Triticum spp.

Wheat

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Agricultural Science Monograph

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Chapter 1: Introduction

Wheat. A worldwide known cereal plant with an incredible story behind it. Wheat refers to the set of cereals, both cultivated and wild, and belongs to the genus *Triticum*. They are annual plants of the grass family, widely cultivated throughout the world.

How does wheat work? How is it planted? Where is wheat most popular? What are the necessary cares to have a successful wheat plantation? Are there any diseases? What are the most popular uses of wheat? Next, you will know the answers to all these questions that arise when talking about wheat. Chapter 2, Ecology will specifically deal with the affinity, fossil records, origins, present distributions, and elevation and climate. Chapter 3, Biology of Wheat will include chromosome complements, life cycles, productivity and pollination and reproduction. Chapter 4, Management of Wheat will especially focus on propagation, planting, and management and disease control. And finally, chapter 5, Market and Uses will conclude the monograph with an exploration of the value and products that are associated with this genus.

Chapter 2: Ecology

2.1: Affinity

Kingdom: Plantae

Division: Magnoliophyta

Class: Liliopsida

Order: Poales

Family: Poaceae

Genus: *Triticum*

Wheat. Majorly cultivated for its seed is a cereal grain known all over the world. There are many species of wheat making up the genus *Triticum*. Bread wheat, or common wheat, is the most commonly cultivated wheat species in the world, actually accounting for 90-95% of total production. The Botanical name for wheat is *Triticum*. It is an allohexaploid plant, due to its conformation of 42 chromosomes divided into 6 sets from three different species (*Triticum spelta, Aegilops cylindrica*, with 7 chromosomes each). Some other species and their genomes are visible in the table below.

Table 1.

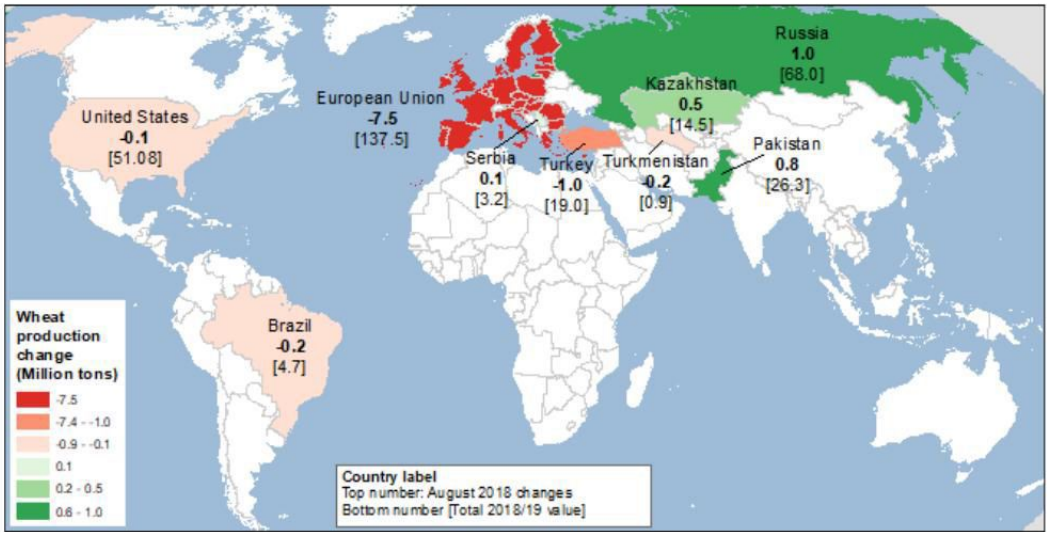
Types of common wheat species and their genomic makeup

Common Names	Species	Genomes
Bread Wheat	*Triticum aestivum*	Hexaploid
Durum wheat	*Triticum durum*	Tetraploid
Einkorn	*Triticum monococcum*	Diploid
Emmer	*Triticum dicoccum*	Tetraploid
Spelt	*Triticum spelta*	Hexaploid
Kamut® or QK-77	*Triticum plonicum* or *T. durum*	Tetraploid

World trade in wheat is greater than for all other crops combined. Wheat is grown on more land than any other food crop, actually being grown in 220.4 million hectares in 2014 and in 2017, world production of wheat was 772 million tonnes. Map 1 below shows the location of where wheat is produced in the world (Amended from Foreign Agriculture Service, Production, Supply and Distribution online database, 2018).

Map 1.

Places around the world that produce and trade wheat.



2.2: Fossil Records

The evolution of bread wheat, however, has not depended solely on the accumulation of mutations; hybridization has also been an important factor. The evolution of wheat has been slowly acknowledged by collecting evidence from many different studies, for example, botany, genetics, archaeology, and the current distribution of the various grass species that are believed to have contributed to its evolution. Palynologists (scientists who study pollen), state that the earliest finds of fossilized grass-like pollen date to between 60 and 70 million years ago (Kellogg, 2001). However, other studies indicate that the grasses might be more ancient still.

Grasses could have originated 80 million years ago. By examining the contents of fossilized excrement of herbivorous dinosaurs, scientists have discovered that it contained cell types found only in the epidermis of grass leaves (Prasad et al., 2005).

2.3: Origins

The earliest archeological findings of domesticated wheat were found in the Karacadag mountain region (today, southeastern Turkey) and are thought to be around 12,000 years old. The earliest collected wheat (of the wild kind) was wild emmer in the southern Levant which were an estimated amount of 23,000 years old. A few years later, cultivated wheat arrived in Greece, India and Cyprus around the year 65000 BCE, and afterwards, Egypt, shortly after the year 6000 BCE. Germany and Spain followed up, around the year 5000 BCE, and after 3000 BCE, England had also started producing wheat along Scandinavia.

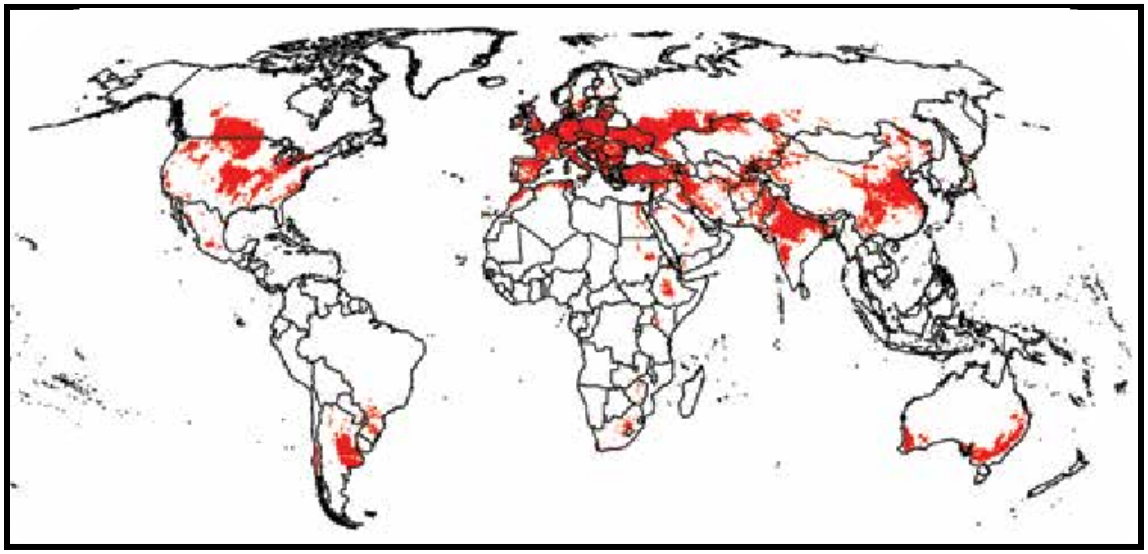
2.4: Present distribution

Today, wheat is grown on more land area than any other commercial crop and continues to be the most important food grain source for humans. Its production leads all crops, including maize, rice and potatoes. Wheat was domesticated around 10,000 years ago. Since then it has spread worldwide to become one of the major crops. Studies suggest that for about 8,000 years, wheat has been the basic staple food of the major civilizations of Europe, West Asia and North Africa. Although cultivation is most successful between latitudes 30° to 60°N and 27° to 40°S (Shavanov & Shigapov, 2020), wheat can be grown beyond these limits, which we would not really think possible. From within the Arctic Circle, to higher elevations near the equator. Studies conducted by the International Maize and Wheat Improvement Center (CIMMYT) have shown

that wheat production in much warmer areas is technologically feasible. At altitude, the crop develops from sea level to more than 3,000 masl, and has been reported at 4,570 masl in Tibet (Percival, 1921).

Map 2.

Places around the world where wheat is more commonly distributed.



2.5: Elevation and Climate (and other environmental factors)

The conditions for growing wheat have to be exact and specific. Wheat needs a lot of sunshine, especially when the grains are filling. Also, wheat needs 31 to 38 cm, (12 to 15 inches) of water to produce a good crop. It grows best when temperatures are warm, from 21° to 24° C, (70° to 75° F) but of course, not too hot.

On the other hand, rice grows in the temperature of 20º to 27º C. Rice requires abundant rainfall; a minimum of 115 cm rainfall is required for rice and wheat requires 38 cm to 80 cm rainfall. There is a type of wheat that thrives during cold temperatures, it's typically known as winter wheat (Mariospartan, 2018). Winter wheat will not produce seed if not vernalized: vernalization

is the process where plants need to sense exposure to cool temperatures in order to reach flowering (Buetow & Endres, 2021). The vernalization period is very important to wheat production, because just as the name states, if the seed did not germinate in the fall due to dry conditions, there is still an opportunity for the crop to vernalize.

Wheat can be grown in a variety of soils. Hence, studies show that wheat best grows in a clay loam textured soil, since it is very well known for its texture and its water holding capacity. It has to have specific cares; in order to avoid very porous and excessively drained oils. Under dry conditions, heavy soil with good drainage is suitable for wheat cultivation due to their capacity to hold/retain/absorb water rain well. Contrary, heavy soils with poor structure and poor drainage are not suitable as wheat is sensitive to water logging (Department of Agriculture, 2021).

Figure 1.

Wheat plantations. They get plenty of sunlight.

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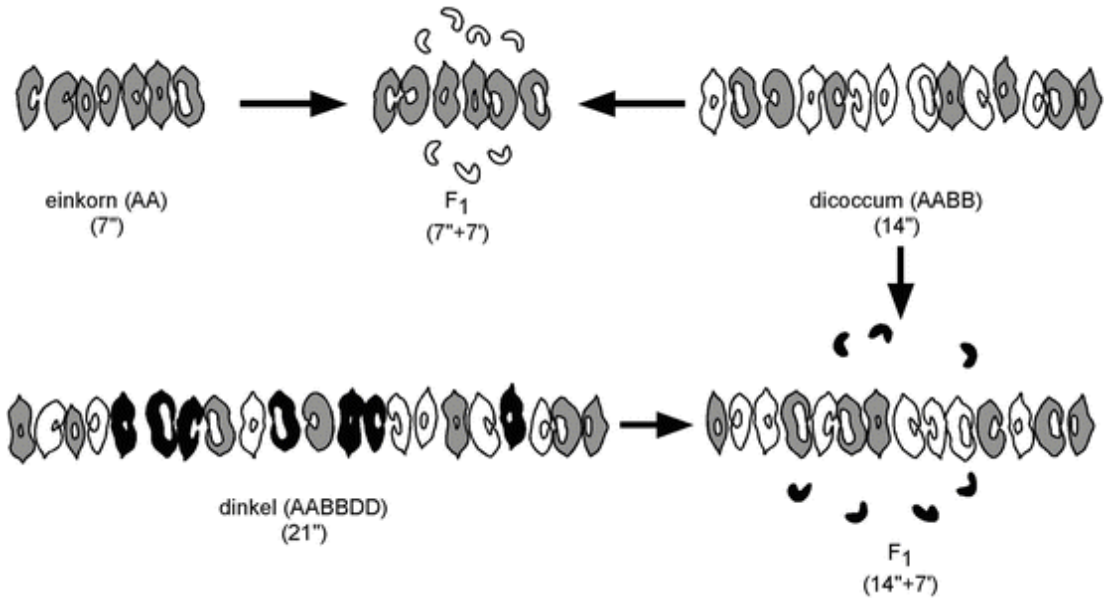
Chapter 3: Biology of Wheat

3.1: Chromosome Complement

Wheat (*T. aestivum* L., 2n = 42). In the year of 1915, botanists classified three types of cultivated wheat, the one-seeded monococcum (*Triticum monococcum* L.), the two-seeded emmer (*T. turgidum* L.), and dinkel (*T. aestivum* L.) (Springnature, 2020)

Figure 2.

The F1 hybrid between einkorn and dicoccum showed 7" and 7', indicating that they share one set of chromosomes in common.



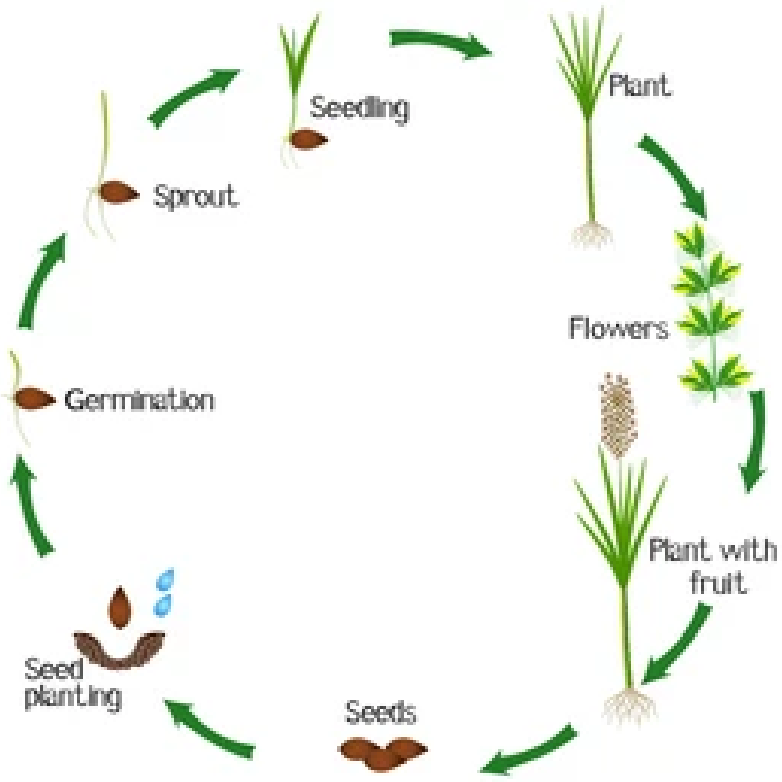
3.2: Life Cycles

Wheat is known to be measured in six growing stages (Adams,2017). It is crucially important to help farmers understand the stages of growth in order to optimize the yield. Stress and drought affect plants differently during each stage of growth. **Seedling stage**: the first stage, occurs after germination. It begins when the first true leaves emerge from the soil, and ends when the first tiller emerges. At this point, the second leaves are just emerging and beginning to unroll, and there are as many as six seminal roots. **Tillering stage**: it can occur either before or after the winter dormancy stage in winter wheat, and a plant can have as many as six tillers. Each tiller can grow its own seed head. That way, the number of tillers will determine the potential yield of the plant. **Jointing stage**: it starts when the stalk forms its second node (which is typically a hard joint from which the plant telescopes upwards). During the jointing stage, it is important that all the wheat in a field reaches the jointing stage at the same time so that the heads will all be mature at harvest time, if not, the less-formed tillers often die off. **Booting stage**: this is the part when the head of the wheat develops and becomes visible beneath the sheath on the stalk. The booting stage ends when the tips of the head, called awns, begin to emerge. It's typically one of the short stages. **Heading and flowering stage**: the awns are now emerging from the sheath. It is important again during the flowering stage that all the plants in a field flower at the same time. And, when the awns have emerged the flowering begins and pollination and fertilization occurs. **Maturity stage**: the final stage consists in maturing, as its own name states. The maturity stage immediately follows fertilization. The milk stage is the first step of maturing, and this is when the formation of the kernel happens. The kernel is fully formed during the dough stage, and the plant takes nutrients from the stalk and leaves and transfers them to the kernel. The kernel contains about 30 percent of water, which makes it very moist at the end of

the dough stage. Finally, during the ripening stage the kernel loses the rest of its moisture and is ready to be harvested.

Figure 3.

Brief illustration of the wheat cycle.

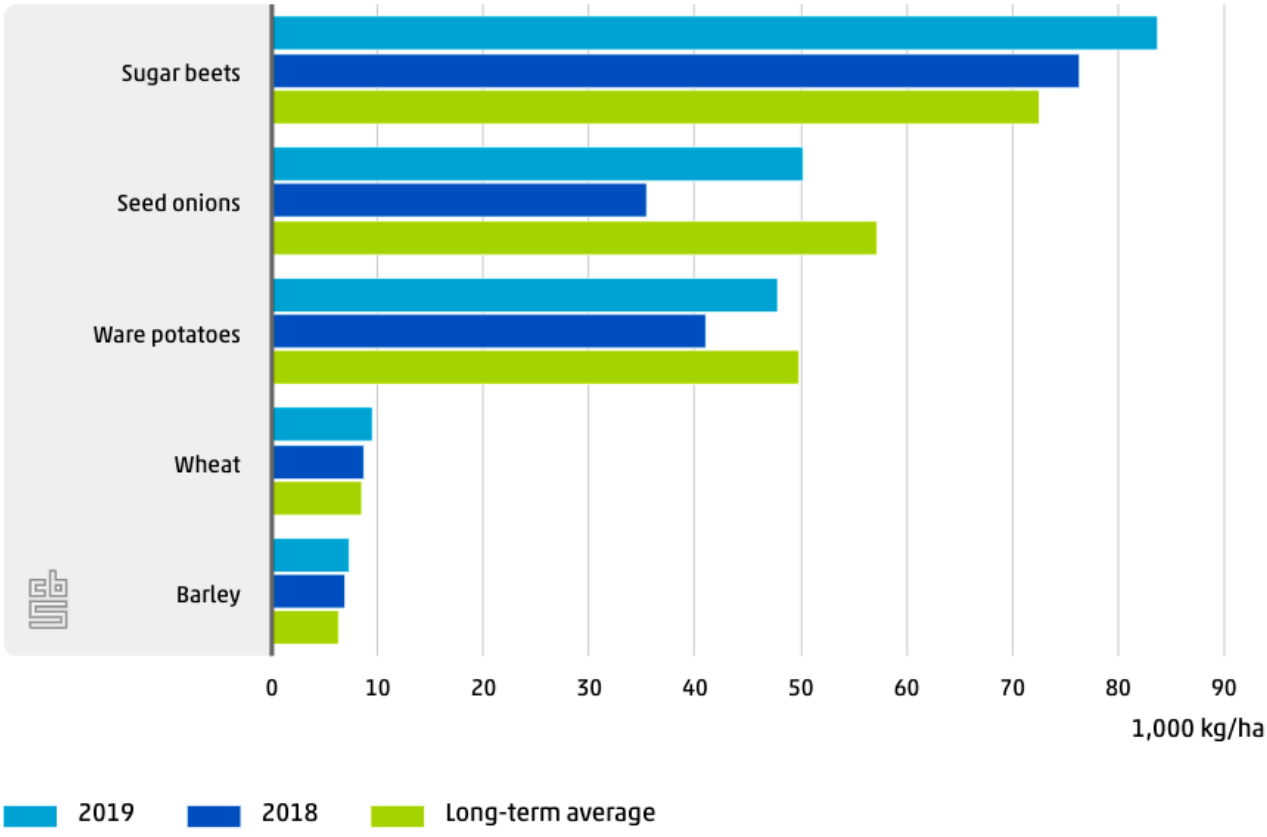


3.3: Productivity

Winter production was at 9.8 tonnes per hectare, as a difference from 7.1 tonnes per hectare for summer wheat. Barley production reached up to 9.1 tons of winter barley and 6.6 tonnes per hectare of summer barley.

Chart 1.

Yields per hectare from 2019 to Long-term average



3.3.1: Pollination and Reproduction

Wheat is a **self-pollinating crop**. Know that it produces seed when pollen from anthers fertilizes the receptive ovary in the same flower of a single parent plant. One way to prevent self-pollination in wheat is the use of male-sterile lines that do not produce pollen. These plants can then be cross-pollinated by male-donor lines. Yes, wheat has its males and females. In this case, for cross-pollination to occur, wheat florets of the female line must be open to allow pollen from the male donor line to reach the ovary. Known as the "first opening", wheat flowers only open for less than 30 minutes then close, just as the self-fertilization process occurs within the same flower. (Okada et al., 2018)

Figure 4.

Images of male-fertile and male-sterile plants during flowering time and early seed development.

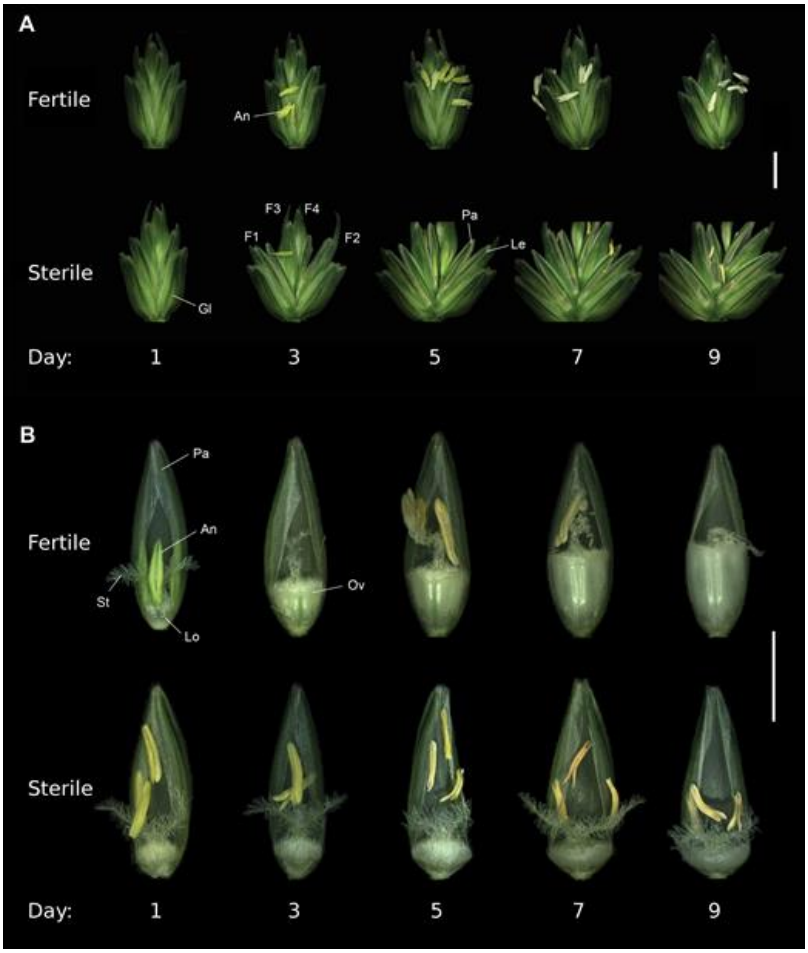
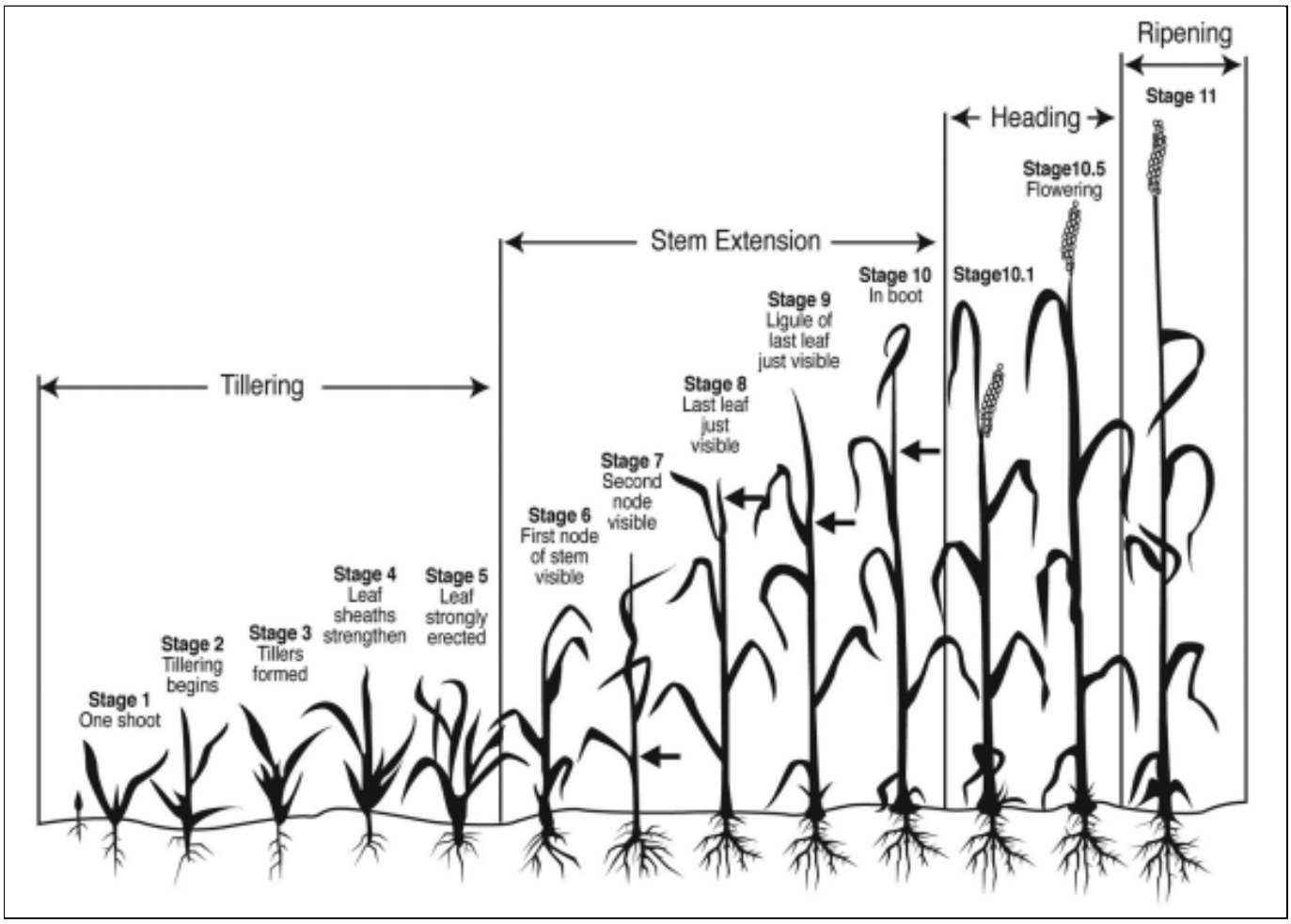


Figure 5.

Division of Wheat growth in several stages:



Note: The picture shows the following stages: germination/emergence, tillering, stem elongation, boot, heading/flowering, and grain-fill/ripening (reference).

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Chapter 4: Management of Wheat

4.1: Propagation

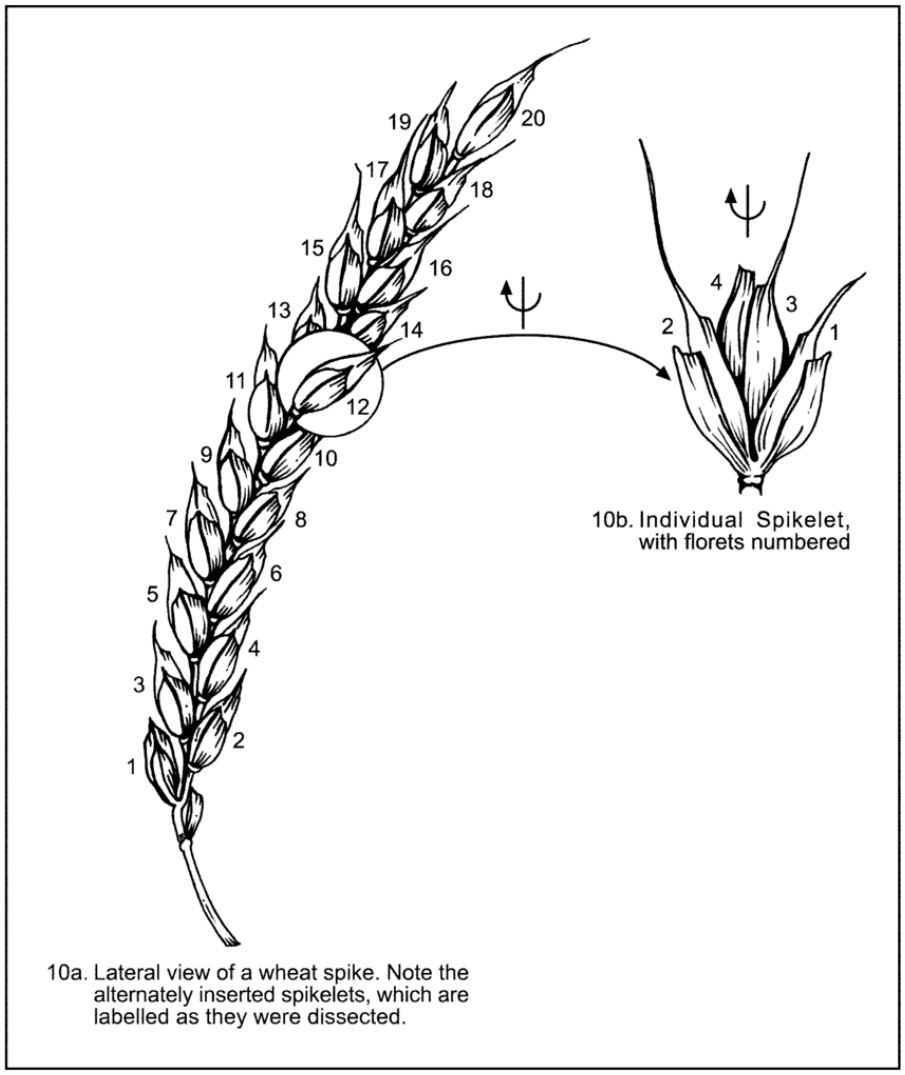
The propagation of wheat is quite precise, as its physical form is key. Wheat species have an erect smooth stem with linear leaves that grow in two rows on either side of the stem with larger 'flag' leaves at the top of the stem. The stem's end is a spike that is made up of individual spikelets, each possessing 3–9 florets. The wheat develops inside the spikelets, maturing to a seed (kernel). Wheat can reach 1.2 m (4 ft) in height and like other cereals, has been developed into different varieties that are adapted to planting at different times of the year. There is no problem for wheat to grow in a different variety of climates, but it has been said that it grows better in cool temperatures. Temperature can go from 10 to 24°C (50–75°F). Keep in mind that wheat will hardly or not grow at temperatures above 35°C (95°F). It can grow in a deep, fertile, well draining and well aerated soil

Figure 6.

Seedlings of wheat, more specifically, young seedlings of cereal crops.

Figure 7.

Figure of a wheat skiplet with the demonstration of an individual floret.



4.2: Planting

The different species of wheat have very specific dates to start their planting process. For example, the Winter wheat varieties have a date set to be planted in the Fall, approximately 6 to 8 weeks before the first frost date. On the other hand, Spring wheat varieties can be a bit more flexible; they should be planted as soon as the soil can be worked in the Spring. Differently, commercially grown wheat is a whole different situation; sometimes wheat is mechanically drilled using a machine that creates a furrow and drops the seed which later on, it will be covered back up. Seeds should be sown deeper in drier soil. They are generally sown at depths ranging from 2 to 12 cm (0.8 to 4.7 in) depending on soil conditions. And, they can be sown in smaller areas or using a hand seeder and once the seeds have been spread the soil should be raked marginally to place the seeds to the desired depth.

Figure 8.

Winter wheat plantations on the left and Spring wheat plantations on the right.

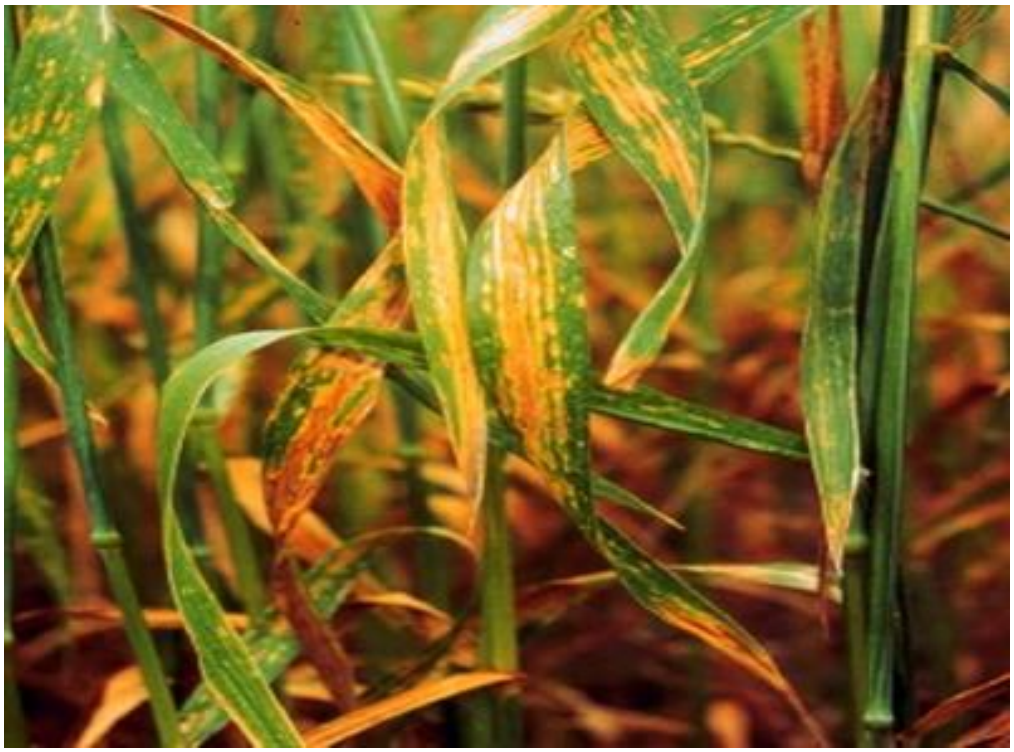
4.3: Management and disease control

There are several diseases that threaten the wheat plantations. For example: **Barley Yellow Dwarf Virus**. A viral disease transmitted by several species of aphid. Infection can vary, it may occur during the fall or spring. Symptoms commonly show in patches throughout the field and can include stunting, reduced tillering, and a yellow or reddish discoloration of the flag leaf, leaf tips and margins. **Fusarium head blight**, commonly known as head scab. It may become a serious problem when favorable conditions for spore production, (meaning warm and humid weather) occur when wheat is blooming. The individual spikelet to its entire head becomes infected. The infected spikelets will turn dark; tan to brown and may have salmon-colored fungal growth. **Stripe or yellow**. Known for the linear rows of bright yellow or orange that follow the leaf veins. Significant losses may occur due to the big loss of tissue resulting in reduction in kernels, test weight, and grain quality, as well as lodging. It develops rapidly in appropriate temperatures and prolonged periods of leaf wetness. While there are many diseases of wheat, there are also many treatments/cures. When limited management options are available, **broad fungicide seed treatments** can provide little to some protection from soilborne pathogens and certain seeds. For good maintenance of wheat, it is crucial to start planting at a certain time of the year. For example, for Winter wheat, planting must start in early fall. Crop rotation and variety selection have a specific impact on yield and wheat quality. According to wheat rotation, Winter wheat is best planted after soybeans. Soybeans are commonly used for industrial uses, engine oil, biodiesel, and even animal feed. Wheat must never be planted after wheat or corn due to several diseases that can occur. However, there's a bigger problem with planting wheat after wheat, and it's root diseases which offer even fewer solutions: root diseases such as take-all. Fungicides are said to be very little help, therefore the solution is to plant wheat right after soybeans to avoid

any problems related to diseases. Winter wheat should be sown after the safe fly-free date. This date is based on when the burlap fly and aphids carrying barley yellow dwarf virus can affect wheat yield.

Figure 9.

Fungal wheat disease as leaf rust.



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Chapter 5: Market and Uses

5.1: Potential markets

Talking about feeding properties, with an average annual growth of 1.9% since 2000, the global wheat-to-feed complex seems to post decent growth rates. The annual wheat intake for feed was relatively stable back in the year of 2000 and ten years later, benefitting from a large wheat availability on the back of the 2011 harvest. Nevertheless, these supplies quickly went downhill with the 2012 Russia crop being reduced by a drought. It was a major hit to global wheat production and the use in feeding properties. Consequently, over the last years it has slowly recovered.

Chart 2.

Global wheat use grew by 25% in the last 15 years, 2001/02-2016/17

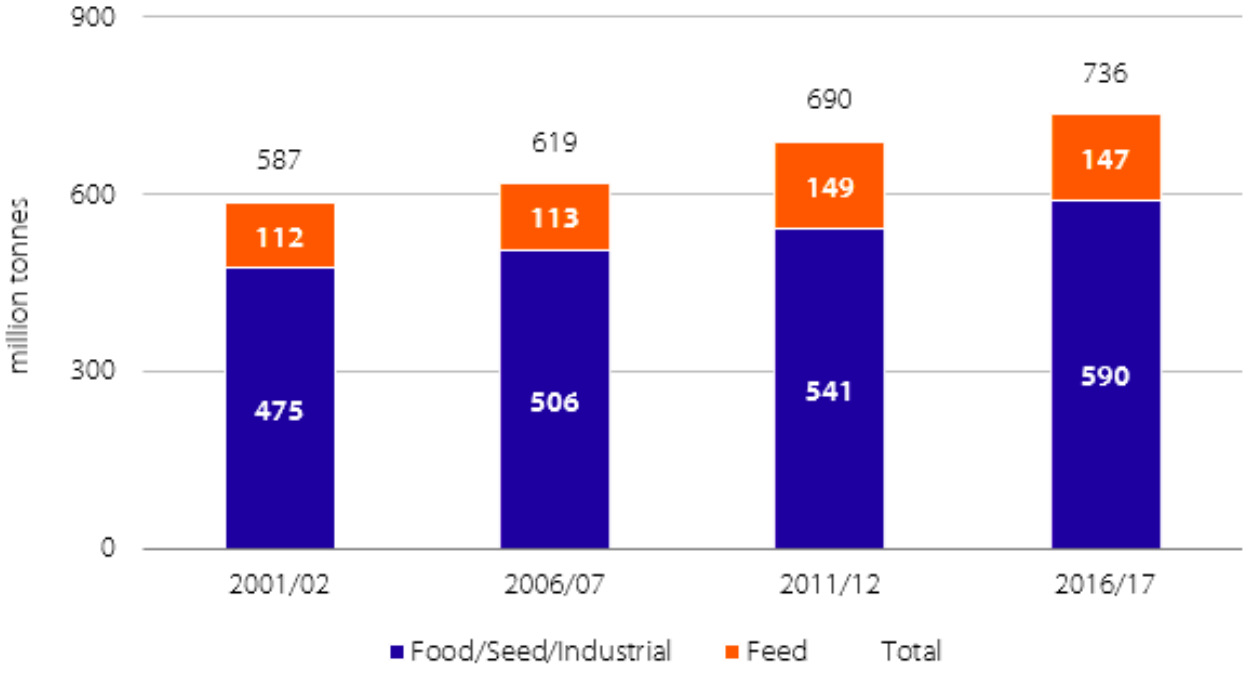
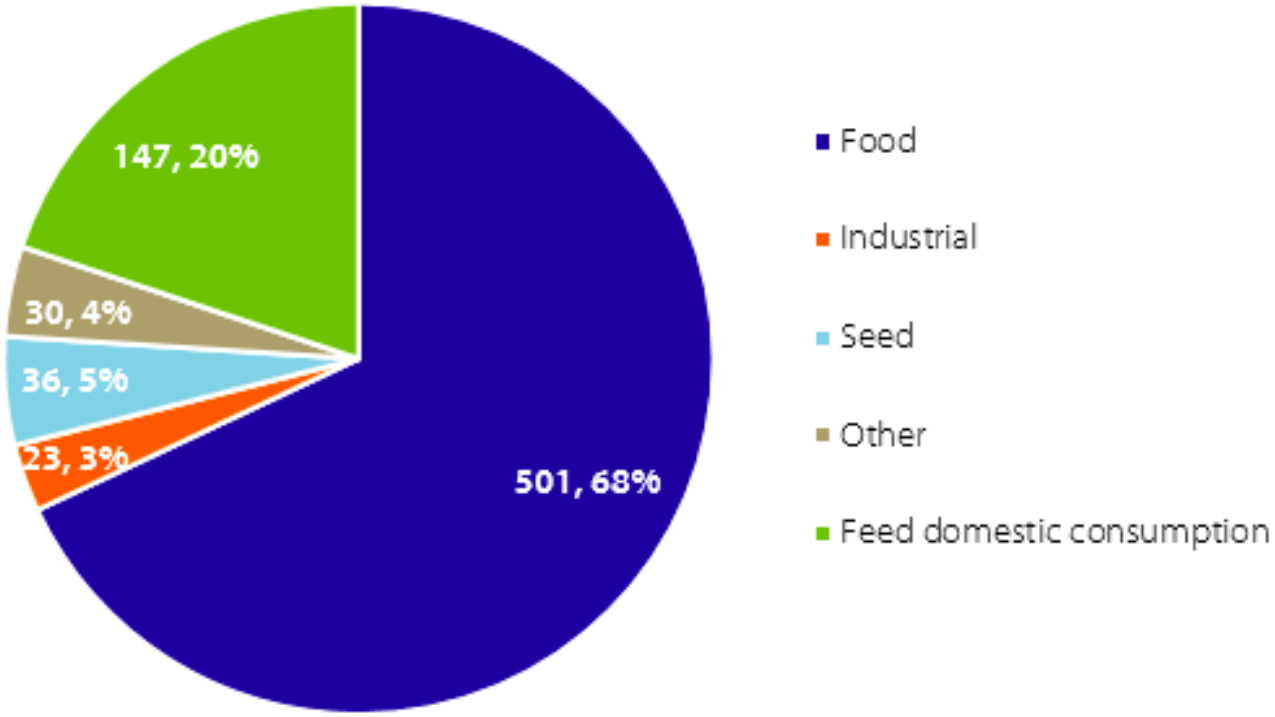


Chart 3.

Wheat use per sector in the years of 2016/17



5.1.2: Food uses

Wheat has a great reputation in supermarkets for being a nutritious and great-tasting food. We see wheat mostly being part of the flours. Flours to make either bread, crumpets, muffins, noodles, pasta, biscuits, cakes, pastries, cereal bars, sweet and savory snack foods, crackers, crisp-breads, sauces and confectionery. Wheat has very positive properties, since we see wheat being present in cereals, these being the healthiest low in sugar and high in carbohydrate (mainly starch). Also high in insoluble dietary fiber. It contains B-group vitamins such as thiamin, riboflavin, niacin, vitamin B6, folate and pantothenic acid, Vitamin E, iron, zinc, magnesium, phosphorus and selenium, and it has small amounts of copper, manganese and calcium.

Figure 10.

The wheat berries.

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