Wheat

Einkorn wheat (Triticum monococcum), one of the earliest domesticated crops. Source: Kurt Stueber

Wheat is any of a number of species of the genus ***Triticum*** within the grass family of Poaceae.

The wheat harvest in Palouse, Idaho, USA. Source: USDA

Wheat is an important grain food crop supplying the second highest caloric intake for humans, closely behind rice. Wheat is used to produce flour for bread, pasta, couscous and other foods.

However, wheat generally consumes large amounts of nitrate and other fertilizers, so that the outcome of widespread wheat farming is often associated with extensive water pollution impacts, expecially related to nitrate laden runoff.

Wheat is one of the earliest cultivated crops, and has a clear association with the emergence of sedentary agriculture around twelve millennia ago.

Products Made From Wheat: 1. Crossaint; 2. Wheat Flour; 3. Noodles;
4. Wheat Dalia; 5. Sewai; 6. Refined Wheat Flour; 7. Common Brown Bread;
8. Semolina; 9. Pasta; 10. Cookie; and 11. Flat Bread
(Source: Saikat Basu, own work)

Wheat is one of the most adaptable of crops, grown from the equator to near the Arctic, and from sea level to the Tibetan Plateau. Recent research demonstrates that production of the world wheat crop is likely to increase if atmospheric carbon dioxide levels rise.

Dry and Matured Wheat Seed (Source: Saikat Basu)To feed the burgeoning worldwide human population explosion, intensification of wheat farming has brought the by-product of increased crop diseases; such practices as intensive irrigation, lack of crop rotation and dependence on monocultures have promoted the propagation of many fungal pathogenic infections that reduce the yields of wheat and other cereal crops, and in some cases can lead to human disease via mycotoxin production.

History of cultivation

Domestication and cultivation of wheat was one of the earliest farming activities of prehistoric man, at the outset of sedentary agriculture.

A number of sites in the Levant are associated with early wheat cultivation, a site at Iraq ed-Dubb (Cave of the Bear), in present day Jordanis arguably the oldest radiocarbon dated location at 9600 BC.
Other archaeological records from:

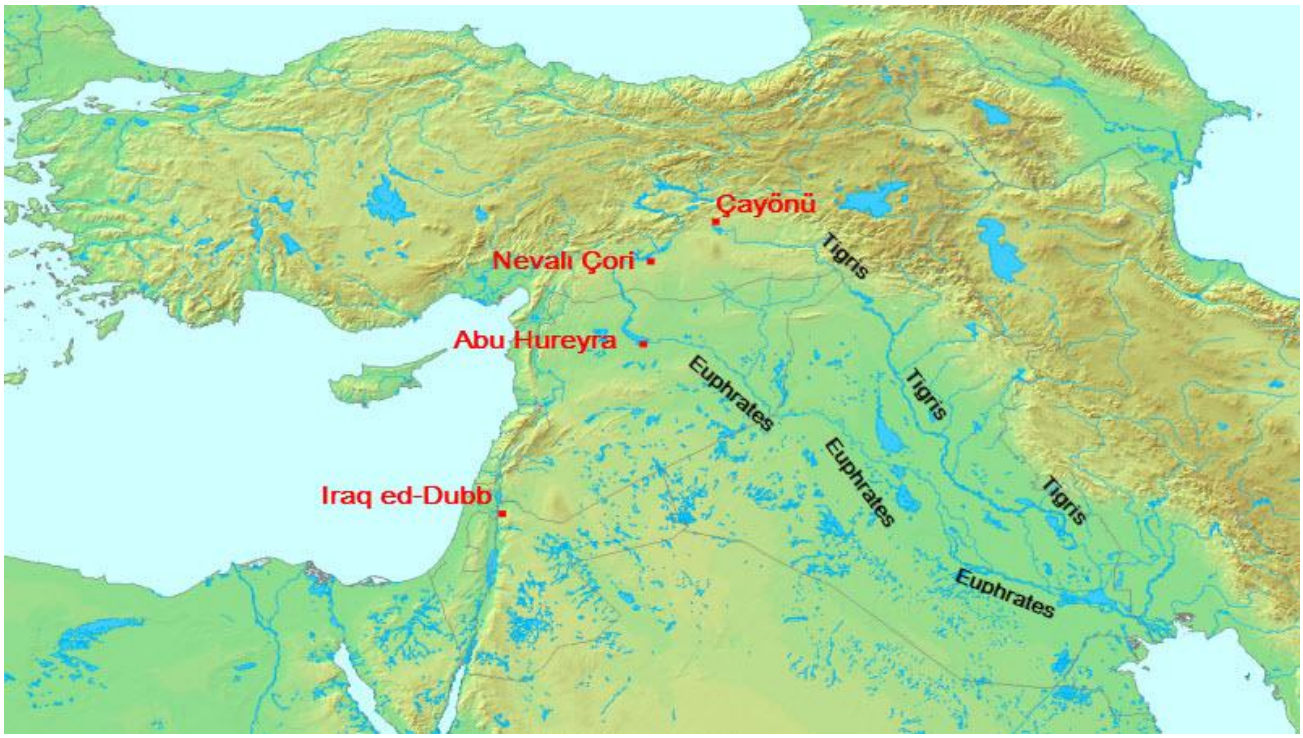
a. The Abu Hureyra site in the valley of the Euphrates in Syria

b. The Nevalı Çori site; and (in southern Turkey)

c. From Cayonu in the Karacadag Moutains of Turkey


Archaeological site of Volubilis with extant Roman ruins. @ C.Michael Hogan

At each site wheat cultivation is dated to the eight and ninth millennia BC.



Sites showing evidence of early wheat cultivation in the levant. Base map source: DEMIS

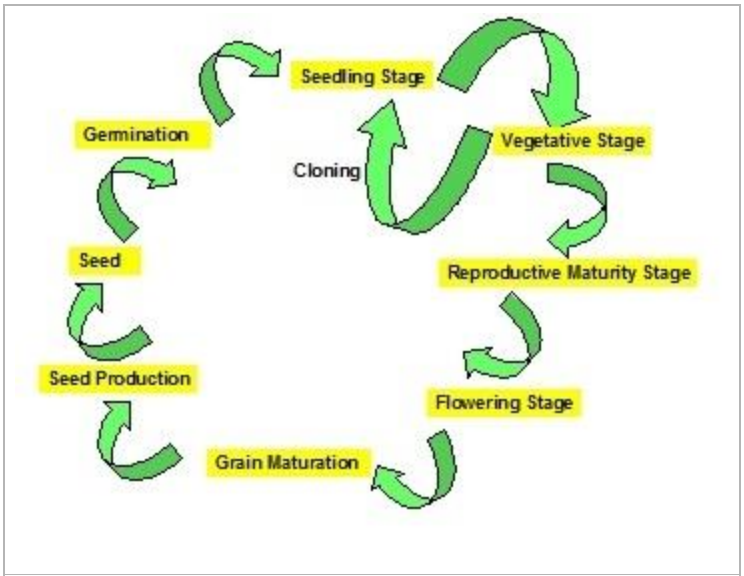
Even in North Africa, where the present day climate is arid, there is evidence of Neolithic farming of emmer wheat; for example at the Volubilis archaeological site in Morocco, DNA analysis shows that the climate was mild and wet enough to support emmer production thousands of years ago. The site was eventually developed to be the regional capital of the Phoenicians and Romans as a western outpost for each of these conquering early colonial powers.

Principal species

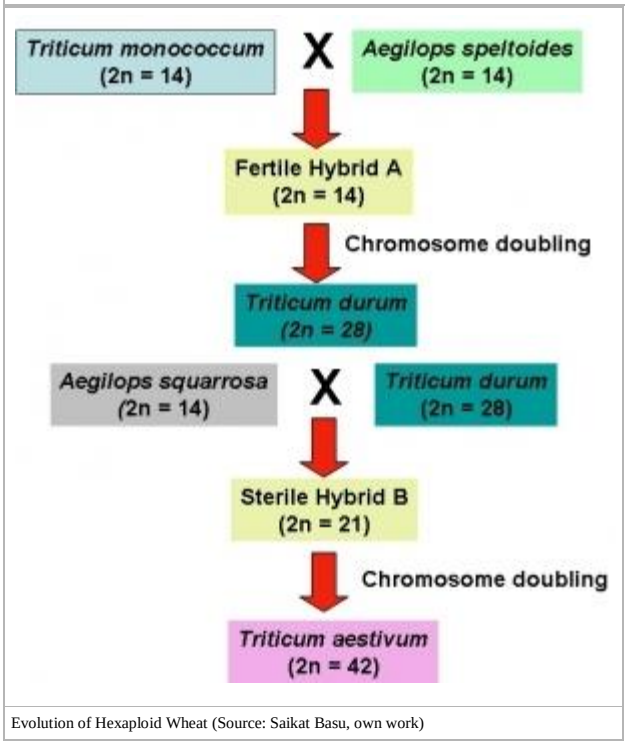
There are several key species of wheat, chief among them being:

- Bread Wheat (*Triticum aestivum*), an**allohexaploid** species most commonly used in production of bread
- Einkorn Wheat (*Triticum monococcum*), a [diploid] species with 2n=14
- Wild Emmer (*T. dicoccoides*), a[tetraploid] hybrid formed by *T. urartu*and an extinct wild grass of genus*Aegilops*
- Emmer Wheat (*T. dicoccum*), a tetraploid species derived from wild emmer
- Durum Wheat (*T. durum*), a tetraploid species derived from wild emmer

Scientific Classification	
Kingdom:	Plantae (Plants)
Phylum:	Viridaeplantae (Green Plants)
	- Streptophyta (Land Plants)
	-- Tracheophyta (Vascular Plants)
	--- Spermatophytina (Seed Plants)
	---- Angiospermae (Flowering Plants)
Class:	Magnoliopsida (Dicotyledons)
	-Lilianae (Monocotyledons)
Order:	Poales (Grasses)
Family:	Poaceae (Grasses)
Genus:	Triticum (Wheat)
Species:	Many



Simplified Life Cycle of Wheat (Source: Saikat Basu, own work)



Evolution of Hexaploid Wheat (Source: Saikat Basu, own work)

Fertilizer requirements

Use of nitrate fertilizers for wheat production have been common in Western nations since the mid 1800s. In China, widespread use of nitrates for wheat crops began in the 1950s subsequent to widespread famines. The concomitant outcome of massive nitrate usage is broad water pollution impacts from nitrate and other chemical fertilizer usage, driven by surface runoff. In India, for example, wheat and rice farming account for the vast majority of nitrate usage, even though other cereal grains constitute the majority of acreage planted to cereal crops.

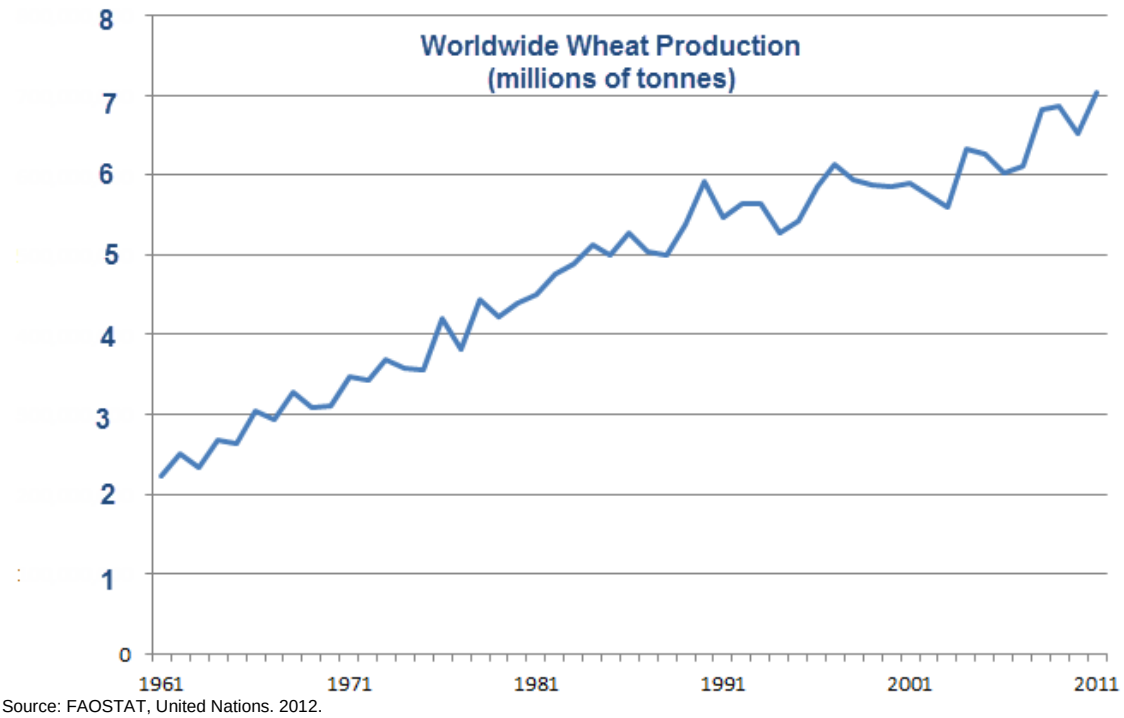
Water requirements

Desertification and aquifer overdrafting in evidence, North China Plain. @ C.Michael HoganApproximately one cubic meter of water is required to produce one kilogram of wheat. This value is about one half of the water needed to produce the same quantity of rice and one fifteenth that to produce one kilogram of beef. Nevertheless, world demand for water to irrigate wheat crops is extraordinarily high, owing to the massive amount of land planted to wheat.

Particular areas where overdrafting of groundwater have created ecological and agricultural disasters are the North China Plain and the Great Plains of the USA overlying the Ogallala aquifer. In both cases the aquifer has been mined at an unsustainable level over a period of decades, such that the peak agricultural yield was reached some time ago. In the case of the Ogallala aquifer, overmining of water has been occurring since the 1940s, when cheap electrical power provided by misguided federal stimulus programs led to unsustainable water extraction. In the case of the North China Plain, wheat production peaked in the 1990s as the depth to groundwater started to become prohibitive in costs for some farms.

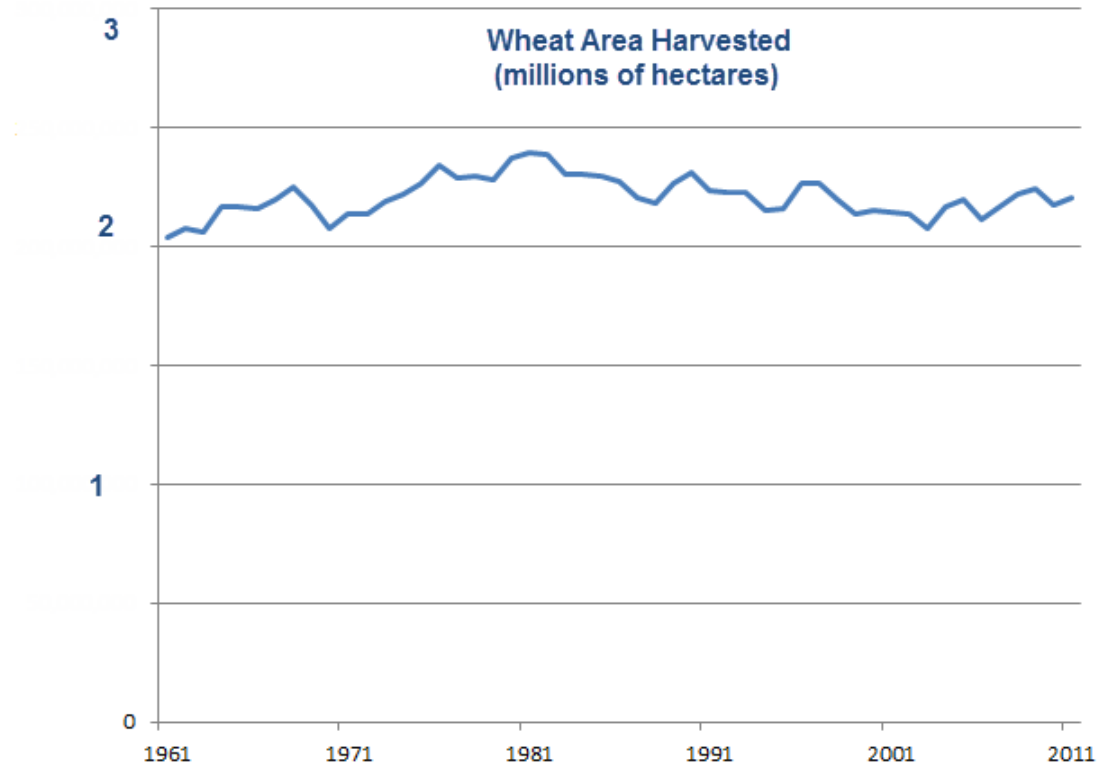
Worldwide production

Over the past fifty years (1961-2011) world wide wheat production tripled from 222 million tonnes to 704 million tonnes as shown in the figure below using data from the Food and Agriculture Organization of the United Nations (FAO). During the same period the world's population doubled (2.2-fold) from 3.1 billion to 6.9 billion (mid-year populations estismates from the UN)



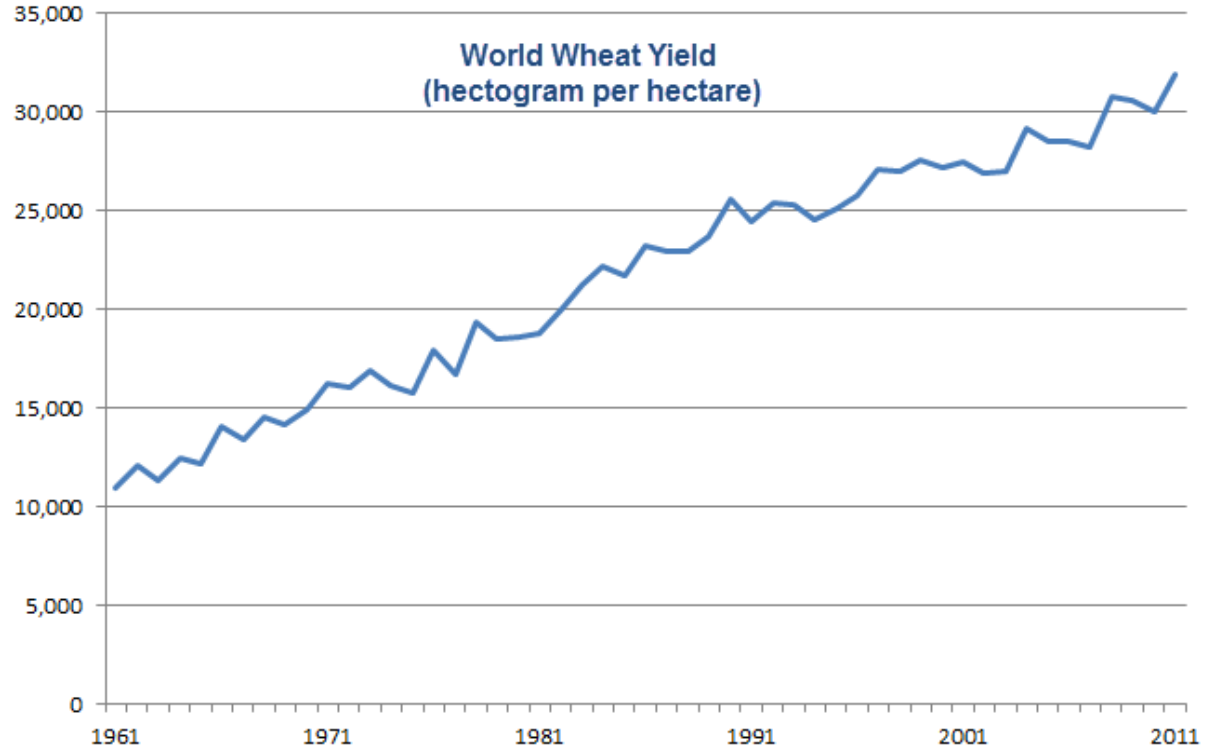
Source: FAOSTAT, United Nations. 2012.

The dramatic increase in wheat production was not driven by a increase in land being farmed for wheat, which increased just 8% from 204 million hectares (2.04 million km^2 or 788,000 miles^2) to 220 million hectares (2.20 million km^2 or.851,000 miles^2).



Source: FAOSTAT, United Nations. 2012.

The increase in wheat production is primarily related to a nearly three-fold increase in yield, from an average of just 11,000 hectograms (1.1 tonnes) of wheat per hectare on average to to nearly 32,000 hectograms (3.2 tonnes) per hectare (see figure below).



Source: FAOSTAT, United Nations. 2012.

The increase in yield has been due to a number of factors including:

- New varieties/cultivars of wheat;
- More irrigation and more effective methods of irrigation;
- Wider use of pesticides and more effective pesticides;
- Wider use of fertilizer and more effective fertilizers; and,
- Improvements in agricultural practices and mechanization

Top Wheat Producing Nations

The top wheat producing nations of the world 2011 are as follows:

	Nation	**Wheat** (tonnes) **Production**
1.	China	117,410,300
2.	India	86,874,000
3.	Russia	56,240,000
4.	USA	54,413,300
5.	France	38,037,000
6.	Australia	27,410,100
7.	Canada	25,261,400

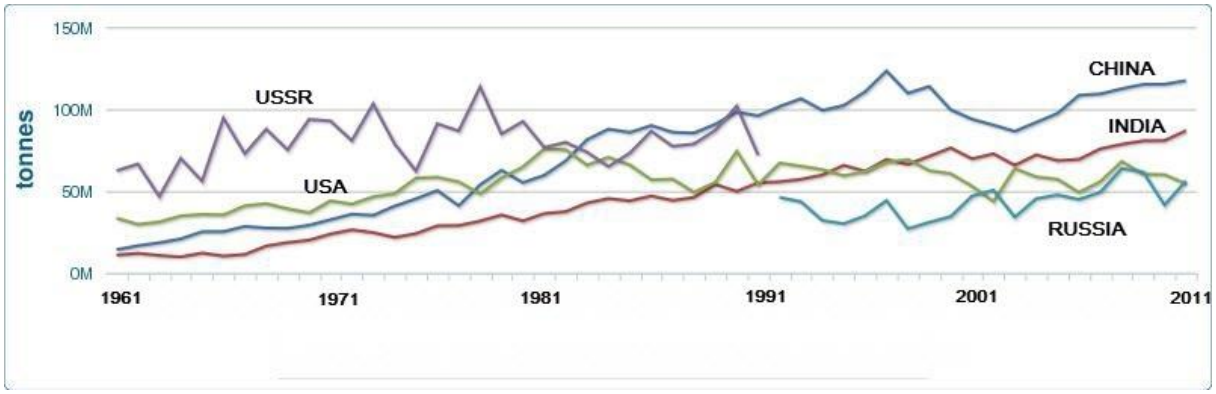
8.	Pakistan	25,213,800
9.	Germany	22,800,000
10.	Ukraine	22,323,600
11.	Turkey	21,800,000

Source: United Nations. 2012. Searchable online statistical database from Food and Agriculture Division of the United Nations. FAOSTAT

These eleven nations produced a total of 498 million tonnes or nearly 71% of worldwide production.

Changes in National Wheat Production over the Past Fiifty Years

In 1961, the USSR was the world largest produced followed by the USA, China, India, and France. In those fifty years, the most dramatic increases in wheat production have occurred in China (8.2 times 1961 harvest), India (7.9 times), and, Pakistan (6.6 times).



Source: United Nations. 2012. Searchable online statistical database from Food and Agriculture Division of the United Nations. FAOSTAT

Top Wheat Exporting Nations

However, the major wheat exporting countries are somewhat different than those of total production. In 2010, the country with the highest export total was the USA, with 35.5 million tons, with deliveries largely to Nigeria, Mexico, Japan and Philippines; in a distant second place was France with 19.2 million tons, with principal markets in North Africa. Close to France was the Canadian total export, with 17.5 million tons, delivering chiefly to markets in China, Iran and Japan. Australia was the fourth largest wheat exporter with 13.5 million tons, mainly serving demand in China and Indonesia.

Figure1. Different wheat genotypes varying in colour and texture from across the globe: A. Iran, B. India, C. Australia, D. USA, E. Canada, F. Hungary, G. Mexico, H. Pakistan and I. Brazil.

Source: Saikat Basu, own work

Comparison of Wheat and Other Major Food Crops

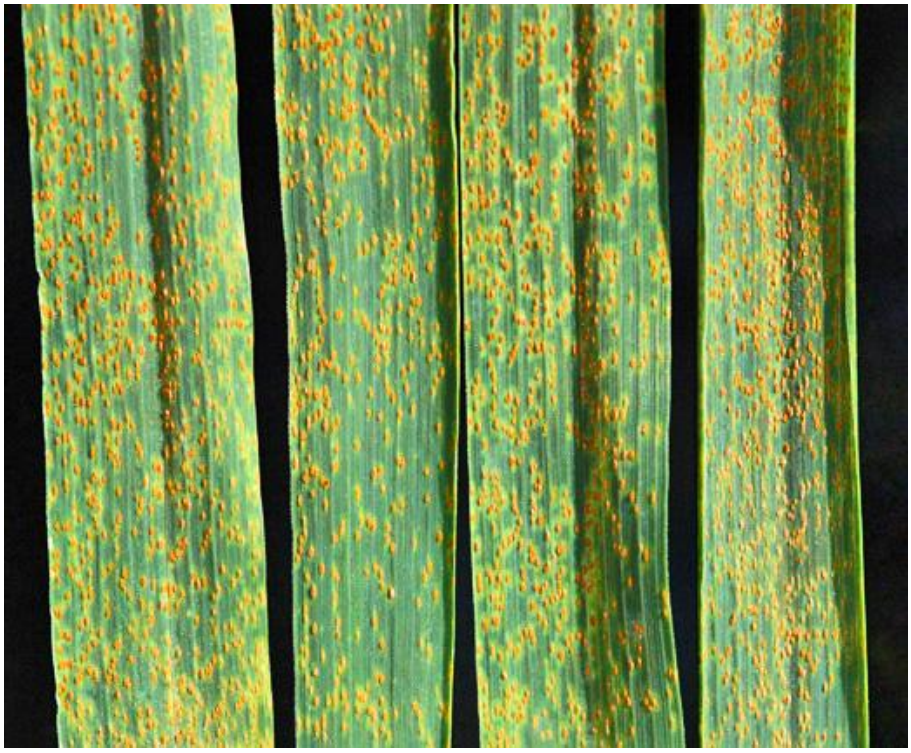
The following table summaries worldwide production, harvested area, and average yield for eleven major food crops in 2011 as reported by the Food and Agriculture Organization of the United Nations.

Crop	**Production** (tonnes)	**Area** (Hectares)	**Yield** (Hectograms/Hectare)
Sugar Cane	1,794,359,190	25,436,924	705,415
Maize	883,460,240	170,398,070	51,847

Rice	722,760,295	164,124,977	44,037
Wheat	704,080,283	220,385,285	31,948
Potatoes	374,382,274	19,248,586	194,499
Soybeans	260,915,871	102,993,246	25,333
Casava	252,203,769	19,644,071	128,387
Oil Palm Fruit	233,810,539	16,265,248	143,749
Tomatoes	159,023,383	4,734,356	335,892
Barley	134,279,415	48,603,576	27,627
Bananas	106,541,709	5,157,466	206,578

Source: United Nations. 2012. Searchable online statistical database from Food and Agriculture Division of the United Nations. FAOSTAT

Diseases in wheat



Wheat leaf rust. Source: James Kolmer

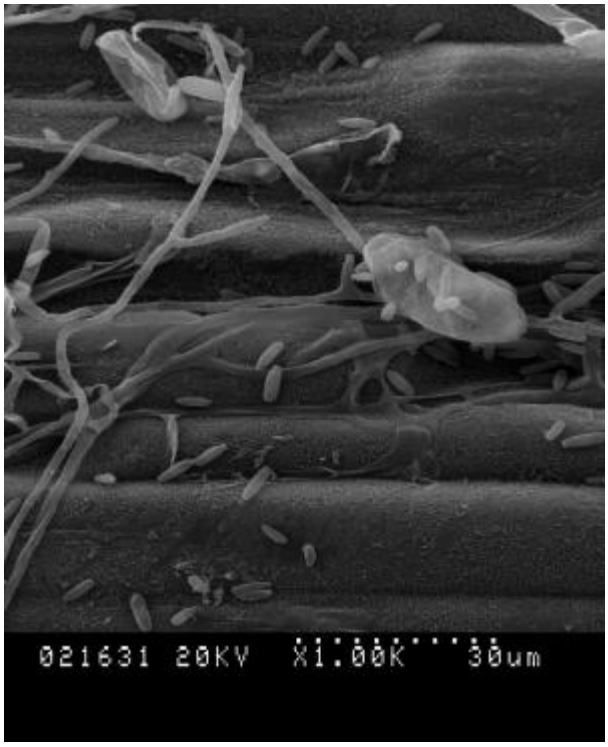
Considerable research has been conducted in wheat diseases, owing to the fundamental importance of wheat as a human food staple. Some of the chief diseases that affect wheat are: wheat leaf rust, Fusarium crown rot, powdery mildew, ergot, foliar blight and root rot.

Wheat leaf rust is typified by infestation by the windblown fungal pathogen *Puccinia triticina*, a diseaseorganism that can cause significant damage to wheat and other grain crops; control can be effected by the fungicide class of triazoles, but more promising techniques are being developed to use cultivars produced from DNAanalysis of disease resistant wheat strains.

Fusarium crown rot is induced by the fungal pathogen Fusarium pseudograminearum, a disease agent transmitted in the atmosphere or via animal dispersal. As the name implies, this disease primarily infects the crown of the plant, but not only is plant growth and

development hindered, the pathogen generates a trichothecene mycotoxin that is harmful to animal or human consumers of infected wheat. This pathogen is more limited in host than others, and infects only barley and wheat.

Powdery Mildew on Wheat Leaf (Source: Saikat Basu, own work)Powdery mildew in wheat is caused by the fungal pathogen*Blumeria graminis*, which particulary thrives in cool humid areas such as much of the eastern USA. Crop yields can be significantly reduced, with control effected through chemical treatment or genetic resistance. The pathogen B. graminis overwinters in most fields and thus is difficult to eradicate by ploughing or crop rotation techniques.



Micrograph of Powdery Mildew Fungal Mycelium
and Conidispores on Wheat Leaf (Source: Saikat Basu, own work)

Micrograph of Powdery Mildew Infecting Mycelia on Wheat
(Source: Saikat Basu, own work)

Micrograph of Pure Culture of Powdery Mildew on PDA Culture Plate (Source: Saikat Basu, own work)

Relationship to atmospheric CO_2

Both foliar blight and root rot can be caused by infection by the pathogen *Bipolaris sorokiniana*. Besides attacking important crops such as wheat and barley, this organism can infect a wide variety of native grasses ahd

forbs, and operates on almost a worldwide basis. Control of this pathogen may be effected by crop rotation, seed quality control and ploughing of fields in a pattern of precise timing.

Research in growth response of wheat to variations in atmospheric carbon dioxide demonstrate a small effect on wheat plant development to elevated CO2 levels. The rate of development of leaf primordia was observed to accelerate according to reports in Carver (2009); thus, increasing atmospheric carbon dioxide concentrations are expected to result in higher production levels of wheat, or a reduced growing season necessary to bring the wheat crop to harvest.

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