuberous part exhibits a smooth shiny outer surface, a well developed epidermis, vascular bundles, and innumerable parenchyma cells, which store a large amount of starch grains (Fig. 11). The maximum girth of the tuberous parts is about 2.5 cm. From base to tip it measures about 15 cm. An elongated groove on the juvenile leaf indicates its adaxial side (Fig. 8).

The morphology of the fleshy tuberous region appears not to have been correctly understood. Tomlinson (1960, p. 57) writes, "In *Borassus* and *Hyphaene*, for example, the fleshy cotyledon may be up to two feet long and it is often eaten as a succulent vegetable by the natives of India and parts of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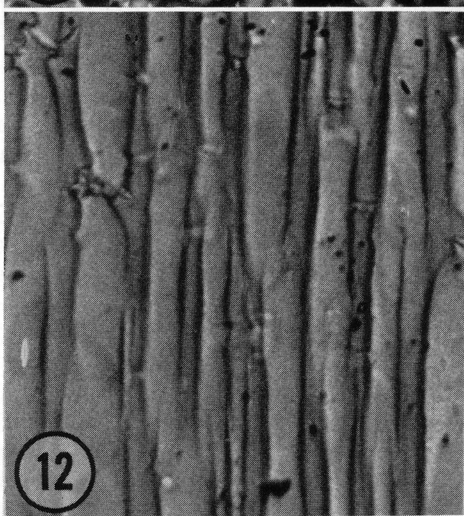
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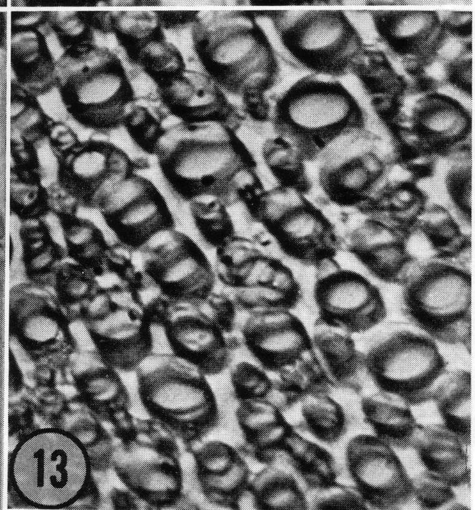
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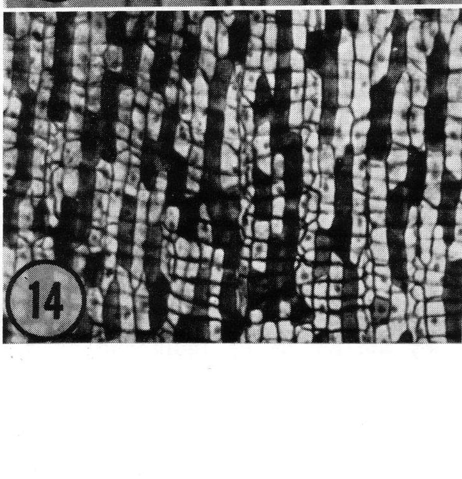
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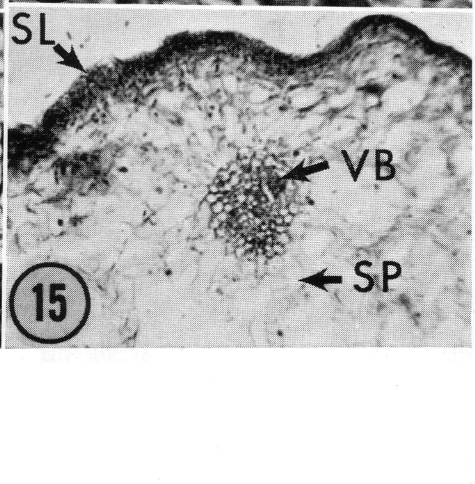
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Table 1. Products and yield from fruit and seedlings of Borassus flabellifer

Product	Yield/pyrene (g)	Yield/fruit (g)	Yield/tree (kg)	Yield/acre (kg)
Starch	30	90	18–27	18,000–27,000
Fresh endosperm (Mature)	80	240	48–72	48,000–72,000
The hard shell* (Endocarp)	32	96	20–30	20,000–30,000
Mesocarp fiber** (From fruit)	6	18	4–6	4,000–6,000

* A good fuel.
** A good filling material and insulator.

Africa." However, it is the first bladeless juvenile leaf that becomes tuberous and not the cotyledon or apocole.

The starch content: The starch in the tuberous part of the seedling was isolated (Fig. 10) after cutting it into smaller bits, grinding with alcohol, and evaporation. In sections of fresh material, each parenchyma cell was found to contain about 15–20 grains (Fig. 11). The quantity of starch in the tuberous structure was remarkably high. One gram of the fresh material yielded 500 mg of starch. The average fresh weight of a tuberous juvenile leaf is about 60 g, from which about 30 g of starch could be derived. On this basis, a fruit containing three pyrenes would yield ultimately 90 g of starch, and the quantity that can be obtained from the seeds of a tree bearing 200–300 fruits on an average would be 18–27 kg. Considering that an acre of land can support not less than a thousand trees, the yield per acre would be very high (i.e., 18,000 to 27,000 kg.). In other words palm seedling starch is a potential supplement to rice. In fact, palmyras could be grown without much input on dry sandy soil where rice cultivation is out of question.

The total output of tuberous seedlings annually raised in the state would be a very considerable quantity. On an average about 5,000 to 8,000 kg of seedlings are being produced annually in a village. The normal custom is to cook these by boiling and the cooked tuberous parts are eaten with salt and spices. At present, starch is not extracted from the tuberous seedlings on a commercial scale. However, the potential in the southern districts of the state of Tamil Nadu is very high. The seedling starch could also be used in the fermentation industry as well as in sizing fabrics in the textile industry.

The relative importance of seedling starch: The Khadi and village Industries Board (Tamil Nadu State) has

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10–15. Tissues of seed and seedling. 10, microscopic view of starch grains isolated from the tuberous, bladeless, first seedling leaf; 11, sectional view of a part of a tuberous tissue showing dense distribution of starch grains; 12, vertical section of a portion of a mature endosperm tissue showing highly thickened cell walls laden with hemicellulose; 13, transverse section of the mature endosperm tissue showing thickened cell walls; 14, microscopic view of the inner papery epidermis of the cotyledonary sheath. The cells with dark contents of tanniniferous compounds appear to act as chemical protectives; 15, sectional view of the peripheral zone of the cotyledon showing the secretory outer layer and the inner loosely packed parenchymatous cells. Note the vascular bundles adjoining the surface. Details: SP, spongy parenchyma; SY, secretory layer; VB, vascular bundle.

set up small scale industries for the production of refined and crude palm sugar, fiber brush, and various other handicraft products based on *Borassus*. However, the potentiality of the tuberous seedlings as a source of starch has not been exploited. The results of the present study indicate the tremendous possibilities of utilizing the starch of the tuberous seedlings on a commercial scale (Table 1). This would also avoid the wastage of useful energy content of the fruits and the seeds. The present practice of utilizing the tender endosperm as the basic material for the production of jam appears to be less economical considering the total energy in the mature endosperm. Thus, it is suggested that the commercial production of seedlings for starch should be taken up immediately in order to tap the vast resources of the palmyra plantations to a greater extent.

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Notice

The Third Meeting of the International Council on Lethal Yellowing was held at the Jupiter Hilton Hotel, Palm Beach County, Florida on October 30 to November 3, 1977. The Proceedings of this meeting, with abstracts of papers presented, has been published as Publication FL-78-2, Agricultural Research Center, Institute of Food and Agricultural Sciences, University of Florida, Fort Lauderdale, Florida, 1978. Copies of the Proceedings were sent to all participants and are available to others who may have specific interest and ask to receive a copy from the Agricultural Research Center, 3205 S.W. 70th Avenue, Fort Lauderdale, Florida 33314.

The meetings were conducted in an introductory session and six particular sessions dealing with basic biology of yellows diseases (I), disease diagnosis (II), mycoplasma isolation and culture (III), vectors (IV), disease control (V), and emerging problems in palm culture (VI). Reports of earlier meetings have appeared in *Principes* 17: 151–159, 1973 and 20: 57–69, 1976.

Palm Research

Dr. Dennis Johnson of the University of Houston has suggested that an annual listing of palm research in progress be published in PRINCIPES. Persons conducting research on palms are invited to submit appropriate information to one of the editors for publication in January 1979.

Errata

Volume 15, page 105, column 2, line 5; for **S. texana** read *S. texana.*
Volume 20, page 103, line 22: for **drymophloeiodes** read **drymophloeoides**.
Volume 21, page 169, column 2, line 5: for currently read current.
Volume 22, page 23, column 1, line 15: for *precatoria* read *oleracea.*
Volume 22, page 33, column 2, line 24: for *tumuca* read *tucuma.*