

Saving the Store Banana: A Jigsaw on Biodiversity and Disease

Learning target: I can teach my group evidence about bananas, diseases and wild relatives, and use that evidence to evaluate competing solutions for protecting a food supply while maintaining biodiversity.

Collaborative investigation

About 55 min

Jigsaw

MS-LS2-5 · assesses

MS-ETS1-2 · practice

collaboration

discussion

reading

Standards connections

MS-LS2-5 (assesses, the individual evaluation of competing solutions in Part C): In Part C each student evaluates three competing solutions for protecting the banana supply (holding the line with one variety, borrowing traits from wild relatives, diversifying varieties) by how well they maintain biodiversity and the provisioning service it supports. The group matrix is practice; the individual recommendation is evidence toward the PE.

MS-ETS1-2 (practice): Home groups score the three solutions against shared criteria in a decision matrix and cite card evidence for each score, a systematic comparison of competing solutions.

Purpose: practice · **Time:** about 55 minutes · **Format:** jigsaw

Answers with reasoning

The problem

Nearly every banana sold in U.S. stores is one variety, the Cavendish, and a soil fungus is spreading through Cavendish farms around the world. Banana growers, scientists and governments are arguing about what to do. Your team will weigh the evidence and evaluate three competing solutions.

Twelve expert cards (teacher cuts these apart; expert groups A, B, C and D take three cards each)

1 Card A1: One plant, many copies

Cavendish bananas, the kind sold in almost every U.S. grocery store, have no working seeds. Farmers start new plants from shoots that sprout at the base of a parent plant, or from tiny pieces of plant tissue grown in a lab. So the Cavendish plants on farms around the world are near-identical genetic copies, called clones.

2 Card A2: Why breeding bananas is slow

Most bananas people eat have three sets of chromosomes instead of the usual two. That is why they make few or no seeds: good for eating, bad for breeding. Crossing them with other bananas rarely produces seeds that grow, so developing a new variety by crossing can take many years.

3 Card A3: The banana before Cavendish

Until the mid-1900s the main banana sold in the United States and Europe was a variety called Gros Michel. A soil fungus that causes Panama disease, a wilt that kills the plant, spread through Gros Michel plantations in Central America. By the 1960s exporters had switched to Cavendish, which resisted that strain. Gros Michel did not go extinct; small farmers in some countries still grow it.

4 Card B1: A new strain arrives

A newer strain of the same fungus, called Tropical Race 4 (TR4), does attack Cavendish. It blocks the tubes that carry water inside the plant, so the leaves yellow and the plant wilts and dies. TR4 was found in Asia, later spread to Australia, Africa and the Middle East, and reached South America in 2019.

5 Card B2: Hiding in the soil

TR4 can survive in soil for decades. It travels in mud on boots, tools and vehicles, in moving water, and in infected planting material. No fungicide cures an infected plant. Farms use boot-washing stations, fences and strict rules for moving plants, which slow the spread but have not stopped it.

6 Card B3: A leaf disease too

Black Sigatoka, also called black leaf streak, is a fungus that kills patches of banana leaves. With less leaf area, plants make less sugar by photosynthesis and grow smaller bunches. Large Cavendish plantations often spray fungicides many times a year to control it, in some places dozens of times, which is costly and can harm workers and streams if not handled carefully.

7 Card C1: Wild bananas

Wild bananas grow in forests and forest edges of Southeast Asia and nearby regions. They are packed with hard seeds, so they are not good to eat, but they reproduce from seed and their populations are genetically varied. Some wild bananas carry genes that help them resist TR4 and other diseases. Some wild banana populations are shrinking as forests are cleared.

8 Card C2: A library of living bananas

An international gene bank in Belgium keeps well over a thousand kinds of bananas, wild and cultivated, as living plant tissue in test tubes. Breeders and researchers around the world can request samples to search for useful traits. A gene bank holds only the kinds someone has already collected, so it cannot replace wild populations that keep changing in nature.

9 Card C3: Borrowing a gene

Researchers in Australia gave Cavendish plants a disease-resistance gene from a wild Southeast Asian banana. In years of field trials the modified plants resisted TR4, and in 2024 Australian regulators approved the banana, although it was not yet being grown on a large scale. Some shoppers and countries are cautious about genetically modified foods.

10 Card D1: Many kinds on one farm

In parts of East Africa and Southeast Asia, many small farms grow several banana varieties side by side: some for cooking, some for eating fresh, some for brewing. When a disease hits one variety, the others often survive, so the family still has bananas. Many of these varieties bruise more easily or ripen less evenly than Cavendish, so they are harder to ship long distances.

11 Card D2: Built for shipping

Cavendish bananas are picked green, travel thousands of kilometers by ship without bruising badly, and ripen evenly when they are treated with ethylene, a natural ripening gas. Ships, ripening rooms and supermarkets are set up for this one kind. Switching to other varieties would mean changes for growers, shippers, stores and shoppers.

12 Card D3: Who depends on bananas

Bananas, including cooking bananas and plantains, are among the world's most important food crops. In some countries of East and Central Africa they are a staple food that many families eat every day. Most bananas grown in the world are eaten in the countries where they are grown rather than shipped abroad.

Teaching model: disease spread in two 1,000-plant plots (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Year	Plot A: plants infected (of 1,000)	Plot B: plants infected (of 1,000)
0	5	5
1	40	12
2	150	30
3	400	65
4	720	110
5	940	160

Simulated results from a simple computer model, for teaching. Plot A has one variety, and every plant can be infected. Plot B has four varieties of 250 plants each, mixed together; only one variety can be infected. The disease starts in 5 plants in each plot.

Three competing solutions — Solution 1, Hold the line: keep growing only Cavendish; slow TR4 with quarantine, cleaning stations and strict plant-moving rules, and keep spraying for leaf disease. **Solution 2, Borrow from the wild:** protect forests where wild bananas grow and fund gene banks; use wild genes to breed or engineer resistant bananas that ship like Cavendish. **Solution 3, Mix it up:** grow several varieties on each farm and in each region, including resistant ones, and help shippers, stores and shoppers accept new kinds.

Part A: Expert round

1. Your expert set (A, B, C or D): _____. For each of your three cards, write the single most important fact in your own words and one sentence explaining how it connects to biodiversity or to disease.

Answer: Set A: Cavendish plants are clones (A1); triploid bananas make few seeds, so breeding is slow (A2); Gros Michel was replaced after Panama disease (A3). Set B: TR4 kills Cavendish (B1); it survives in soil for decades and cannot be cured, only slowed (B2); black Sigatoka forces heavy fungicide use (B3). Set C: wild bananas are genetically varied and some resist TR4 (C1); a gene bank stores over a thousand kinds (C2); a wild gene gave Cavendish resistance (C3). Set D: mixed-variety farms keep some bananas when disease strikes (D1); the trade is built around Cavendish (D2); millions of people rely on bananas as food, mostly grown locally (D3). Each connection should mention variety of traits, uniformity, or disease spread.

Why: Experts must restate facts accurately and link them to biodiversity or disease before teaching.

Also acceptable: Any accurate fact from each card with a sensible link.

- Three accurate facts in the student's words
- Each linked to biodiversity or disease

Part B: Home group task

1. Teach in order A, B, C, D. Each expert gets two minutes and may not read the cards aloud; explain them in your own words.
 2. As each expert teaches, everyone notes which solution each card helps or hurts.
 3. Score each solution from 1 (poor) to 3 (strong) on each criterion in q2. Agree on every score and write the card numbers that support it.
 4. Use the teaching dataset to answer q3 together.
 5. Choose the solution, or combination, your group would recommend. Every member must be able to explain why.
2. Group answer: complete the decision matrix.

Answer: One defensible matrix: Solution 1: stores 2 (works for now, but cards B1 and B2 show TR4 spreading anyway), biodiversity 1 (keeps one clone, A1), cost/time 3 (uses existing systems, D2), new disease 1 (every plant shares the same weakness). Total 7. Solution 2: stores 2 (resistant plants exist, C3, but breeding is slow, A2, and approval and acceptance take time), biodiversity 2 to 3 (protects wild populations and gene banks, C1, C2; though the farm crop may still be one variety), cost/time 1 (years of research, A2, C3), new disease 2 (the wild gene pool can supply new traits, C1, but each new disease needs new work). Total 7 to 8. Solution 3: stores 2 (other kinds ship less well, D1, D2), biodiversity 3 (many varieties on farms, D1), cost/time 2 (varieties exist, but the shipping and store system must change, D2), new disease 3 (a new disease is unlikely to hit every variety, D1 and the dataset). Total 10.

Why: Scores are judgments; credit depends on consistency and card evidence, not on matching this matrix.

Also acceptable: Groups may rate Solution 2 highest if they argue that wild genes can protect the shipping system already in place; accept any matrix whose scores are supported by cited cards.

- Every cell scored
- Totals added correctly
- Card numbers cited for the scores
- Solution 1 scored low on biodiversity and new-disease resilience

3. Group answer: at year 5, what percent of all plants are infected in Plot A and in Plot B? What percent of the 250 susceptible plants in Plot B are infected? Use the numbers to explain two ways that mixing varieties protected Plot B.

Answer: Plot A: $940 \div 1,000 \times 100 = 94\%$ infected. Plot B: $160 \div 1,000 \times 100 = 16\%$ infected. Susceptible plants in Plot B: $160 \div 250 \times 100 = 64\%$ infected. Two protections: (1) three-quarters of Plot B's plants could not be infected at all, so most of the farm kept producing (84% healthy vs 6% in Plot A); (2) even the susceptible plants in Plot B were infected more slowly (64% vs 94% by year 5) because resistant plants between them slowed the spread from plant to plant.

Why: The model shows both a direct effect of resistant varieties and a slowing effect of spacing susceptible plants apart.

Also acceptable: Accept 6% and 84% healthy as equivalent statements.

- 94% and 16% computed correctly
- 64% for susceptible plants
- Explains resistant plants protecting the total
- Explains slower spread among separated susceptible plants

4. Group answer: which card or result changed your group's thinking the most, and how?

Answer: Example: 'Card B2 changed our thinking: we thought cleaning stations could stop TR4, but the fungus lives in soil for decades and cannot be cured, so Solution 1 only buys time.' Or: 'The dataset showed us that mixing varieties protects most of the harvest even when the disease gets in.'

Why: Reflection on how evidence changed a judgment.

Also acceptable: Any specific, honest reflection tied to evidence.

- Names a specific card or result
- Explains how the group's thinking changed

Part C: Individual accountability (complete alone)

5. Using cards A1 and C1, explain why a field of Cavendish plants is more at risk from a new disease than a population of wild bananas.

Answer: Cavendish plants are clones (A1), so they share the same genes and the same weaknesses: if TR4 can infect one, it can infect all of them. Wild bananas reproduce from seed and are genetically varied (C1), so some individuals have traits that resist a disease and survive, and the population can carry on.

Why: Variation within a population is what lets some individuals survive a new disease.

Also acceptable: None.

- Clones share the same genes and weaknesses
- Wild populations vary, so some resist
- Uses both cards

6. Solution 2 depends on wild bananas. Explain why protecting the forests where they grow is a way of maintaining an ecosystem service. Which category of service is it?

Answer: Wild banana forests hold genetic variety, including disease-resistance genes, that breeders and researchers use to develop crops that keep bananas available (C1, C3). That supply of useful genes is a benefit people get from a healthy ecosystem. If the forests are cleared, those genes can be lost before anyone collects them, and a gene bank cannot replace populations that keep changing (C2). It is a provisioning service, because the ecosystem supplies genetic material used to make food.

Why: Genetic resources are counted as a provisioning service; protecting habitat maintains biodiversity and the service.

Also acceptable: Accept 'supporting' if the student argues that biodiversity supports all services, for partial credit.

- Forests hold genetic variety or resistance genes
- Explains it as a benefit to people
- Names provisioning (accept supporting with a reason)

7. Card A3 shows that switching from Gros Michel to Cavendish solved one problem. Using card B1, explain why replacing one uniform variety with another uniform variety is not a lasting fix.

Answer: Switching to Cavendish worked because it resisted the old strain, but Cavendish is also a single clone. When a new strain, TR4, appeared that could infect it (B1), every Cavendish plant was at risk again. Replacing one uniform crop with another only works until the next disease that can attack the new one; it does not restore the variety of traits that protects a crop over time.

Why: Uniformity, not the particular variety, is the underlying weakness.

Also acceptable: None.

- Cavendish resisted the old strain but is also uniform
- TR4 can infect all Cavendish
- Explains why uniformity is the lasting problem

8. Write your own recommendation: one solution or a combination. Use evidence from at least three cards from at least two different expert sets, including one card that argues against your choice, and explain how your choice maintains biodiversity. You may disagree with your group.

Answer: Example: 'I recommend combining Solutions 2 and 3. Card D1 and the dataset show that farms with several varieties keep most of their harvest when a disease strikes (16% infected vs 94%). Card C1 shows wild bananas hold resistance genes, and card C3 shows those genes can protect Cavendish, so protecting wild forests and gene banks (C2) keeps the source of future fixes. Card D2 argues against my plan: the shipping system is built for one variety, so stores may resist new kinds. That is why I would use wild genes to make resistant bananas that ship well while also growing more varieties for local markets. This maintains biodiversity both on farms and in the wild.'

Why: The recommendation must use evidence from several sets, address a counter-card, and explain the link to biodiversity.

Also acceptable: Any solution can earn full credit if the argument meets all criteria; Solution 1 alone must address B1, B2 and A1 to be convincing.

- Clear recommendation
- Evidence from at least three cards and two sets
- Addresses one card that argues against the choice
- Explains how biodiversity is maintained
- Accurate science

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Expert teaching	Teaches all three cards accurately in own words and links each to biodiversity or disease; answers group questions.	Teaches all three cards accurately, with one weak link.	Reads cards aloud or leaves out a card; links unclear.	Does not teach, or teaches inaccurately.
Decision matrix	All cells scored consistently, totals correct, and card evidence cited for every score.	All cells scored with most evidence cited; one inconsistency.	Matrix partly complete or scores given without evidence.	No systematic comparison.
Use of the teaching dataset	Correct percents (94%, 16%, 64%) and both protective effects of mixing explained.	Correct percents with one effect explained.	Some calculations wrong or no interpretation.	Dataset not used.
Individual recommendation (Part C)	Clear recommendation using three or more cards from two or more sets, addresses a counter-card, and explains how biodiversity and the food supply are maintained.	Clear recommendation with sufficient evidence; counter-card or biodiversity link is thin.	Recommendation with one or two cards and little reasoning.	No recommendation, or one unsupported by the cards.

Teacher notes

The cards were written to be accurate where the textbook is not. The lesson says Cavendish is safe from Panama disease and that yellow Sigatoka kills Cavendish plants; in fact Cavendish resisted Race 1 of Fusarium wilt (Panama disease) but is susceptible to Tropical Race 4, and Sigatoka diseases are leaf-spot diseases that cut yield rather than killing plants outright (black Sigatoka has largely displaced yellow Sigatoka). Gros Michel was abandoned by the export trade, not driven extinct. The approved genetically modified Cavendish (QCAV-4, approved by Australian regulators in February 2024) carries a resistance gene from the wild banana *Musa acuminata* ssp. *malaccensis*. Only the plot dataset is simulated. Home groups of four work best, one expert per set; in a group of three, one student takes two sets, or the teacher briefly presents set D to the whole class. Expert groups gather everyone holding the same set (A, B, C or D). Debrief: most groups land on a combination of Solutions 2 and 3; push them on what each costs and who has to change.

Scaffold offered to students: Teaching frame for experts

When it is your turn to teach, use this frame for each card: 'The big fact is _____. This matters because _____. It helps (or hurts) Solution _____ because _____.' Listeners write one question for each expert. If your group gets stuck on a score, ask: 'What would have to be true for this solution to work, and does any card say that is true?'

Extension: The next uniform crop

Bananas are not the only crop grown as near-identical plants over huge areas. Choose another crop that is often propagated as clones, such as potatoes grown from seed pieces or apples grown by grafting, and research one disease outbreak that affected it. Write a one-page brief that names the crop, explains why uniformity raised the risk, and describes one way wild relatives or crop diversity helped, or could help, the recovery.