

## Unit 3 - Sustainability and Interdependence

### The Science of food production

#### 1 Food supply, plant growth and productivity

##### (a) Food supply

###### **Food security**

Food security is the ability of human populations to access food of sufficient quality and quantity. As a result of the increase in human population and concern for food security there is a continuing demand for increased food production. There is also a demand that food production is sustainable and does not degrade the natural resources on which agriculture depends.

###### **Agricultural food production**

All food production is dependent ultimately upon photosynthesis. (Photosynthesis traps light energy to produce carbohydrates) Most human food comes from a small number of plant crops (cereals, potato, roots, legumes). If the area to grow crops is limited, increased food production will depend on the factors that control plant growth, the breeding of higher yielding cultivars, use of fertilisers, protecting crops from pests, diseases and competition. Livestock produce less food per unit area than plant crops due to loss of energy between trophic levels. Livestock production may be possible in managed and wild habitats unsuitable for cultivation of crops.

##### (b) Plant growth and productivity

###### **Photosynthesis**

Photosynthetic pigments capture energy for photolysis and to generate ATP. Particular wavelengths of light are absorbed by

photosynthetic pigments. Transmission and reflection of light occurs if it is not absorbed by pigments.

The absorption spectra of Chlorophyll a and b and carotenoids can be compared to the action spectra for photosynthesis. Carotenoids extend the range of wavelengths absorbed by photosynthesis and pass the energy to chlorophyll.

Absorbed energy excites electrons in the pigment molecule. Transfer of these high-energy electrons through electron transport chains releases energy to generate ATP by ATP synthase. Energy is also used for photolysis, in which water is split into oxygen, which is evolved, and hydrogen, which is transferred to the coenzyme NADP.

The enzyme RuBisCO fixes carbon dioxide by attaching it to ribulose biphosphate (RuBP) in the Calvin cycle. The 3-phosphoglycerate produced is phosphorylated by ATP and combined with hydrogen from NADPH to form glyceraldehyde-3-phosphate (G3P). G3P is used to regenerate RuBP and for the synthesis of glucose. These sugars may be synthesised into starch or cellulose or pass to other biosynthetic pathways to form a variety of metabolites.

### **Plant Productivity**

Net assimilation is the increase in mass due to photosynthesis minus the loss due to respiration and can be measured by the increase in dry mass per unit leaf area. Productivity is the rate of generation of new biomass per unit area per unit of time. Biological yield of a crop is the total plant biomass. Economic yield is the mass of desired product. The harvest index is calculated by dividing the dry mass of economic yield by the dry mass of biological yield.

## **2 Plant and animal breeding**

### **(a) Breeding**

Plant and animal breeding involves the manipulation of heredity to develop new and improved organisms to provide sustainable food sources. Breeders seek to develop crops and stock with higher yields, higher nutritional values, resistance to pests and diseases, physical characteristics suited to rearing and harvesting as well as those that can thrive in particular environmental conditions.

### **(b) Plant Field trials**

Plant field trials are carried out in a range of environments to compare the performance of different cultivars or treatments and to evaluate GM crops. In designing field trials account has to be taken of: the selection of treatments (to ensure fair comparisons); the number of replicates (to take account of the variability within the sample) and the randomisation of treatments (to eliminate bias when measuring treatment effects).

### **(c) Selecting and breeding**

Animals and cross pollinating plants are naturally outbreeding. In inbreeding, selected plants or animals are bred for several generations until the population breeds true to the desired type due to the elimination of heterozygotes. Test crosses can be used to identify unwanted individuals with heterozygous recessive alleles. An Inbreeding depression is the accumulation of recessive, deleterious homozygous alleles. Self-pollinating plants are naturally inbreeding and less susceptible to inbreeding depression due to the elimination of deleterious alleles by natural selection. In outbreeding species inbreeding depression is avoided by selecting for the desired characteristic while maintaining an otherwise genetically diverse population.

### **(d) Cross breeding and F1 hybrids**

New alleles can be introduced to plant and animal lines by crossing a cultivar or breed with an individual with a different, desired genotype.

In animals, individuals from different breeds may produce a new crossbred population with improved characteristics. As a F<sub>2</sub> population will have a wide variety of genotypes a process of selection and backcrossing is required to maintain the new breed. Alternatively the two parent breeds can be maintained to produce crossbred animals for production.

### **(e) Test Cross**

In plants F<sub>1</sub> hybrids, produced by the crossing of two different inbred lines, creates a relatively uniform heterozygous crop. F<sub>1</sub> hybrids often have increased vigour and yield. The F<sub>2</sub> generation is genetically variable and of little use for further production although it can provide a source of new varieties. Test Crosses can be used to identify unwanted individuals with heterozygous recessive alleles

### **(f) Genetic Technology**

As a result of genome sequencing, organisms with desirable genes can be identified and then used in breeding programmes. Genetic transformation techniques allow a single gene to be inserted into a genome and this genome can then used in breeding programmes.