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VCE Biology ¾
AOS 1 Revision [1.0]
SAC 2 Solutions

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)

The genetic code's universality.

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

Translation steps as usual – but with reference to the gene conferring resistance to the herbicide.

- mRNA molecule binds to the ribosome at the 5' end.
- tRNA anticodons complementary to the mRNA codons, delivering specific amino acids in their correct order.
- Adjacent amino acids are joined together by condensation polymerisation by the ribosome.
- Translation ends when the stop codon is reached.

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)

PCR – the gene is cycled through different temperatures in a buffer solution.

Denaturation – temperature is raised to 95 degrees in order to separate the DNA strands by breaking apart the hydrogen bonds between complementary nucleotides.

Annealing – lowered to 50 - 55 degrees, to allow for the primers to anneal to each respective DNA strand, whilst the strands themselves remain separated.

Elongation – raised temperature to 72℃, allowing a heat-resistant polymerase to function optimally, replicating the DNA strand, extending the primers until the DNA is replicated.

This process is repeated many times, with the number of DNA molecules doubling each time.

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)

Translated at a ribosome embedded within the membrane of the rough endoplasmic reticulum.

Enters the rER (abbreviation only acceptable when previously defined), where it undergoes modifications and is folded.

Travels via a transport vesicle to the Golgi Apparatus, where it undergoes further modifications, folding before being packaged into a secretory vesicle.

Leaves the cell via exocytosis.

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)

No, we do not have enough information to determine whether this is transgenic or cisgenic, as the gene conferring herbicides resistance's origin is unknown.

Transgenic organisms are those in which a foreign gene has been inserted for genetic modification from a different species to the organism being edited.

By contrast, cisgenic organisms are those in which the gene has been inserted from a different individual of the same species.

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

Herbicide can be applied indiscriminately which saves farmers time and effort.

This can reduce the impact of weeds on yields and productivity.

Any others as well.

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

Beneficence is the moral obligation to do good things.

Seeing how the benefits above can be implemented means that there are good things that can happen – it is our moral obligation to complete these to achieve benefits. However, there are some risks as mentioned which many mean that this technology isn't in the greatest public interest.

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)

Resultant overuse of herbicides may cause weeds to develop herbicide resistant which might make management of them more difficult.

Some "good" weeds might be eliminated, which has flow on effects (reference the monarch butterfly example).

Reliance of company based genetically modified plants may allow companies undue control over farmers.

Cross pollination with wild plants may cause a reduction in genetic diversity as it confers a selection pressure.

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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)

Social implications
- Farmers have to buy new seeds every year which makes them dependent on the companies, and circumvents traditional farming practices.
- Pesticides resistance means less people impacted by pesticide poisoning – THIS MAY BE BIOLOGICAL.
- Better sales and financial stability for farmers with higher yields and productivity.

Biological implications
- Reduction in genetic diversity due to traditional practices and seed collection being finished.
- Improved nutrition = better health outcomes.
- Cross pollination with wild plants and also farmers who do not want to grow GMOs.

There are more answers!

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

Justice – the principle that all benefits and burdens should be distributed equally.

Everyone should see the benefits of farming with GMOs so the justification stands that Africa is included.

Could also argue against that notion as it violates the notion of equality in that all farmers should get a choice.

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)

Duty based ethical approach refers to those following the rules and practices that have been set.

Goes against the traditional principles of farming that are used and the usage of GMO's even by some farmers may violated others.

Ethical duty to do good – beneficence – and hence the stated benefits of this program mean that using a duty-based approach we should implement this.

A LOT of perspectives on this – check your answer with Aaliyan – this given answer is not the best there could be!

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)

Neutralises viral DNA.

- A virus inserts its DNA into a bacterium, and a spacer is cut out and incorporated into the CRISPR locus.
- This is then transcribed to form crRNA which is then combined with tracrRNA to from guideRNA.
- This will from a CRISPR-Cas9 complex with Cas9 enzyme and float around the cell until it encounters complementary viral DNA.
- Viral DNA is cleaved and inactivated.

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

Cheaper and faster.

More precise and targeted.

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

PAM is a short sequence which needs to be present before Cas9 can cut at a gRNA complementary sequence.

In gene editing, this can be altered to suit the target sequence for a precise cut.

In bacteria, this prevents the bacterial chromosome from being recognised and cut as viral DNA.

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)

Non-maleficence – do no harm.

- CRISPR-cas9 may do some harm to an organism as it may have unforeseen consequences, especially germline mutations – we just don't know the consequences.
- As the benefits are yet not confirmed, cannot say they are proportional to the potential harm as well.

Respect

- The ability of an embryo, the actual being having the edits being completed is up in the air and not confirmed.
- Respect for the sanctity of human life may not be considered when doing experiments on embryos.
- Looking out for welfare = respect, edits may result in benefits improving welfare!

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