

# Arable agriculture

These are the crops that provide the staple foods both for Man and our animals.

We use cereals (= grass seeds), as they are:

- High in protein (up to 12%) and high in energy (low water content)
- Quick to grow (up to 3 harvests/year)
- High yielding (1-14 tonnes/ha)
- Easy to store (being dry, they can easily be kept for months in a dry container)

Which cereal is grown in a region depends on the climate.

- In temperate zones, (*warmest*) wheat; barley; oats; rye (*coldest*) are grown.
- All can withstand frost at some stage of their life-cycle.

In warmer climates, higher-yielding crops are grown – their adaptations are the basis of this topic.

## Rice (*warm and wet*)

- Adapted to reduce competition from weeds (which drown in the paddy-fields)
- The stem and roots are hollow. This allows **oxygen** (from photosynthesis) to reach the roots which are under water.
- The germinating seed forces a hollow **coleoptile** through the water, forming a ‘snorkel’ allowing oxygen to reach the whole plant.
- The hollow stems - **aerenchyma cells** -ensure the leaves float and thus get maximum light for photosynthesis.
- The roots are shallow, nearer any oxygen diffusing in from the air.
- **Young** rice plants can **respire anaerobically**, producing ethanol;
  - Ethanol is toxic, but root cells of rice are ethanol-tolerant.
- They contain **alcohol dehydrogenase** to break down the ethanol they produce.
- Once the seedling plants are 10-20 cm high, they are moved to flooded paddy-fields
  - The flooding reduces competition from weeds
- Paddy-fields are later drained - adult rice is as intolerant of flooding as any other crop.
- *Note that this is a **physiological adaptation**, whilst the other crops have **physical or anatomical adaptations**.*



## Sorghum (*hot and dry*)

- A **dense root system** that is to extract water from the soil (both **wide** and **deep**).
- A **thick waxy cuticle** that prevents water loss through the leaf surface.
- The presence of special cells (**motor cells**) on the underside of the leaf allowing the leaf to roll inwards in dry conditions.
  - This traps moist air in the rolled leaf and reduces water loss.
- Reduced number of sunken stomata on leaves (they are in pits, surrounded by hairs).



## Maize – (hot, damp, intense light)

Maize grows in the tropics, where bright light and adequate water make low [CO<sub>2</sub>] a real problem

- Maize uses a different type of photosynthesis (C<sub>4</sub>) compared to normal plants (C<sub>3</sub>).
- Using **the C<sub>4</sub> pathway**, maize can fix CO<sub>2</sub> at low levels (as C<sub>4</sub> compound **malate**).
- Malate is then used to boost CO<sub>2</sub> levels **in a different cell**, where normal, C<sub>3</sub>, photosynthesis then takes place.
- This extra step takes place in **sheath cells**, surrounding the vascular bundles
  - This allows easy transport (water in, sucrose out) from the leaf
- Photosynthesis itself takes place in the **palisade cells**, as in any other plant
  - The **chemistry** of photosynthesis (P/S) is the same as any other plant
  - The **source** of CO<sub>2</sub> in those cells **is** different (malate, not the air)
- This mechanism speeds up P/S since oxygen is no longer inhibiting it.
  - *Essentially, the light reaction is no longer inhibiting the dark reaction (see A2!!).*
- The normal limiting factor for photosynthesis (even in the UK) is low [CO<sub>2</sub>]
  - Maize needs **much** more water than sorghum – quickly dies in droughts
- Normal (C<sub>3</sub>) plants are inefficient and fail to grow at low CO<sub>2</sub> – but maize grows well
- Attempts are being made to ‘GM’ wheat etc. to use this C<sub>4</sub> pathway – no luck yet!



## Controlling the crop environment

### A. Removing limiting factors

#### 1. Outdoors:

- Crops are chosen to suit the local conditions (frost dates, soil pH, type, etc)
- Provided with sufficient fertiliser (N, P, K)
- Irrigated/drainage to provide roots with water/oxygen

#### 2. Indoors:

- Total control of growing environment – but very expensive, so **high value crops** grown
  - Out-of-season crops, tomatoes, cut flowers
- **Warmer** inside - ‘greenhouse effect’(!) - but **less light**.
- Law of **limiting factors** applies, so **all** plant requirements must be optimised:
  - **CO<sub>2</sub> levels** raised from 350ppm to 1000ppm
    - 1. In winter, by burning fossil fuels (warm, so added low down)
    - 2. In summer, from compressed gas (cold, so added high up)
  - **Light levels** raised
    - 1. day-length (affects flowering);
    - 2. intensity (affects growth rate)
  - **Temperature** optimised at 25-30°C
    - 1. Fossil fuels burned in winter (also add CO<sub>2</sub>)
    - 2. Adequate (= fan) ventilation in summer
- Irrigated, fertiliser levels optimised, pests rigidly controlled
- Grower must balance **additional cost** against **additional income**



#### 3. Fertilisers: essential, since cropping removes nutrients

**Organic:** + free, harmless, improve soil, wildlife benefits;

– slow-acting, smelly, heavy, variable strength, not available on arable-only farms

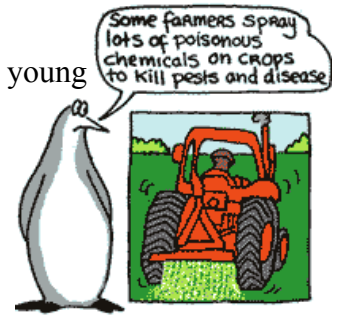
**Artificial:** + fast-acting, very soluble, concentrated, easy to apply/transport, odourless;

– expensive, may cause eutrophication, needs fossil fuels, toxic in excess

## B. Reducing competition

**Pests** are organisms that compete with the crop and reduce yield

- **Weeds** compete for water, light, nutrients, space, mainly when crops are young
  - Can be removed by hand (slow) or by chemicals (costly)
- **Fungi** cause most (treatable) plant diseases (black spot, rust)
  - Can be minimised by growing resistant varieties and by spraying
  - Sprays can be organic (outside), or synthetic (**systemic** – go inside the plant)
- **Slugs/snails** may seriously damage to young crops – use pellets or biological control
- **Insects** cause most damage – reduce yields globally by 30%
  - **Sucking insects** (aphids) remove products of photosynthesis
  - Are major vectors of crippling diseases (spread viruses)
  - **Biting insects** (caterpillars, locusts) reduce photosynthetic area **and** remove food
  - Treatment (sprays) again, can be organic or synthetic



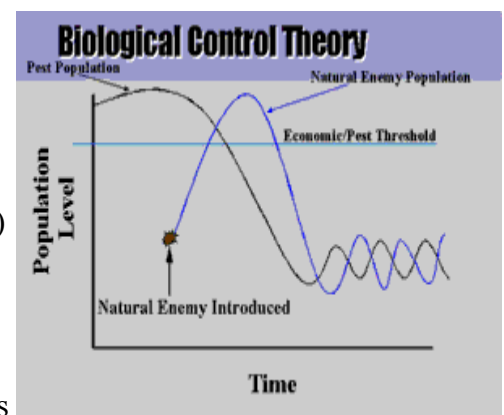
- **Biological control** possible in some cases:

- Ladybirds eat aphids
- *Encarsia* eats whitefly
- Very effective (and cheap – replicates itself)
- Does not **eliminate** the pest (or predator dies out)
- keeps pest at low level – below **economic threshold**



- **Drawbacks:**

- Most pests do **not** have suitable control agents
- Cannot use chemical sprays as well as biological control



## Extensive v. intensive farming

**Extensive** (*Low input = low output*):

- Now confined to developing countries, and marginal land
- Traditional – uses old techniques and varieties of crop – thus genetically diverse
- Labour intensive – often human/animal labour
- Uses little/chemical fertiliser/pesticides – thus ‘organic’
- Very energy efficient



**Intensive** (*high input = high output*):

- Necessary to feed World's growing population
- Modern, industrial farming, relying on modern varieties, thus genetically very limited
- Relies on chemicals (fertiliser, pesticides), made with fossil fuels
- Low labour (tractors only), high yield
- Inefficient in energy use – but high yield /ha

