



Plant Science | The Quest to Feed 9.7 Billion: Conventional vs. Organic Production

Audience: 9-12 grade

Activity Length: 3 class periods

TEKS:

English

- English I §110.36.c
 - 1.A, 1.C, 1.D, 3, 4.G, 5.D
- English II §110.37.c
 - 1.A, 1.C, 1.D, 3, 4.G, 5.D
- English III §110.38.c
 - 1.A, 1.C, 1.D, 3, 4.G, 5.D
- English IV §110.39.c
 - 1.A, 1.C, 1.D, 3, 4.G, 5.D

Science

- Biology §112.42.c
 - 1.A, 1.B, 7.C, 7.D, 13.D

Agriculture, Food, and Natural Resources

- Principles of Agriculture, Food, and Natural Resources §130.2.c
 - 1.B, 4.B, 4.E, 6.A, 6.B, 11.C, 13.B, 13.C
- Advanced Plant Science §130.25.c
 - 1.B, 15.A, 15.E, 17.B, 17.C, 18.B, 18.C

Objectives:

- Explain the difference in organic and conventional production, including practices, costs, yield, environmental impacts, and reliability.
- Compare the costs of both production types.
- Identify three modern agricultural practices that have helped increase food production.
- Identify the 11 genetically modified products on the market today.

Introduction:

In their quest to determine how agriculture is going to feed a growing population, students will evaluate the differences in conventional and organic production. This evaluation and comparison will include the use of pesticides and herbicides, modern agriculture practices and technologies, and genetic modification. Students will discuss the costs, safety, and reliability associated with both conventional and organic production. This lesson should follow the "Soybeans and Genetic



Modification" lesson. (*Note: this lesson uses the term 'conventional' to also include biotech crops*).

Materials Needed:

- PowerPoint Presentation (prepared by teacher)
 - Information from Explain section
- Copies of GMO issues, results, and solution cards (provided)
- Copies of GMO foods cards (provided)
- Copies of worksheet (provided)

Engage:

1. Play 'High-Low' with students. Put a number on the board (8 billion) and ask students to guess if that number is higher or lower than what the world population is going to be in 2050. Have students vote by raising their hands if they think the answer is higher or lower. Reveal the answer to be higher...it's 9.7 billion.
 - Discuss how the population continues to grow, but the land to produce food and fiber is not.
 - 35% of the world's land area is used for agricultural land (this includes crops and open land for grazing).
2. This lesson is going to utilize the same Bloom's Taxonomy questioning strategy used in the 'Soybeans & Genetic Modification' lesson. After presenting students with the facts above, begin asking questions at the end of each section to encourage deeper thinking of the problem at hand and how it has been/could be solved. Present the question to the students, give them one minute to write down their answer (one minute per question) and then solicit a few volunteers to share their answers to encourage discussion. By writing them down, students can refer back to their answers throughout the lesson to gauge how their answers and thoughts have changed as a result of the content learned. Throughout the lesson, questions will become increasingly harder to encourage deeper thinking and evaluation of the problem (based off Bloom's taxonomy). Early on in the questioning, students may or may not have the correct answers. However, the goal of these questions is to encourage them to think about the problem and potential solutions before the material and solution are taught.
 - **KNOWLEDGE:** Describe how you think the agriculture industry is responding to this problem.
 - *Teacher note:* Solicit a few answers and use them to help segue to the next section where you'll define conventional and organic production.



Explore:

3. Tell students we are going to be focusing on how agricultural production has, and will continue to, keep up with a growing population while exploring conventional and organic production practices. Ask students to write down their definitions of conventional production and organic production. Solicit a few answers and then show students the following definitions of each:
 - Conventional production varies from farm to farm; however, they share many characteristics: rapid technological innovation; large capital investments in order to apply production and management technology; large-scale farms; single crops/row crops grown continuously over many seasons; uniform high-yield hybrid crops; extensive use of pesticides, fertilizers, and external energy inputs; high labor efficiency; and dependency on agribusiness (USDA).
 - Organic production is a system that relies more on ecosystem management rather than external agricultural inputs (FAO).
 - Organically produced food is grown without the aid of most synthetic pesticides or chemical fertilizers and was produced without the use of genetically modified organisms or chemical food additives (Monsanto).

4. Ask more questions to continue moving up Bloom's scale. Give students one minute to write down their answers (one minute per question). Solicit a few volunteers to share their answers to encourage a brief discussion.
 - **COMPREHENSION:** Knowing what you do about conventional and organic production, write three to five sentences comparing the two types of production and how they differ.
 - Consider your answers to your questions from earlier and revise as needed based off any new knowledge.

Explain:

5. Pass out worksheet (provided). Explain that they will fill in the blanks as the lesson progresses. There is a second part to the worksheet that will be filled out during student presentations and a Q&A section at the end. Worksheets will be collected by teacher at the end for grading and/or participation points and to evaluate if students understand the concepts from the lesson.

6. Output Efficiencies
 - Agricultural output has more than doubled in the last 60 years. Between 1948 and 2011, soybean yields per acre more than doubled, corn yields grew more than fourfold, and labor productivity increased by nearly 16 times.



- Currently, 35% of the earth's ice-free land is used for agriculture; if the entire industry were to switch to organic practices, it would take 20% more land to produce the same amount of food.
- Without biotechnology, we would need more acreage to meet the growing demand:
 - 17 million more acres of corn
 - 12.1 million more acres of soybeans
 - 7.6 million more acres of cotton
 - 49 million more acres of canola

7. Pesticides & Herbicides

- Since becoming commercially available in 1996, the use of genetically modified organisms has reduced pesticide application by almost 10%.
- Corn varieties produced through biotechnology have reduced pesticide use by eight percent in the U.S.
- Since its introduction in 1996, biotechnology has reduced the impact of herbicides and insecticides on the environment by 18.7%.
- 'Organic' does NOT mean 'no pesticides'
 - Organic production can use approved pesticides, fertilizers, and herbicides.
 - Some are natural, and some are synthetic.
 - More than 50 pesticides have been approved by USDA for organic produce.
 - Organic farmers will sometimes use compost or manure. Manure has to compost for months, and if it doesn't reach a certain temperature, it could be unsafe to use. Improper compost management can result in harmful bacteria such as E. Coli.
 - Often time, conventional production uses less pesticides than their organic counterparts.

8. Biotechnology

- In a study conducted by the National Academies of Sciences, Engineering, and Medicine, it was found that GMO crops are no greater threat to human health or the environment than organically grown crops.
 - A comprehensive review conducted by the USDA found no differences between the health benefits of organic and conventional foods.
- Genetically modified foods have been in the marketplace since the 1990s. To ensure the safety and well-being of consumers, agencies of all different types perform extensive testing on GMOs before they ever reach the store. Testing can take as long as 13 years and cost as much as \$136 million for one product.



- Organizations that test GMOs are the American Medical Association, United Nations Food and Agriculture Organization, Food and Drug Administration, and World Health Organization.
 - Not only have GMOs reduced pesticide needs, but they have also reduced prices on many commodities.
 - Corn prices would be 5.8% higher without GMOs. Everyday products like cereal, fuel ethanol, and corn syrup would be more expensive.
 - Soybean prices would be 9.6% higher, resulting in more expensive cooking oils, biodiesel, and printing ink.
 - Canola prices would be 3.8% higher, increasing the prices of cooking oil and animal feed.
9. The last part of this lecture is the Corn Showdown, GMO vs. Organic. The worksheet has a table that students will fill out as you go through the content. As you, the teacher, are working through each comparison, conduct a poll to see who students think will win the showdown, GMO corn or organic corn. Students will vote in the poll by raising their hand. Questions will include the following:
- Who will have higher yields, GMO corn or organic corn?
 - GMO: 161 bushels/acre
 - Organic: 118 bushels/acre
 - Who will have higher seed costs, GMO corn or organic corn?
 - GMO: \$85/acre
 - Organic: \$60/acre
 - Who will have lower labor costs, GMO corn or organic corn?
 - GMO: \$26/acre
 - Organic: \$71/acre
 - Who will have lower fertilizer and chemical costs, GMO corn or organic corn?
 - GMO: \$143/acre
 - Organic: \$58/acre
 - Who will have lower fuel costs, GMO corn or organic corn?
 - GMO: \$25/acre
 - Organic: \$37/acre
 - Who will have lower overall production costs, GMO corn or organic corn?
 - GMO: \$1.73/bushel
 - Organic: \$1.92/bushel
10. Ask more questions to continue moving up Bloom's scale. Give students one minute to write down their answers (one minute per question). Solicit a few volunteers to share their answers to encourage a brief discussion.



- **APPLICATION:** Predict how you see that both conventional and organic production can coexist.
- **ANALYSIS:** Considering what you know about both types of production in regard to output, costs, environmental impact, etc., draw a conclusion on the type of production you believe to be the most efficient in feeding 9.7 billion by 2050.
- Consider your answers to your questions from earlier and revise as needed based off any new knowledge.

Elaborate:

11. Students will first be handed a stack of cards with pictures of foods. Instruct students to get into groups of three and hand each group a stack of cards. Each card has a picture of a food. As a group, they need to separate the stack into two piles, GMO and non-GMO. Give them three to five minutes to complete this.

- After students complete the activity, begin discussion about what they got right and what they got wrong. In regard to those they got wrong by labeling as a GMO, ask why they thought it was a GMO. Ask if any of the answers surprised them and if so, why.

12. In that same group, students will then work through the GMO issues cards (source: Iowa Ag Literacy Foundation)

- Instruct students to stay in their groups of three. Hand each group a stack of issues cards. Students will read the cards aloud, lay them out flat on the table, and discuss the issues. (1) Why is it important? Who is affected? (2) Brainstorm possible solutions based on content learned and prior knowledge.
- The teacher will then pass out a stack of solutions cards to each group. The students will match the solution to the issue and discuss (1) Does the solution address the issue? And (2) What types of technology are involved in the solution? What types of science are involved in the solution? Give students five minutes to complete this.
- Finally, the teacher will pass out a stack of results cards to each group. The students will match the results to the other cards and discuss (1) Is the result safe? Why or why not? (2) Could this technology be applied to other foods? If so, what? Give students another four to five minutes to complete. Once complete, teacher will lead a discussion about each scenario and provide the correct answers. Discussions can include student reasoning, pros and cons of solutions, and the importance of these solutions to both the farmer and consumer. Below are the correct answers:



Issue	Solution	Result
1	A	Arctic apples won't...
2	H	Golden Rice could...
3	F	Rice is the primary...
4	G	Norman Borlaug...
5	B	Innate potatoes reduce...
6	D	Bt Corn has revolutionized...
7	C	The Rainbow Papaya...
8	E	RoundUp Ready...

Evaluate:

13. Staying in their group of three from the previous section, students will be assigned to research one modern agricultural technology or practice that is helping farmers and ranchers feed a growing population. Each group will present to the class using a visual of some sort (PowerPoint, poster, video of the technology or practice, etc.). Examples could include conservation tillage, drones, biotechnology, precision agriculture, GPS, cover crops, computer-controlled irrigation. Teachers could also consider assigning each group a topic to prevent any repeats. Presentations will be short, but should include the following information:

- Name of technology or practice
- What it does/how it works
- What production type it can be used in (conventional and/or organic)
- Costs
- How it increases yield and/or cuts costs
- Environmental benefits

Provide groups with list of resources to aid with research:

- American Farm Bureau Federation
- Arkansas Farm Bureau
 - Eatology
 - 9,000,000 Changes Everything
 - Farming for the Future
- GMO Answers
- Genetic Literacy Project
- USDA
- Monsanto
- University of Arkansas Division of Agriculture
- Texas A&M AgriLife Extension Service
- Precisionag.com
- U.S. Farmers & Ranchers Alliance
- Findourcommonground.com



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During presentations, students will be taking notes on their worksheets. Following the presentations, allow students some time to answer the questions at the end of the worksheet and then turn in.

Sources:

- USDA
- USDA Economic Research Service
- Food and Agriculture Organization of the United Nations
- Monsanto
- National Academies of Science
- GMOanswers.com
- Iowa Ag Literacy Foundation
- Arkansas Farm Bureau
 - Eatology
 - Farming for the Future
 - 9,000,000 Changes Everything



Variation & Probability of Expressed Traits

Output Efficiencies

1. Agricultural output has more than doubled in the last _____ years.
2. Between 1948 and 2011...
 - a. _____ yields more than doubled.
 - b. Corn yields grew more than _____.
 - c. _____ increased by nearly 16 times.
3. Currently, _____ percent of the earth's ice-free land is used for agriculture.
 - a. If the entire industry were to switch to organic practices, it would take _____ percent more land to produce the same amount of food.
4. Without _____, we would need more acreage to meet the growing demand.
 - a. _____ more acres of corn
 - b. _____ more acres of soybeans
 - c. _____ more acres of cotton
 - d. _____ more acres of canola

Pesticides & Herbicides

5. Since 1996, the use of _____ has reduced pesticide application by almost _____ percent.
6. Corn varieties produced through biotechnology has reduced pesticide use by _____ percent in the U.S.



7. There has been a _____ percent decrease in environmental impact caused by herbicides and insecticides since the introduction of biotechnology in 1996.

8. Organic production can not use pesticides or herbicides.

TRUE FALSE

- a. More than _____ pesticides have been approved by the USDA for organic produce.
- b. Organic farmers will sometimes use _____ or _____.
- c. Manure has to compost for months, and if it doesn't reach a certain temperature, it could be unsafe to use. Improper compost management can result in harmful bacteria such as _____.
- d. Often time, conventional production uses _____ pesticides than their organic counterparts.

Biotechnology

9. In a study conducted by the _____, it was found that GMO crops are _____ to human health or the environment that organically grown crops.

- a. A comprehensive review conducted by the _____ found _____ differences between the health benefits of organic and conventional foods.

10. Genetically modified foods have been in the marketplace since the _____.



11. Testing on GMOs can take as long as _____ and cost as much as _____ for one product.

12. List the organizations that test GMOs:

a. _____

b. _____

c. _____

d. _____

13. Corn prices would be _____ percent higher without GMOs. Everyday products like _____, _____, and _____ would be more expensive.

14. Soybean prices would be _____ percent higher, resulting in more expensive _____, _____, and _____.

15. Canola prices would be _____ percent higher, increasing the prices of _____ and _____.



Just like the consumer in the aisle of a grocery store, farmers face numerous decisions when it comes to production on their farm. The GMO vs Organic debate is a matter of farmer choice, with consumer safety remaining a top priority.

Thanks to rigorous scientific studies, GMO and organic products have continually been proven to be nutritionally equal and safe to eat.



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Modern Agriculture Technology/Practice Presentations

Group:

Name of Technology:

What it does/how it works:

Costs:

How much it increases yield and/or cuts costs:

Environmental Impact:



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Group:

Name of Technology:

What it does/how it works:

Costs:

How much it increases yield and/or cuts costs:

Environmental Impact:



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Group:

Name of Technology:

What it does/how it works:

Costs:

How much it increases yield and/or cuts costs:

Environmental Impact:



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Group:

Name of Technology:

What it does/how it works:

Costs:

How much it increases yield and/or cuts costs:

Environmental Impact:



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Group:

Name of Technology:

What it does/how it works:

Costs:

How much it increases yield and/or cuts costs:

Environmental Impact:



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Group:

Name of Technology:

What it does/how it works:

Costs:

How much it increases yield and/or cuts costs:

Environmental Impact:



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Group:

Name of Technology:

What it does/how it works:

Costs:

How much it increases yield and/or cuts costs:

Environmental Impact:



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1. Select three practices/technologies you believe to be the most effective for feeding 9.7 billion people by 2050 and discuss why.



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2. Imagine you have a farm of your own. What would you grow and what technologies/practices would you implement to help that commodity have a high/profitable yield? Explain your answer.



Variation & Probability of Expressed Traits
ANSWER KEY

Output Efficiencies

1. Agricultural output has more than doubled in the last **60** years.
2. Between 1948 and 2011...
 - a. **Soybean** yields more than doubled.
 - b. Corn yields grew more than **corn**.
 - c. **Labor productivity** increased by nearly 16 times.
3. Currently, **35** percent of the earth's ice-free land is used for agriculture.
 - a. If the entire industry were to switch to organic practices, it would take **20** percent more land to produce the same amount of food.
4. Without **biotechnology**, we would need more acreage to meet the growing demand.
 - a. **17.1 million** more acres of corn
 - b. **12.1 million** more acres of soybeans
 - c. **7.6 million** more acres of cotton
 - d. **49 million** more acres of canola

Pesticides & Herbicides

5. Since 1996, the use of **Genetically Modified Organisms** has reduced pesticide application by almost **10** percent.
6. Corn varieties produced through biotechnology has reduced pesticide use by **8** percent in the U.S.



7. There has been a **18.7** percent decrease in environmental impact caused by herbicides and insecticides since the introduction of biotechnology in 1996.
8. Organic production can not use pesticides or herbicides.

TRUE **FALSE**

- a. More than **50** pesticides have been approved by the USDA for organic produce.
- b. Organic farmers will sometimes use **compost** or **maunre**.
- c. Manure has to compost for months, and if it doesn't reach a certain temperature, it could be unsafe to use. Improper compost management can result in harmful bacteria such as **E.coli**.
- d. Often time, conventional production uses **less** pesticides than their organic counterparts.

Biotechnology

9. In a study conducted by the **National Academies of Sciences, Engineering, and Medicine**, it was found that GMO crops are **no greater** to human health or the environment that organically grown crops.
 - a. A comprehensive review conducted by the **USDA** found **no** differences between the health benefits of organic and conventional foods.
10. Genetically modified foods have been in the marketplace since the **1990s**.
11. Testing on GMOs can take as long as **13 years** and cost as much as **\$236 million** for one product.
12. List the organizations that test GMOs:



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- a. **American Medical Association**
- b. **United Nations Food and Agriculture Organization**
- c. **Food and Drug Administration**
- d. **World Health Organization**

13. Corn prices would be **5.8** percent higher without GMOs. Everyday products like **cereal, fuel ethanol,** and **corn syrup** would be more expensive.

14. Soybean prices would be **9.6** percent higher, resulting in more expensive **cooking oils, biodiesel,** and **printing ink.**

15. Canola prices would be **3.8** percent higher, increasing the prices of cooking oil and **animal feed.**

Alfalfa



Texas Ag in the Classroom STEM Lessons

ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



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Canola



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ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



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Corn (Field + Sweet)



Texas Ag in the Classroom STEM Lessons

ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



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Cotton



Texas Ag in the Classroom STEM Lessons

ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



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Hawaiian Papaya



Texas Ag in the Classroom STEM Lessons
ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



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Innate Potatoes



Texas Ag in the Classroom STEM Lessons
ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



Soybeans



Texas Ag in the Classroom STEM Lessons
ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



Squash



Texas Ag in the Classroom STEM Lessons
ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



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Sugar Beets



Texas Ag in the Classroom STEM Lessons
ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



TEXAS FARM BUREAU

Arctic Apple



Texas Ag in the Classroom STEM Lessons

ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



TEXAS FARM BUREAU®

AquAdvantage Salmon



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ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



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Wheat



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ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



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Tomatoes



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Sweet Potatoes



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ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



Asparagus



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ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



Lettuce



Texas Ag in the Classroom STEM Lessons
ANIMAL SCIENCE | VARIATION & PROBABILITY OF EXPRESSED TRAITS



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Issue

1

Apples start to oxidize almost immediately after they have been sliced and exposed to air. This causes them to turn brown and a little mushy. The brown color is unappetizing, and consumers often throw away the apples rather than eat them. This results in wasted food.



Issue

2

Children in Africa can suffer from malnutrition and poor diets. They don't get enough fruits and vegetables in their diet that provide a wide range of nutrients. A deficiency of vitamin A can result in blindness. Rice is one of the staples of their diet, which is an excellent source of calories.



Issue

3

Global warming has caused rising sea levels. Lowlands of southeast Asia are experiencing an increase in the salinity of their soil from ocean water flooding and underground salt water seepage. Rice crops cannot grow in the salty soil, resulting in poor yields and crop failure. Rice is a staple crop and is essential to feeding the local population.



Issue

4

Wheat naturally grows on a tall shaft. But the taller the shaft, the weaker it is. A strong wind storm can easily blow down standing wheat which is heavy from the seeds on top. Once blown down, the wheat doesn't recover and cannot be harvested. The crop is lost.



Issue

5

Potatoes can be bruised by impact and pressure during harvest and storage. This results in black spots on the potato. Consumers will not purchase discolored potatoes, and potatoes with these black spots are thrown away. This results in a lot of food waste.



Issue

6

The corn borer is a moth that lays eggs on corn plants. When the eggs hatch, the larva that looks like a small worm eats the corn plants and can cause millions of dollars of damage to the corn field.



Issue

7

Papayas are susceptible to a disease called the papaya ring spot virus. This virus deforms fruit of young plants and can prevent the plant from producing fruit at all. The virus is spread by insects and cannot be contained. Papaya production was cut in half because of the virus.



Issue

8

Weeds in soybean and cotton fields compete for the water, nutrients, and sunlight that the soybeans and the cotton need to grow. Because they are broadleaf plants (same as the weeds) farmers can't spray herbicides while the plants are growing. This results in a significant reduction in crop yield.



The results are in....

Arctic® apples won't brown after they've been bitten, sliced or bruised. Consumer research has shown that people prefer the eye-appeal of the new variety. Approximately 40% of apples are wasted because of browning. The new variety maintains a longer shelf life of the cut fruit so it won't be thrown away. There is no need to treat apples with ascorbic acid to try to prevent browning.

The results are in....

Golden Rice could significantly reduce vitamin A deficiency syndrome. More than 1.1 million children die every year from vitamin A deficiency. Up to 500,000 more lose their eyesight and others become susceptible to diseases. This biofortification could improve the primary food source for billions of people.

The results are in....

Rice is the primary source of calories for more than 3 billion people in the world—many in southeast Asia. The International Rice Research Institute has used a variety of techniques to change the genetic architecture of rice so that it can be grown in soil that has a higher salinity. This has led to increased harvests for poor farmers in salt affected areas.

The results are in....

Norman Borlaug initially worked with high producing varieties of wheat that had tall, thin stalks. In 1953, his semi-dwarf variety produced more stalks and more heads of grain per plant. Borlaug's semi-dwarf, disease resistant varieties changed the potential yield of spring wheat dramatically. This increased production by six-fold in Mexico.

The results are in....

Innate™ potatoes reduce black spots from bruising. Previously, tons of bruised potatoes never made it to market, costing millions of dollars. The technology also resulted in the reduced production of the amino acid asparagine. Asparagine is a precursor to acrylamide, which is a suspected carcinogen when cooking potatoes. The new potato reduces the risk of getting cancer.

The results are in....

Bt corn has revolutionized pest control in corn crops by providing protection from hungry corn borer larva. This means that growers will be handling and applying fewer chemical insecticides, which has health benefits for the growers and important environmental benefits. Bt corn reduces the use of insecticides, protects yields, and improves the quality of the grain.

The results are in....

The Rainbow Papaya grown in Hawaii is resistant to the papaya ring spot virus and has been proven to be safe to eat and of commercial quality. This new variety yields up to 125,000 lbs. of fruit per acre—a 25x increase. The fruits are exactly the same nutrition and have been safely consumed for more than a decade.

The results are in....

RoundUp Ready soybeans and cotton were first commercially produced in the mid-1990s. This transgenic variety can be sprayed with RoundUp (glyphosate) with no damage to the plant. The RoundUp will kill other plants (weeds) that compete with the soybeans and cotton. This can improve yields of the soybeans and cotton.

Possible Solution

A

Scientists discovered a gene silencing technique to turn off the expression of polyphenol oxidase. This plant enzyme causes a chemical reaction when cells are damaged resulting in brown melanin. By suppressing this gene, no polyphenolics are produced and no browning occurs.



Possible Solution

B

Scientists discovered a gene sequencing technique using similar wild plant species RNA to suppress natural enzymes. The gene sequence from wild plant species is so similar that the domesticated version easily recognizes it. This means that bruising can be reduced by up to 40%.



Possible Solution

c

Scientists use a process called transformation to copy traits from one organism and insert them into another organism's cell. By copying a protein from a virus and inserting it into the seed of a fruit, the fruit becomes resistant to that virus.



Possible Solution

D

A naturally occurring soil bacterium—*Bacillus thuringiensis* (or Bt)—produces a protein that is toxic to caterpillars but safe for other insects and other animals like mammals, birds and fish. Scientists can insert the gene from the Bt into a plant's genetic code, and the plant can produce the protein that is toxic to the caterpillars.



Possible Solution

E

Many farmers spray glyphosate to control weeds. Glyphosate kills plants by interfering with their ability to produce essential amino acids. Using a gene gun, scientists can insert germplasm from a bacterium into seeds so they can still produce the amino acids. Then, when glyphosate is sprayed, it kills the weeds but leaves the desired crop.



Possible Solution

F

Some varieties of a plant are more salt tolerant than other varieties. But those salt tolerant varieties don't produce as much. Scientists are working on recombinant DNA that will inter-mate salt-tolerant plants with high-producing varieties. This will hopefully yield a high-producing, salt-tolerant variety.



Possible Solution

G

Scientists crossed a high-yielding American variety with a dwarf Japanese variety. This created a semi-dwarf variety that is half the height and can produce thick stems. The thick stems can hold more heads of grain per plant. The semi-dwarf variety was then crossed with disease-resistant varieties to add those traits.



Possible Solution

H

Many fruits and flowers that are orange produce beta-carotene and is necessary to produce vitamin A. Scientists added two genes (one from a grass and one from a bacterium) to turn on the production of carotenoids. The resulting grain was golden in color and produced beta-carotene.

