

ITEM 5

Farmers in Kumi District have reported increasing losses of stored maize despite repeated pesticide treatment of storage facilities. Agricultural officers observed that maize weevil infestations remain high and continue to spread between grain stores.

Researchers found that 36% of the maize weevil population expressed a recessive trait associated with survival after exposure to a commonly used pesticide. Population monitoring showed that weevil abundance was highest in poorly sealed storage facilities and stores containing old grain residues.

Ecological investigations revealed that predatory insects were less abundant in storage environments where pesticides were frequently used. Pesticide residues were detected in stored maize and surrounding insects. Farmers reported increasing grain losses, declining household food reserves and rising pest-control costs.

Agricultural officers warned that continued use of the same pesticide could alter allele frequencies within maize weevil populations and reduce effectiveness of future pest-control programmes.

Proposed strategies

- Store maize in airtight metal silos that prevent entry of maize weevils.
- Alternate pesticides with different modes of action during storage programmes.
- Remove grain residues and clean stores thoroughly before introducing new stocks.
- Maintain untreated refuge areas to preserve pesticide-susceptible maize weevils within the population.

Task

- (a) Analyse how allele frequencies within maize weevil populations, development of pesticide tolerance, changes in maize weevil population density and impacts on stored grain influenced food security and ecosystem stability.
- (b) Evaluate the effectiveness and sustainability of the proposed strategies for controlling maize weevils, reducing post-harvest losses and improving food security.

ANALYSIS

Allele Frequencies within Maize Weevil Populations

The repeated use of the same pesticide acted as a selection pressure on the maize weevil population. As a result, individuals carrying the allele associated with survival after pesticide exposure remained alive while many susceptible individuals died. This occurred because the pesticide removed susceptible genotypes from the population, allowing resistant individuals to contribute a larger proportion of offspring to subsequent generations.

The recessive phenotype occurs in 36% of the population.

Using Hardy–Weinberg equilibrium:

$$q^2 = 0.36$$

$$q = \sqrt{0.36} = 0.6$$

Frequency of dominant allele:

$$p = 1 - q$$

$$p = 1 - 0.6$$

$$p = 0.4$$

Genotype frequencies:

$$p^2 = (0.4)^2 = 0.16$$

$$2pq = 2(0.4)(0.6) = 0.48$$

$$q^2 = 0.36$$

Therefore:

Genotype	Frequency
<i>RR</i>	0.16 (16%)
<i>Rr</i>	0.48 (48%)
<i>rr</i>	0.36 (36%)

Since resistant individuals survive pesticide exposure and continue reproducing, the frequency of allele **r (0.6)** is expected to rise further while allele **R (0.4)** declines. Consequently, future populations become increasingly dominated by pesticide-tolerant individuals.

Development of Pesticide Tolerance

Continuous application of the same pesticide favoured maize weevils possessing the resistance-associated recessive genotype. As a result, pesticide treatments became less effective over time because a greater proportion of the population survived exposure.

This happened because resistant weevils possessed inherited genetic characteristics that allowed them to withstand the pesticide. Survivors reproduced and transmitted resistance alleles to their offspring. During each generation, susceptible individuals were removed while resistant individuals remained within the breeding population.

Consequently, the proportion of resistant genotypes increased through natural selection, leading to the development and spread of pesticide tolerance within maize weevil populations.

Changes in maize weevil population density. Poorly sealed storage facilities and the presence of old grain residues provided favourable conditions for survival and reproduction of maize weevils. As a result, maize weevil abundance remained high despite repeated pesticide treatment.

This occurred because grain residues supplied food and breeding sites, while openings in storage facilities allowed continuous movement of insects between stores. Female weevils laid eggs within grain kernels, where larvae developed and emerged as adults. The availability of food, shelter and breeding sites supported rapid population growth.

Consequently, maize weevil population density remained high and infestations spread between grain stores.

Impacts on stored grain, food security and ecosystem stability. High maize weevil populations caused extensive damage to stored maize. As a result, grain losses increased, household food reserves declined and pest-management costs rose.

This occurred because both larvae and adults fed on grain tissues, reducing grain mass, nutritional quality and seed viability. At the same time, repeated pesticide use reduced populations of predatory insects that naturally suppress pest populations. Pesticide residues also accumulated in stored maize and surrounding organisms.

The reduction of natural predators disrupted predator-prey interactions while pesticide contamination affected non-target organisms. Consequently, ecosystem stability declined and food security was threatened through reduced grain availability and increased production costs.

EVALUATION

- **Airtight Metal Silos.** Airtight metal silos involve storing maize in sealed metal containers that prevent entry, movement and reproduction of maize weevils. This strategy is effective because it physically excludes pests from stored grain and greatly reduces dependence on pesticides. Reduced pesticide use lowers contamination of grain and protects beneficial predatory insects, thereby promoting ecosystem stability.
- However, metal silos require relatively high initial investment costs and may not be affordable for some small-scale farmers.
- Rather than relying solely on metal silos, the strategy can be improved by combining silo storage with community-based silo ownership programmes. Shared storage facilities reduce installation costs while maintaining effective exclusion of maize weevils, allowing more farmers to benefit from the technology.
- **Alternating pesticides with different modes of action.** This strategy involves using pesticides that target different physiological pathways in maize weevils during successive treatment periods. The strategy slows the development of resistance because weevils that survive one pesticide may be susceptible to another. Consequently, the rate at which resistance alleles accumulate in the population is reduced.
- However, pesticides may still affect non-target organisms, contaminate stored grain and continue exerting selection pressure on weevil populations.
- An alternative strategy is Integrated Pest Management (IPM). IPM combines sanitation, biological control, improved storage structures and limited pesticide use. Because several control methods operate simultaneously, selection pressure for resistance is reduced and dependence on pesticides becomes lower, making control programmes more sustainable.
- **Removal of grain residues and thorough store cleaning.** This strategy involves removing old grain residues and cleaning storage facilities before introducing new stocks.
- The strategy reduces food sources, breeding sites, eggs and larvae that may remain within storage structures. Consequently, initial pest populations entering new storage cycles are reduced.
- However, cleaning alone may not eliminate all maize weevils because some individuals may survive in cracks, crevices or neighbouring stores and later recolonise the facility.
- The strategy can be strengthened by sealing cracks and repairing storage structures after cleaning. Eliminating hiding sites prevents surviving weevils from establishing breeding populations and further reduces reinfestation rates.
- **Maintaining untreated refuge areas.** This strategy involves preserving populations of pesticide-susceptible maize weevils that are not exposed to pesticide treatments. Susceptible weevils from refuge areas mate with resistant individuals, increasing the proportion of susceptible alleles within the population and slowing the rise of resistance-associated alleles.
- However, refuge areas may also act as reservoirs from which maize weevils disperse into storage facilities, potentially increasing infestations if poorly managed.
- The strategy can be improved by carefully regulating the size and location of refuge areas while regularly monitoring allele frequencies within weevil populations. Maintaining only a controlled proportion of untreated refuges preserves susceptible alleles without allowing excessive growth of pest populations, thereby slowing resistance development while maintaining effective pest suppression.

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