A review of wheat cultivation and its cultural significance

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Abstract. This paper is a review of what wheat meant in the past and what it means today for human society. Wheat (genus *Triticum*) played a particularly important role in the survival and numerical expansion of the human population and in the evolution of the culture of human society. Today, global wheat production has reached 781-803 million metric tons. Production is very likely to increase further in the future as a major necessity for human food and animal feed.
Key Words: wheat, *Triticum*, global production, cultural issues.

Introduction. Wheat is a grass widely cultivated for its seed, a cereal grain that is a worldwide staple food (Belderok et al 2000; Mauseth 2014; Shewry 2009). The many species of wheat together make up the genus *Triticum*, and the most widely grown is common wheat (*Triticum aestivum*). Wheat is grown on more land area than any other food crop (United Nations 2014). World trade in wheat is greater than world trade for all other crops together (Curtis et al 2002). By 2018, wheat was cultivated on an estimated 217 million ha of land globally (Triennium Ending – TE2018, cited by Erenstein et al 2022). In comparison, another important cultivated plant, maize (*Zea mays*), has nearly 200 M ha and rice (*Oryza sativa*) 165 M ha (Erenstein et al 2022; Table 1). Since 1961, the global surface of land under wheat production has oscillated between 200 and 240 million ha. Wheat area peaked around the year 1980 and has slowly oscillated downwards towards the current 217 million ha (Erenstein et al 2022) (see Figure 1).

Through this review paper we aim to present what wheat meant in the past and what it means today for human society.

Table 1

Global cereal production indicators

Grain	*Area/Production/Yield*	*1992–1994 (TE1994)*	*2016–2018 (TE2018)*	*Relative change (%)*
Wheat	Area (M ha)	220	217	−1.1%
	Production (M mt)	552	752	36.3%
	Yield (mt/ha)	2.5	3.5	37.8%
Rice (Paddy)	Area (M ha)	147	165	13%
	Production (M mt)	532	768	44%
	Yield (mt/ha)	3.6	4.6	28%
Maize	Area (M ha)	135	196	44%
	Production (M mt)	527	1146	118%
	Yield (mt/ha)	3.9	5.9	51%

Source: Erenstein et al (2022).

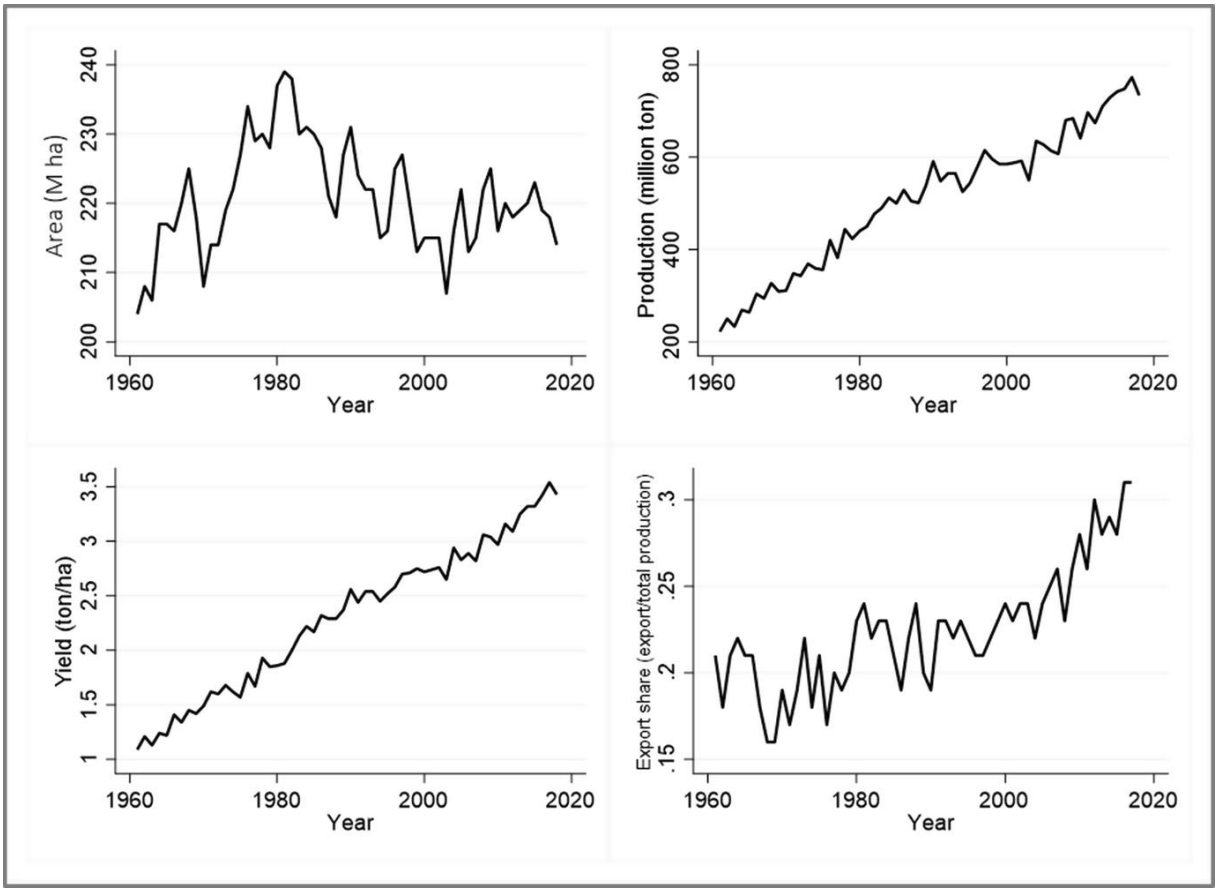

Figure 1. Dynamics of key wheat indicators between 1961 and 2018: wheat area (million ha), production (million ton), yield (ton/ha) and export share (export/total production) (Source: Erenstein et al 2022).

The origins of wheat cultivation. Humans began cultivating wheat around 10,000 years ago during the Neolithic period (Velimirović et al 2021), a pivotal era in human history characterized by the transition from nomadic hunting and gathering to settled farming communities. This period is sometimes referred to as the Agricultural Revolution (Velimirović et al 2021). The exact timeline and location of the first wheat cultivation can vary depending on archaeological findings and interpretations. However, it is generally believed to have originated in the Fertile Crescent (Lev-Mirom & Distelfeld 2023), a region in the Middle East that includes parts of modern-day Iraq, Syria, Turkey, and Iran. Wild wheat varieties like einkorn (*T. boeoticum*) and emmer (*T. turgidum* subsp. *dicoccoides*) were among the first cereals to be domesticated (Ahmed et al 2023). Early humans observed that these wild grasses produced edible seeds, and they likely started to deliberately cultivate them by saving and replanting seeds from the most desirable plants (Ahmed et al 2023).

Over generations of selective breeding, these early farmers favored plants with desirable traits such as larger seeds, higher yield, and resistance to pests and diseases. This process eventually led to the development of more modern varieties of wheat, like durum (*Triticum turgidum* subsp. *dicoccum* and *T. t.* conv. *durum*) and bread wheat (*T. aestivum*). The cultivation of wheat played a crucial role in the development of agriculture and the establishment of permanent settlements. Wheat became a staple food crop for many ancient civilizations and remains one of the most widely cultivated and consumed grains in the world today.

The significance of wheat in religious practices. Wheat has held significant religious and symbolic importance in various cultures and religions throughout history. The symbolic importance of wheat in religious practices often stems from its association with fertility, sustenance, and the cycle of life and death. It represents the fundamental role of

agriculture and food in sustaining human life, and it serves as a powerful metaphor in various spiritual contexts.

Ancient Near East and Mediterranean Civilizations. In ancient Mesopotamia, Greece, and Rome, wheat was associated with fertility and abundance (Al-Rubaye & Altai 2022). It was often linked to deities associated with agriculture and harvest, such as Demeter (Greek) and Ceres (Roman) (Al-Rubaye & Altai 2022). Wheat was used in various religious ceremonies, including offerings to the gods.

Judaism. Wheat is mentioned numerous times in the Hebrew Bible (Old Testament). It is one of the Seven Species, a group of agricultural products that were traditionally considered the primary products of the Land of Israel (Goodfriend 2020). Wheat, along with barley, grapes, figs, pomegranates, olives, and dates, was seen as a sign of God's blessing.

Christianity. Wheat plays a significant role in Christian symbolism. The Eucharist, a central sacrament in Christianity, involves the consumption of bread (often made from wheat) and wine, which are consecrated to represent the body and blood of Jesus Christ (Briola 2022). In Christian art and literature, wheat is often used as a symbol of resurrection, abundance, and the harvest.

Islam. Wheat is mentioned in the Quran, the holy book of Islam, as one of the blessings from Allah (Abrar Awan & Manj 2022). It is often used in traditional Islamic cuisine and is a staple food in many Muslim-majority regions (Abrar Awan & Manj 2022). Additionally, during the month of Ramadan, wheat-based foods like bread are commonly consumed to break the fast.

Ancient Egypt. Wheat was a vital crop in ancient Egypt and held religious significance. It was associated with the goddess Isis and was used in offerings and rituals related to the afterlife (Fotiadi 2011).

Sikhism. In Sikhism, one of the five articles of faith (Kakars) for initiated Sikhs is a steel bracelet called a Kara. This bracelet is to be made of pure iron or steel, signifying strength and integrity. Wheat flour is used in the traditional Sikh ceremony (Karah Parshad) where it is prepared and distributed to the congregation as a blessed offering (Crawford 2011).

Mithraism. Mithraism was an ancient mystery religion that was practiced in the Roman Empire from about the 1st to the 4th century AD (Clauss 2017; Ruck et al 2021). The religion centered around the worship of the god Mithras, who was often depicted slaying a bull in a ritual known as the tauroctony (Clauss 2017; Ruck et al 2021). While there isn't a wealth of detailed information about Mithraic practices due to the secretive nature of the religion, some references suggest that bread played a role in Mithraic rituals (Richmond 2014; Ruck et al 2021). Specifically, a ritual meal known as the "Mithraic banquet" or "Mithraic sacred meal" was a central element of Mithraic worship (Richmond 2014). In this banquet, initiates of Mithraism would partake in a communal meal together. The exact details and specific foods involved varied, but bread was often considered a significant part of this ritual (Richmond 2014). The consumption of bread in this context likely held symbolic and spiritual significance, though the precise meaning and ritualistic elements are not well-documented. It is important to note that our knowledge of Mithraism is somewhat limited, as it was a mystery religion with secretive rites. Much of what we know comes from archaeological finds, inscriptions, and occasional references in texts from other cultures (Richmond 2014; Ruck et al 2021). As a result, some aspects of Mithraic practices, including the exact significance of bread in their rituals, remain subject to scholarly debate and interpretation.

Continents and regions. Wheat is a versatile crop that can be grown in a wide range of climates (Arif et al 2021), but it thrives best in regions with specific conditions. Almost all continents meet conditions for wheat cultivation (Bushuk & Rasper 1994).

Asia. Asia is the largest producer of wheat in the world. Countries like China, India, Russia, and Kazakhstan are major wheat-producing nations (Tursunaliyevna 2022). The region provides a variety of climates, from the cool, temperate zones of northern China and Russia to the warmer areas in India and Pakistan (Bushuk & Rasper 1994; Mahpara et al 2012; Ramadas et al 2019; Abbas et al 2022).

North America. Both the United States and Canada have significant wheat production (Oleson 1994). The Great Plains region, spanning across parts of the U.S. and Canada, is known as the "breadbasket of the world" (Caparas et al 2021) due to its fertile soils and favorable climate for wheat cultivation (Oleson 1994; Caparas et al 2021).
Europe. Many European countries have suitable conditions for wheat cultivation (Le Gouis et al 2020; Sun et al 2022). Major wheat-producing countries in Europe include France, Germany, the United Kingdom, Ukraine, and Russia (Oleson 1994; Bushuk & Rasper 1994; Sun et al 2022). The Mediterranean region also supports wheat farming (Oleson 1994; Yang et al 2019; Mefleh 2021).
Africa. Northern Africa, particularly countries like Egypt, Algeria, and Morocco, has favorable conditions for wheat cultivation (Oleson 1994; Mrabet et al 2003). Some sub-Saharan African countries also grow wheat, although the production levels are lower compared to other continents (Tadesse et al 2019).
Australia. Australia is a significant wheat-producing country, particularly in the southern and eastern regions where the climate is more favorable for cereal crops (Oleson 1994; Bushuk & Rasper 1994; Naser et al 2020). The country is known for its high-quality, export-grade wheat (Simmonds 1989; Hunt et al 2019).
South America. While not as prominent as in other continents, several South American countries do cultivate wheat (Bushuk & Rasper 1994; Achilli et al 2022). Argentina, Brazil, and Chile are among the notable wheat-producing nations in this region (Oleson 1994; Achilli et al 2022).
Antarctica. While not a significant wheat producer due to its extreme climate, it is theoretically possible to cultivate wheat in controlled environments like greenhouses or research stations on the continent. Moreover, the microbiological studies show that wheat germination in Antarctica is possible at very low temperatures (Yarzábal et al 2018).

Within each continent, there are regions with varying climates and conditions, and these can affect the type of wheat that can be successfully grown (Oleson 1994; Yang et al 2019). For instance, some areas may be better suited for winter wheat, while others are more conducive to spring wheat varieties (Bushuk & Rasper 1994; Yang et al 2019). Additionally, factors like soil type, water availability, and temperature fluctuations can impact successful wheat cultivation.

Soil quality. Wheat can be grown in a variety of soil types, but it tends to thrive in well-drained soils with specific characteristics (Carew et al 2009; Abro et al 2009).
Loam soils. Loam soils are a balanced mixture of sand, silt, and clay (Whalley et al 2008). They have good water-holding capacity while still allowing for adequate drainage. Loam soils are considered ideal for wheat cultivation because they provide a stable environment for root growth and nutrient absorption (Whalley et al 2008; Abro et al 2009).
Clay loam soils. Clay loam soils have a higher proportion of fine particles (clay) compared to sand. They hold moisture well, making them suitable for wheat (Whalley et al 2008; Abro et al 2009). However, good drainage is essential to prevent waterlogging.
Sandy loam soils. They also tend to be fertile, which can support healthy wheat growth. Sandy loam soils have a higher proportion of sand compared to clay. They drain well and warm up faster in the spring, which can be beneficial for early planting. However, they may require more frequent irrigation (Kukal & Aggarwal 2003; Whalley et al 2008; Abro et al 2009).
Well-drained soils. Regardless of soil type, good drainage is crucial for successful wheat cultivation. Waterlogged soils can lead to root diseases and adversely affect plant growth (Yamuangmorn et al 2020).
Neutral to slightly alkaline pH. Wheat typically grows best in soils with a pH range between 6.0 and 7.5. This range provides an optimal environment for nutrient availability (Ghimire et al 2017).
Fertile soils. Fertile soils are rich in essential nutrients like nitrogen, phosphorus, and potassium. Proper soil fertility is important for healthy wheat plants and high grain yields (Ghimire et al 2017).

Organic matter. Soils with adequate organic matter content promote beneficial microbial activity and nutrient availability. Well-decomposed organic matter helps retain moisture and improve soil structure (Ghimire et al 2017).
Saline or alkaline soils to be avoided. High levels of salinity or alkalinity in soils can be detrimental to wheat growth (Ghimire et al 2017). These conditions can lead to osmotic stress and nutrient imbalances in plants.

While these are the general characteristics of soils conducive to wheat cultivation, local conditions and climate can influence which specific soil types are best in a given area. Soil testing and analysis are valuable tools for farmers to understand and manage their specific soil conditions for successful wheat production.

Climate conditions. Wheat is a versatile crop that can be grown in a range of climates, but it thrives best under specific conditions (Carew et al 2009).
Temperature. Wheat is a cool-season crop and requires a relatively cool growing season (Porter & Gawith 1999). The optimal temperature range for wheat growth is between 50°F and 70°F (10°C-21°C) during the growing season (Porter & Gawith 1999). However, it can tolerate temperatures outside of this range depending on the stage of growth (Porter & Gawith 1999).
Day length. Wheat is a long-day plant, meaning it requires longer daylight hours to initiate flowering. This is important for the timing of reproduction and seed development (Villegas et al 2016).
Rainfall or irrigation. Adequate moisture is crucial for successful wheat cultivation. The amount of rainfall required depends on the specific wheat variety and the local climate (Oweis et al 1998). In regions with limited rainfall, supplemental irrigation may be necessary (Oweis et al 1998).
Well-defined growing season. Wheat requires a well-defined growing season with distinct periods of planting, vegetative growth, flowering, and grain filling. Sudden changes in temperature or photoperiod during key growth stages can affect yield and quality.
Avoidance of frost. While wheat is relatively cold-tolerant, it is susceptible to frost damage, especially during the early growth stages (Cromey et al 1998). Therefore, regions with late spring frosts or early fall frosts may not be suitable for wheat cultivation.
Dry harvest conditions. A dry period during harvest is essential to prevent pre-harvest sprouting and to facilitate efficient harvest operations.
Avoidance of high temperatures at flowering. High temperatures during the flowering period can lead to poor grain filling and reduced yield. Therefore, regions with extreme heat during the flowering stage may not be suitable for wheat.
Photoperiod sensitivity. Some wheat varieties are sensitive to day length, while others are day-neutral. Understanding the photoperiod requirements of the chosen wheat variety is important for proper timing of planting (Villegas et al 2016).
Winter vs. spring wheat. Depending on the climate, farmers can choose between winter wheat and spring wheat varieties. Winter wheat is planted in the fall, goes dormant during the winter, and resumes growth in the spring. Spring wheat is planted in the spring and grows through the summer.

While wheat can adapt to a variety of climates, it is important to select the appropriate wheat varieties for the specific environmental conditions of a given region. Additionally, good management practices, including proper soil preparation and pest control, are crucial for successful wheat cultivation regardless of the climate.

Global wheat production. Wheat is one of the most widely grown and consumed cereal crops in the world. In 2022/2023, global wheat production was estimated to be around 781 million metric tons (USDA Foreign Agricultural Service, 2023, via Statista 2003, Figure 2). This was an increase as compared to the previous marketing year. The FAO shows that global wheat production in 2022/2023 is about 803 million metric tons (as an estimate), while production estimates for 2023-2024 are 785 million metric tons (FAO 2023). Considering both sources of information and looking at production history, production is likely to maintain an upward trend.

Top wheat producing countries. China was the largest producer of wheat, followed by India, Russia, and the United States. Other significant wheat-producing countries included Canada, Australia, Pakistan (Punjab region), Ukraine, Argentina, and France (Statista 2023). The United States produces a large amount of wheat per year, a great deal of which is subsequently exported (Shahbandeh 2023a). In 2018/2019, the country imported under four million metric tons of wheat, while exporting almost 28 million metric tons (Shahbandeh 2023a). Kansas, North Dakota, and Montana were the leading states in terms of wheat production in the year 2019 (Shahbandeh 2023b).
Types of wheat. The two main types of wheat produced globally are hard wheat, or durum wheat, *Triticum t. durum* (commonly used for making pasta) and soft wheat, *Triticum aestivum* (which includes varieties used for making bread).
Production trends. Wheat production has generally seen an upward trend over the past few decades due to increased global demand for grain products. Weather conditions, technological advancements, and changes in agricultural practices can affect yearly production levels.
Consumption and trade. Wheat is a staple food in many countries and is consumed in various forms, including bread, pasta, noodles, and pastries. Global wheat trade is significant, with major exporting countries like the United States, Canada, Russia, and Australia (Statista 2023).
Challenges and considerations. Factors affecting wheat production include weather events (such as droughts or excessive rainfall), pest and disease pressures, fluctuating commodity prices, and evolving consumer preferences.
Impact of COVID-19 pandemic. The COVID-19 pandemic led to disruptions in various sectors, including agriculture. While there were some challenges in the agricultural supply chain, including wheat production, the overall impact varied by region.

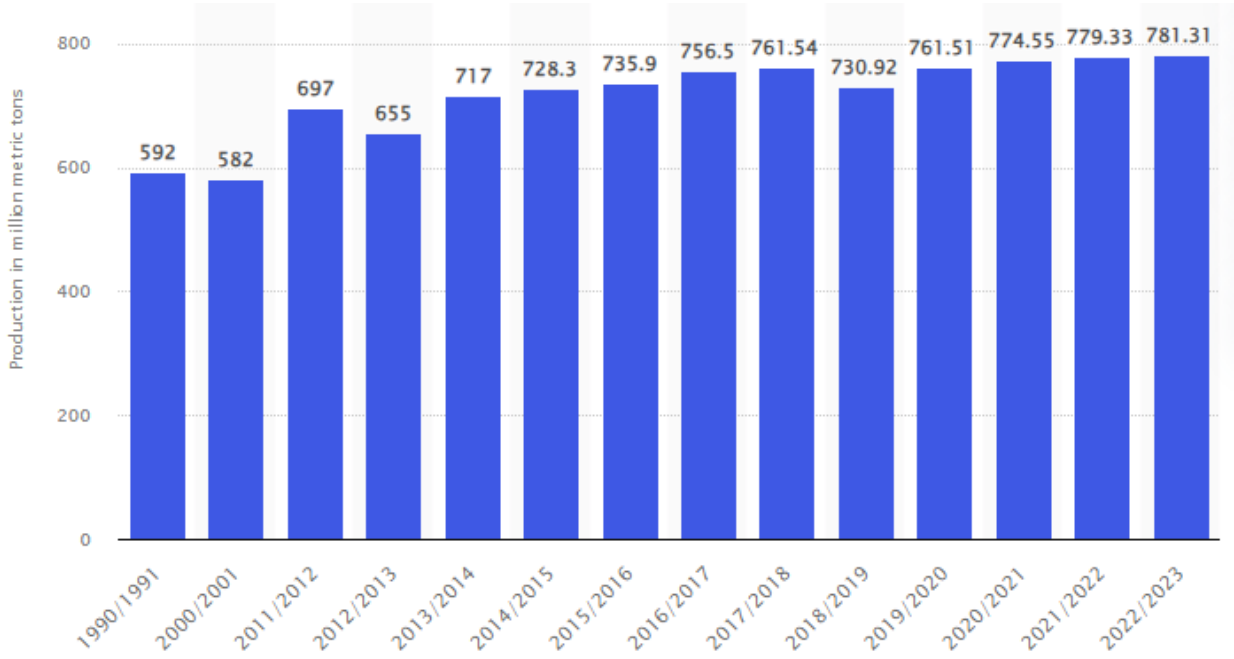

Figure 2. Global wheat production from 1990/1991 to 2022/2023 (in million metric tons, USDA Foreign Agricultural Service, 2023, via Statista 2003).

Genetically engineered wheat. Genetically engineered (GE, also called genetically modified - GM) varieties of wheat had been developed, but they were not widely cultivated on a commercial scale. This is because there was limited acceptance of genetically modified (GM) wheat by consumers and some key export markets (Mufson 2013). A few GE wheat varieties have been developed for traits such as resistance to certain pests, diseases, or herbicides. Some examples of GE wheat varieties include:

Herbicide-resistant wheat: These varieties are engineered to be resistant to specific herbicides, allowing farmers to apply herbicides to control weeds without harming the wheat crop (Vasil et al 1992).
Insect-resistant wheat: Some GE wheat varieties have been developed to resist certain insect pests, reducing the need for chemical insecticides (Qiong-Fang et al 2004).
Disease-resistant wheat: Genetic engineering has been used to develop wheat varieties with increased resistance to specific diseases (Sautter 2009).

It is worth noting that regulatory approval and consumer acceptance play a significant role in the commercial cultivation of GE crops. Regarding specific regions where GE wheat may be cultivated, there have been field trials of GE wheat in several countries, including the United States, Canada, Australia, and some European countries. These trials are conducted to assess the performance, safety, and environmental impact of the genetically modified varieties. However, it is important to check for updates or new developments in the field of agricultural biotechnology, as the status of genetically engineered crops can change over time due to advancements in technology, shifts in public opinion, and regulatory decisions. Always current, reliable sources for the most up-to-date information on genetically engineered wheat varieties and their cultivation status must be considered.

Hybrid wheat management. Wheat hybrids refer to plants that result from the crossbreeding of two distinct wheat varieties or species. This process is carried out to combine desirable traits from both parent plants, such as disease resistance, yield potential, and adaptability to specific environmental conditions (Gupta et al 2019).

Wheat is a self-pollinating plant, which means that it generally fertilizes itself. However, hybridization requires controlled cross-pollination, where pollen from one wheat plant is manually applied to the stigma of another plant. One of the primary benefits of creating wheat hybrids is the phenomenon of hybrid vigor or heterosis. This refers to the increased growth, yield, or other desirable traits seen in hybrids compared to their parent plants (Gupta et al 2019). Hybrid vigor is particularly valuable in agriculture because it can lead to higher crop yields. Hybrids are typically heterozygous, meaning they have two different alleles (gene variants) for each trait. This can result in a wider range of genetic diversity, which may lead to improved adaptability, disease resistance, and overall performance (Gupta et al 2019).

The first generation of hybrids is often referred to as the F1 generation. This generation tends to exhibit the highest degree of hybrid vigor. However, subsequent generations (F2, F3, etc.) may not retain the same level of vigor. For this reason, the degree of heterozygosity must be maintained. Unlike some other crops, maintaining the desirable traits of hybrid wheat over successive generations can be complex (Gupta et al 2019). It often requires careful selection and controlled breeding to stabilize the desired characteristics.

In commercial agriculture, it is important for crops to be relatively uniform in terms of characteristics like height, flowering time, and disease resistance. Achieving this uniformity can be challenging in hybrid wheat production.

Hybrid wheat can be developed for various purposes, including higher yields, improved disease resistance, enhanced nutritional content, and better tolerance to specific environmental conditions like drought or salinity (Gupta et al 2019). Despite the potential benefits, there are challenges associated with hybrid wheat production. These may include the cost and labor involved in controlled cross-pollination, difficulties in maintaining heterozygosity, and potential issues with seed production and distribution.

Diseases and pests. Wheat is susceptible to a variety of diseases and pests that can have significant impacts on yield and quality.

Diseases. Some of the most dangerous diseases of wheat include the following:
Rusts (stripe rust, leaf rust, stem rust): These fungal diseases can cause significant yield losses if not managed properly. They are characterized by rust-colored pustules on leaves, stems, and grains (Roelfs et al 1992).

Powdery mildew: A common fungal disease, powdery mildew appears as white, powdery spots on the leaves and stems of plants. It can reduce photosynthetic capacity and yield (Cowger et al 2012).
Fusarium head blight (Scab): Caused by various species of the Fusarium fungus, this disease affects the head or spike of the wheat plant. It can lead to shriveled, discolored grains and reduce yield (Dweba et al 2017).
Septoria leaf blotch: This fungal disease affects the leaves of the wheat plant, causing small, dark lesions. It can lead to reduced photosynthesis and yield (Danon et al 1982).
Tan spot: Caused by a fungus, tan spot causes tan-colored lesions on the leaves. It can reduce photosynthetic capacity and yield (Running et al 2022).
Take-all root rot: A soil-borne disease caused by a fungus, take-all root rot affects the roots, leading to stunted growth and poor nutrient uptake (Zhao et al 2023).

Pests. Some of the most dangerous pests of wheat include the following:
Aphids: Aphids are small insects that can feed on the sap of wheat plants, causing stunted growth and transmitting viral diseases.
Hessian fly: The Hessian fly is a significant pest of wheat. Its larvae feed on the plant's stem, which can lead to lodging and reduced yield (Tadesse et al 2022).
Wireworms: Wireworms are the larvae of click beetles. They feed on the roots and stems of young wheat plants, causing stunting and reduced vigor.
Nematodes: Certain species of nematodes can infect the roots of wheat plants, leading to reduced nutrient uptake and stunted growth.
Birds: Birds, particularly sparrows and pigeons, can cause damage to wheat fields by feeding on the grains.
Rodents: Rodents like mice and voles can feed on wheat plants, causing significant damage, especially in high-density populations.
Weeds: While not pests in the traditional sense, competitive weeds can compete with wheat for nutrients, water, and sunlight, leading to reduced yields.

It is important for farmers to implement integrated pest and disease management strategies, which may include a combination of cultural practices, crop rotation, resistant varieties, biological control, and, in some cases, chemical treatments to mitigate the impact of these threats to wheat crops.

Wheat as a plant for the energy industry. Wheat is not traditionally considered a primary plant for the energy industry. Unlike certain crops like corn and sugarcane, which are commonly used for biofuel production, wheat is primarily grown for food and animal feed purposes. However, it is possible to use wheat for bioenergy production through processes like wheat straw or wheat bran conversion.
Wheat straw. After the grain is harvested, the remaining plant material, known as straw, can be used for bioenergy production. It can be converted into various forms of biofuel, such as cellulosic ethanol or used in biomass power generation (Zhang et al 2022).
Wheat bran. Wheat bran is a byproduct of milling wheat into flour. It is a rich source of fiber and nutrients. In some cases, it can be used as a feedstock for biofuel production.
Biogas production. Wheat can be used in anaerobic digestion processes to produce biogas, a mixture of methane and carbon dioxide (Sivamania et al 2021). This can be used for heating, electricity generation, or as a vehicle fuel (Dutta & Kumar 2022).

While these methods can contribute to bioenergy production, they are not as widely implemented or economically significant as dedicated bioenergy crops like corn for ethanol or sugarcane for bioethanol in many parts of the world. It's worth noting that the primary economic value of wheat lies in its use as a staple food for human consumption and as a major component in animal feed. Additionally, wheat has a wide range of applications in the food industry beyond direct consumption, including the production of flour, semolina, and various processed foods.

Conclusions. Wheat is a grass widely cultivated for its seed, a cereal grain that is a worldwide staple food. Wheat played a particularly important role in the survival and numerical expansion of the human population and in the evolution of the culture of human

society. Today, global wheat production has reached 781-803 million metric tons. Production is very likely to increase further in the future as a major necessity for human food and animal feed.

Conflict of interest. The authors declare no conflict of interest.

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