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VCE Biology ¾
AOS 1 Revision [1.0]
SAC 2

50 Marks. 5 Minutes Reading. 60 Minutes Writing.

Section A: SAC Questions (50 Marks)

Question 1 (25 marks)

Read the following case studies about genetically modified plants and crops, and use this information to answer the questions posed in this SAC.

Soybeans

Genetically modified soybean plants resistant to the herbicide glyphosate ('Roundup®') were produced so that weeds competing with the 'Roundup Ready®' soya plants could be killed with the herbicide. This is an example of a first-generation GM plant, in which the main advantage appeared to be to the company producing the herbicide. The American Soybean Association, however, states that growing glyphosate-resistant soybean plants protects the environment because herbicide application is, in fact, reduced, and tillage practices (used to control weeds) are changed.

Possible risks include the potential for the gene for herbicide resistance to pass into weeds, producing 'superweeds', or for increased use of herbicide to increase the selection pressure on weeds, encouraging the development of herbicide resistance. The more farmers rely on glyphosate, rather than rotating different herbicides or using other weed-control methods, the more this problem is compounded, leaving the resistant weeds to spread unchecked. However, this has not appeared to have created serious problems so far.

Another risk is to the wider ecosystem. The rapid decline of the monarch butterfly population in North America, for example, may be partly due to climate change and logging, but the major cause seems to be the elimination of milkweed, the breeding habitat for monarch butterflies and food for their caterpillars, by herbicides used on GM soya and maise.

a. The *Roundup Ready*® soybean was engineered to resist glyphosate using a gene from another organism. Based on this information, how would the soybean be classified? (1 mark)

A. Cisgenic, because the gene was taken from another soybean plant.

B. Transgenic, because the gene was sourced from a different species.

C. Mutagenic, because the gene was altered using radiation.

D. Epigenetic, because the gene was silenced rather than inserted.

b. Before inserting the herbicide resistance gene into soybeans, scientists use PCR (polymerase chain reaction) to amplify the gene. However, the experiment fails, and no DNA amplification is detected.

Which of the following is the most likely cause of the PCR failure? (1 mark)

A. The use of bacterial plasmids as the DNA template, preventing the amplification of the plant gene due to sequence incompatibility.

B. A low voltage setting in gel electrophoresis, reducing the movement of DNA fragments and causing amplification failure.

C. An excessive concentration of free nucleotides (dNTPs), which inhibits the ability of Taq polymerase to extend the DNA strand.

D. The absence of primers complementary to the flanking regions of the herbicide resistance gene preventing DNA polymerase from initiating replication.

c. A scientist is verifying whether the pest-resistance gene was successfully inserted into soybeans. They compare DNA from modified and unmodified plants using gel electrophoresis.

What banding pattern would confirm successful gene insertion? (1 mark)

A. A new band appears in the modified soybean DNA that is absent in the unmodified soybean.

B. The modified soybean DNA shows no bands, indicating complete gene replacement.

C. The modified soybean DNA shows identical bands to the unmodified soybean DNA.

D. The modified soybean DNA bands appear lower in the gel because the gene makes the DNA lighter.

d. After inserting a herbicide resistance gene into soybean DNA, scientists run a gel electrophoresis test to confirm the successful modification. However, one sample produces multiple unexpected DNA bands instead of the expected single band.

What is the most likely explanation for this result? (1 mark)

A. The inserted gene was too large to migrate through the gel, causing multiple bands to appear.

B. The gel concentration was too high, forcing the DNA to split into separate fragments.

C. The herbicide resistance gene caused the DNA to fragment spontaneously.

D. The plant cells repaired the DNA cut in multiple ways, resulting in genetic variation among the samples.

e. A farmer growing genetically modified (GM) soybeans notices that some nearby non-GM soybean plants also show resistance to herbicides.

Which of the following provides the best explanation for this unexpected result? (1 mark)

A. The herbicide resistance trait spread through the soil, affecting nearby non-GM plants.

B. Pollen from the GM soybeans cross-pollinated with the non-GM soybeans, passing the herbicide resistance gene to them.

C. The CRISPR-edited gene caused spontaneous genetic mutations in neighbouring soybean plants.

D. Herbicide-resistant bacteria in the environment transferred resistance to the non-GM plants through horizontal gene transfer.

f. The soybean plant obtains the gene conferring resistance to the herbicide from a foreign source.

i. What principle of the genetic code describes how the gene can be expressed in soybeans despite coming from a foreign source? (1 mark)

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ii. Describe the process of translation of the gene conferring resistance to the herbicide in the soybean plant. (3 marks)

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iii. Describe the process that is used to increase the amount of gene available to be transferred into a soybean plant during a genetic modification experiment. (3 marks)

The protein that causes resistance against the herbicide is postulated to act outside of a cell in plants.

iv. Explain how this protein may be exported outside the cell after its translation. (3 marks)

g. As described in the article above, there are a lot of considerations that are being made when considering the use of genetically modified soybeans.

i. Do we have enough information to determine whether the genetically modified soybean is transgenic or cisgenic? In your answer, explain the difference between the two concepts. (3 marks)

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ii. Using your own knowledge and the ideas listed in the article, list two benefits of genetically modified soybeans. (2 marks)

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iii. Applying the principle of beneficence, discuss the ethics of soybean genetic modification. (2 marks)

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iv. Using your own knowledge and the ideas mentioned in the article, describe some of the risks associated with the genetic modification of soybeans. (3 marks)

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Question 2 (25 marks)

Africa Harvest

A biotechnology company in Kenya, Africa Harvest, led by Dr Florence Wambugu and with backing from Monsanto and the Rockefeller Foundation, is producing plantains that are nutritionally enhanced to contain more zinc. In areas where people eat very little meat, the diet may be deficient in zinc, an important enzyme cofactor and essential for regulating insulin secretion. Zinc is also important in gene regulation via certain transcription factors called zinc finger proteins.

Africa Harvest is also developing GM seed that is resistant to pests. This would eliminate the need for farmers to spray pesticides onto their growing crops. Each year, in parts of the world where safety equipment is not readily available or carefully used, the incidence of acute pesticide poisoning is high. In Sri Lanka, for example, the incidence is around 180 per 100,000 people (in comparison to 18.2 per 100,000 people in some developed countries).

Many small-scale farmers in Africa, however, do not want GM crops. They feel they already have effective agricultural practices that are more environmentally and farmer-friendly than GM. Using traditional farming methods, farmers throughout Africa have developed a great diversity of seed varieties bred for their flavours and nutritional value, which have evolved with local pests and diseases and are adapted to different soils and weather patterns. Such diversity is far safer than relying on a single crop that may fail widely in an event such as a pest infestation or a drought, events that may be more likely as climate change progresses.

Of further concern is the control of seeds exercised by some companies, which make it illegal for farmers to save seeds so that they are forced to buy GM seeds each year. Farmers in many countries, however, do see the benefits of GM seeds.

The introduction of pest-resistant genetically modified (GM) plants in Africa has sparked debate over ethical concerns, particularly in relation to the principle of justice.

a. Which of the following describes a valid ethical concern under this principle? (1 mark)

A. The plants may require artificial light to grow, resulting in lower overall yields.

B. The inserted gene may cause the plantains to become toxic to all consumers, leading to widespread health risks in local communities.

C. Small-scale farmers may become economically dependent on seed companies for GM crops, limiting their financial independence and access to traditional farming practices.

D. The GMO will cause mutations in local animal species that consume it, leading to unintended ecological consequences.

b. Scientists at *Africa Harvest* are considering using CRISPR-Cas9 to modify plantains for pest resistance, reducing the need for pesticides. However, they need to ensure that gene insertion is highly specific to prevent unintended mutations in the plant genome.

Which of the following strategies would best improve the precision of CRISPR-Cas9 editing in this context? (1 mark)

A. Increasing the concentration of Cas9 enzyme to enhance the likelihood of a successful DNA cut at the target site.

B. Running gel electrophoresis before gene insertion to ensure that only correctly sized DNA fragments are used.

C. Using a guide RNA with an extended sequence to increase binding specificity to the target DNA.

D. Using multiple guide RNAs for the same gene to ensure that Cas9 recognises the correct DNA sequence.

c. Scientists at *Africa Harvest* are considering using bacterial fermentation to produce a plant-based protein as an alternative to direct genetic modification of plantains. To maximise efficiency, they introduce the plant protein-coding gene into a recombinant plasmid and transform it into a bacterial host for large-scale production.

Which of the following best explains why plasmids are an efficient system for producing recombinant proteins in bacteria? (1 mark)

A. Plasmids replicate independently of the bacterial chromosome, allowing for high-copy expression of the inserted gene.

B. Plasmids permanently integrate into the bacterial chromosome, ensuring stable protein expression across multiple generations.

C. Plasmids allow bacteria to photosynthesise, providing the energy needed for increased protein production.

D. Plasmids increase the mutation rate in bacteria, leading to spontaneous improvements in protein production efficiency.

d. A Kenyan farmer is sceptical about GM plantains, arguing that traditional crops have evolved resistance to local pests over centuries. What is a valid ethical concern regarding the large-scale adoption of GM crops in Africa? (1 mark)

A. The loss of traditional crop varieties and reduced genetic diversity in local farming.

B. The inability of GM crops to grow outside of controlled laboratory conditions.

C. The immediate extinction of all traditional African plant species.

D. The genetic modification of plants causing permanent changes in human DNA.

e. Using the information in the article, answer the following questions.

i. Discuss some of the social and biological implications of using the GM crops mentioned in Africa. (4 marks)

ii. Applying the principle of justice, discuss the ethics and justifications for applying GMO farming to Africa. (2 marks)

iii. Using a duty-based approach, discuss the ethics of implementing GM crops in Africa, with reference to some ethical concepts in your answer as well. (3 marks)

f. Although the technology is still unproven and requires to be tested, CRISPR-Cas9 has been explored as a method by which scientists can gain more specificity in their edits, which may be more useful and acceptable to African farmers.

i. Describe how CRISPR-Cas9 works in bacteria and what its function is. (4 marks)

ii. What are two benefits of CRISPR over conventional methods of gene editing? (2 marks)

iii. What is the significance of the PAM in gene editing and bacteria? (2 marks)

CRISPR has not only been touted as a tool for plants, but it has also been raised as a technology used to edit humans themselves.

iv. With reference to the principles of non-maleficence and respect, discuss the ethics of applying CRISPR-Cas9 technology to humans. (4 marks)

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