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MAIZE

Family: *Gramineae*

Genus: *Zea* (Tribe: *Maydeae*)

Species: *mays spp. Mays*

Source: CSL Files

Source: www.illusionmasks.com/images3/maize.jpg

Contents

General Background

The International Centre for the Improvement of Maize and Wheat provides a range of information along with world maize facts and trends in the publication 'Meeting World Maize Needs: Technological opportunities and priorities for the public sector', this publication can be viewed by clicking here.

Maize belongs to a small highly specialised tribe. It is a large annual with a single stout stem, usually 2-3m high (but can vary from 1-6m), with approximately 14 nodes. Leaves have long broad lanceolate blades and are large at 30-150cm by 5-15cm. The terminal panicle bears only male flowers and is called the tassel, it can be up to 40cm long. The female inflorescence is ear borne in the axils of middle leaves approximately half way up the stem, 1-3 per plant. Each ear consists of a short stout axis or cob. The ear and the grains are sheathed in closely packed leaves which completely enclose the upper fertile part of the ear and originate at the base of the lower nodes of the cob. The spike is very dense with a number of vertical rows of very much reduced spikelets. Pollination is made possible by the very great development of the single style of each ovary forming a long thread extending up from each flower to the apex of the husk, the numerous threads emerge as a conspicuous tuft known as the silks. The upper part of each style is receptive and wind-borne pollen germinate on its surface, the pollen tube then grows down through the whole length of the thread to reach the ovule. After pollination the silks wither and enlargement of the grain proceeds. The husk leaves become dry and papery but remain around the mature ear.

Maize is the native grain crop of the New World where it has been cultivated in a wide range of environmental conditions from sea-level to over 3000m, from Chile to southern parts of Canada for more than 5000 years. The species has arisen entirely in cultivation and is structurally very different from its wild ancestors which had tiny, unsheathed cobs. In its present form it is probably the crop mankind has influenced most. The maize crop of today cannot reproduce without human intervention as the ensheathed ear is prevented from shedding its seed.

Maize has advantage over other cereals in that it has a wide tolerance of different climates, the highest yield of grain per man-hours of labour and resistance to depredation by birds. Soon after the Spanish conquest maize spread throughout the world. It is the most important crop in the United States and is supplanting native grain crops in many tropical countries, it is also widely grown as a secondary crop. Western European countries together form the world's largest importer of maize.

Details of Quality Characteristics

The nutritional value of maize is lower than most other cereals but after wheat and rice it is the most important cereal in the world. Although the energy content of the crop is generally higher than that of wheat the protein value is slightly lower. There are three main energy sources in maize, these are soluble sugars, structural sugars and starch. Starch quality can be categorised as being either 'slow' or 'fast' starch. 'Slow starch is slow to breakdown in the rumen and reduces rumen function. it may even by-pass the rumen and is therefore of little or no use to the animal. 'Fast' starch is high in energy, easily degraded in the rumen and is found to enhance the rumen function. Varieties with high 'fast' starch content should always be selected for animal feed.

Maize varieties vary in quality depending on end uses, for feed purposes ME of fresh plant (MJ/kg dry matter) is generally 11.0 or slightly higher, cell wall digestibility is usually between 48-56. ME/ha x 1000 (MJ/kg DM) is generally between 150-185.

There are many different applications for maize, due to its different sites of origin and application, there are segregated gene pools as shown below:

Waxy Corn	- Origin South-East Asia - Contains 100% amylopectin starch - Starch is used as a stabiliser/thickener in the food industry and as an adhesive in the paper industry - Very little is currently grown
Flint and Dent Corn	- Hard types, important for human nutrition - Dent corn is softer than flint corn - Used as a livestock feed and also to make processed foods
Yellow Dent Corn ('Field Corn')	- Most of the US corn crop is yellow dent - High vitamin A content, high feed value and availability of adapted superior hybrids account for its extensive use

	- Of all cereal grains it has the highest carotene content (Vitamin A) - Contains 75% amylopectin and 25% amylose starch
Flint Corn	- Early maturing maize with a hard aleurone coat - Has good storage potential and resistance to insect damage due to hard coat - Contains little soft starch - In temperate zones it matures earlier, has better germination and has earlier plant vigour than dent corn
Soft Corn	- Well adapted for starch production - Kernels consist almost entirely of soft starch
Pop or Puff Corn	- Limited production volume - Produced mainly for snacks but also has potential for packaging materials - Natural moisture inside the kernel turns to steam when heated, the outer coat is so hard that the moisture is trapped. Steam builds up the pressure and causes the kernel to explode - US produces almost all of the worlds popcorn
Sweet Corn	- Synthesises low molecular weight polymers and sugars - Contains almost 70% water - Contains more natural sugar than other types of corn - Grown almost exclusively for human consumption (fresh or processed) - Comes in three colours – yellow, white and bicolour (yellow and white)
White Corn	- Appears to be replacing some yellow corn in food applications - Preferentially used for dry milling i.e. cereal products - Can also be used for wet milling to produce speciality starch products with very bright whiteness
High Amylose Corn	- Speciality corn producing kernels with more than 50% amylose content - Starch is used in textiles, candies and adhesives
High Oil Corn	- Contains 7-8% oil, 2-3% more than dent corn - Also has enhanced protein quality and quantity
High Lysine Corn	- Has increased levels of 2 amino acids that are essential for non-ruminant diets - The two amino acids are lysine and tryptophane

Current Production and Yields

The United States remain the largest producer of maize in the world with around 32 million hectares being grown annually. The other two main producers are China and Brazil, these three countries total 52% of the global surface area of the crop. The European Union is the fifth largest producer after Russia. In 1999 the European Union

produced 3,857,000ha of silage maize and 3,673,000ha of grain maize. European production of the crop in 2001 can be seen in the table below:

Country	Area Harvested ('000 ha)	Yield (t/ha)	Production ('000 tonnes)
Austria	194.9	7.66	1,493
Belgium-Lux	43.3	10.15	439
France	1,917.0	8.60	16,472
Germany	397.0	9.19	3,648
Greece	195.0	8.50	1,658
Italy	1,184.0	8.94	10,587
Netherlands	20.0	7.50	150
Portugal	159.0	6.13	975
Spain	504.2	10.13	5,108
EU-15	**4,614.4**	**8.78**	**40,531**
World	**137,597.0**	**4.43**	**609,182**

Source: FAO Stat (2001)

In 1995 world demand for maize was 558Mt, this figure is expected to increase by 50% by 2020 to around 837Mt.

Romania and France are currently the two major hybrid maize markets in Europe, followed by Germany, Serbia and Italy.

Current yields of the crop are in the region of 40t/ha fresh weight, this can be increased to around 60t/ha fresh weight on favourable sites. At a typical 30% dry matter content this equates to between 12-20t/ha DM yield. Although grain maize is not currently grown commercially in the UK yields as high as 11t/ha have been achieved on a trial basis.

Constraints upon Production

The minimum temperature for germination is 10°C and seedling growth before 13°C is very slow so it is not adapted to cooler parts of the temperate zones. It has the C4 metabolic pathway and is photosynthetically highly efficient in conditions of high temperature and light intensity. Southern England, Netherlands and Northern

Germany form the northernmost barrier for the cultivation of maize in Europe. Elsewhere in Europe it is grown on a very large scale.

In Southern Europe where drought conditions are frequent the crop may struggle in the centre of countries like Spain due to the problem of not being able to irrigate.

Erosion of soil from maize crops is a major problem to the environment in many European areas. As the area of maize is predicted to increase this problem will also increase. Other common problems which will need to be reduced as the crop area is increased is the loss of nitrates, phosphorus and herbicides from the maize crops which are being washed into the water systems. This problem has already been tackled in some areas of Europe by introducing understorey crops to protect the ground, this could also be done using the cereal-bicropping system which have been developed in the UK.

Markets and Market Potential

Maize has a vast number of uses in many different industries, some of these uses are: ethanol alcohol, cosmetic or skin care products, drugs, batteries, rubber, beverages, crayons, soaps, absorbent material for diapers, food additives, biodegradable plastics and food supplements. This is only a small sector of the list which consists of hundreds of potential uses for different plant parts or extracts.

Starch is a carbohydrate polymer that occurs in granular form in the organs of higher plants and is composed almost exclusively of anhydro-α-D-glucose units. It is the most abundant storage polysaccharide in the plant kingdom. Its digestibility in the human and animal intestine makes it the most important nutritional component in food and feed. Industrially, starch consists of starch polysaccharides, minor constituents and moisture and is obtained by industrial wet milling, refining and drying. The paper and board industries are the largest non-food starch-using sector, using approximately 60% of the total industrial starch.

Maize has been the par excellence source of pure starch ('corn flour') because of the high yield of the plant in the USA and other countries with a suitable climate. Maize

starch production is a very efficient process that gives rise to a number of useful by-products and practically no waste with a low input of water. Corn is used for 75% of the world's starch production.

Applications of starch and its derivatives:

	Textile	Adhesive	Paper	Building Industry	Surfactant	Polymers	Pharmaceutical Industry	Cosmetics
Native Starches	*	*	*	*		*	*	
Etherified Starches	*	*	*	*				*
Thinned Starches	*		*	*				
Oxidised Starches	*	*	*	*			*	
Dextrins	*	*	*	*			*	
Maltodextrins	*				*		*	
Glucoses				*			*	
Dextrose	*			*	*		*	
Maltitiol							*	
Sorbitol					*	*	*	*
Mannitol							*	
Cyclodextrins	*						*	*

Source: J. Michaud (1998)

Corn oil is obtained from the corn germs, total maize grain contains 3-7% oil, approximately 87% of which is in the germ (corn germ oil), the rest is in the other part of the kernel. Both oils have approximately the same fatty acid content:

C16:0	C18:0	C18:1	C18:2
8-12%	1-3%	20-32%	40-68%

Maize oil is used mainly in the food industry for cooking and salad dressing, it is hydrogenated to produce margarine. It also has applications in cosmetics and pharmaceuticals as an oleaginous vehicle. Worldwide production of corn oil exceeds 800,000Mt per annum and is increasing.

Maize gluten meal is the name given to the insoluble protein complex obtained as a by-product of corn starch production. It is used as a protein basis in animal and poultry feed, although it is not a rich source of protein it is an important source of

xanthophylls and provitamin A. It is acid hydrolysed to yield seasonings and vegetable protein, the latter is hydrolysed to produce amino acids. Zein is isolated a raw material for non-food applications. Alkaline heat treatment results in natural glues with industrial application.

Maize gluten feed is obtained during corn starch production and contains fibre, gluten starch and a small amount of oil. It is used for animal feed.

Maize steep extract is the viscous liquid obtained after low temperature concentration of water that has been used for steeping of maize in starch production. The liquid is concentrated to the dry state to give an average composition:

Dry Matter	Crude Protein*	Ash	Lactic Acid
35-50%	44-48%	16%	25%

* Crude protein contains free amino acids and ammonia, polypeptides of various chain length and vitamins, enzymes and other biocatalysts.

It is used in industrial fermentation operations for production of enzymes, antibiotics, nutritional yeast and amino acids. It also has application as an additional component in feed formulations.

Corn cobs are the by-product of removing the kernel and are used in the production of furfural. Furfural is produced from fibrous residues of food crops, maize is suitable as a raw material. Precursors of furfural are the pentosans xylan and arabinan, pentosan content of the raw material is important and must be between 25-40%. Furfural is used in the manufacture of furan, an intermediate in the synthesis of pharmaceuticals, agricultural chemicals, stabilisers and fine chemicals, it is also used in the manufacture of furfuryl alcohol, methylfuran and nitrofurans which are intermediates for making antimicrobial agents. It is also used as a selective solvent in separation of saturated and unsaturated compounds in lubricating oils, gas oil and diesel fuels.

There appears to be a distinct divide between Northern and Southern Europe with relation to marketing of maize. Northern countries concentrate more on growing

silage maize whereas southern countries appear to concentrate more on growing grain silage.

Other Information

Maize is very temperature sensitive and a favourable site is important to encourage good growth. Ideally the site should be south facing, sheltered and less than 120m in altitude. Friable, well structured soils are necessary to allow the preparation of good seedbeds and easy rooting. Heavy soils are not suited due to the difficulty of preparing a good seedbed and the risk of not being able to get on the land at harvest. Shallow soils are also not suited due to the risk of poor crops being established in dry years.

Maize has a high demand for nutrients shortly after germination, any shortage will limit the growth and yield potential. Due to the small root system in the early stages of growth the plants require nutrients close to the seed at planting. The average maize crop (40t/ha fresh weight) will remove 160kgN/ha (occasionally up to 210kgN/ha) from the soil, however applications of more than 100kg/ha are rarely necessary due to the efficiency of maize crops at removing N directly from the soil. Phosphate removal of the average crop of maize is in the region of 55kg/ha, almost 360kg/ha of potassium is required along with 175kg/ha of potash for the average yielding crop. Magnesium will be required at around 40kg/ha and sulphur may be required in small quantities depending on manure applications. Also if manure is not applied regularly small quantities of boron, copper, zinc, manganese and iron may be necessary.

The crop will be sown when soil temperature reaches 8-10°C, usually late April-early May. Harvest will take place in the autumn, usually in October/November, newer varieties reach maturity earlier and can generally be harvested in early October.

The main diseases that are likely to be present in the maize crops are Eyespot and Rust, these become more of a problem in wetter conditions. Such diseases can reduce the yield or quality of the crop however, it is not practical to treat a six foot tall crop with relevant chemicals. The major pest problem will be slugs, particularly in fields which were over wintered cereal stubble with green re-generation throughout the

winter in combination with fields where manure had been applied. Slug pellets can be used on the crop to reduce the effect of such problems.

Research

Currently the main research programmes being carried out on the maize crop in Europe are modifying the cereal-bicropping system to be more effective and investigation of other methods of reducing soil erosion. These other methods include; using ryegrass understorey, using winter cover crops and using narrower row spacing.

Useful Websites

http://maizegrowersassociation.co.uk - Technology and products for maize growers
http://www.pda.org.uk/leaflets/17/leaflet17-1.htm - General agronomy of maize crops
http://apps.fao.org - Statistics on production and yields across the world
http://maize.agron.iastate.edu/general.html - The Maize Page

BioMat Net

AGRE-0016 – Adding Value to European Maize Use in the Starch Industry in Relation to Growing Areas and Cultivation Techniques Used

AIR1-CT92-0205 – Engineering Stress Tolerance in Maize (ESTIM)

AIR2-CT94-1187 – Thermoplastic Starches for Industrial Non-Food Uses

AGRE-0063 – High Temperature Ethanol Fermentation of Lignocellulosic Waste

FAIR-CT95-0837 – Novel Polyol Intermediates Derived from Biosustainable Starch for Polymer Technologies – STARPOL

QLKS-1999-01110 – Threat to European Maize production by Invasive Quarantine Pest, Western Corn Rootworm: A New Sustainable Crop Management Approach

FAIR-CT95-0568 – Production of Novel Starch Polymers in Maize, Wheat, Barley and Potatoes

FAIR-CT96-5036 – The Improvement of Industrial Corn Gluten for Non-Food Applications

AIR1-CT92-0026 – New Processes for the Biological Transformation of Agricultural Residues for the Production of High Added Value Flavours

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