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_2] a real problem

- Maize uses a different type of photosynthesis (C4) compared to normal plants (C3).
- Using **the C_4 pathway**, maize can fix CO_2 at low levels (as C4 compound **malate**).
- Malate is then used to boost CO_2 levels **in a different cell,** where normal, C_3, 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_2 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_2]
  - Maize needs **much** more water than sorghum – quickly dies in droughts
- Normal (C_3) plants are inefficient and fail to grow at low CO_2 – but maize grows well
- Attempts are being made to 'GM' wheat etc. to use this C_4 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/drained 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_2 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^{o}C
    1. Fossil fuels burned in winter (also add CO_2)
    2. Adequate (= fan) ventilation in summer
- Irrigated, fertiliser levels optimised, pests rigidly controlled
- Grower must balance **additional cost** against **additional income**

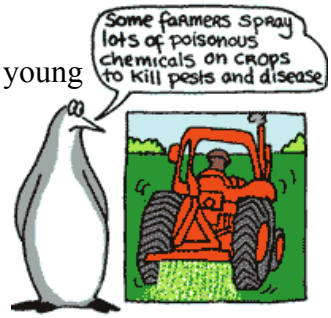
3. Fertilisers: essential, since cropping removes nutrients

Organic: + free, harmless, improve soil, wildlife benefits;
– slow-acting, smelly, heavy, variable strength, not available on arable-only farms

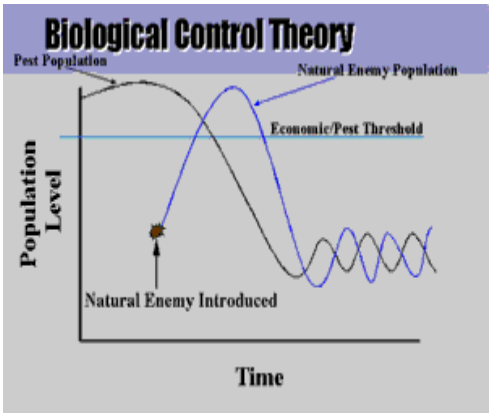
Artificial: + fast-acting, very soluble, concentrated, easy to apply/transport, odourless;
– expensive, may cause eutrophication, needs fossil fuels, toxic in excess

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



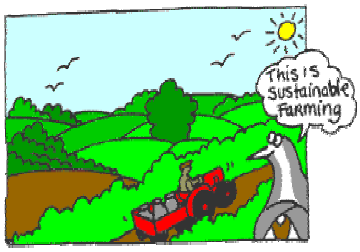
- **Biological control** possible in some cases:

  - 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

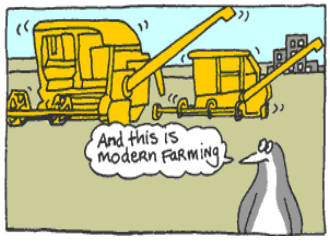
Extensive v. intensive farming

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