

VIVEKANANDA COLLEGE
THAKURPUKUR
KOLKATA 700063

NAAC Accredited Grade—A



Topic: Starchy Tuber Crops: Sugarcane

Course Title: BSc Botany Honours (CBCS)

Paper: Core Course 9 (Theoretical) Economic Botany

Unit: 4B

Semester: 4

Name of the Teacher: Kuntal Narayan Chaudhuri

Name of the Department: Botany

STARCHY TUBER CROPS: POTATO

Starchy tuber crops are **food crops** with **subterranean tuberous** parts that are rich in **starch**. Starch is a **polysaccharide (carbohydrate)**. This **common** and **readily-extractable** plant **reserve food** is produced by **photosynthesis** and **stored** in **storage organs** such as **roots, tubers, corms, seeds, grains**, etc. **Starch** is present in plant cells as **starch grains** and these are either **simple** as in **potato** (tuber, *Solanum tuberosum* of Solanaceae) and **wheat** (grains, *Triticum aestivum* of Poaceae), or **compound** as in **rice** (grains, *Oryza sativa* of Poaceae). **Simple starch grains** are either **eccentric**¹ as in **potato**, or **concentric**² as in **wheat**. The two most important **commercial sources** of **starch** are **maize** (grains, *Zea mays* of Poaceae) and **cassava** (root, *Manihot esculenta* of Euphorbiaceae). Other important sources include **cereal grains** such as **wheat** and **rice** as well as a host of **tuber crops** such as **potato, sweet potato** (root, *Ipomoea batatas* of Convolvulaceae), **arrowroot** (root, *Maranta arundinacea* of Marantaceae), **sago palm** (stem pith, *Metroxylon sagu* of Arecaceae), **yams** such as the **greater yam** (tuber, *Dioscorea alata* of Dioscoreaceae), etc. Many of the **starchy tuber crops** such as **potato, sweet potato** and **yams** are also used as **root vegetables**.

Potato (Alu B.)

Solanum tuberosum L.

Solanaceae

Tuber (underground modified stem)

Potato is the leading **tuber starch crop** in the **temperate regions** and one of the leading **staple crops** across the **globe**. This cosmopolitan **food crop** originated in the **Andes** mountains of **Peru** (and adjoining **Bolivia**), South America (**centre of origin**), near **Lake Titicaca**, where it was domesticated by indigenous Andean people about 8,000 years ago. The **wild ancestors** of this crop had tubers with **bitter taste** due to potentially toxic **steroidal alkaloids**. This domestication involved **artificial selection** of **less bitter variants** to establish **alkaloid-free diploids** in the form of the *Solanum stenotomum* from which other **polyploids** were developed including the **tetraploid** *S. tuberosum* which is the dominant form of cultivated potato with two **subspecies**: the **Andean** *S. tuberosum* ssp. *andigena* and the **Chilean** *S. tuberosum* ssp. *tuberosum*. There are about 5,000 potato varieties worldwide of which 3,000 are found in the **Andes** alone. Among the eight cultivated species are: four **diploid**, two **triploid**, one **tetraploid** (*S. tuberosum*) and one **pentaploid** species. European colonists introduces potato to **Europe** and then to the rest of the world about 500 years ago as part of the **Colombian Exchange**.³ In **India**, it was introduced nearly 400 years ago by the **Portuguese**. The world's largest producers are **China** and **India**, while the **largest exporters** are the **Netherlands, France** and **Germany**. In **India**, potatoes are cultivated throughout, but the **largest producers** are **Uttar Pradesh, West Bengal** and **Bihar**.

¹ Hilum peripheral in position.

² Hilum central in position.

³ Refers to the widespread transfer of plants, animals, humans, culture, technology and ideas between the Americas and Oceania (New World) with the rest of the 'known' world (Old World).

Ecology

Habit: Perennial herb, erect or semi-erect or prostrate, up to 1 m (height).⁴

Habitat: Terrestrial, ranging from sub-tropical rainforests to cold alpine meadows (1,000 to 4,300 m).

NB: Cultivated in agricultural fields (anthropogenic) as an annual.

Morphology*Stem:*

Underground stem tuberous, short, solid, white, red, purple or yellow, borne terminally by long, solid, cylindrical, horizontal axillary branches (**stolons**) arising from the base of the **aerial stem**, both bearing adventitious roots; **tubers** with **stem end** (or **heel** attached to the stolon) and **bud end** (or **rose** with apical bud), present between the ends are spirally arranged axillary buds (or **eyes**) and leaf scars (or **eye brows**) as well as scattered lenticels; aerial stem 5-20 mm (diameter) at the base, hollow (except nodes), cylindrical, glabrous, green, purple or green-purple mottled.

Leaf:

Pinnately compound-imparipinnate, alternate, exstipulate but with auricular or semi-lunate false stipules (or pseudostipules)⁵ at the base, pedicellate, green, glabrous to finely pubescent (both adaxially and abaxially), membranous to papery, both petiole and rachis winged, petiole 2-6 cm (length), size 8-22 cm (length) x 6-12 cm (width); leaflets in 3-4 sub-opposite pairs with terminal odd leaflet (and smaller secondary leaflets or **folioles** present between the primary ones), sessile or subsessile, ovate to elliptic-lanceolate, unicostate-reticulate, apex acute, base rounded, margin entire to serrate, petiolules winged, size 4-8 cm (length) x 1.5-4.5 cm (width).

Inflorescence:

Terminal, 5-10 cm (length) cymose panicle.

Flower:

Axillary, up to 8 clustered, white, pinkish to purple, actinomorphic (regular), pentamerous, complete, bisexual, hypogynous, pedicel 1-2 cm (length), size 3-4.5 cm (diameter).

Calyx: Sepals 5, gamosepalous, tubular, persistent, valvate, green.

Corolla: Petals 5, gamopetalous, rotate, deciduous, valvate, white to purple.

Androecium: Stamens 5, epipetalous; anthers basifixed and porous.

Gynoecium: Carpels 2 (syncarpous); ovary superior, obliquely placed, placentation axile, 2-celled with swollen placenta bearing numerous ovules in each chamber (in T.S.); style terminal; stigma capitate.

Fruit:

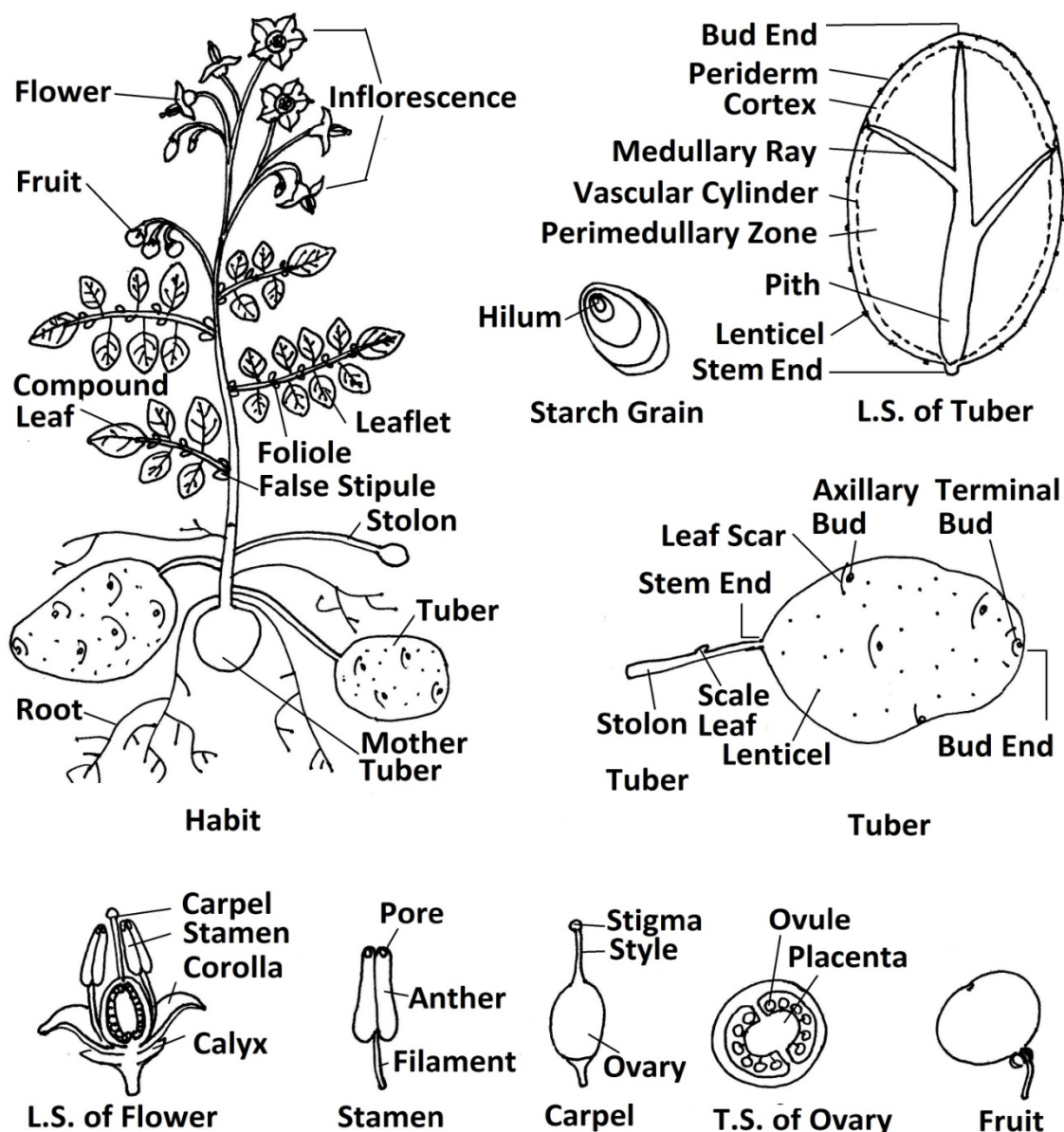
Berry, globose to ovoid, glabrous, white, green or purple, many-seeded, size 1.5-2.5 cm (diameter).

Seed:

Small, ovoid, brown, size 2-4 mm (diameter).

⁴ Varieties classified as dwarf (up to 30 cm), short (30-45 cm), medium (45-60 cm) and tall (more than 60 cm).

⁵ Modified basal pair of leaflets of a compound leaf appearing very close to the stem.

Diagram: Morphology and Anatomy of *Solanum tuberosum* (Solanaceae)**Anatomy**

L.S. (or T.S.) of the tuber shows the following six regions:

Periderm: Also called **skin**, this outermost region consists of a **suberized** multiseriate layer of **cork** (or **phellem**) with vegetative buds (or eyes) and lenticels, followed by a **meristematic** uniseriate layer of **cork cambium** (or **phellogen**).

Cortex: This is the **parenchymatous** multiseriate layer beneath the periderm and contains reserve food in the form of simple, oval, eccentric **starch grains** (30-100 μm).

Vascular Cylinder: This consists of patches of **outer phloem** and a ring of **xylem**.

Perimedullary Zone: Also called **inner phloem**, this massive zone consists of **parenchymatous** tissue between the **xylem ring** and **medulla** with most of the **starch grains**.

Medullary Rays: This links the **pith** or **medulla** with the **lateral buds** and has **starch grains**.

Pith: This is the central axis of **parenchymatous** tissue connecting the **apical bud (bud end)** with the **stolon (stem end)** and also has **starch grains**.

Cultivation

Potato is both a **food crop** as well as a **cash crop**. Originally a **high-altitude temperate crop**, but it has been adapted for both **subsistent** and **commercial** cultivation in **agricultural plots** during the **cool** and **moist seasons** across the **sub-tropical plains** and **temperate hills**. This crop requires **rainfall** between **120 to 200 cm per annum** and a **temperature** range of **20 to 24°C** with frost-free conditions during early growth. The **soil** must be **well-drained** (as **terraces** with **inward slope** and **drainage canals** along the **inner edge** to prevent **soil erosion** in the **hills**), **loam** or **sandy loam**, **acidic** (pH between 5-6), **free of stones** and rich in **organic matter**. In India, cultivation is done during the **winter** in the **plains** and the **summer** in the **hills** in five diverse **agroclimatic zones**: the **northern hills**, the **northern plains**, the **eastern hills**, the **plateau region** and the **southern hills**.

Propagation:

This crop is usually **vegetatively propagated**. The **tubers** as the **sowing material** are known as '**seed tubers**.' These are treated with **carbon disulphide** (30 g per 100 kg of seed) to **break dormancy** and **induce sprouting** of the '**eyes**.' **Tubers** remain **dormant** for at least 8 weeks which can be extended by storing below 5°C. However, for many **hybrids**, **sexual propagation** with '**true-seeds**' (*i.e.* botanical seeds from the berries) are used to overcome **shortage**, reduce **cost**, avoid **bulky transportation** and prevent **diseases**. These **seeds** are germinated in **nursery beds** and the **seedlings** are **transplanted** 30 days after **sowing**.

Planting:

The land is prepared by **ploughing** (up to 25 cm deep so that it offers **least resistance** to the **enlargement** of **tubers**) to a fine **tilth**. Then **ridges** and **furrows** are made by hand **hoe** or mechanized **ridger** with a **spacing** of 45-60 cm between **ridges**. The **whole** or transversely **cut** pieces of **well-spouted tubers** (weighing 40-60 g) are used for **sowing**. About 800–1,500 kg per hectare of seed tuber is required. **Seedlings** (like most other vegetables) can also be **planted**. Seedlings raised from 100 g true seed per hectare is enough. **Sowing** or **planting** is done on the **ridges** at a **space** of 15-20 cm apart and at a **depth** of 5-10 cm.

Irrigation:

This crop is usually a **rainfed** one and planted in March-April and August-September in the **hills** and October-November in the **plains**. However, planting in the **dry period** (January-February) in the hills requires light **furrow irrigation** in the first week on a **daily** basis, but later this is done only **once a week**. **Drip** and **sprinkler** systems are also used.

Weeding:

The crop develops **canopy** in about 4 weeks after planting and **weeds** must be controlled by this time up to 60 days after planting to gain **competitive advantage** for the crop. This is done by manual **hoeing** the **ridges** and **earthing** up the **furrows** without disturbing the **stolons** once in two weeks. This improves **soil aeration** for better **subterranean growth**.

Manuring:

For maintaining good growth, **fertilizers (inorganic)** are added as **nitrogenous** (at 30-70 kg per hectare), **phosphatic** (at 50-100 kg per hectare) and **potassic** (at 85-140 kg per hectare). **Farm yard manure (organic)** is added during **land preparation** (25-30 tonne per hectare).

Earthing Up:

The objective of this process is **soil aeration** and **weed control**. This is done by **digging up** the **soil** in the **furrows** and **depositing** them on the **ridges** either manually or with mechanized tools. The first one is done when the plants are 15-25 cm high. The second one is done to cover up the tubers properly. Then this is done at 15-20 day intervals.

Crop Rotation & Intercropping:

The **crop rotation sequences** are as diverse such as potato-mung-paddy, potato-mung-groundnut, etc. Being a **short-duration** and **fast growing** crop, **potato** is an ideal for **intercropping** with other crops such as **sugarcane** as the **cultural operations** and **resource utilization** are **complimentary**. Using **leguminous** crops having **root nodules** for **nitrogen-fixing bacteria** increases **nitrogenous nutrients** in the **soil**.

Harvesting & Storage:

The maturity period of this crop varies from three and a half months for **early cultivars** and four to five months for **medium cultivars** and up to seven months for **late cultivars**. The **harvest time** is **critical**. The growth of the tubers continue till the canopy of aerial shoots ('vines') die. The **harvest time** is usually when the **tubers** reach **sufficient size** with the **ripening** of the **vines** as most of the **leaves** turn **yellow-brown**. In the hills, the crop should be normally harvested when the soil is not very wet. First, the **vines** are manually **cut (defoliated)** near the **ground level**. This is often done by spraying **defoliants**, *e.g.* maleic hydrazide, about two weeks before the harvest. Next, after a week, the **tubers** are **dug out** from the field by **ploughing**. Finally, the **tubers** are **picked** from the field by manual or mechanized means. The yield ranges from 20 to 30 tonne per hectare. After the harvest, the tubers are **washed** and then **surface dried** by **heaping** for 10-15 days in shade for **curing** of the **skin**. Exposure to **direct sunlight** turns them **green** (see below). All damaged and rotten tubers are removed and kept in a **cool place** for **storage**. The best **storage method** is **cold storage**. In India, if cold storages are not available the **tubers** are stored in **pits** lined with *neem*⁶ leaves or sugarcane trash (dry leaves) and covered with bamboo chimney.

Chemistry

The chemical composition of potato is variable and this is greatly influenced by variety, environment and farming practices. The raw tuber contains **water** (70-80%), **carbohydrates** mostly as **starch** along with some **sugars** (10-30%), **proteins** (1-3%), **fibres** (2-3%), **ash** (0.5%) and **fat** (0.1%), etc. **Starch** is a **polysaccharide** with **glucose (dextrose)** residues. It constitutes 65 to 80% of the **dry biomass**. It is present in the cells as **starch grains** (see above) with a mixture of **amylose** (25%) and **amylopectin** (75%). The **relative amount** of **starch** and **moisture** in the tubers can vary and is characteristic of the varieties. A **floury** variety (*e.g.* **Kufri Badshah**) has the highest starch content followed by the **mealy** (*e.g.* Kufri Bahar), **waxy** (*e.g.* Kufri Giriraj) and **soggy** (*e.g.* Kufri Ashoka) ones. Potatoes are also an important source of trace nutrients such as **minerals** *e.g.* potassium, phosphorous, iron, magnesium, etc. and **vitamins** *e.g.* carotene, thiamine, riboflavin, ascorbic acid, etc. **Green potatoes** are **toxic** as they develop the **glycoside** called **solanin** which at high concentrations can cause illness, even death, in humans and livestock.

⁶ *Azadirachta indica* (Meliaceae).

Uses

Globally, potato is grown for **subsistent cultivation** as **food crop** and **commercial** cultivation as **cash crop**. In Europe, and later other parts of the world, this **Andean tuber** became a popular **staple food**⁷ at least 300 years ago. The **Irish Potato Famine** of 1845 was caused by its devastation by the **late blight**.⁸ In **British India**, **wild yams** (*alu*) began to be replaced by **cultivated potato** (*bilayti alu*) about 150 years ago. Its uses further diversified after the **industrial revolution**. This crop is a source of (1) **food**, (2) **fodder**, (3) **fuel**, and (4) **chemicals**.

Food:

These **starch-rich** tubers are an **easily-available, low-cost energy source**. These also provide **proteins, fats, fibres, minerals** and **vitamins**. **Fresh potatoes** as **tuber vegetables** are **boiled, steamed, fried, roasted** and **baked** as the **main ingredient**, as an **accompaniment** to others and as one of many in a **mishmash**. It is increasingly being used by the **food-processing industry** for making **value-added** products or **processed food** such as **ready-to-eat** fried or baked "chips" and "crisps," **ready-to-cook** canned "dices" or frozen "fries" and **ready-to-use** dehydrated "flakes" for preparing **mashes** or "flour" as **binder** and **thickener** in cooking. **Potato starch**, with **higher viscosity** than those from wheat and maize, is used as a **binder** by **bakeries** and **confectionaries**. **Chuño** is a **freeze-dried** traditional potato product of the indigenous inhabitants of the **Andes**. **Tender shoots** are also used in rural Bengal as a minor **herbage vegetables** (*shak*). In **Eastern Europe**, **potato starch** is converted to **sugars** and **fermented** to produce the **alcoholic beverage** called **vodka**.

Fodder:

Discarded potato are used as **farm feed**. In **Eastern Europe**, **cattle** are fed **raw potato** and **pigs** are fed **boiled potatoes** for **fattening**. It is also **stored** by adding to **silage**.⁹

Fuel:

Potato peel, a **starch-rich by-product** from potato processing industry, can be **liquefied** and **fermented** to produce **ethanol**. In **Canada** this is used as a **biofuel**.

Chemicals:

Potato starch (or **farina**) is used in **laundries** and **textile mills** for **stiffening fabrics**, in **pharmaceutical**, **wood** and **paper** industries as **adhesive**, **binder** and **filler**. This **biodegradable** polymer is a substitute for **polystyrene** in making disposable **tableware**. It also yields **industrial chemicals** such as **dextrin** and **glucose** by **enzymatic degradation**.

Further Reading:

Kochhar, SL (2016) *Economic Botany: A Comprehensive Study*. Oxford University Press, Delhi.

Mukherjee, SK (2016) *College Botany (Vol. 3)*. New Central Book Agency, Kolkata.

Sambamurthy, AVSS & S Subrahmanyam (1989) *A Textbook of Economic Botany*. Wiley Eastern, New Delhi.

⁷ Food that is consumed regularly as a dominant part of the diet for a given people or culture.

⁸ Plant disease caused by the fungus *Phytophthora infestans*.

⁹ Type of fodder made from green foliage crops through preservation.