Name:..Signature.........

PRE-REGISTRATION EXAMINATIONS 2026

SENIOR SIX

BIOLOGY

Paper 1

3 HOURS

INSTRUCTTIONS TO CANDIDATES:

This paper consists of two sections: A and B. It has **SIX** examination items.

Section A has **Two** Compulsory items.

Section B has **Four ITEMS**: Answer **TWO ITEMS.**

Responses to section A must be written in the spaces provided while **Responses** to Section B must be written in the answer booklet(s) provided.

Answer **FOUR** items in all.

Any additional item(s) answered will not be scored

SECTION A

This section is compulsory

ITEM 1

A rural community started a small cassava flour processing factory to improve food security. After six months, workers began complaining of headaches, dizziness, and muscle weakness. Some fish in a nearby stream were also found dead. The factory uses crushed cassava soaked in water before drying. During processing, a bitter smell similar to almonds was noticed. The wastewater from the factory is discharged into the stream.

Further laboratory tests produced the following results:

Parameter	Normal fish	Fish near factory
Dissolved oxygen (mg/L)	9.0	3.5
ATP per mitochondrion	28	12
Cytochrome c oxidase activity (%)	100	30
Rate of glycolysis	Normal	Increased
Mutation rate in liver cells (%)	2	18

Additional findings:

- Cyanide was detected in wastewater.
- High temperature recorded in discharged water.
- Fish gill epithelial cells showed damaged plasma membranes.
- Ribosomes in liver cells appeared detached from rough ER.

Task

(a) Explain how the factory wastewater disrupts fish cell function by affecting mitochondrial structure and ATP production, inhibiting enzymes, damaging plasma membranes, and increasing DNA mutation rates through impaired protein synthesis.

(b) Suggest practical measures to reduce environment harm and protect human and aquatic health while sustaining cassava production.

Response

*Release of cyanide from cassava processing wastewater causes inhibition of mitochondrial respiration leading to reduced ATP production. Cyanide binds to **cytochrome c oxidase** in the **electron transport chain (ETC)** on the inner mitochondrial membrane, blocking electron transfer to oxygen which is the final electron acceptor. **Oxidative phosphorylation** stops and **ATP synthase** cannot produce ATP,* *resulting in reduced ATP per mitochondrion from 28 to 12 and failure of energy-dependent cellular processes.*

Low oxygen levels limit its availability in the ***ETC****, further reducing ATP production. Cells increase* ***glycolysis*** *to compensate, producing small amounts of ATP and leading to accumulation of metabolic by-products, causing cellular fatigue and dysfunction. Blocking* ***cytochrome c oxidase*** *prevents oxidation of* ***NADH to*** NAD^+*, reducing activity of the Krebs cycle and limiting synthesis of essential biomolecules required for normal cell function.*

Elevated temperature alters enzyme structure, reducing activity of key metabolic enzymes including those in mitochondria and affecting membrane-bound proteins responsible for transport and respiration.

Toxic substances and heat disrupt the phospholipid bilayer, increasing permeability and causing leakage of ions and metabolites, which interferes with ***osmotic balance*** *and reduces efficiency of gas exchange.*

Damage to the ***rough ER*** *leads to loss of ribosomes, reducing* ***translation*** *of mRNA into proteins, including essential enzymes such as* ***DNA polymerase*** *and metabolic enzymes required for cell maintenance and repair. Reduced production of* ***DNA repair enzymes*** *combined with toxic stress increases replication errors, raising mutation rates from 2% to 18 and resulting in faulty proteins and dysfunctional cells.*

(a) Practical measures to reduce environmental harm and protect health

- ***Cyanide detoxification treatment****, treating wastewater, converting cyanide to less toxic compounds, preventing inhibition of* ***cytochrome c oxidase*** *and restoring* ***ATP production****.*
- ***Effluent cooling system****, cooling ponds or heat exchangers, lowering temperature, preventing enzyme denaturation, and maintaining metabolic function.*
- ***Aeration of discharged water****, mechanical aeration, increasing dissolved oxygen, supporting* ***aerobic respiration*** *and* ***ATP synthesis****.*
- ***Proper cassava processing (extended soaking and fermentation)****, prolonged soaking, breaking down cyanogenic compounds, reducing cyanide release.*
- ***Wastewater containment and filtration****, sedimentation tanks and biofilters, removing toxins, protecting gill cells, and maintaining water quality.*
- ***Worker safety measures (ventilation and protective equipment)****, ventilation and masks, reducing cyanide inhalation and preventing disruption of* ***cellular respiration****.*
- ***Regular environmental monitoring****, testing cyanide, temperature, and oxygen levels, ensuring safe aquatic conditions.*
- ***Sustainable waste reuse systems****, converting waste to biogas or compost, reducing toxic discharge and environmental contamination.*

ITEM 2

Tea farmers in Kabale pruned their plants heavily just before the cold season to increase branching. However, after pruning, plants showed slow recovery, smaller leaves, and delayed flowering.

Kabale experiences cool temperatures (14–16°C), frequent fog, and shorter daylight hours during this period.

Data collected:

Parameter	Before Pruning	After Pruning (Cold Season)
Leaf area	Large	Small
CO_2 uptake	Moderate	Low
Chloroplast activity	Normal	Reduced
Gibberellin level	Moderate	Low
Cytokinin level	Moderate	Low
Growth rate	Moderate	Very slow

Task

(a) Explain how low temperature combined with pruning affects photosynthesis, hormone balance, primary growth, and photoperiod response.

(b) Explain how pruning and seasonal management should be adjusted to improve yield.

Response

(a) *Cold conditions reduce activity of enzymes such as **RuBisCO** in the **Calvin cycle**, slowing carbon fixation, while reduced kinetic energy limits stomatal opening, lowering CO_2 uptake and reducing **chloroplast activity**.*

*Reduced light limits **photolysis of water** and excitation of chlorophyll in **photosystems I and II**, decreasing production of **ATP and NADPH**, which are required for the Calvin cycle, thus lowering photosynthetic efficiency.*

*Reduced light duration affects **phytochrome-mediated photoperiodism**, limiting activation of flowering signals such as **florigen**, resulting in delayed flowering. Removal of apical buds reduces synthesis of **auxins**, which normally stimulate cell elongation and coordinate growth, disrupting hormonal regulation.*

*Reduced levels of **gibberellins** limit stem elongation, while reduced **cytokinins** decrease cell division in meristematic tissues, causing slow growth and smaller leaves. Limited **ATP production**, reduced hormone levels, and suppressed enzymatic activity reduce **mitosis** and cell expansion in **apical meristems**, resulting in smaller leaves and very slow growth rate.*

(b) Explain how pruning and seasonal management should be adjusted to improve yield

- ***Adjusted pruning timing**, pruning before warm seasons, ensuring higher temperature supports enzyme activity and **photosynthesis**, promoting faster recovery and growth.*
- ***Moderate pruning intensity** involves reducing excessive removal of shoots, maintaining sufficient leaf area for **photosynthesis** and hormone production, ensuring continued growth.*
- ***Light management practices**, reducing shading or spacing plants, increasing light exposure, enhancing **light-dependent reactions** and **ATP production**.*
- ***Temperature regulation strategies**, use of windbreaks or mulching, maintaining warmer root and canopy conditions, supporting enzyme function and metabolic processes.*
- ***Hormonal support through agronomic practices**, proper fertilisation, promoting synthesis of **gibberellins** and **cytokinins**, enhancing cell division and elongation.*
- ***Photoperiod management**, aligning pruning with favourable daylight periods, ensuring effective **phytochrome response** and timely flowering.*

SECTION B
Part I
Attempt one item from this section

ITEM 3

At a secondary school in Mbale (Altitude 1,200 m), students participated in a tree-planting exercise near a busy roadside. After several hours, four students showed unusual signs.

- Musa felt dizzy and had a headache.
- Lillian developed itchy eyes and sneezing.
- Tom reacted slowly when called and staggered slightly.
- Aisha complained of blurred vision in dim light.

The health club recorded the following:

Parameter	Musa	Lillian	Tom	Aisha	Normal
Blood oxygen saturation (%)	82	96	88	95	95–100
Carboxyhaemoglobin (%)	18	1	10	1	<2
Heart rate (beats/min)	120	90	110	85	70–100
Reaction time (s)	0.32	0.19	0.30	0.18	0.18
Tear secretion	Normal	High	Normal	Normal	Normal
Rod cell response (retina test)	Normal	Normal	Normal	Low	Normal

Later it was discovered that traffic had been heavy and some students had not eaten or drunk water all morning.

TASK

(a) Using the data, explain how carbon monoxide exposure, dehydration, allergic reactions, and sensory receptor function affected the students' oxygen transport, heart activity, nervous coordination, and vision.

(b) Suggest practical strategies to prevent such conditions during outdoor school activities.

Response

*In Musa and Tom, high **carboxyhaemoglobin** (18% and 10%) shows carbon monoxide bound to **haemoglobin**, reducing **oxyhaemoglobin** formation and lowering oxygen saturation (82% and 88%), thus limiting oxygen delivery to tissues. Low oxygen triggers increased heart rate (Musa 120, Tom 110 beats/min) to compensate, but reduced oxygen supply to the brain causes dizziness, headache, and weakness. Limited oxygen reduces mitochondrial ATP production, impairing neurone function, causing slow responses and staggering in Tom with increased reaction time (0.30 s).*

Lack of water reduces blood volume, lowering transport efficiency and increasing heart workload, contributing to dizziness and weakness.

*In Lillian, allergens stimulated mast cells to release **histamine**, increasing tear secretion and causing sneezing and itchy eyes despite normal oxygen levels. . Lillian's normal oxygen saturation (96%) and low carboxyhaemoglobin (1%) confirm symptoms are due to allergic reactions, not oxygen transport failure.*

*In Aisha, low **rod cell** response reduced activity of **rhodopsin**, limiting detection of low light and causing blurred vision despite normal oxygen transport. Slightly reduced oxygen availability at altitude combined with carbon monoxide exposure further limits oxygen delivery, worsening symptoms in affected students.*

(b) Suggest practical strategies to prevent such conditions during outdoor school activities

- ***Roadside exposure control*** *involves conducting activities away from heavy traffic, reducing inhalation of **carbon monoxide** and allergens, and preventing formation of carboxyhaemoglobin and allergic irritation.*
- ***Hydration scheduling*** *involves ensuring students drink water before and during activities, maintaining plasma volume, supporting circulation, and reducing dizziness and rapid heart rate.*
- ***Pre-activity feeding programme*** *involves giving students breakfast or light meals before outdoor work, supplying glucose for **cellular respiration** and reducing weakness and poor coordination.*
- ***Health screening for sensitive learners*** *involves identifying students with allergies or visual problems before activity, allowing early protection and preventing severe irritation*

ITEM 4

During a school mountain hiking trip to the slopes of Mount Elgon (elevation 3000 m), students participated in a survival challenge. The weather was cold (10 °C), and the air was thin.

Two students, Musa and Joel, showed unusual responses:

- Musa complained of headache and dizziness. His lips appeared slightly blue.
- Joel fainted briefly near a charcoal stove used for cooking inside a tent.
- Both had increased breathing rates.

- Later that night, some students developed itchy rashes after eating packed groundnuts.
- One student, Aisha, had recently received a tetanus booster vaccine.
- Rapid malaria test kits were used on two febrile students and were negative.

The teacher recorded the following:
Thought for a few seconds

Parameter	Musa	Joel
Breathing rate (breaths/min)	30	28
Pulse rate (beats/min)	120	130
Blood oxygen saturation (%)	82	78
Carboxyhaemoglobin level (%)	2	25
Core body temperature (°C)	35.5	36.8
Urine output	Low	Normal

The school nurse suspected problems related to oxygen transport, temperature regulation, immunity, and nerve function.

TASK

(a) Analyse the physiological causes of Musa's and Joel's symptoms by linking oxygen dissociation, haemoglobin function, carbon monoxide effects, nervous and hormonal control of heart rate, hypothalamic temperature regulation, histamine action, vaccination, and rapid test kit mechanisms.

(b) Propose biologically justified preventive and management strategies for future mountain hikes.

Response

- *In Musa, thin mountain air reduced partial pressure of oxygen in the alveoli, so less oxygen diffused across alveolar surfaces into blood. Less **oxyhaemoglobin** formed, lowering blood oxygen saturation to 82%, reducing oxygen delivery to tissues and causing headache, dizziness, and blue lips due to inadequate oxygenation.*
- *haemoglobin carried less oxygen at high altitude, chemoreceptors in the carotid and aortic bodies detected low oxygen and stimulated the medulla to increase breathing rate. The **sympathetic nervous system** and **adrenaline** also increased pulse rate to 120 beats/min in Musa and 130 beats/min in Joel to deliver available oxygen faster.*
- *Musa's core body temperature of 35.5 °C shows mild hypothermia. Cold receptors stimulated the **hypothalamus**, which triggered vasoconstriction to reduce blood flow to the skin and conserve heat. Increased release of **ADH** promoted water reabsorption by the kidneys, causing low urine output.*
- *Low temperature reduces activity of metabolic enzymes and slows nerve impulse transmission, decreasing ATP production and impairing brain and muscle function, which contributed to Musa's headache, dizziness, and general weakness.*
- *In Joel, inhaled carbon monoxide bound strongly to **haemoglobin** to form **carboxyhaemoglobin** at 25%, preventing oxygen binding. This greatly reduced oxygen-carrying capacity and lowered blood oxygen saturation to 78%, causing fainting due to severe cerebral hypoxia.*
- *Even the oxygen still bound to haemoglobin was released less easily because carboxyhaemoglobin increases haemoglobin affinity for oxygen. This reduced oxygen dissociation in tissues, worsening oxygen deprivation in the brain and muscles and contributing to Joel's collapse.*
- *Hypoxia activated chemoreceptors and the cardiovascular centre in the medulla, while stress stimulated release of **adrenaline** from the adrenal medulla. These responses increased heart rate and cardiac output in both students to compensate for reduced tissue oxygenation.*

- *In affected students, allergens from groundnuts triggered immune responses in sensitised individuals.* ***Mast cells*** *released* ***histamine****, which caused vasodilation and increased capillary permeability in the skin, producing itchy rashes.*
- *In Aisha, the booster vaccine introduced tetanus antigen, activating* ***memory cells*** *formed from earlier vaccination. This promotes rapid production of antibodies by plasma cells, giving quicker and stronger protection against tetanus toxin.*
- *The kits work by* ***antigen-antibody binding*** *on a test strip, where malaria antigens in blood bind to immobilised antibodies to produce a visible line. Negative results mean malaria antigens were not detected, so the fever was likely due to another condition such as cold stress, allergy, or another infection.*

(b) Propose biologically justified preventive and management strategies for future mountain hikes

- ***Gradual altitude acclimatisation****, ascending in stages before strenuous activity, allowing increased breathing efficiency and adjustment to low oxygen, which improves tissue oxygen supply and reduces hypoxia.*
- ***Strict ban on charcoal stoves inside tents****, cooking only in open, well-ventilated areas, preventing inhalation of carbon monoxide and formation of* ***carboxyhaemoglobin****.*
- ***Warm protective clothing and shelter management****, use of insulated clothing, dry bedding, and proper tent covering, reducing heat loss, maintaining hypothalamic temperature regulation, and preventing hypothermia.*
- ***Hydration and energy intake planning****, giving regular water and carbohydrate-rich meals, maintaining blood volume, supporting* ***cellular respiration****, and reducing fatigue and dizziness.*
- ***Routine symptom monitoring****, checking breathing rate, pulse rate, temperature, and alertness, allowing early detection of hypoxia, hypothermia, or carbon monoxide poisoning before severe collapse occurs.*
- ***Emergency oxygen and fresh-air response****, immediately removing affected students to fresh air and giving oxygen where available, restoring haemoglobin oxygen loading and improving tissue oxygenation.*
- ***Allergy screening and food control****, identifying students with known food allergies and avoiding trigger foods such as groundnuts, preventing* ***histamine*** *release and allergic skin reactions.*
- ***Vaccination review before travel*** *involves confirming booster doses for relevant diseases, ensuring active immunity through memory-cell response and reducing risk of preventable infections.*
- ***Use of rapid test kits with clinical follow-up****, interpreting negative malaria tests alongside symptoms and other findings, preventing misdiagnosis and ensuring correct treatment for non-malarial illness.*

PART II

Attempt one item from this section

ITEM 6

In the bean-growing regions of eastern Uganda, farmers are battling an outbreak of black bean aphids (*Aphis fabae*). A researcher from Makerere University found that the aphids exist in two main strains: one that is resistant to a common pyrethroid pesticide, and one that is susceptible. The resistance is controlled by a dominant allele (R). The aphids also vary in their colour: some are shiny black, while others are dull brown. The colour is controlled by a separate gene (B for black, dominant over b for brown). The researcher performed a cross between a true-breeding resistant, black aphid and a true-breeding susceptible, brown aphid. The F1 generation were all resistant and black. However, when these F1 males were crossed with susceptible, brown females (a test cross), the offspring were not in a 1:1:1:1 ratio. The 500 offspring produced were:

- Resistant, Black: 205
- Resistant, Brown: 45
- Susceptible, Black: 48
- Susceptible, Brown: 202

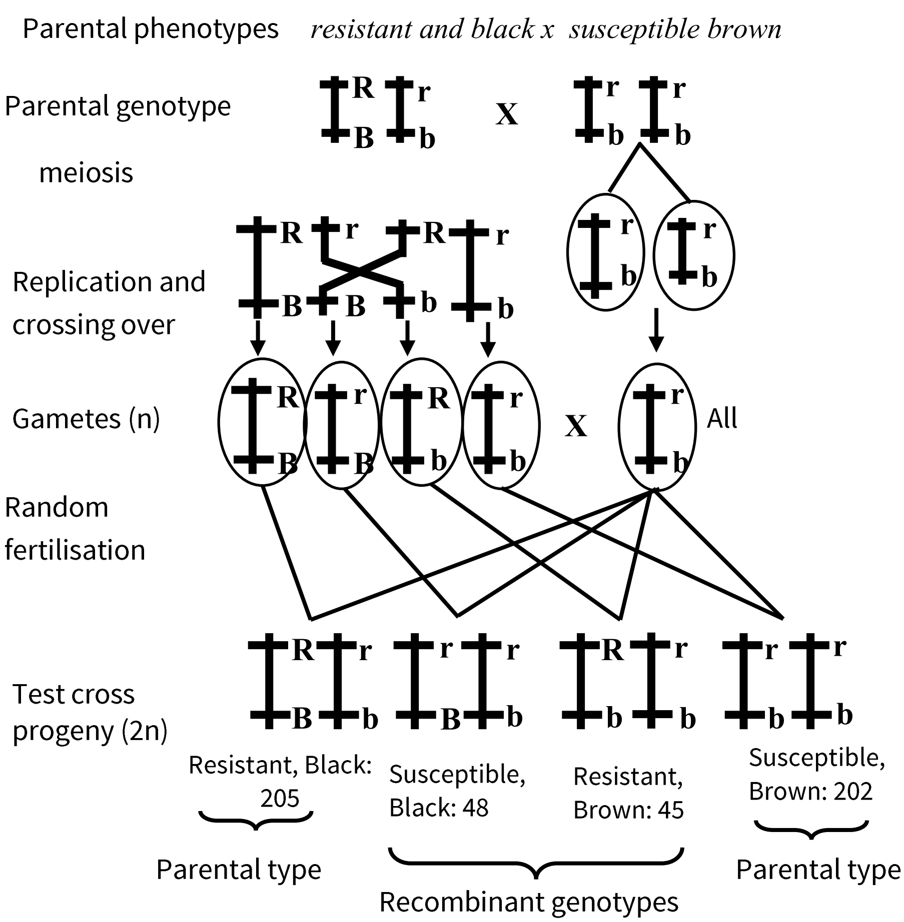
The researcher also noted that ladybird beetles (a natural predator of aphids) prefer to eat the brown aphids, as they are more visible against the green bean leaves.

Task: Analyse the genetic data from the test cross to explain the inheritance pattern of the resistance and colour genes, predict how the interaction between pesticide use and predator preference will affect the allele and phenotype frequencies in the aphid population over time, and propose an integrated pest management strategy for farmers that combines chemical and biological controls sustainable.

Response

A cross between true-breeding resistant black (RRBB) and susceptible brown (rrbb) aphids produces F_1 (RrBb) all resistant and black, showing dominance of alleles R and B.

A test cross (RrBb × rrbb) produces unequal offspring ratios, showing linkage of resistance and colour genes. Parental types resistant black (205) and susceptible brown (202) are high, while recombinant types resistant brown (45) and susceptible black (48) are low.



High parental frequencies show genes are linked on the same chromosome as RB/rb, with dominant alleles inherited together and recessive alleles inherited together.

Low recombinant frequencies show crossing over during prophase I of meiosis, producing Rb and rB gametes in small numbers.

Recombination frequency is 18.6% (93/500 × 100), confirming partial linkage and moderate distance between the genes.

Continuous pyrethroid use causes selection for allele R, increasing resistant aphids as susceptible (rr) are eliminated.

- *Predator preference for brown aphids causes selection against allele b, increasing frequency of black aphids (B_).*
- *Combined selection increases resistant black (RB) phenotype most rapidly, as both traits are favoured and linked.*
- *Susceptible brown (rb) declines due to both pesticide and predator pressure, while recombinant types remain low due to linkage and partial disadvantage.*
- *Over time, directional selection increases frequencies of alleles R and B, leading to dominance of resistant black aphids.*

Integrated pest management strategy

- *Pesticide rotation involves alternating insecticides, reducing selection pressure on allele R and slowing resistance development.*
- *Reduced and targeted spraying involves applying pesticides only at threshold levels, maintaining susceptible populations and limiting resistance spread.*
- *Biological control conservation involves protecting ladybird beetles, increasing natural predation and reducing aphid populations.*
- *Selective pesticide use involves choosing chemicals less harmful to predators, maintaining ecological balance.*
- *Refuge strategy involves leaving unsprayed areas, allowing susceptible aphids to survive and dilute resistance alleles.*
- *Field monitoring involves regular assessment of aphid phenotypes and resistance levels, enabling timely management adjustments.*
- *Cultural control measures involve crop rotation, sanitation, and removal of infested plants, reducing aphid breeding and spread.*
- *Farmer education involves training on resistance management and sustainable practices, ensuring long-term pest control.*

ITEM 7

In the rice-growing region of Jinja District, farmers have noticed that brown planthoppers are causing reduced yields despite pesticide application. Observations include:

- Some planthoppers carry alleles for pesticide resistance showing incomplete dominance.
- Resistant allele frequency increased from 10% to 55% over four years.
- Paddy fields with high bird populations report fewer planthoppers, while frog populations have declined.
- Waterlogged fields favour planthopper nymph survival, increasing over the wet season.
- Some planters practice crop rotation; others leave paddies fallow.

Task: Analyse the genetic, ecological, and population factors contributing to the increase in pesticide-resistant planthoppers and propose a sustainable, biologically informed pest management strategy for Jinja rice fields.

Response

- *Heterozygotes (Rr) show intermediate resistance, so both RR and Rr survive spraying better than rr, allowing allele R frequency to rise from 10% to 55% through natural selection.*
- *Repeated pesticide use causes directional selection favouring resistant genotypes leading to rapid allele frequency change. Continuous exposure eliminates susceptible (rr) individuals, increasing survival and reproduction of Rr and RR, accelerating spread of resistance.*
- *High reproductive rate of planthoppers causes rapid population growth leading to faster spread of resistance alleles. Short generation time increases number of breeding cycles, allowing quicker accumulation of resistant genotypes in the population.*

- *Waterlogged field conditions favour nymph survival leading to increased population size and higher selection pressure. Moist environments enhance egg hatching and nymph development, increasing population density and probability of resistant individuals surviving and reproducing.*
- *Reduced frog populations cause loss of biological control leading to increased planthopper survival. Frogs act as predators, so their decline reduces predation pressure, allowing more planthoppers, including resistant ones, to survive.*
- *High bird populations cause increased predation leading to reduced planthopper numbers in some fields. Birds act as natural predators, lowering population size and slowing spread of resistance in those areas.*
- *Variation in farming practices causes differences in selection pressure and population dynamics across fields. Crop rotation disrupts life cycles and reduces host availability, lowering population size, while fallow or continuous cropping supports survival and reproduction.*
- *Combined genetic and ecological factors cause increase in resistant phenotypes and overall pest pressure over time. Selection for R allele, favourable environmental conditions, and reduced predation together drive population expansion and resistance spread.*

Sustainable, biologically informed pest management strategy

- *Pesticide rotation and mixture use, alternating or combining chemicals with different modes of action, reducing selection pressure on resistance alleles and slowing spread of R.*
- *Reduced and threshold-based pesticide application, spraying only when pest levels exceed economic thresholds, maintaining susceptible (rr) individuals and reducing rapid resistance buildup.*
- *Biological control enhancement, conserving and reintroducing predators such as frogs and birds, increasing natural predation and lowering planthopper populations.*
- *Water management control, intermittent drainage of paddies, reducing waterlogging, disrupting nymph survival, and lowering population growth.*
- *Crop rotation and field sanitation, alternating rice with non-host crops and removing residues, breaking life cycles and reducing breeding sites.*
- *Habitat management for predators, maintaining vegetation and ecological niches, supporting predator populations and enhancing biological control.*
- *Refuge strategy implementation, maintaining unsprayed areas, allowing susceptible planthoppers to survive and dilute resistance alleles.*
- *Regular monitoring and resistance tracking involves assessing allele frequencies and population levels, enabling early intervention and adaptive management.*

END