# Topic: Cereals

**By: Anjana Singh**

**Assistant Professor**

**Department Of Botany**

**Deshbandhu College**

A **cereal** is any grass cultivated (grown) for the edible components of its grain (botanically, a type of fruit called a caryopsis), composed of the endosperm, germ, and bran. The term may also refer to the resulting grain itself (specifically "**cereal grain**"). Cereal grain crops are grown in greater quantities and provide more food energy worldwide than any other type of crop and are therefore staple crops. Edible grains from other plant families, such as buckwheat (Polygonaceae), quinoa (Amaranthaceae) and chia (Lamiaceae), are referred to as pseudocereals.

In their natural, unprocessed, *whole grain* form, cereals are a rich source of vitamins, minerals, carbohydrates, fats, oils, and protein. When processed by the removal of the bran, and germ, the remaining endosperm is mostly carbohydrate. In some developing countries, grain in the form of rice, wheat, millet, or maize constitutes a majority of daily sustenance. In developed countries, cereal consumption is moderate and varied but still substantial.

The word *cereal* is derived from *Ceres*, the Roman goddess of harvest and agriculture.

**Wheat**

**Wheat** is a grass widely cultivated for its seed, a cereal grain which is a worldwide staple food. The many species of wheat together make up the genus ***Triticum***; the most widely grown is common wheat (*T. aestivum*).

The archaeological record suggests that wheat was first cultivated in the regions of the Fertile Crescent around 9600 BCE. Botanically, the wheat kernel is a type of fruit called a caryopsis.

Wheat is grown on more land area than any other food crop (220.4 million hectares, 2014). World trade in wheat is greater than for all other crops combined In 2017, world production of wheat was 772 million tonnes, with a forecast of 2019 production at 766 million tonnes, making it the second most-produced cereal after maize. Since 1960, world production of wheat and other grain crops has tripled and is expected to grow further through the middle of the 21st century. Global demand for wheat is increasing due to the unique viscoelastic and adhesive properties of gluten proteins, which facilitate the production of processed foods, whose consumption is increasing as a result of the worldwide industrialization process and the westernization of the diet.

Wheat is an important source of carbohydrates. Globally, it is the leading source of vegetable protein in human food, having a protein content of about 13%, which is relatively high compared to other major cereals but relatively low in protein quality for supplying essential amino acids. When eaten as the whole grain, wheat is a source of multiple nutrients and dietary fiber.

In a small part of the general population, gluten – the major part of wheat protein – can trigger coeliac disease, noncoeliac gluten sensitivity, gluten ataxia, and dermatitis herpetiformis.

| Wheat | |
|---|---|
| **Scientific classification** | |
| Kingdom: | Plantae |
| *Clade*: | Tracheophytes |
| *Clade*: | Angiosperms |
| *Clade*: | Monocots |
| *Clade*: | Commelinids |
| Order: | Poales |
| Family: | Poaceae |
| Subfamily: | Pooideae |
| Supertribe: | Triticodae |
| Tribe: | Triticeae |
| Genus: | *Triticum* L. |
| **Type species** | |
| *Triticum aestivum* | |

**Origin and history**

Cultivation and repeated harvesting and sowing of the grains of wild grasses led to the creation of domestic strains, as mutant forms ('sports') of wheat were preferentially chosen by farmers. In domesticated wheat, grains are larger, and the seeds (inside the spikelets) remain attached to the ear by a toughened rachis during harvesting.[In wild

strains, a more fragile rachis allows the ear to easily shatter and disperse the spikelets.[ Selection for these traits by farmers might not have been deliberately intended, but simply have occurred because these traits made gathering the seeds easier; nevertheless such 'incidental' selection was an important part of crop domestication. As the traits that improve wheat as a food source also involve the loss of the plant's natural seed dispersal mechanisms, highly domesticated strains of wheat cannot survive in the wild.

Archaeological analysis of wild *emmer* indicates that it was first cultivated in the southern Levant, with finds dating back as far as 9600 BCE. Genetic analysis of wild *einkorn* wheat suggests that it was first grown in the Karacadag Mountains in southeastern Turkey. Dated archeological remains of einkorn wheat in settlement sites near this region, including those at Abu Hureyra in Syria, suggest the domestication of einkorn near the Karacadag Mountain Range.With the anomalous exception of two grains from Iraq ed-Dubb, the earliest carbon-14 date for einkorn wheat remains at Abu Hureyra is 7800 to 7500 years BCE.

Remains of harvested emmer from several sites near the Karacadag Range have been dated to between 8600 (at Cayonu) and 8400 BCE (Abu Hureyra), that is, in the Neolithic period. With the exception of Iraq ed-Dubb, the earliest carbon-14 dated remains of domesticated emmer wheat were found in the earliest levels of Tell Aswad, in the Damascus basin, near Mount Hermon in Syria. These remains were dated by Willem van Zeist and his assistant Johanna Bakker-Heeres to 8800 BCE. They also concluded that the settlers of Tell Aswad did not develop this form of emmer themselves, but brought the domesticated grains with them from an as yet unidentified location elsewhere.

The cultivation of emmer reached Greece, Cyprus and Indian subcontinent by 6500 BCE, Egypt shortly after 6000 BCE, and Germany and Spain by 5000 BCE.[23] "The early Egyptians were developers of bread and the use of the oven and developed baking into one of the first large-scale food production industries." [By 3000 BCE, wheat had reached the British Isles and Scandinavia. A millennium later it reached China.

The oldest evidence for hexaploid wheat has been confirmed through DNA analysis of wheat seeds, dating to around 6400-6200 BCE, recovered from Çatalhöyük. The first identifiable bread wheat (*Triticum aestivum*) with sufficient gluten for yeasted breads has been identified using DNA analysis in samples from a granary dating to approximately 1350 BCE at Assiros in Macedonia.

From Asia, wheat continued to spread across Europe. In the British Isles, wheat straw (thatch) was used for roofing in the Bronze Age, and was in common use until the late 19th century.

**Farming techniques**

Technological advances in soil preparation and seed placement at planting time, use of crop rotation and fertilizers to improve plant growth, and advances in harvesting methods have all combined to promote wheat as a viable crop. When the use of seed drills replaced broadcasting sowing of seed in the 18th century, another great increase in productivity occurred.

Yields of pure wheat per unit area increased as methods of crop rotation were applied to long cultivated land, and the use of fertilizers became widespread. Improved agricultural husbandry has more recently included threshing

machines and reaping machines (the 'combine harvester'), tractor-drawn cultivators and planters, and better varieties (see Green Revolution and Norin 10 wheat). Great expansion of wheat production occurred as new arable land was farmed in the Americas and Australia in the 19th and 20th centuries.

## Physiology

Leaves emerge from the shoot apical meristem in a telescoping fashion until the transition to reproduction ie. flowering. The last leaf produced by a wheat plant is known as the flag leaf. It is denser and has a higher photosynthetic rate than other leaves, to supply carbohydrate to the developing ear. In temperate countries the flag leaf, along with the second and third highest leaf on the plant, supply the majority of carbohydrate in the grain and their condition is paramount to yield formation. Wheat is unusual among plants in having more stomata on the upper (adaxial) side of the leaf, than on the under (abaxial) side. It has been theorised that this might be an effect of it having been domesticated and cultivated longer than any other plant. Winter wheat generally produces up to 15 leaves per shoot and spring wheat up to 9 and winter crops may have up to 35 tillers (shoots) per plant (depending on cultivar).

Wheat roots are among the deepest of arable crops, extending as far down as 2m. While the roots of a wheat plant are growing, the plant also accumulates an energy store in its stem, in the form of fructans, which helps the plant to yield under drought and disease pressure, but it has been observed that there is a trade-off between root growth and stem non-structural carbohydrate reserves. Root growth is likely to be prioritised in drought-adapted crops, while stem non-structural carbohydrate is prioritised in varieties developed for countries where disease is a bigger issue. Depending on variety, wheat may be awned or not awned. Producing awns incurs a cost in grain number,[39] but wheat awns photosynthesise more water-use-efficiently than their leaves, so awns are much more frequent in varieties of wheat grown in hot drought-prone countries than those generally seen in temperate countries. For this reason, awned varieties could become more widely grown due to climate change. In Europe, however, a decline in climate resilience of wheat has been observed.

## Genetics and breeding

In traditional agricultural systems wheat populations often consist of landraces, informal farmer-maintained populations that often maintain high levels of morphological diversity. Although landraces of wheat are no longer grown in Europe and North America, they continue to be important elsewhere. The origins of formal wheat breeding lie in the nineteenth century, when single line varieties were created through selection of seed from a single plant noted to have desired properties. Modern wheat breeding developed in the first years of the twentieth century and was closely linked to the development of Mendelian genetics. The standard method of breeding inbred wheat cultivars is by crossing two lines using hand emasculation, then selfing or inbreeding the progeny. Selections are *identified* (shown to have the genes responsible for the varietal differences) ten or more generations before release as a variety or cultivar.

Major breeding objectives include high grain yield, good quality, disease and insect resistance and tolerance to abiotic stresses, including mineral, moisture and heat tolerance. The major diseases in temperate environments

include the following, arranged in a rough order of their significance from cooler to warmer climates: eyespot, Stagonospora nodorum blotch (also known as glume blotch), yellow or stripe rust, powdery mildew, Septoria tritici blotch (sometimes known as leaf blotch), brown or leaf rust, Fusarium head blight, tan spot and stem rust. In tropical areas, spot blotch (also known as Helminthosporium leaf blight) is also important.

Wheat has also been the subject of mutation breeding, with the use of gamma, x-rays, ultraviolet light, and sometimes harsh chemicals. The varieties of wheat created through these methods are in the hundreds (going as far back as 1960), more of them being created in higher populated countries such as China. Bread wheat with high grain iron and zinc content was developed through gamma radiation breeding.

International wheat breeding is led by CIMMYT in Mexico. ICARDA is another major public sector international wheat breeder, but it was forced to relocate from Syria in the Syrian Civil War.

**Yields**

The presence of certain versions of wheat genes has been important for crop yields. Genes for the 'dwarfing' trait, first used by Japanese wheat breeders to produce short-stalked wheat, have had a huge effect on wheat yields worldwide, and were major factors in the success of the Green Revolution in Mexico and Asia, an initiative led by Norman Borlaug. Dwarfing genes enable the carbon that is fixed in the plant during photosynthesis to be diverted towards seed production, and they also help prevent the problem of lodging. 'Lodging' occurs when an ear stalk falls over in the wind and rots on the ground, and heavy nitrogenous fertilization of wheat makes the grass grow taller and become more susceptible to this problem. By 1997, 81% of the developing world's wheat area was planted to semi-dwarf wheats, giving both increased yields and better response to nitrogenous fertilizer.

The world record wheat yield is about 17t/ha, reached in New Zealand in 2017.A project in the UK, led by Rothamsted Research has aimed to raise wheat yields in the country to 20t/ha by 2020, but in 2018 the UK record stood at 16t/ha, and the average yield was just 8t/ha.

**Disease resistance**

Wild grasses in the genus *Triticum* and related genera, and grasses such as rye have been a source of many disease-resistance traits for cultivated wheat breeding since the 1930s.

**Hybrid wheats**

Because wheat self-pollinates, creating hybrid varieties is extremely labor-intensive; the high cost of hybrid wheat seed relative to its moderate benefits have kept farmers from adopting them widely despite nearly 90 years of effort.

F1 hybrid wheat cultivars should not be confused with wheat cultivars deriving from standard plant breeding. Heterosis or hybrid vigor (as in the familiar F1 hybrids of maize) occurs in common (hexaploid) wheat, but it is difficult to produce seed of hybrid cultivars on a commercial scale as is done with maize because wheat flowers are perfect in the botanical sense, meaning they have both male and female parts, and normally self-pollinate.[42] Commercial hybrid wheat seed has been produced using chemical hybridizing agents, plant growth regulators that selectively interfere with pollen development, or naturally occurring cytoplasmic male

sterility systems. Hybrid wheat has been a limited commercial success in Europe (particularly France), the United States and South Africa.

Synthetic hexaploids made by crossing the wild goatgrass wheat ancestor *Aegilops tauschii* and various durum wheats are now being deployed, and these increase the genetic diversity of cultivated wheats.

**Gluten**

Modern bread wheat varieties have been cross-bred to contain greater amounts of gluten, which affords significant advantages for improving the quality of breads and pastas from a functional point of view.

**Water efficiency**

Stomata (or leaf pores) are involved in both uptake of carbon dioxide gas from the atmosphere and water vapor losses from the leaf due to water transpiration. Basic physiological investigation of these gas exchange processes has yielded valuable carbon isotope based methods that are used for breeding wheat varieties with improved water-use efficiency. These varieties can improve crop productivity in rain-fed dry-land wheat farms.

**Genome**

In 2010, a team of UK scientists funded by BBSRC announced they had decoded the wheat genome for the first time (95% of the genome of a variety of wheat known as Chinese Spring line 42). This genome was released in a basic format for scientists and plant breeders to use but was not a fully annotated sequence which was reported in some of the media. On 29 November 2012, an essentially complete gene set of bread wheat was published. Random shotgun libraries of total DNA and cDNA from the *T. aestivum* cv. Chinese Spring (CS42) were sequenced in Roche 454 pyrosequencer using GS FLX Titanium and GS FLX+ platforms to generate 85 Gb of sequence (220 million reads) and identified between 94,000 and 96,000 genes.[61] The implications of the research in cereal genetics and breeding includes the examination of genome variation, analysis of population genetics and evolutionary biology, and further studying epigenetic modifications.

## Varieties

There are around 30,000 wheat varieties of 14 species grown throughout the world. Of these about 1,000 are commercially significant. In the United States over 500 varieties are available. In Canada different varieties are blended prior to sale. "Identity preserved" wheat that has been stored and transported separately (at extra cost) usually fetches a higher price.

Wheat genetics is more complicated than that of most other domesticated species. Apart from mutant versions of genes selected in antiquity during domestication, there has been more recent deliberate selection of alleles that affect growth characteristics. Some wheat species are diploid, with two sets of chromosomes, but many are stable polyploids, with four sets of chromosomes (tetraploid) or six (hexaploid).

Einkorn wheat (*T. monococcum*) is diploid (AA, two complements of seven chromosomes, 2n=14).[4]

Most tetraploid wheats (e.g. emmer and durum wheat) are derived from wild emmer, *T. dicoccoides*. Wild emmer is itself the result of a hybridization between two diploid wild grasses, *T. urartu* and a wild goatgrass such as *Aegilops searsii* or *Ae. speltoides*. The unknown grass has never been identified among non extinct wild grasses, but the closest living relative is *Aegilops speltoides*. The hybridization that formed wild emmer (AABB) occurred in the wild, long before domestication, and was driven by natural selection.

Hexaploid wheats evolved in farmers' fields. Either domesticated emmer or durum wheat hybridized with yet another wild diploid grass (*Aegilops tauschii*) to make the hexaploid wheats, spelt wheat and bread wheat.These have *three* sets of paired chromosomes, three times as many as in diploid wheat.

**Major cultivated species of wheat**

- **Common wheat** or **bread wheat** (*T. aestivum*) – A hexaploid species that is the most widely cultivated in the world.
- **Spelt** (*T. spelta*) – Another hexaploid species cultivated in limited quantities.[*quantify*] Spelt is sometimes considered a subspecies[*by whom?*] of the closely related species common wheat (*T. aestivum*), in which case its botanical name is considered to be *T. aestivum* ssp. *spelta*.

Tetraploid species

- **Durum** (*T. durum*) – A tetraploid form of wheat widely used today, and the second most widely cultivated wheat.
- **Emmer** (*T. dicoccon*) – A tetraploid species, cultivated in ancient times but no longer in widespread use.
- **Khorasan** (*T. turgidum ssp. turanicum*, also called *T. turanicum*) is a tetraploid wheat species. It is an ancient grain type; Khorasan refers to a historical region in modern-day Afghanistan and the northeast of Iran. This grain is twice the size of modern-day wheat and is known for its rich nutty flavor.

Diploid species

- **Einkorn** (*T. monococcum*) – A diploid species with wild and cultivated variants. Domesticated at the same time as emmer wheat.

**Hulled versus free-threshing species**

The four wild species of wheat, along with the domesticated varieties einkorn, emmer and spelt, have hulls. This more primitive morphology (in evolutionary terms) consists of toughened glumes that tightly enclose the grains, and (in domesticated wheats) a semi-brittle rachis that breaks easily on threshing.

The result is that when threshed, the wheat ear breaks up into spikelets. To obtain the grain, further processing, such as milling or pounding, is needed to remove the hulls or husks. Hulled wheats are often stored as spikelets because the toughened glumes give good protection against pests of stored grain.

In free-threshing (or naked) forms, such as durum wheat and common wheat, the glumes are fragile and the rachis tough. On threshing, the chaff breaks up, releasing the grains

**Naming**

There are many botanical classification systems used for wheat species, discussed in a separate article on wheat taxonomy. The name of a wheat species from one information source may not be the name of a wheat species in another.

Within a species, wheat cultivars are further classified by wheat breeders and farmers in terms of:

- Growing season, such as winter wheat vs. spring wheat.[69]
- Protein content. Bread wheat protein content ranges from 10% in some soft wheats with high starch contents, to 15% in hard wheats.
- The quality of the wheat protein gluten. This protein can determine the suitability of a wheat to a particular dish. A strong and elastic gluten present in bread wheats enables dough to trap carbon dioxide during leavening, but elastic gluten interferes with the rolling of pasta into thin sheets. The gluten protein in durum wheats used for pasta is strong but not elastic.
- Grain color (red, white or amber). Many wheat varieties are reddish-brown due to phenolic compounds present in the bran layer which are transformed to pigments by browning enzymes. White wheats have a lower content of phenolics and browning enzymes, and are generally less astringent in taste than red wheats. The yellowish color of durum wheat and semolina flour made from it is due to a carotenoid pigment called lutein, which can be oxidized to a colorless form by enzymes present in the grain.

**Wheat Cultivation in India: Harvesting, Milling and Uses**

India account for about 3.5 per cent of the global wheat production. The area under wheat constitutes roughly 14.0 per cent of the total area under cereals and 10.0 per cent of the total area not of much significance in the south.

It is cultivated as a food crop mainly in Uttar Pradesh, Punjab. Madhya Pradesh, Maharashtra, Bihar and Rajasthan. Wheat is the second staple food crop of India and occupies about 29 million acres of land. It is consumed mainly by the people in the north. The wheat grains discovered as a result of Indus Valley excavations at Mohenjo-Daro indicate that north-western India was one of the ancestral lands of this cereal.

The carbonised grains resemble those of Triticum sphaerococcum Percival an endemic species which is still found in a few places in India. The wheat growing area in India can be divided into three zones-the Gangetic alluvium, the Indus valley, and the black soil tract of Peninsular India.

Wheat is also cultivated in Gujarat. A special feature of Indian wheat is the relatively short season in which it completes its life cycle. While the crop stands in the field for 9 to 10 months in some western countries in India

ready for harvest in four to six months after sowing. However, in the hilly tracts of Northern India the growing season for wheat is about nine months but the area under the crop in this region is very small.

Of the 18 recognized under the genus Triticum, five are cultivated in India. Of these Triticum aestivum Linn, commonly known as bread wheat, occupies the largest area and is mainly grown in the northern regions.

Next in importance is the macaroni wheat, T. durum Desf., which is the predominant species in Central and Western India. The area under T. dicoccum Schrank is grown in South India. T. turgidum Linn., the revet wheat, and T sphaerococcum Percival, the dwarf wheat are even less important.

Wheat was the first crop to attract the attention of Indian breeders. The main object was to evolve high-yielding varieties with good grain quality. Notable achievement of the last few years has been the evolution of a new series of improved wheat. Their special characters include adaptability to certain regions, high-yield, good grain quality, tolerance to rusts, land resistance to lose smut.

**Cultivation, Harvesting and Thrashing:**

In Northern India sowing of wheat is done in October-November. Wheat may be sown broadcast, either by hand or by sewing machines. Germination begins immediately and the first leaves appear within a fortnight. Wheat is properly mannered and irrigated.

The crop is harvested by cutting the plants with a sickle close to the ground, in March-April. Thrashing is the next process, and this involves the separation of the grain from the spike. Thrashing is generally done under the feet of bullocks or by Thrashing machines.

After Thrashing the wheat is winnowed and sifted. In the Punjab recently the combines are introduced for the purpose. The combines reap, clean, thresh, winnow and sift the grains: wheat must be stored in firmly built structures, and it must be well ventilated.

**Milling:**

In India in most of the motor driven flour mills there remains a fixed lower stone upon which a movable upper one revolves. The grains are dropped in the openings in the upper stone land gradually worked out between the stones which possess grinding surfaces cut in radiating lines. In this process whole grain is used.

The roller process of milling is an advanced and perfect process. The first step in this process comprises cleaning and scouring. After making the grains clean they are thoroughly washed and scoured. The next step is tempering.

In this process a little water is added, which toughens the bran and prevents its breaking up, so that it will flake out all in one piece, in the last the conditioned and tempered wheat is submitted to breaking, grinding and rolling. The grain is first cracked or crushed gradually through a series of four to six pairs of chilled iron break rolls.

The surface of the break rolls is made rough by sharp length-wise folding. The break flour is separated out by sieves, while the main portion goes to the second break. This process is repeated until five sets of rollers have been utilized. All bran is removed during this process and the purified material is passed to smooth rollers for final granulation. The final product is flour.

**Uses:**

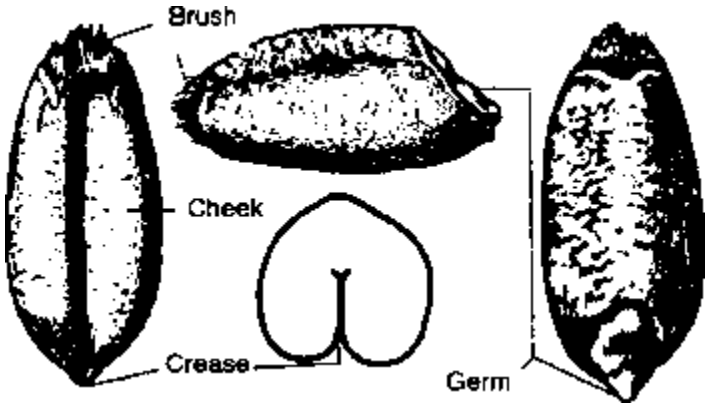
There are three main kinds of flour-suji, and atta which are used for various purposes. The flour is used chiefly for making bread, chapattis, biscuits, cakes, pastry and similar articles. Wheat flakes are used as breakfast food.

Wheat is also used in the manufacture of beer and other alcoholic beverages. Wheat straw is used for seating chairs, chairs, stuffing mattresses fodder etc. It makes a good for livestock's.

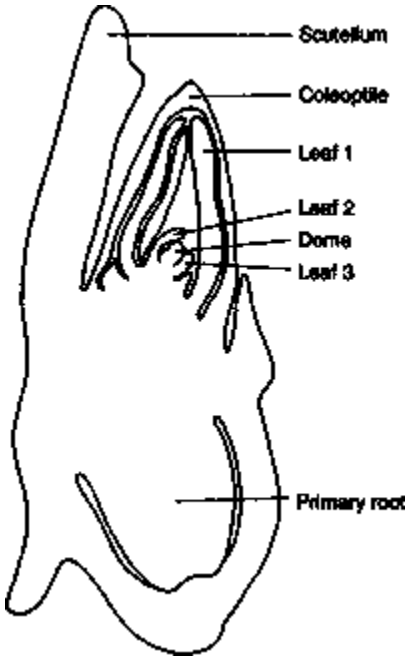
**Economic importance and taxonomy of the wheat**

Wheat (Triticum aestivum L. em Thell.) is the first important and strategic cereal crop for the majority of world's populations. It is the most important staple food of about two billion people (36% of the world population). Worldwide, wheat provides nearly 55% of the carbohydrates and 20% of the food calories consumed globally (Breiman and Graur, 1995). It exceeds in acreage and production every other grain crop (including rice, maize, etc.) and is therefore, the most important cereal grain crop of the world, which is cultivated over a wide range of climatic conditions and the understanding of genetics and genome organization using molecular markers is of great value for genetic and plant breeding purposes. The grass family Poaceae (Gramineae) includes major crop plants such as wheat (Triticum aestivum L.), barley (Hordeum vulgare L.), oat (Avena sativa L.), rye (Secale cereale L.), maize (Zea mays L.) and rice (Oryza sativa L.). Triticeae is one of the tribes containing more than 15 genera and 300 species including wheat and barley. Wheat belongs to the tribe Triticeae (= Hordeae) in the grass family Poaceae (Gramineae) (Briggle and Reitz, 1963) in which the one to several flowered spikelets are sessile and alternate on opposite sides of the rachis forming a true spike. Wheats (Triticum) and ryes (Secale) together with Aegilops, Agropyron, Eremopyron and Haynalidia form the subtribe Triticineae (Simmonds, 1976). Linnaeus in 1753 first classified wheat. In 1918, Sakamura reported the chromosome number sets (genomes) for each commonly recognized type. This was a turning point in Triticum classification. It separated wheat into three groups. Diploids had 14 (n=7), tetraploids had 28 (n=14) and the hexaploids had 42 (n=21) chromosomes. Bread wheat is Triticum aestivum. T. durum and T. compactum are the other major species. All three are products of natural hybridization among ancestrals no longer grown commercially (Briggle, 1967).

***Wheat grain, showing different aspects and cross section to illustrate the depth of the crease***

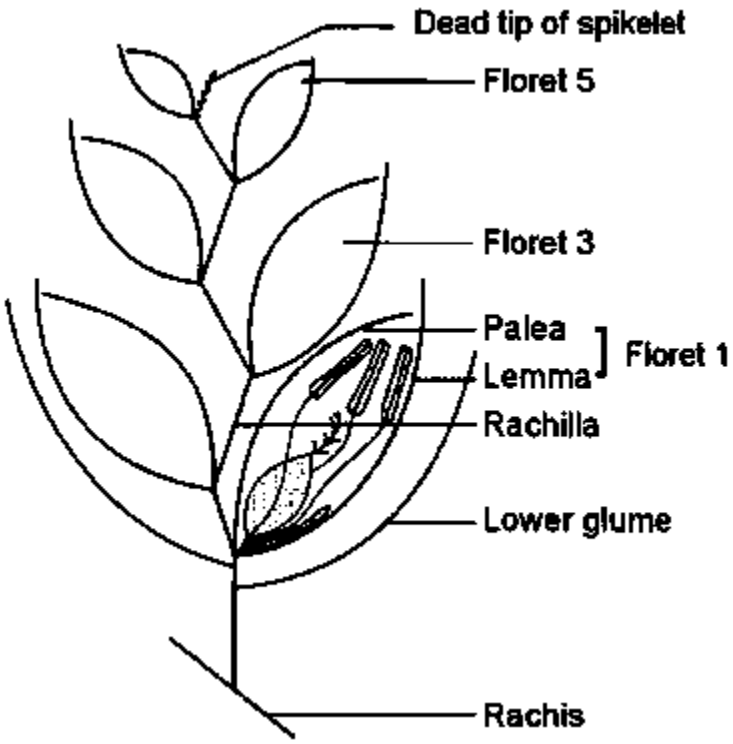



***Longitudinal section of the embryo from a mature grain, with the apex and leaves of the shoot present and a tiller bud visible***




*Source:* Kirby and Appleyard, 1985. (Courtesy of Kluwer Academic Publishers)

***Diagram of a spikelet***




*Source*: Kirby and Appleyard, 1987. (Courtesy of Arable Unit RASE)

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