19. Genetic Technology

19.3 Genetically Modified Organisms in Agriculture

Paper 4

Question Paper

1 **(b)** Give **two** advantages of genetically engineering herbicide resistance in crop plants such as soybean.

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2 Biodiversity can be assessed at three different levels. One of these is the genetic variation within each species.

To calculate the genetic variation that exists within a species, scientists:

- obtain DNA sequences from many individuals of one species
- count the number of nucleotides that differ when the sequences of two individuals are compared
- repeat this with different pairs of individuals.

This allows scientists to calculate the **mean** number of differences at every nucleotide position along the sequence (mean number of nucleotide differences per site).

(b) Explain why scientists use databases and computers to calculate the mean number of nucleotide differences per site.

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3 The potato plant, *Solanum tuberosum*, is an important food crop. Crop yield is reduced if the leaves of the plant are eaten by the larvae (immature stages) of the Colorado beetle, *Leptinotarsa decemlineata*.

Crop scientists used recombinant DNA technology to create two genetically modified (GM) varieties of potato plant. These plants produce proteins that are poisonous to insects.

- GM potato variety **A** contains two new genes, *SN* and *Bt*.
- GM potato variety **B** contains two new genes, *SN* and *OCII*.

The new varieties were tested by having a constant number of Colorado beetle larvae introduced to the plants at time 0 hours. The number of larvae that were alive after 24, 48 and 72 hours was recorded. The percentage of the larvae that had died in each time interval was calculated. This was repeated for potato plants that had not been genetically modified (non-GM).

Table 4.1 shows the percentage of Colorado beetle larvae that had died on the GM potato plant varieties and on non-GM potato plants.

Table 4.1

type of potato plant	percentage of Colorado beetle larvae that had died		
	24 h	48 h	72 h
GM potato variety **A**	50	93	100
GM potato variety **B**	37	70	93
non-GM potato	0	0	0

(a) (i) Suggest what is meant by recombinant DNA technology.

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(ii) Suggest why the scientists created two different types of GM potato plant.

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(iii) State why the scientists also performed the test on non-GM potato plants.

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(b) Discuss how the results in Table 4.1 provide information that could help to solve the global demand for food.

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4 In 1973 a technique for genetic engineering was used for the first time. Recombinant DNA was made using a plasmid and this was successfully transferred into an organism.

In 2012 a new technique for genetic engineering, called gene editing, was developed.

(b) Orange trees, *Citrus sinensis*, produce fruits that are an important food crop. The functional leaf area of orange trees may be reduced by the growth of citrus canker bacteria. These bacteria cause citrus canker disease.

Scientists used gene editing to develop two types of orange tree with different mutations (changes to the DNA). The mutant orange tree leaves showed resistance to citrus canker disease.

Fig. 4.1 shows the area of leaf with citrus canker disease in wild type (not gene edited) and gene edited orange tree leaves after they have been exposed to citrus canker bacteria.

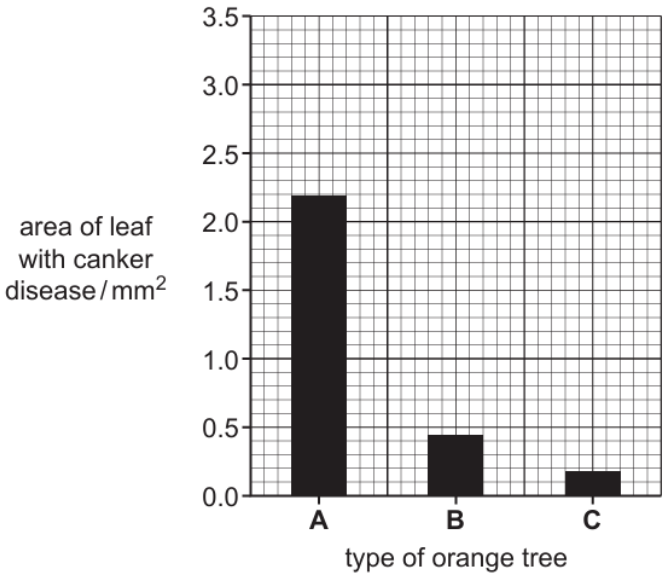


Fig. 4.1

(ii) Explain the social benefits of this example of gene editing.

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5 In 1973, a technique for genetic engineering was used for the first time. Recombinant DNA was made using a plasmid and this was successfully transferred into an organism.

In 2012, a new technique for genetic engineering, called gene editing, was developed.

(b) Cassava plants, *Manihot esculenta*, produce roots that have a high starch content. These roots are an important food source in tropical regions. The growth of cassava plants is reduced by competition from weeds.

Scientists used gene editing to develop two types of cassava plant with different mutations (changes to the DNA). The gene edited cassava plants showed resistance to the herbicide glyphosate. In susceptible plants, glyphosate prevents synthesis of three amino acids from a precursor molecule called shikimate.

Fig. 4.1 shows the concentration of shikimate in the wild type (not gene edited) and the two types of gene edited cassava plant after they were exposed to three different concentrations of glyphosate.

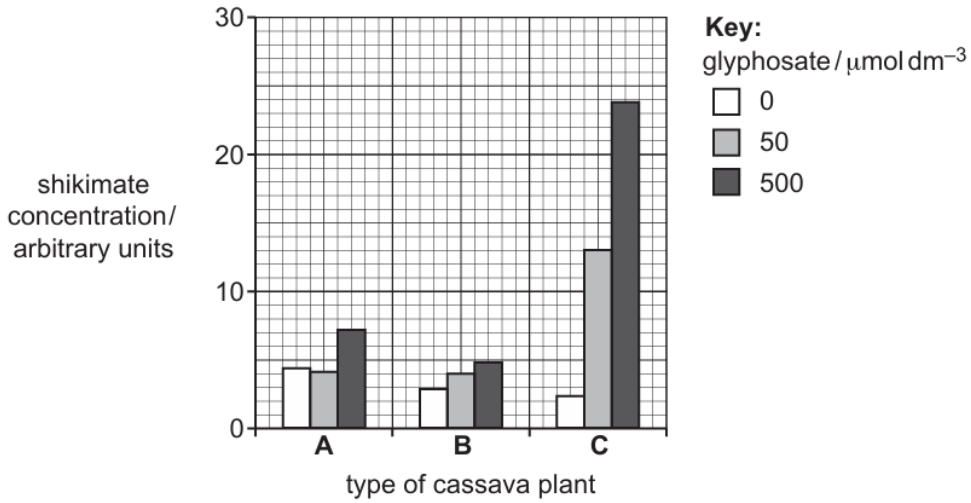


Fig. 4.1

(i) Identify the letter in Fig. 4.1 that represents the wild type cassava plant.

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(ii) Explain the social benefit of this example of gene editing.

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6 **(b)** A new application of recombinant DNA technology uses the genetic modification of a plant to prevent disease. It aims to prevent the most common source of food-borne disease, which is caused by eating food contaminated with pathogenic *Escherichia coli* bacteria.

Scientists genetically modified edible spinach plants to produce colicins. Colicins are antimicrobial proteins that can kill pathogenic *E.coli*. Colicins are normally made by other bacteria.

An experiment was carried out to test this application by spraying an extract of genetically modified (GM) spinach in buffer solution onto raw meat contaminated with pathogenic *E.coli*. The meat was stored at 10 °C for varying lengths of time before the numbers of viable (living) pathogenic *E.coli* bacteria were counted. Fig. 4.1 shows the results.

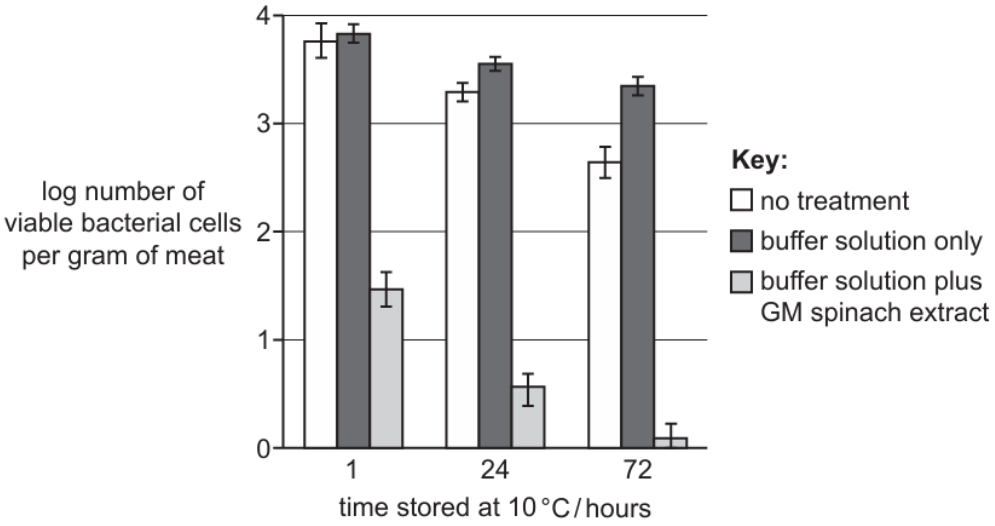


Fig. 4.1

(i) With reference to Fig. 4.1, evaluate the effectiveness of using GM spinach spray on raw meat to prevent food-borne disease.

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(ii) Regulatory authorities may not approve the use of GM spinach spray on raw meat to protect consumers.

Discuss the concerns that may stop regulatory authorities approving this application of recombinant DNA technology.

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7 **(b)** Genetically modified organisms (GMOs) include crop plants. Genetically modified (GM) crop plants have been grown in North America in increasing quantities since 1996. They are now grown in many areas of the world and are eaten by millions of people and farm animals.

Table 4.1 compares the area of land used to grow GM crop plants on six continents in 2013.

Table 4.1

continent	**area of land used to grow GM crop plants / million hectares**	**edible GM crop plants grown**
Africa	3.5	maize, soybean
Asia	19.1	maize, papaya, tomato
Australasia	0.6	canola
Europe	0.2	maize
North America	81.1	canola, maize, papaya, soybean, squash, sugar beet
South America	70.9	canola, maize, soybean

(i) Suggest how North America and South America benefit from growing large areas of GM crop plants rather than non-GM crop plants.

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(ii) Only a small area of land is used to grow GM crop plants in Europe. This is mainly because most of Europe uses a 'precautionary principle'. The precautionary principle prevents GM crop plants being grown if there is a possible risk of harm to human health or to the environment, even if there is no proof of harm.

Many European citizens have concerns about the safety of eating GM food, but Europe imports large quantities of GM maize and GM soybean to feed farm animals.

Use this information and Table 4.1 to deduce two arguments **in favour of** growing more GM crop plants in Europe.

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(iii) Explain why the data in Table 4.1 are not enough to calculate the extent to which different continents have replaced traditional crop plants with GM versions.

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8 The summer squash plant, *Cucurbita pepo*, produces edible fruits that vary in shape.
Fig. 2.1 shows the fruits of three different varieties of squash plants.



Patty pan (disc-shaped) | Di Nizza (spherical) | Alfresco (long)

Fig. 2.1

Fruit shape in squashes is controlled by two genes, **A/a** and **B/b**, that are located on different chromosomes.

- A disc-shaped fruit is produced when both dominant alleles, **A** and **B**, are present.
- A spherical fruit is produced when either allele **A** or allele **B** is present, but not if both **A** and **B** are present.
- A long fruit is produced when both allele **A** and allele **B** are absent.

(b) (i) Genetically modified (GM) summer squash plants with resistance to viral diseases have been grown in the USA since 1995.

Scientists have been concerned that viral resistance genes pass easily from GM squash plants to their wild relative, the Texas gourd, *Cucurbita texana*.

Explain why the possibility of gene flow from GM squash plants to the Texas gourd is a cause of social and environmental concern.

social .....

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environmental .....

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(ii) A study compared the survival of two different types of hybrids that were formed by cross-pollination between GM virus-resistant squash plants and wild Texas gourd plants:

- virus-resistant hybrids that had inherited the viral resistance gene
- non-resistant hybrids that had **not** inherited the viral resistance gene.

Viral disease outbreaks caused many of the non-resistant hybrids to die. Leaf-eating beetles then moved in larger numbers to the surviving healthy virus-resistant hybrids. The beetles carried a pathogenic bacterium *Erwinia* which was capable of killing the plants.

Fig. 2.2 compares infection with *Erwinia* in the virus-resistant hybrids and the non-resistant hybrids.

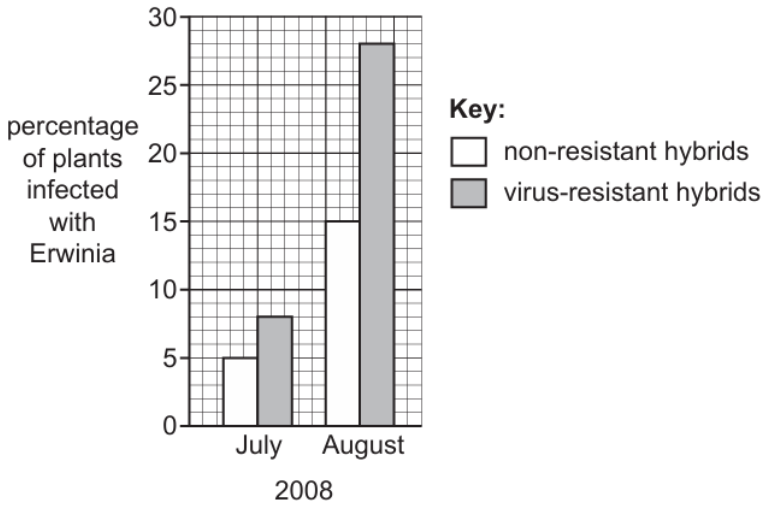


Fig. 2.2

Discuss whether these results provide support for the use of genetically modified organisms (GMOs) in food production.

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(iii) Suggest why the GM virus-resistant squashes grown by farmers rarely suffer infection by *Erwinia*.

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9 **(c)** One goal of genetic engineering is to make crops that are heat tolerant. This means that crops can grow and produce a good yield at high environmental temperatures.

Use the information given in Question 2 to suggest **and** explain a way to improve the tolerance of a crop to high temperatures.

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10 The patty pan squash plant, *Cucurbita pepo*, produces edible fruits that vary in colour.

(b) In 1994, two new varieties of squash were grown in the USA. Both varieties showed resistance to two viral diseases of squash plants.

- The variety 'Tigress' was developed by selective breeding.
- The variety 'Freedom II' was developed by adding genes for viral coat proteins to the squash genome.

(ii) Outline **one** social advantage and **one** social disadvantage of the recombinant squash variety compared to non-resistant squash varieties.

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disadvantage .....

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11 Domestic goats are small, herbivorous animals that provide milk for human use. This is an important source of food for people in rural South Africa.

Three Northern European goat varieties (breeds) have been imported to South Africa because they have higher milk yields than the native South African goats.

Table 2.1 compares the mean daily milk yields of these three breeds of Northern European goat in three locations, Northern Europe, Barbados and South Africa.

Table 2.1

goat breed	mean daily milk yield / kg in different locations		
	Northern Europe	Barbados	South Africa
British Alpine	4.09	2.55	0.75
Saanen	5.17	1.73	1.45
Toggenburg	4.54	3.46	0.56

(d) Children in developing countries may drink unpasteurised goats' milk. Some may develop diarrhoea caused by live bacteria ingested in the milk.

Scientists have used genetic engineering to develop goats that produce human lysozyme in their milk. Lysozyme is an enzyme that kills bacteria and so reduces the number of bacteria in the milk.

State a social advantage **and** a social disadvantage of making these GM goats available in developing countries.

advantage .....

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disadvantage .....

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12 Soybean, *Glycine max*, is an important food crop for human consumption and for feeding to animals.

Two varieties of soybean are Vinton 81 and GTS 40-3-2.

Vinton 81 has been developed in the traditional way by selective breeding (artificial selection) and GTS 40-3-2 is an example of a genetically modified (GM) organism.

(b) Countries vary in the extent to which they grow GM varieties, such as GTS 40-3-2, instead of traditional varieties such as Vinton 81.

- In the USA, 94% of soybeans grown are GM.
- In Europe, 0% of soybeans grown are GM.

Scientists used computer models to predict the effect of two different changes in agricultural practice on soybean crop yields:

- a global ban that reduces the cultivation of GM soybeans to 0% everywhere
- all countries increasing the cultivation of GM soybeans to the 94% level of the USA.

Table 3.1 shows the results of this modelling for four countries.

Table 3.1

country	percentage change in yield of soybeans	
	decrease GM soybean cultivation to 0% of total	increase GM soybean cultivation to 94% of total
Argentina	0.00	+6.23
Bolivia	–10.82	0.00
Brazil	0.00	+6.23
USA	–5.87	0.00

Explain what the data in Table 3.1 suggests about the social and ethical implications of growing GM soybeans.

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13 Maize, *Zea mays*, is an important food crop for human consumption and for feeding to animals.

Two varieties of maize are MON810 and Justina. Justina has been developed in the traditional way by selective breeding (artificial selection) and MON810 is an example of a genetically modified (GM) organism.

(b) Countries vary in the extent to which they grow GM varieties such as MON810, instead of traditional varieties such as Justina.

- In the USA, 88% of the total maize that is grown is GM.
- In most European countries, 0% of the maize that is grown is GM.

Scientists used computer models to predict the effect of two different changes in agricultural practice on maize crop yields:

- a global ban that reduces the cultivation of GM maize to 0% everywhere
- all countries increasing the cultivation of GM maize to the 88% level of the USA.

Table 6.1 shows the results of this modelling for four countries.

Table 6.1

country	percentage change in yield of maize	
	decrease GM maize cultivation to 0% of total	increase GM maize cultivation to 88% of total
Argentina	–8.86	+2.90
Honduras	–1.26	+16.75
Spain	–3.82	+5.39
USA	–7.63	0.00

Explain what the data in Table 6.1 suggests about the social and ethical implications of growing GM maize.

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14 **(a)** Pigs are farm animals used for livestock in some parts of the world. The first genetically modified (transgenic) pigs were produced in 1985. Foreign DNA was injected directly into the nuclei of zygotes. The foreign DNA was made up of two components:

- the gene coding for human growth hormone
- a section of mouse DNA that, in the presence of metal ions, allows transcription to begin.

(i) The human growth hormone synthesised by the transgenic pigs had the effect of making the pigs grow faster, larger and heavier than non-genetically modified pigs.

Suggest reasons for this difference.

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(ii) Suggest **and** explain why the mouse DNA was included in the foreign DNA.

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Only 1% of the attempts successfully produced transgenic pigs. These pigs showed higher body mass and a greater muscle to fat ratio than normal pigs. Monitoring of the pigs' behaviour revealed that they rested more than normal pigs, suffered from stomach ulcers and were unwilling to mate.

(b) (i) Discuss whether these transgenic pigs have long term economic value.

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(ii) Comment on the ethics of producing transgenic pigs showing the features described.

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