Applied Plant Science

'Applied Plant Science' bridges the gap between plant biology and studies in agriculture at a higher level, making it a readable introduction for students at (UK) Advanced Level and beyond. The reader is assumed to have a grounding in biology but no more than a rudimentary knowledge of plant structure and reproduction.

Common crop plants are used to illustrate the principles of seed and vegetative plant propagation and topics like plant anatomy and physiology are brought alive through the context of commercial applications. The problems of weeds, fungi and insects are considered from both biological and agricultural standpoints. This book also takes the reader on a basic but comprehensive journey through the most recent developments in cell culture and genetic manipulation, exploring a number of potential applications for these techniques.

The author recognizes the contentious issues surrounding the environmental impact of the use of many of the chemicals and techniques described in the text but the consideration of such issues in more than a cursory way remains the subject of another work. It is hoped that this volume will serve rather to inform the debate.

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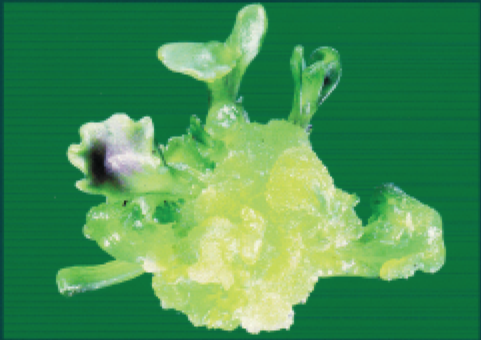

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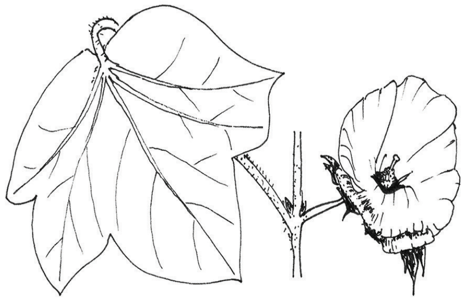
an intoxicating drink called ‘pulque’ is still produced from its fermented juice.

Cotton



(Left) Fig. 1.5 Cotton crop (pacific coast of Nicaragua)

(Top Right) Cotton flower

(Bottom Right) Cotton boll

There are a number of different cotton plant species occurring naturally in both the Old and the New World, but the type most commonly grown, *Gossypium hirsutum* (fig. 1.5), produces the longest fibres, and is a native of tropical and sub-tropical America. It belongs to the hollyhock and hibiscus family, producing large yellow flowers, which produce hard leathery fruit capsules called **bolls** containing about thirty seeds. What gives this fruit its beauty and economic importance is the method by which the seeds are dispersed.

Each seed is equipped with thousands of tiny hairs designed to catch the wind and carry the seed to far destinations when the

boll splits. The hairs are of two types: linters, which are short fluffy hairs closely attached to the seed surface, and lints, which are longer and more easily detached. The lints are spun into cotton while the linters are extracted and sold as pure raw cellulose for other manufacturing industries. The first ever billiard ball was made in 1818 by mixing camphor with treated cellulose extracted from cotton linters! Lints are referred to as fibres but they are not sclerenchyma cells. They have no lignin and their walls are composed almost entirely of cellulose. The cellulose is laid down in spiral bands so that each fibre binds firmly together when twisted into a yarn.

Cotton is still generally harvested by hand because it is grown mostly in regions where labour is cheaper than machinery. After the boll is separated from other debris, it is passed through a **ginning process** where the cotton fibres are drawn through slits too small for the seed to pass. The separated seed is used for oil extraction, linters are baled up for sale, and the lint is spun into yarn or compressed into the thick composition material called **felt** used to make hats and handicraft materials.

Cotton fibre is greatly superior to others for its multiplicity of uses. In clothing it has the advantage of absorbing water up to 25% of its weight before feeling wet, conducting heat so that it feels cool, and it can be woven into both fine and heavy grade fabrics.

Timber

Wood is what remains when the bark of a tree has been removed. In botanical terms, it is **xylem**, the water conducting tissue (the Greek word ‘xylos’ means ‘wood’). Xylem is continually formed as a tree grows by the activity of a cylinder of **meristematic** (dividing) cells called the lateral (vascular) **cambium** lying immediately inside the bark. New cells differentiate in different ways, according to whether they are formed to the outside or the inside of the cylinder. Towards the outside, they become **phloem** cells, making up a thin layer of

Woody perennials survive year to year, strengthening and increasing the girth of their stem and roots by secondary growth of woody tissue from a cylindrical meristematic layer called the lateral cambium.

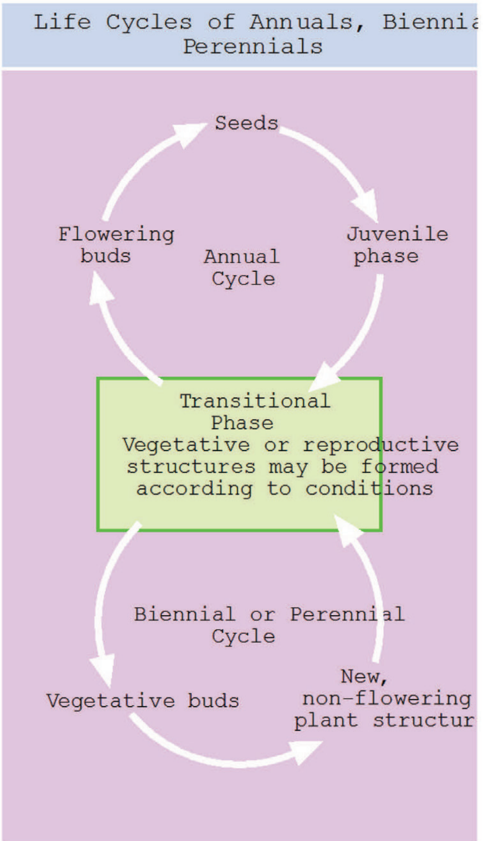


Fig. 2.1 Reproductive cycles of flowering plants

Deciduous species of woody perennials protect themselves against water loss in cold or dry seasons by dropping their leaves, whereas evergreens do so by special leaf modifications such as a thickened cuticle and/or reduced leaf surface area. Trees of commercial importance, like apple trees, and herbaceous perennials like strawberries and potatoes, are commonly propagated by their vegetative structures as opposed to seeds, a practice described in the Chapter 3.

Figure 2.1 illustrates the pattern of alternate sexual and vegetative phases in annual, biennial and perennial flowering plants. The critical part of the life cycle for crop growers is the transitional phase because, at this point, it is possible to control a number of environmental and internal factors in order to induce early flowering or to delay flowering and crop production. Apples and pears can be induced to flower after only sixteen months, rather than the usual five years, for example, if the juvenile plant is grown in optimum greenhouse conditions. Alternative methods for bringing on flowering include girdling of

woody stems, that is, pruning off all the side shoots, or changing the mineral input, usually by decreasing the nitrogen uptake.

Factors, which delay flowering include water and mineral stress, competition from seedlings, or defoliation caused by pests and disease.

Flower structure

Flowers are the reproductive organs of plants in which sex cells, or gametes, are produced and fertilisation occurs. Most flowers are bisexual (**hermaphrodite**) bearing both male and female organs, the **stamens** and **carpels**. The following section describes the illustrate the floral structure of three important crop plants, oilseed rape, pea, and wheat, all of which are grown for the harvesting of their seeds.

Fig. 2.2 Oilseed rape inflorescence

Fig. 2.3 ripe fruit pods split when dry to release the seeds

Oilseed rape (*Brassica napus*)

After wheat and barley, oilseed rape is the most widely grown crop in the U.K. (1998). It belongs to the Cruciferae family, so named because of their four-petalled, cross-shaped flowers. The flowers are produced in clusters (**inflorescences**) creating a blaze of yellow in the spring fields (fig. 2.2). The female carpel is a single central organ containing between 15 and 20 ovules. When fertilised, these become the oil-bearing seeds and the carpel elongates into a long dry pod, which is harvested (fig 2.3).

Pea (Pisum sativum)

The pea belongs to a large and important group of pod-bearing plants called **legumes** belonging to the family **Leguminosae** which are cultivated as forage crops for animal fodder (e.g. clover and lucerne) and as seed crops (e.g. beans, peas and lentils). They form mutualistic associations with nitrogen fixing bacteria in root nodules (see Chapter 4) and are used in crop rotation systems to enhance soil fertility. Pea flowers have five petals: a large 'standard' petal with markings to attract insects, two lateral 'wing' petals, and two which join together underneath to cup the reproductive organs in what is called the **'keel'**. The ten stamens with their fused filaments form a crown around a single central pod-like carpel, which produces 5 to 10 ovules (fig. 2.4).

Fig. 2.4 Pea plant showing flower and fruit pods

Wheat (*Triticum aestivum*)

Fig. 2.5 spike of wheat

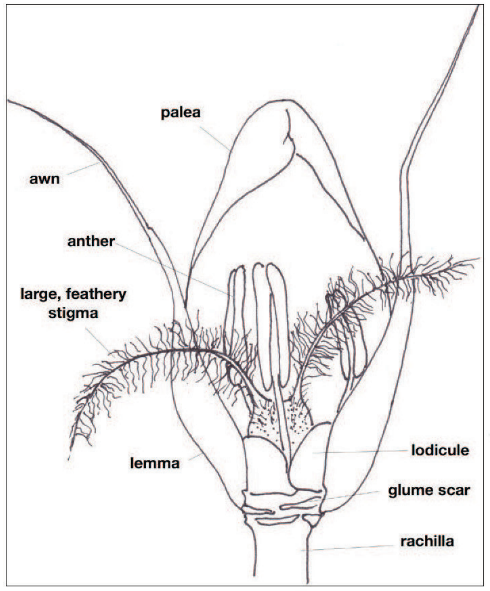


Fig. 2.6 Wheat floret

Wheat accounts for more than 16% of the world's food production. The seeds may be ground into flour for human consumption or used as animal fodder, and the remaining stems constitute straw which, whilst not particularly valued by cereal farmers, may in the future contribute to alternative energy supplies. Like all members of the grass family (Graminae) wheat produces a flower, which is hard to recognise as such because it has no petals.

The flowering shoot, or **inflorescence**, in grass species is called a **spike**. Individual flowers (**florets**) (fig. 2.5) are very small (5-7mm), occurring in bunches (**spikelets**) of six to nine, on a tiny branch (**rachilla**), of the main axis (**rachis**). At the base of the spikelet are a pair of stiff bud leaves called **glumes**, and each floret is enclosed by two sepal-like structures, an upper **palea**, and a lower **lemma** with a sharp pointed awn attached which in where the end product becomes inevitably fixed, or determined. Competency is genetic, whereas determination is achieved by specific hormonal or environmental signals acting on the genotype.

Micropropagation has many advantages, not least of which is the capacity of commercial laboratory nurseries to produce millions of micropropagated plants all year round. This is particularly useful for plants with a slow natural rate of increase such as orchids, succulents, bulb species, palms and ferns. It also satisfies a market demand to get new plant varieties on mass sale as quickly as possible. Another very important aspect of micropropagation is that by selecting a pathogen-free part of a plant such as a meristem tip, and cloning it in sterile conditions, pathogen free seedlings can be obtained. These can be distributed in vitro to sites of crop production all over the world without international quarantine.

Where large numbers of known genotype parents are needed for F1 hybrid seed production, micropropagated clones may be used as parents to produce seed. Commercially, this applies to asparagus, tomato, broccoli and cucumber.

Against these advantages are the considerable setting up and maintenance costs as the techniques require sterile laboratory conditions and a highly skilled labour force. This tends to mean that only large-scale operations are economically viable. High aseptic standards must be maintained, as infection can cause severe losses very quickly. Precautions must be taken also to conduct rigorous field trials in order to eliminate ‘rogue’ mutants amongst the cloned plants

There are an increasing number of different techniques for micropropagation. Two of these, namely **callus culture** and **meristem tip culture** are explained in some detail in the following sections. Research in plant breeding and biotechnology has led to the development of other methods, such as the isolation and **fusion of protoplasts**, and the technique of **embryogenesis**. You can read more about these in Chapter 7.

Callus culture

A callus is a mass of undifferentiated cells produced as a result of wounding. It divides and differentiates in response to hormones, either natural (endogenous) or externally applied (exogenous). Callus cultures may be made from root, stem, or leaf explants, and the callus, once formed can be divided and multiplied, or used as a basis for suspension cultures (described in Chapter 7). Figure 3.11 shows a callus derived from stem tissue of young seedlings regenerating shoots. The general procedure for treating explants and callus tissue is outlined in step by step fashion in the following section and summarised in figure 3.12

Fig. 3.11 callus culture

1 Disinfestation

Fungal and bacterial contaminants, once introduced, will grow to the exclusion of all else in culture media. Most commercial laboratories use a culture indexing procedure, incubating cubes of parent plant material in nutrient broth for a few days, to identify specific pathogens in advance of disinfestation. The explant is then immersed for five to fifteen minutes in a disinfesting solution commonly made up of 80% alcohol and 5%