Seed to STEM

Kansas Corn: Corn Genetics and Statistical Analysis

This lab is made possible with the support and content contributions of the Kansas Corn Commission.

Kansas Corn Commission

kscorn.com

Kansas Corn: Corn Genetics and Statistical Analysis
Grade Level: Middle School

Overview
One form of genetic modification that has been used for centuries is artificial selection, or selective breeding. This is the selection of individuals or populations possessing desirable traits to produce the next generation. This process has given rise to many of the plants and animals we encounter every day. For example, different breeds of dogs. Some are good at hunting and retrieving game, and others are specifically bred for companionship and living in a house. An additional example, different breeds of cattle. Some are bred for milk production, and others bred specifically for beef. Corn has been developed over the years and is currently being improved to produce higher yields in drought conditions, resistance to pests, and other advantageous characteristics through this process. Artificial selection also played an important role in the development of the theory of natural selection. An understanding of Mendelian inheritance and statistical analysis of the results of crosses is important in determining the genes of an organism and the ability to produce offspring with the desired traits.

In this lab, students will observe ears of corn from F2 plants produced by a dihybrid cross for the traits of kernel color and endosperm composition, which changes the shape of the kernel. The color blue is dominant to yellow, and the starchy nonwrinkled endosperm is dominant to a sugary wrinkled endosperm. Students will hypothesize the genotypes of the parents (F1 generation). First, students will look at each trait independently, then look at the independent assortment or linkage between the two traits. These hypotheses will be used to make predictions that will be analyzed by collecting data and applying a chi-square test.

Kansas College and Career Ready Standards
Science
- **MS-LS3-1.** Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.
- **MS-LS3-2.** Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.

Learning Objectives
- Students will develop a hypothesis of the genotypes of the parents in monohybrid.
- Students will predict the outcome of their hypothesis using knowledge of inheritance and probability.
- Students will quantify the results of monohybrid crosses and analyze their hypotheses with their data collection by performing chi-square analysis.

Kansas Corn: Corn Genetics and Statistical Analysis
Grade Level: Middle School

Materials
- Corn Genetics and Statistical Analysis PowerPoint (available at www.kscorn.com)
- Monohybrid corn ears from Carolina Biological, R Color (item #176500) and Su Endosperm Alleles 3:1 (item #176540) one for each group
- Copies of student handout (one for each student)
- Transparency markers

Safety Considerations
Students should be cautioned to be careful when handling ears of corn. If handled with care, ears may last many years, but may be damaged if handled roughly. Kernels may occasionally fall off of the ears, but may be glued back into place.

Procedures for Instruction
Length of Time for Preparation: 15 minutes
Length of Time for Classroom Teaching: 1.5-2 hours

Preparation Procedure Lab Set-up
1. Group or pair students so that there are enough materials for each group.
2. Each lab group will need one dihybrid ear and a transparency marker.
3. Each student will need a student handout.

It is recommended to follow the teaching of Mendelian inheritance for this lab as students will need basic knowledge of inheritance and probability as well as the vocabulary associated with this subject and experimental procedures. Students should be familiar with the following terms: Allele, gene, hybrid, purebred, P generation, F1 generation, F2 generation, homozygous, heterozygous, dominant, recessive, genotype and phenotype.

Students should also be able to predict ratios of offspring from monohybrid crosses using Punnett squares.

Background Information
A chi-square test is used to evaluate the proposed genotypes of the parent generation that produced the observable offspring. The proposed genotype is called the null hypothesis. Probability is used to predict the number of individuals with different traits that would be expected in the next generation if the hypothesis is correct. The equation for performing a chi-square test is show in in **Figure 1.**

Kansas Corn: Corn Genetics and Statistical Analysis
Grade Level: Middle School

Figure 1.

$$\overset{\text{Chi-square value}}{x^2} = \overset{\text{sum}}{\sum} \frac{(\overset{\text{observed}}{O} - \overset{\text{expected}}{E})^2}{\underset{\text{expected}}{E}}$$

The chi-square value is compared with a critical value shown on the table in **Figure 2**.

Figure 2.			
Degrees of Freedom	**Probability of exceeding critical value**		
	0.10 or 10%	0.05 or 5%	0.025 or 2.5%
1	2.706	3.841	5.024
2	4.605	5.991	7.378
3	6.251	7.815	9.348
4	7.779	9.488	11.143

When only two phenotypes are possible, there is only one degree of freedom. With the agreed upon probability of a Type I error of 0.05, or 5%, the critical value for simple, monohybrid traits is 3.841.

Classroom Discussion

Introduce the topic and assess students for prior understanding.

- Have students observe the ears of corn and record observations.
- Have each group report one observation to be recorded collaboratively as a class.
- Students should report that there are yellow and blue kernels.
- They should also observe more blue than yellow kernels.

Let students discuss their ideas, and guide the discussion without telling them if they are right or wrong.

- What characteristics do you see that are different from what you are used to seeing?
- How many different types of kernels do you see?
- Which traits seem to be more common? Less common?
- Which allele for each trait do you think would be dominant or recessive? Why do you think so?
- If this is the F2 generation, what do you think the genotypes of the F1 generation would most likely be for color?
- If your answer is correct, what ratios for each phenotype should be observed?
- Do the traits appear to be linked or inherited independently?

Kansas Corn: Corn Genetics and Statistical Analysis
Grade Level: Middle School

Procedure for Lab

Guided Introduction Monohybrid (Kernel Color)

1. Instruct students to focus on the trait of kernel color.
2. Have them record which allele, either blue or yellow, that they infer is the dominant and recessive alleles.
3. Instruct students to form a hypothesis of the parents' (F1 generation) genotypes that would produce the ear they observed in the ears (F2 generation).
4. Have them predict the ratio of phenotypes that this cross would produce.
5. Students then need to determine the number out of 100 that should express each phenotype.
6. Students should then select four or five rows to count 100 kernels, recording the number of each phenotype.
7. Guide the class through a chi-square analysis of their data to determine if their prediction and hypothesis used to make it is statistically reasonable.
8. If the chi-square analysis suggests a new hypothesis, have the students come up with a new one. Predict and run a chi-square analysis to see how it fits.
9. Have each group report out their hypothesis, prediction and chi-square analysis results.

Smooth vs. Round

1. Instruct students to repeat the above procedure focusing on the wrinkled and not wrinkled kernel trait.
2. If the chi-square analysis suggests a new hypothesis, have the students come up with a new one. Predict and run a chi-square analysis to see how it fits.
3. Have each group report out their hypothesis, prediction and chi-square results.

Teachers Tips

Visit www.kscorn.com for videos and resources to assist with this lab.

Reflection and Conclusion

A lab group received an F2 ear of corn that appeared to have equal numbers of blue and yellow kernels.

1. What F1 genotypes would most likely produce this ear of corn?
   - *Because blue is dominant, the convention would be to use B to represent the blue allele and b to represent yellow.*
   - *Heterozygous x homozygous recessive (Bb x bb) would be most likely to produce the colors seen on this ear of corn.*

2. If this hypothesis is correct, how many kernels out of 100 should be blue? How many should be yellow?

    ½ x 100 = 50 blue and ½ x 100 = 50 yellow

3. If the kernels were counted and 44 were yellow and 56 were blue, conduct a chi-square test on your hypothesis.

$$x^2 = \sum \frac{(O-E)^2}{E}$$

$$x^2 = \sum \frac{(44-50)^2}{50} + \frac{(56-50)^2}{50}$$

$$x^2 = \sum \frac{(-6)^2}{50} + \frac{(6)^2}{50}$$

$$x^2 = \sum \frac{36}{50} + \frac{36}{50}$$

$$x^2 = \sum 0.72 + 0.72$$

$$x^2 = 1.44$$

Degrees of Freedom	Probability of exceeding critical value		
	0.10 or 10%	0.05 or 5%	0.025 or 2.5%
1	2.706	3.841	5.024
2	4.605	5.991	7.378
3	6.251	7.815	9.348
4	7.779	9.488	11.143

There are only two possibilities for kernel color, meaning there is 1 degree of freedom.
The agreed upon percentage of a Type I error is 5%, giving a critical value for this test of 3.841.

x^2=1.44 < 3.841

Thus we fail to reject the hypothesis.

Assessment

1. In performing a chi-square test for pest resistance that is found to be expressed in three forms, completely resistant, somewhat resistant, and not resistant, how many degrees of freedom should be used?

    3 possibilities -1 = 2 degrees of freedom

2. If a homozygous blue corn plant, BB, was crossed with a homozygous yellow plant, bb, what should be the predicted numbers of blue and yellow kernels if 100 kernels were counted on an ear of the plant produced?

    All offspring would be heterozygous Bb, having blue kernels
    100 blue, 0 yellow

3. A lab group in another section hypothesized the parents were heterozygous for kernel color, Bb. When they counted the kernels, they recorded the following results. Calculate the expected values for their hypothesis and perform a chi-square test on your hypothesis.

	Blue	Yellow
Observed	*80*	*20*
Expected	*75*	*25*

$$x^2 = \sum \frac{(80-75)^2}{75} + \frac{(20-25)^2}{25}$$

$$x^2 = \sum \frac{(5)^2}{75} + \frac{(-5)^2}{25}$$

$$x^2 = \sum \frac{25}{75} + \frac{25}{25}$$

$$x^2 = \sum 0.3333 + 1.000 = 1.333$$

Critical value for 1 degree of freedom, and Type 1 error probability = 3.841, so we fail to reject the hypothesis.

Science and Agriculture Careers

To learn more about agriculture careers, visit www.agexplorer.com. You can also find career profiles at www.kscorn.com.

Sources

- https://newonlinecourses.science.psu.edu/stat414/node/147/
- https://www.biologycorner.com/worksheets/corn_chi.html

Any educator electing to perform demonstrations is expected to follow *NSTA Minimum Safety Practices and Regulations for Demonstrations, Experiments, and Workshops*, which are available at http://static.nsta.org/pdfs/MinimumSafetyPracticesAndRegulations.pdf, as well as all school policies and rules and all state and federal laws, regulations, codes and professional standards. Educators are under a duty of care to make laboratories and demonstrations in and out of the classroom as safe as possible. If in doubt, do not perform the demonstrations.