BIOTECHNOLOGY

Evolution of short corn

Focus question	How will producers' selection practices change allelic frequencies and drive evolution in a corn field?
Learning target	Students will determine allelic frequencies in two different simulations to compare how selective breeding can change evolution.
Vocabulary	Dominant and recessive alleles, allelic frequencies, genotype, phenotype, evolution, Hardy-Weinberg equilibrium

HS-LS3 Heredity: Inheritance and Variation of Traits

Performance expectation HS-LS3-3	**Classroom connection:** Students will use the population of a corn field as a model in order to track the allelic frequency changes caused by artificial selection and check using the Hardy–Weinberg equilibrium.

Science and engineering practices

Analyzing and Interpreting Data	**Classroom connection:** This activity asks students to collect data, then apply the Hardy–Weinberg equilibrium model to show evidence of changes in allelic or genotypic frequency among a population.

Disciplinary core ideas

LS3.A: Inheritance of Traits **LS3.B: Variation of Traits**	**Classroom connection:** This activity directly shows correlation between artificial selection and changes in allele frequency.

Cross-cutting concepts

Cause and Effect **Scale, Proportion, and Quantity**	**Classroom connection:** Students analyze their data to compare to the scale needed to accurately use the Hardy–Weinberg model. Students observe how artificial selection disrupts population equilibrium and increases rates of evolution.

Background

Recent technological advances have shown that corn height has very little impact on production. Shorter corn has advantages such as:

1. Strong stalks due to the reduced height reduce the chances of the plant breaking or falling over due to high winds.
2. Shorter plants allow for materials such as fertilizers, pest control, and herbicides to be applied more precisely and efficiently.
3. Shorter plants give the ability to grow more plants in a smaller land area which minimizes land use.

Evolution in a population is defined as a change in the frequency of its alleles. The Hardy–Weinberg Equation states that "the genetic variation in a population will remain constant from one generation to the next in the absence of disturbing factors." (`nature.com/scitable/knowledge/library/the-hardy-weinberg-principle-13235724/`) Through the use of this equation students can estimate the allele frequencies among a population from generation to generation. The population is considered to be in equilibrium as long as the following five conditions are met:

1. The population is large.
2. Members of the population show no preference in mating.
3. There are no mutations.
4. Members are not moving into or out of the population.
5. There is no natural selection.

If these conditions are met, the allele frequencies of the population will stay the same from generation to generation and we will know no evolution took place within the population.

In this lab we will look at a population of corn (a field of corn) that has met the five conditions and is currently in equilibrium. We will then look at a corn field where the farmer has used selection to produce short corn. How will the farmer's selection affect the gene frequency and evolution within the population?

In this lesson students will use the Hardy–Weinberg equation to observe how artificial selection disrupts genetic equilibrium among a population and drives evolution.

Prior knowledge

In order to successfully complete this activity, students should know the basic concepts of genetics: Mendel's laws, patterns of dominance, and recessive allele inheritance. Students should be able to describe how traits are passed from generation to generation. A general understanding of the concept of evolution and how evolution occurs among a population is fundamental to understanding this activity.

Suggested timing

2 45-minute class periods

Materials

- Allele cards (Corn Allele Cards)
- Scratch paper for calculations
- Calculator

Teacher preparation

This activity is a teacher-guided activity involving the whole class.

- Prior to class the teacher will need to print the Corn Allele Cards (Print these cards on cardstock and laminate them to hold up for multiple classes. Numbering the cards makes it easier to sort them after each activity.)
- For part 1, each student will need:
  - One capital 'A' card
  - One lowercase 'a' card
- For part 2, each student will need:
  - Two lowercase 'b' cards
  - ***OR*** one captial 'B' card and one lowercase 'b' card
- At the beginning of each part of the activity, pass out cards to each student.

Differentiation

Other ways to connect with students with various needs:

- **Local community:** Students can count populations of other types (i.e. insects, fish or trees) and see if they can apply these principles to other populations. (They will need to use various sampling techniques then generalize to a larger scale.)
- **Students with special needs:** This activity can be teacher-led for those students struggling with the concept or done individually at the student's own pace for those students that are comfortable with the concepts after the simulation portion.
- **Extra support:** Students may need extra support with the Hardy–Weinberg calculations. They could watch remedial videos and use practice questions for more practice. `youtu.be/oG7ob-MtO8c`
- **Extensions:** Students could do further research into the technology behind developing short corn seeds and its implications on helping feed the world. `bayer.com/en/us/innovation/short-corn-is-smart-corn`

Student handout

Answers will vary depending on the number of students and the time given for exchanging alleles.

Procedure

Part 1: Calculating the gene frequencies of the equilibrium field

We will run a simulation representing the equilibrium corn field. In this simulation each class member will represent a heterozygous tall corn plant.

Hypothesis: What is your prediction for allelic frequency of the field at the end of this round? Add as a percent next to each allele.

p or A	
q or a	

Most likely answer: 50% A 50% a

After the activity, record the class totals in data table 1.

Data table 1

Genotype	Number of students	Number of alleles	Total of each
AA	8	16 + 18	16 + 18 = 34
Aa	18		
aa	7	14 + 18	14 + 18 = 32
Total number of students	33	**Total number of alleles**	66

Determine the allelic frequencies by totaling the number of A's and the total of a's divided by the total number of alleles in the class.

Data table 2

HW symbol	Allele	Allele frequency (as percentage)
p	A	34/66 = 52%
q	a	32/66 = 48%

Analyze the class data using the variables and the equation ($p^2 + 2pq + q^2 = 1$) to determine if the equation will predict the allelic frequency for your classroom population.

Data table 3

Hardy–Weinberg calculation	Allele frequency (as decimal)
p^2	(0.52)2 = 0.27
2pq	2(.52)(.48) = 0.50
q^2	(0.48)2 = 0.23

Answers will vary depending on the number of students and the time given for exchanging alleles.

Part 2: Calculating the gene frequencies for the field where short corn was selected

In this simulation each class member will have either a homozygous short genotype or heterozygous genotype. All of the homozygous tall genotypes have been removed from the population since we no longer want to have tall plants.

Hypothesis: what is your prediction for the genotypic ratios in the field since all plants are homozygous recessive or heterozygous?

p or A	
q or a	

Most likely answer: 25% B, 75% b

After the activity, record the class totals in the following table:

Data table 4

Genotype	# of students	Number of alleles	Total of each
BB	2	4 + 12	4 + 12 = 16
Bb	12		
bb	19	38 + 12	38 + 12 = 50
Total number of students	33	Total number of alleles	66

Determine the allelic frequencies by totaling the number of B's and the total of b's divided by the total number of alleles in the class in data table 5.

Data table 5

HW symbol	Allele	Allele frequency (as percentage)
p	A	16/66 = .24 × 100 = 24%
q	a	50/66 = .76 × 100 = 76%

Analyze the class data using the variables and the equation ($p^2 + 2pq + q^2 = 1$) to determine if the equation will predict the allelic frequency for your classroom population.

Data table 6

Hardy–Weinberg calculation	Allele frequency (as decimal)
p^2	(0.24)2 = 0.06
2pq	2 (0.24)(0.76) = .36
q^2	(0.76)2 = 0.58

Post analysis questions

1. Did your class results in data table 3 agree with the Hardy–Weinberg predictions?

Possible answer: yes, (it should if folks are exchanging one allele at a time throughout the time for exchanges)

2. If your class results in data table 3 did not agree, what are some of the possible reasons why?

Possible answer: Perhaps more than one allele was exchanged at a time—loss of alleles from the population.

3. Did your class results in data table 6 match the data in your data table 3? If not, what do you think contributed to the difference?

Possible answer: they may not have agreed due to the change in the allelic frequency… more alleles for short corn

4. Which condition of the Hardy–Weinberg equilibrium influenced the greatest difference between your data table 3 and data table 6?

Possible answer: The condition that would have the most influence is the lack of a large population.

5. If farmers continued to artificially select for shorter plants which variable in the Hardy–Weinberg Equation would decrease the most? Which one would increase the most?

Possible answer: The variable that would decrease the most would be p; the variable that would increase the most would be q.

6. How does artificial selection drive evolution?

Possible answer: artificial selection will select for favorable traits in the gene pool (alleles) and extinguish the unfavorable traits. However, some unrelated characteristics may be lost through this process. Therefore, more specific breeding techniques are being developed and used to only influence specific genes, not just phenotypic traits.

Assessments

Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Students are comfortable performing Hardy–Weinberg calculations given a set of alleles in a population.	Understand what each variable in the equation represents and able to set up the equation.	Understand what each variable in the equation represents, able to set up the equation and calculate all allelic frequencies.	Understand what each variable in the equation represents, able to set up the equation, and calculate all allelic frequencies. Can explain how each variable affects the others in the equation.
Students are able to demonstrate how artificial selection changes allele frequency in a population.	Students are able to show how artificial selection changes allele frequency between an equilibrium population and a population that has had pressures of artificial selection.	Students are able to explain how artificial selection changes allele frequency between an equilibrium population and a population that has had pressures of artificial selection.	Students will be able to show how artificial selection changes allele frequency between an equilibrium population and a population that has had pressure from artificial selection. Students would then be able to explain how this would drive evolution among the selected population.

Rubric for self-assessment

Skill	Yes	No	Unsure
I understand the purpose of the Hardy–Weinberg Equation.			
I understand how allelic frequency can determine if evolution is occurring within a population.			
I understand how artificial selection can drive evolution within a given population.			