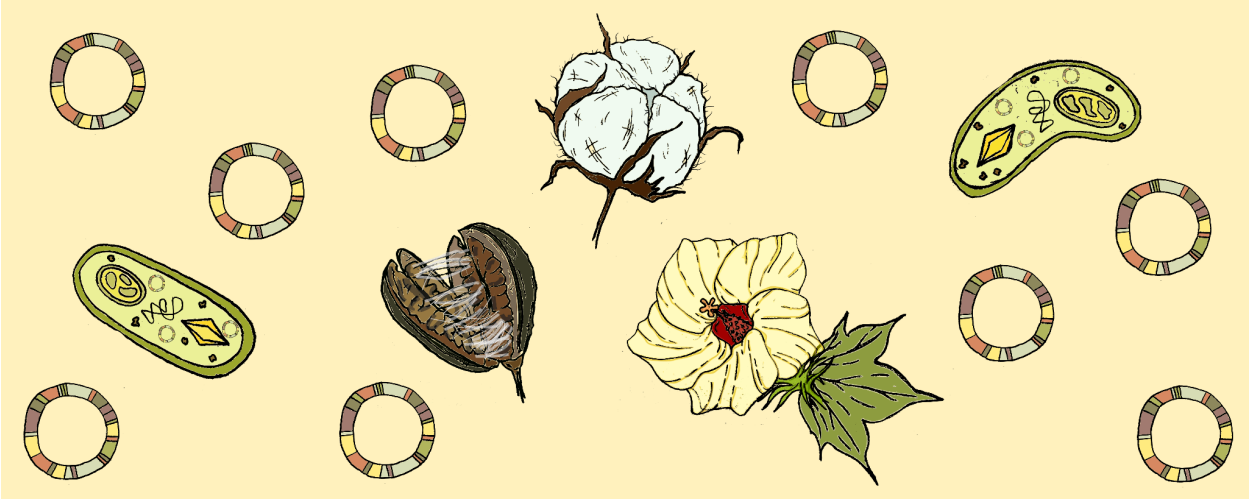
Teaching iThink Biology in your classroom

A Guide to Teaching the Cotton chapter



iThink Biology is different from the types of science textbooks we are familiar with in India. The content, organization and features of the e-book have been developed with different objectives in mind. We hope that the chapter-wise guides prepared by the iThink Biology team will help a teacher make the best use of the resource in their learning spaces. The following text is a guide to teaching the Cotton chapter. Please read through the section on how to read iThink Biology before using this resource.

Table of contents

Introductory notes

- The book has been written in an informal and conversational style of English and important or difficult concepts have been linked to the glossary or elaborated in detail within the text.
- The book is hosted on a website, so the reader will require a computer, mobile or tablet to access it. An internet connection will be required to access the different pages of the website, as well as the different interactive features of the book such as weblinks, glossary terms, video interviews, and downloadable research papers.
- Several exercises in the book may require students to step out of their classroom and observe their surroundings, such as a city area, water bodies or garden. The possibility of such an engagement can be important to meet the learning objectives of the book.

Content Mapping

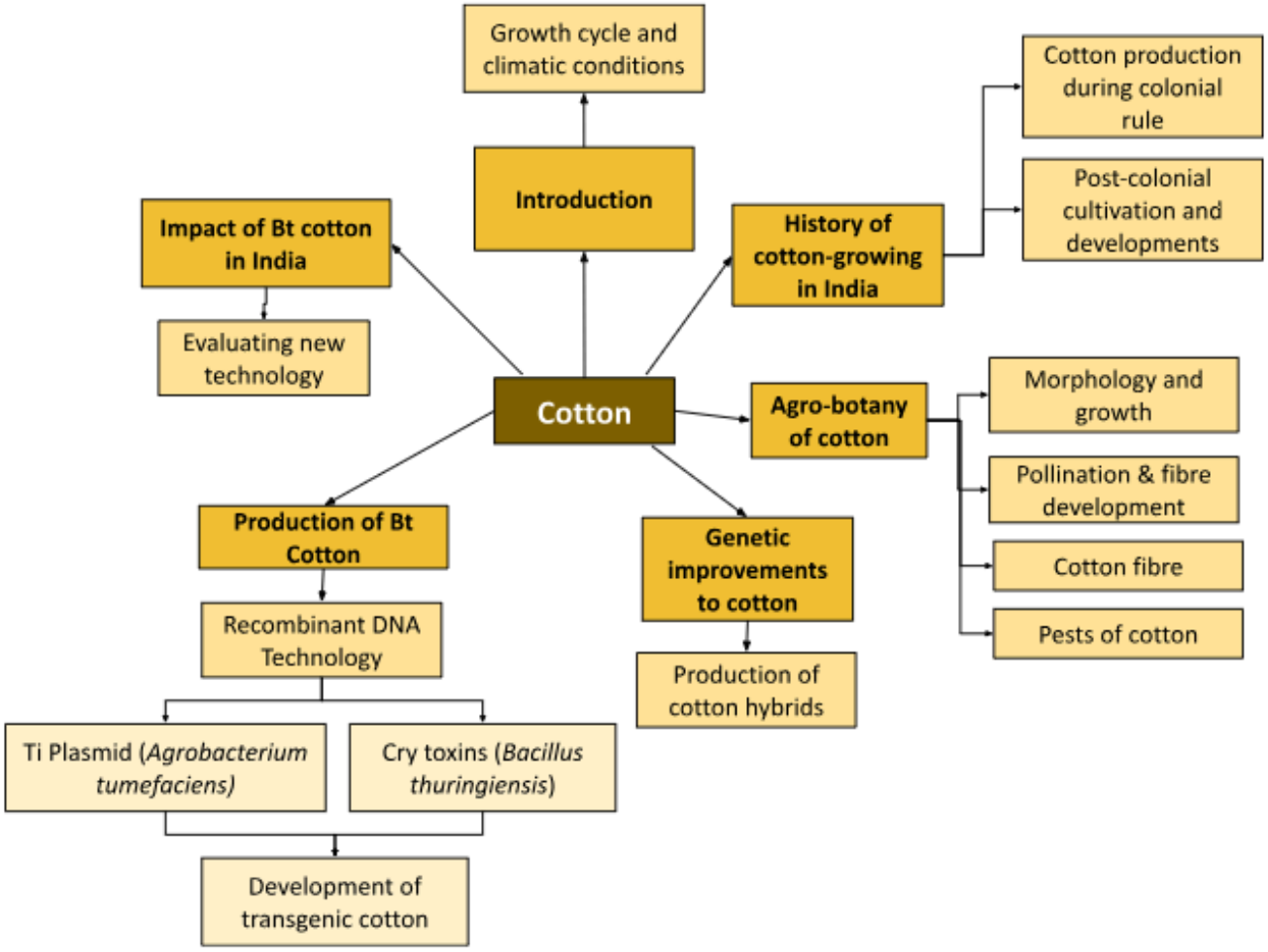
This table will help you map parts of your syllabus to the content and capacity-building approach in iThinkBiology. In the first column, you will find units and topics from your syllabus and the subsequent columns contain the sections, subsections and concepts from our book iThink Biology. By using this table, you can easily identify the relevant concepts from the book that align with your syllabus.

Existing Syllabi	Corresponding Topics in iThink Biology			
Subject, Topic	**Headings/ Sections**	**Subsection**	**Concepts explored**	**Capacities developed**
Economic Botany, Fibres (cotton)	Introduction	Introduction to cotton	Climatic requirements for cotton growth, growth cycle, improvement of cotton yield	Reading and Interpreting
Economic Botany, Fibres (cotton)	Brief history of cotton growing in India	Cotton production during colonial rule	Industrial Revolution and cotton production, demand of long staple cotton, loss of native cotton species	Bridging science, society and the environment
Economic Botany, Fibres (cotton)		Post-colonial developments	Cultivation of *hirsutum* varieties, introduction of Bt cotton	Bridging science, society and the environment
Economic Botany and Biotechnology, Fibre Yielding Plants - morphology of Cotton; **Plant Systematics,** Family Malvaceae	Agro-botany of cotton	Morphology and growth	Characteristics of the Malvaceae family of plants (Extra Reading), Branching pattern on a cotton plant	Reading and Interpreting
Economic Botany and Biotechnology, Fibre Yielding Plants (Cotton); **Plant Anatomy and**		Pollination and fibre development	Insect pollination, growth cycle of cotton from seed to cotton boll	Reading and Interpreting

embryology, pollination and fertilisation				
Economic Botany, Fibres (cotton)		What is a cotton fibre?	Structure of cotton fibre	Reading and Interpreting
Economic Botany and Biotechnology, Fibre Yielding Plants (Cotton)		Pests of cotton	Types of pests, pesticide resistance	Reading and Interpreting
Plant Breeding, Methods of crop improvement, Polyploidy, Heterosis; **Economic Botany,** Origin of tetraploid cotton	Genetic improvements to cotton	Hybridisation in cotton - origin and advances	Plant hybrids, polyploid and allotetraploid chromosomes, heterosis, gene redundancy	Scientific process, Reading and Interpreting
Plant Breeding, Methods of crop improvement, Hybridization		Producing cotton Hybrid-4	Doak's method of hybridisation	Scientific process, Scientific tools
Plant Biotechnology, Recombinant DNA technology	Genetic improvements in cotton: producing Bt cotton	Introduction to recombinant DNA: processes of science	Role of enzymes, process of recombinant DNA production	Reading and Interpreting, Scientific process
Plant Biotechnology, Methods of gene transfer (Agrobacterium-mediated)		Recombinant DNA technology in plants	Ti plasmid, Agrobacterium-mediated gene transfer	Scientific process, Scientific tools
Economic Botany and Biotechnology, Recombinant Technology Applications: Bt cotton; **Plant Biotechnology**, Pest resistant (Bt-cotton)		Development of Bt cotton; Recombinant DNA technology and pest resistance in cotton	Discoveries related to *Bacillus thuringiensis*, Bt sprays, pest-resistant cotton	Reading and Interpreting, Scientific process, Scientific tools

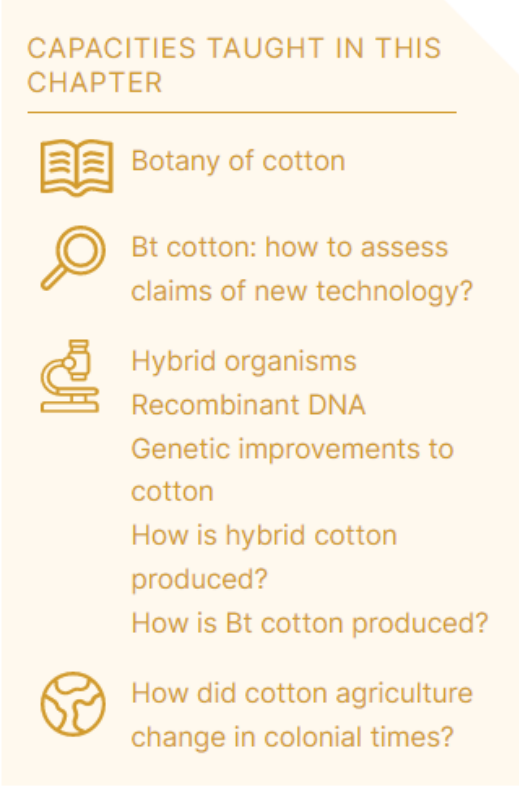
Plant Biotechnology, Pest resistant (Bt-cotton)		Cry toxins and insecticidal action	Lifecycle of Bt, Bt crystal proteins, insecticide	Reading and Interpreting
Plant Biotechnology, Pest resistant (Bt-cotton); **Practical**, steps of genetic engineering for production of Bt cotton		Development of transgenic cotton	Transgenic Bollgard cotton varieties	Scientific process
Plant Biotechnology, Application of biotechnology - Pest resistant (Bt-cotton)	Impact of Bt cotton in India	How do we assess a technology?	Claims for and against Bt cotton	Bridging science, society and the environment
Plant Biotechnology, Application of biotechnology - Pest resistant (Bt-cotton)		Investigating the relationship between Bt cotton area and cotton production	Investigating biases	Scientific process; Bridging science, society and the environment
Plant Biotechnology, Application of biotechnology - Pest resistant (Bt-cotton)		Has Bt cotton increased yield or not?	A comparative study across different states, increased use of pesticides	Scientific process; Quantitative skills

Concepts introduced in the chapter



Capacities developed in this chapter

You will notice that every chapter has a set of questions appearing at the beginning of the chapter. These describe the content (indicated by the questions) related to the capacity (indicated by the icon).



In this guide, we have followed different subsections from the ithinkbiology book. We have suggested different activities that are focused on answering the critical thinking questions given in the book. We have added two annexures to this guide. We have added an annexure to this guide. Annexure-I has two worksheets that teachers can provide to students to record observations for different suggested activities.

Notes for Instructors

In this document, we provide some suggestions for instructors on how to get students to engage with the critical thinking questions that are present throughout the chapter. We have provided the answers and suggested activities for each section in the book. It would be ideal to use these questions along with the book chapter but do adopt these questions and activities to related topics in your curriculum. We hope that this document encourages you to create similar critical thinking questions for the concepts in your course syllabus.

In our experience, there is much value in group work conducted between students. If a student can be accompanied by even one other student while attempting some of the exercises, it will make a difference in their learning experience. If you do conduct these exercises in groups, ensure that the group sizes are not too large (not more than 5 students per group) so that all the students participate in the discussions. Students tend to be curious but having a few pre-prepared questions and hints to promote conversation in groups might be helpful.

A wrap-up discussion to combine and connect the individual group learnings is essential to ensure learning objectives are achieved. Do keep some extra time while conducting group work since they tend to run longer than the time estimated.

C2.1 Introduction

Building Capacity: Reading and interpreting; Quantitative skills

Question

India has attained high proficiency in cotton fabric manufacture. Which states of India produce the highest amount of cotton?

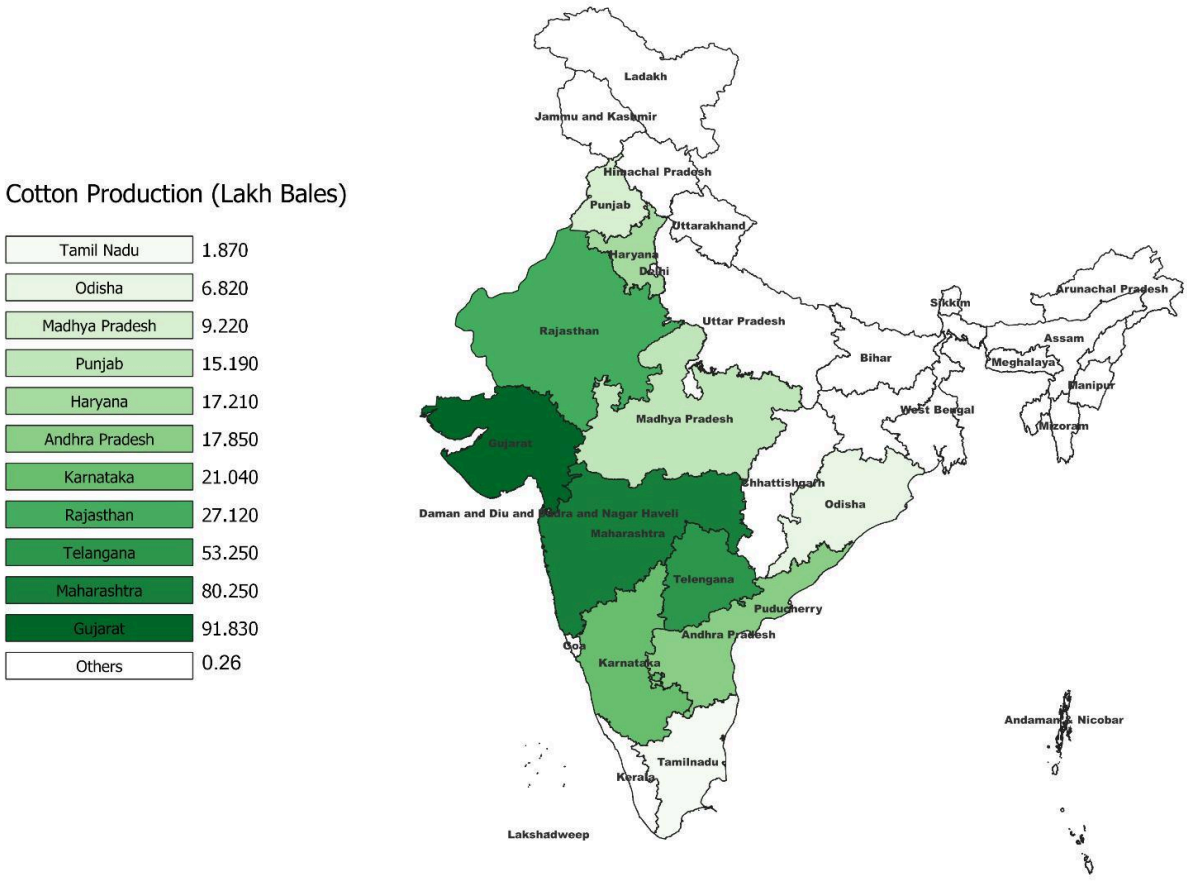
Hint

Cotton naturally grows in tropical and sub-tropical regions of the world. India's subtropical region is ideal for its growth.

Suggested Activity

Suggested time: 1 class

Share this map of the Top 10 Cotton Producing States of India with the students. Encourage them to study the map carefully.



Courtesy: Nimish Subramaniam

Using the data for cotton production from the map, find the percentage of cotton produced by these 10 states. To instil quantitative skills in students, instruct them to create a bar graph and pie chart for the percentage of cotton production in different states of India.
After creating the graph, discuss which graph is a better representation.

Provide worksheet-1 given in the annexure to students.

To learn more about interpreting graphs and data, head to the chapter 'Waterscapes' in the book and attempt Exercise A2.1. Here is the link: https://ithinkbiology.in/book/text/a2-waterscapes.html#a22-why-does-land-harbour-more-diversity-than-water

Here are the answers to the questions above for the teacher's reference:

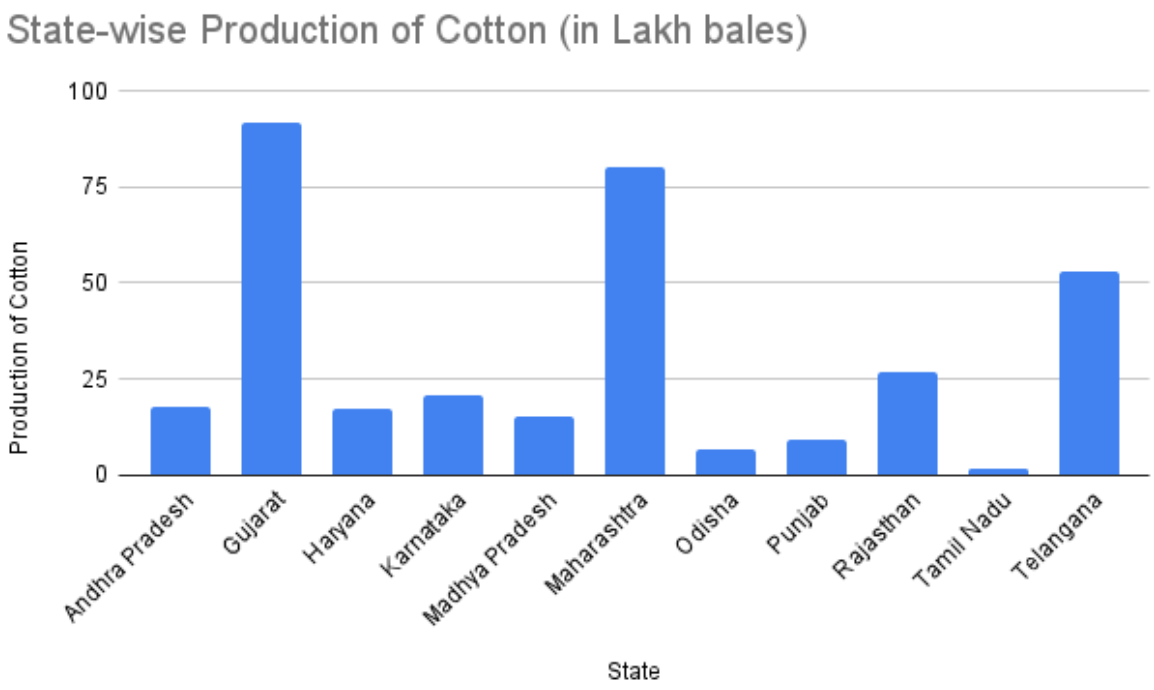
To calculate the percentage of cotton production for each state, find the total cotton production and then calculate the percentage for each state based on its production.

Percentage of cotton production for a state = (cotton production for the state / total cotton production) x 100

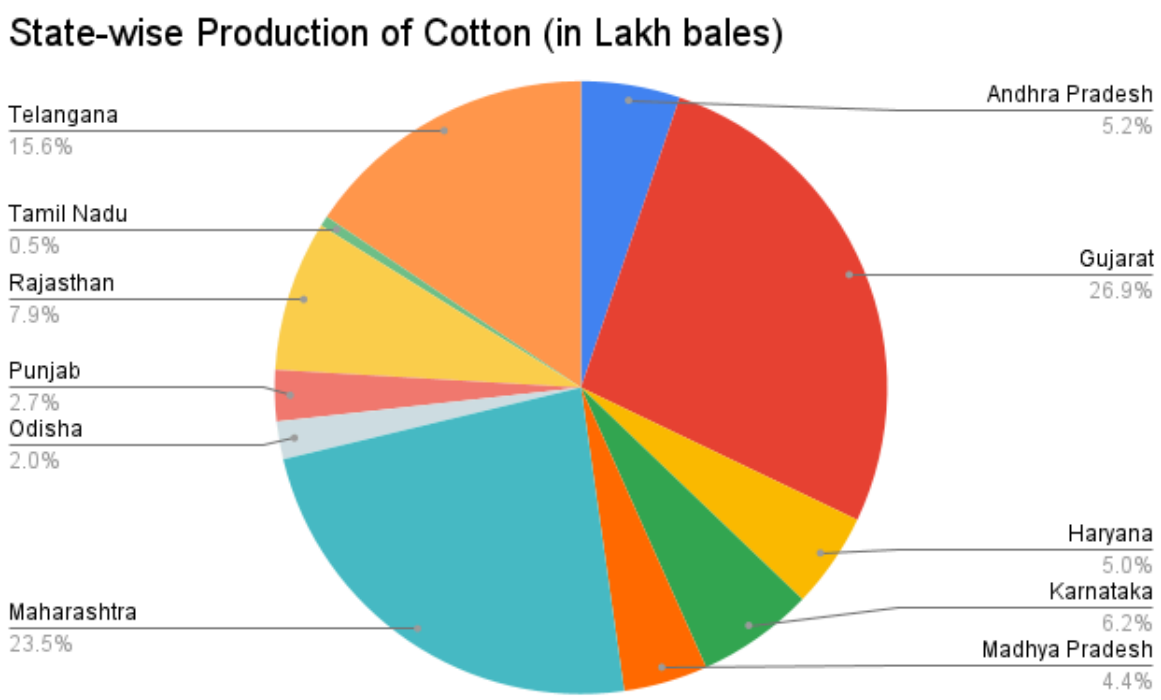
Table-1: Percentage of cotton production in the top 10 states of India

State	Cotton production in Lakh Bales	Percentage of cotton production
Andhra Pradesh	17.85	5.22
Gujarat	91.83	26.86
Haryana	17.21	5.03
Karnataka	21.04	6.15
Madhya Pradesh	15.19	4.44
Maharashtra	80.25	23.47
Odisha	6.82	1.99
Punjab	9.22	2.70
Rajasthan	27.12	7.93
Tamil Nadu	1.87	0.55
Telangana	53.25	15.57

Bar-graph for cotton production



Pie chart for cotton production



Both bar graphs and pie charts represent data effectively, but each serves a different purpose. The bar graph gives a direct visual comparison of the production quantities for cotton. The length of the bar makes it easier to identify states with higher and lower cotton production values. The pie chart is effective in visualising percentages of cotton production in different states. It shows a clear picture of how cotton production is distributed among the states.

Discuss the following questions with students:

- Is there any correlation between the area of a state and cotton production?
- What climatic conditions make Gujarat the highest cotton producer in India?

After asking these questions, share the following table with students:

Table-1: Area under cotton cultivation and production in lakh bales of cotton in the top 10 states of India

State	**Area under cotton cultivation in Lakh Hectares**	**Production in Lakh bales of 170 kg.**
Punjab	2.84	11.5
Haryana	6.65	27
Rajasthan	4.96	22
Gujarat	27.09	92
Maharashtra	41.19	81

Madhya Pradesh	6.97	24
Telangana	17.94	53
Andhra Pradesh	5.51	20
Karnataka	5.75	18
Tamil Nadu	1.4	6
Odisha	1.58	4.5

Source: Cotton Advisory Board

Study the table carefully, and answer the following questions:

- Looking at the map, and area under cultivation in the table given above - does the state with the highest area has the highest area under cotton cultivation?
- What is the correlation between the area in lakh hectares and the production in lakh bales of cotton for the given states?
- Despite Maharashtra having a larger area under cotton cultivation compared to Gujarat, why does Gujarat still have higher cotton production than Maharashtra?
- Identify the state with the highest production-to-area ratio for cotton cultivation.
- Which state has disproportionately higher or lower production of cotton compared to its area under cultivation?

What does this question make students do?

This activity will introduce students to top cotton-producing states in the county. This activity will encourage students to think critically and build their quantitative skills.

C2.2 Brief History of Cotton Growing in India

Building Capacity: Reading and interpreting; Bridging science, society and the environment

Question

How does the historical perspective change your views on the science behind agriculture? Do you think this is important?

Hint

Think about how scientific advancements need to be understood in the context of societal and economic movements.

Suggested Activity-1

Suggested time: This activity can be given to students as a take-home assignment, as this would require extensive research.

Start class by discussing the importance of the historical background of crops and their influence on modern-day practices.

Encourage students to go through section C2.2 - Brief History of Cotton Growing in India in the chapter 'Cotton' and learn the cultivation of cotton changed in India in the last two hundred years. You will learn the importance of historical perspective in understanding current production practices.

- Allow students to choose one crop of their choice and study its historical background and its current cultivation practices. (Some of the crops students can choose from are: rice, wheat, tea, mustard, chickpea, and turmeric. Encourage students to choose their own crops.)
- Instruct students to conduct independent research on their chosen crop's history, including its origins, domestication, spread, and major historical events that impacted its cultivation and production.
- Encourage students to explore various aspects, such as socio-cultural, economic, technological, and environmental factors that influenced the crop's development.
- Ask students to explore if breeding practices have any influence on the botany of the crop.
- Ask students to compile their findings, they are free to use any creative means. Have them present their findings to the class.
- After each presentation, have a class discussion where students can ask questions, share insights, and make connections between different crops and their historical contexts.

What does this question make students do?
This activity will allow students to gain a comprehensive understanding of the historical journey of different crops and appreciate the influence of historical events on current agricultural practices. This activity will promote research skills in students.

Suggested Activity-2

Suggested time: This activity can be given to students as a take-home assignment, as this would require extensive research.

Title: Scientific Process- Timeline

Introduce the concept of scientific processes and explain that each process undergoes changes and improvements over time. Discuss examples of scientific processes with the students, such as the discovery of vaccines, or the development of genetic engineering. Allow students to suggest and choose a specific scientific process they find interesting for further exploration.

Research and Timeline Creation

- Instruct students to research the chosen scientific process (to learn more about how to find reliable information on the internet, head to chapter 'Waterscapes' and go through section A2.7 - "Locating Information").
- Instruct them to research the history and evolution of the process, identifying key milestones, discoveries, and influential figures.
- Encourage students to take notes and create a timeline highlighting significant events and advancements.

Timeline Creation

- Explain to students that they will create a timeline representing the history and evolution of the scientific process.
- Students can use models, diagrams, or interactive components that represent their chosen scientific process.
- Provide guidance on organizing and presenting information in a clear and visually appealing manner.

Presentation and Discussion

- Allow each student or group to present their timeline to the class.
- Encourage students to explain the chosen scientific process, highlight key moments from the timeline, and discuss the significance and impact of the process on society.
- Facilitate a class discussion about the similarities and differences in the evolution of various scientific processes.

Reflection and Future Predictions

- Engage students in a reflection on what they have learned about the chosen scientific process and its evolution.
- Prompt them to think about how the process might continue to evolve in the future and the potential implications for society.
- Discuss the importance of ongoing scientific research and innovation.

What does this question make students do?
This activity promotes research skills, critical thinking and creativity in students. This activity will allow them to delve into the history and evolution of scientific discoveries.

C2.3 Agro-botany of Cotton

Building Capacity: Reading and Interpreting

Question
We see plants and trees every day, but we are not able to identify them. How would you approach identifying the family to which a plant belongs?

Hint
Think of the characteristics you would use to identify a plant.

Suggested Activity

Title: Botanical Scavenger Hunt

Pre-preparatory phase

Take some branches, leaves or flowers of different plants to your classroom. Ask students if they can identify any of these plants. If they can identify these plants, ask them what characters helped them in identification. To facilitate a class discussion, ask them the following questions:

- How many plants do students can identify? What criteria do they use for identifying these plants?
- How can physical characteristics aid in classifying plants?
- Do you know any characteristics that are specific to a particular genus or family of plants?
- What are the challenges or limitations of using the physical characteristics of plants to identify them?
- Why is it important to classify plants?

Preparatory phase

Suggested time: this activity can be done in a single class, or it can be stretched into multiple weeks, depending on availability of time and resources.

Teachers can select a suitable outdoor location, such as a nearby park, garden, or campus with diverse plant species. Let students use smartphones and the internet.

Prepare a list of plant characteristics and taxonomic categories i.e., family that students need to observe and identify.

Divide students into small groups and distribute the scavenger hunt checklist. This list will include specific characteristics to observe and identify. You can provide them with a printed checklist or a digital version on their smartphones or tablets.

- Instruct students to explore the designated outdoor area and find plants that match the characteristics listed on their checklist.
- Encourage them to closely observe leaf shapes, flower structures, stem characteristics, and other unique features to help with plant identification.
- As they find plants, students will work together to identify and classify them based on their observations and knowledge of plant taxonomy.
- They can use field guides or plant identification apps (such as inaturalist, PlantNet, https://plantdatabase.kpu.ca/#gsc.tab=0), if available.

Group Discussions and Presentations:

- After the scavenger hunt, gather the students together for a group discussion.
- Each group can present the plants they found, share their observations, and explain how they classified each plant based on taxonomy.
- Encourage discussions and comparisons between groups, allowing students to ask questions and provide additional information or insights.

Wrap-up and Reflection:

- Conclude the activity with a class discussion on the challenges and successes encountered during the scavenger hunt.
- Reflect on the importance of accurate plant identification and taxonomy in understanding plant relationships and ecological roles.
- Provide opportunities for students to ask questions and clarify any misconceptions.

For teacher's reference: Examples of checklists for a scavenger hunt.

Example-1

Characteristics:
Calyx (sepals): rudimentary or absent.
Leaf arrangement: alternate, rarely whorled or opposite
Inflorescence: composite head with disc florets

Example-2

Characteristics:
Habit: trees or shrubs
Leaves: typically, large and alternate
Plants produce a milky latex.
Inflorescence: syconium

Example-3

Characteristics:
Habit: trees, shrubs, herbs
Leaves: alternate, simple or pinnately compound, stipules are present
Flower: bisexual, zygomorphic, generally five fused sepals and five free petals, ten stamens,
Fruit: legume or pod

Instruct students to look up the internet and find which families of flowering plants show these characteristics.

Answers
Example 1: *Family: Asteraceae.* Some common examples are: Sunflowers (*Helianthus*), daisies (*Bellis*), marigolds (*Tagetes*), chrysanthemums, dandelions, etc.

Example 2: *Family: Moraceae.* Some common examples are: Fig trees (*Ficus)*, mulberry (*Morus),* jackfruit (*Artocarpus*), etc.

Example 3: Family: Fabaceae. Some common examples are: soybeans (*Glycine max*), garden peas (*Pisum sativum*), peanuts (*Arachis hypogaea*), *Acacia*, *Caesalpinia*, etc.

Encourage students to find plants with these characteristics. Students are likely to find many plants with similar characteristics. Ask them to study individual plants that they have collected. They will draw diagrams and write morphological features of the plant. Based on their collected data, encourage them to find the botanical names of those plants.

What does this question make students do?
This activity will promote observational and research skills in students. This hands-on approach will help them to learn plant identification skills.

Building Capacity: Reading and Interpreting

Question
Explore different types of plant fibres used in the textile industry.

Hint
Think of the clothes you wear. Where does the fabric come from?

Suggested Activity

Suggested time: 1 hour

Begin the class by asking the following questions to students to pique their interest and assess prior knowledge:

- Have you ever wondered what material your clothes are made of?
- Do you know if any of these materials come from plant sources?
- Can you name any plants that are used in the textile industry?
- Which cells of plants are used in the textile industry?
- What do you know about cotton or linen?
- Which plant fibre is commonly used to make jeans?

If possible, distribute the samples of different plant fibres (e.g., cotton, flax, hemp, jute, bamboo, sisal, etc.) among students in small groups. Encourage them to examine the fibres using their senses: touch, smell and sight. Ask them to note the physical characteristics such as colour and texture.

If samples are not possible, show them pictures of different types of fibres.

Divide the class into different groups and give them a worksheet to fill out.

The worksheet-2 is provided in the Annexure. The table below is for teachers' reference.

Fibre	**Source of fibre**	**Plant part used for fibre**	**Characteristics**	**Uses**
Cotton	*Gossypium* (Cotton)	Seed	Soft, breathable, good moisture absorption	King of the global textiles industry
Linen	*Linum usitatissimum* (Flax)	Stem	Strong, absorb and release water quickly	Clothing, home textiles, and upholstery
Hemp	*Cannabis sativa*	Stem	conducts heat, dyes well, antimicrobial, blocks ultraviolet light	Agro textiles, car panels and fibreboard
Jute	*Corchorus olitorius* or *Corchorus capsularis*	Stem	Coarse, strong, good insulation properties, low thermal conductivity	Bags, rugs, rope, handicrafts

Sisal	*Agave sisalana*	Leaves	Strong, durable and stretchable, too coarse for textiles	Rugs, rope, twine, etc.

Reference: https://www.fao.org/natural-fibres-2009/about/15-natural-fibres/en/

Facilitate a class discussion by asking questions like:

- What characteristics do you think are important for plant fibres to be suitable for textiles?
- Can you think of any advantages or disadvantages of using certain plant fibres in specific textile applications?
- Can you think of any environmental benefits associated with using plant fibres in textiles? How do they compare to synthetic fibres?
- Can you think of any other industries or applications where plant fibres can be utilized apart from textiles?

Extension activity: As an extension, assign each group one plant fibre to research how raw fibres are processed to be used in the textile industry.

What does this question make students do?
This activity aims to pique students' interest, cultivate hands-on exploration, encourage collaborative learning, and encourage critical thinking and research skills.

C2.4 Genetic Improvements to Cotton

Building Capacity: Scientific Process, Scientific Tools

Question
What do you understand by the terms - species, hybrids, varieties and ploidy?

Hint
Think in terms of chromosome numbers and reproductive compatibility.

Suggested Activity

Suggested time: 1 hour

Start class by introducing students to the terms – species, hybrids, varieties and ploidy.

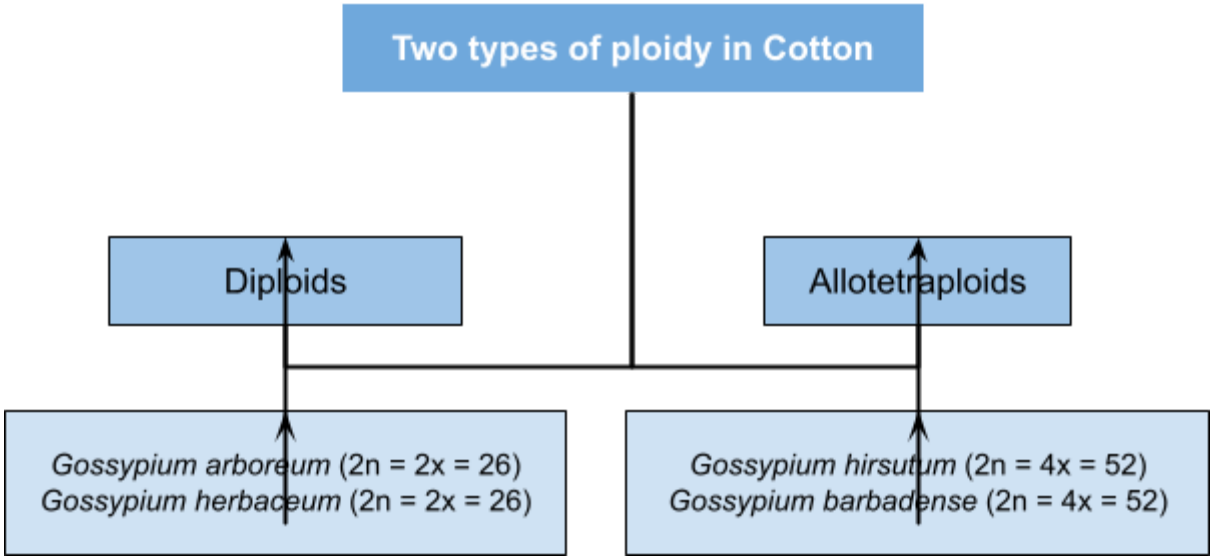
Species - a group of organisms having the same characteristics and can reproduce among themselves.

Hybrid - the product of crossbreeding between different species or varieties.

Variety - variations within the same species that have distinct characteristics but can still interbreed.

Ploidy - number of chromosome sets in a cell.

Introduce students to four cultivated species of cotton and their ploidy.

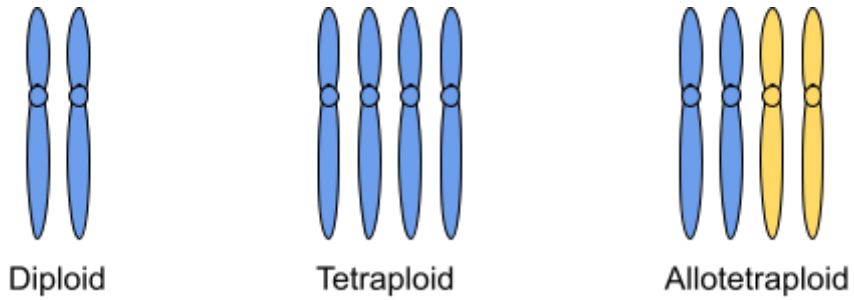


Encourage critical thinking in students by asking them the following questions:

- What do you mean by tetraploid, allotetraploid and diploid?
- What do 2n=2x=26 and 2n=4x=52 (allotetraploid) mean?
- What is the significance of ploidy in genetic diversity and reproductive behaviour?
- How many potential intraspecific hybrids are possible with the species provided?
- How many potential interspecific species are possible with the species provided?
- Can a diploid species hybridise with a tetraploid? Why or why not?
- Theoretically, if we cross *Gossypium arboreum* with *Gossypium hirsutum*, what will be the ploidy of the resultant hybrid?
- Can hybrids occur naturally, or they are formed only through human intervention?
- Both hybridisation and grafting involve creating combinations of different plant species. How do these two processes differ from one another?

Teachers can use the following points for discussion in the class:

- Tetraploid refers to having four sets of homologous chromosomes. Allotetraploid refers to tetraploidy in which there are two different sets of chromosomes derived from two distinct parents. Diploid refers to two sets of homologous chromosomes.



- In 2n=2x=26, there are 26 total chromosomes, and 2n denotes that an organism has two sets of chromosomes. Since the organism is diploid, chromosomes are present in pairs, thus there are 13 pairs of chromosomes. In 2n=4x=52, 2n denotes diploidy, and 4x indicates that the organism is tetraploid. So, the organism has four sets of 14 chromosomes, and within one set, two chromosomes are derived from distinct parents.
- Ploidy contributes to genetic diversity, i.e., the organisms with higher ploidy levels have multiple copies which increases the potential for genetic variation. It also affects reproductive behaviour as organisms with different ploidy levels usually do not reproduce successfully.
- Four intraspecific hybrids i.e., one in each species are possible for the given species.
- Two interspecific hybrids between tetraploids viz., *Gossypium barbadense* and *Gossypium hirsutum* and diploids *G. arboreum* and *G.herbaceum*.
- Theoretically, a diploid and a tetraploid species can hybridise, but the success of this union may vary. In some cases, they cannot hybridise due to genetic and reproductive barriers, or sometimes, their hybridisation may result in infertile hybrids. In rare instances, the hybridisation of diploid and tetraploid species produces triploid offsprings. Again, triploid individuals may face reproductive challenges.
- If *Gossypium arboreum* (2n = 26, diploid) is crossed with *Gossypium hirsutum* (2n = 52, tetraploid), the ploidy of the resultant hybrid will be triploid.
- Hybridisation can occur both naturally and by human intervention. In plants, hybrids can be formed naturally between closely related species with genetic compatibility. Hybridisation is very commonly done by humans for agricultural and horticultural purposes.
- Hybridisation and grafting are two distinct methods used in plant propagation. Hybridisation is a result of sexual reproduction between two different plant species or varieties to produce offspring with a combination of desired traits from both parents. However, grafting involves physically joining two different plant parts, typically a rootstock and a scion, to create a single plant with desired characteristics.

What does this question make students do?

This activity will provide foundation knowledge to students for subsequent discussions. This will allow them to think critically and foster a deeper understanding of the concepts related to species, hybrids, and ploidy.

Suggested video:

Humans have been cultivating different crops for centuries. The food that we eat every day, it looked much different than it currently does. Check out these 10 fruits and vegetables that looked very different before we started cultivating them!

https://www.youtube.com/watch?v=M5Qly-VQfbo

C2.5 Genetic Improvements in Cotton: Producing Bt Cotton

Building Capacity: Scientific Process, Reading and Interpreting

Question
What steps are involved in creating a genetically modified plant?

Suggested Activity

Suggested time: 1 class

Start the class by asking the following questions to students:

- What is genetic engineering?
- What makes it possible to transfer genetic material from one organism to another from different species?
- What are the potential advantages of genetically modifying crops?
- Can you give any examples of genetically modified organisms?

Facilitate a class discussion based on the questions above and give students an exercise to gauge their understanding to isolate genes. Divide them into groups of two and provide them with the given scenario. Instruct them to make a flowchart of the best course of action to find the gene.

Scenario 1- An agricultural scientist observes that a variety of wheat plants is thriving despite very limited water availability. They want to investigate the wheat variety to see if it contains a drought-tolerance gene.

Here are the steps to find a gene of interest for the teacher's reference:

Step 1: Collect tissue samples from the wheat plants. Choose tissues relevant to drought response (e.g., leaves, roots, etc).
Step 2: Isolate the DNA from the collected tissue samples.
Step 3: Develop primers specific to known drought-tolerance genes or related gene families.
Step 4: Amplify or sequence the DNA regions of interest using PCR.
Step 5: Analyse the amplified DNA fragments through gel electrophoresis to confirm their presence and size.
Step 6: Sequence the amplified DNA fragments to determine the nucleotide sequence of the gene.
Step 7: Compare the obtained gene sequence with a known drought-tolerant gene to identify and confirm the presence of a drought-tolerance gene.

Once students are done creating a flowchart for isolating a gene of interest. Discuss the process with them and clarify any doubts they have. Ask them about the potential applications of isolating a gene of interest. Furthermore, give them another scenario to enhance their understanding of genetic engineering.

Scenario 2- The agricultural scientist has successfully determined the presence of the drought-tolerant gene in the wheat variety. Now they want to grow rice plants that have this gene to allow them to grow with less water availability. Ask students to brainstorm with their partners and write down the steps

required to transfer a drought-tolerant gene from wheat to rice. They can use flowcharts to depict the process.

Encourage students to think about the following aspects:

- How will you isolate drought-tolerant gene from wheat variety?
- How can you prepare rice plants to receive the gene?
- How will you transfer the gene from wheat to rice?
- How will you ensure that the gene has successfully transferred to the rice plant?
- How will you select and identify the transformed plants?

Here are the steps to find a gene of interest for the teacher's reference:

Step 1: Isolate the DNA from wheat plants. Using a restriction enzyme, obtain a gene of interest (drought-tolerant gene) from the wheat variety.
Step 2: Insert the recombinant DNA into a cloning vector, such as a plasmid, to create a recombinant DNA construct.
Step 3: Introduce the recombinant DNA construct into the cells of the rice plant. This can be done using Agrobacterium-mediated transformation.
Step 4: Select transformed rice cells by using selectable markers.
Step 5: Grow the transformed rice cells using tissue culture techniques.
Step 6: Evaluate the drought tolerance characteristics of the transformed rice plants. Compare them with non-transformed rice plants under controlled drought conditions.
Step 7: Finally, conduct field trials to assess the performance of transformed plants under varying drought conditions.

Once the groups have completed their flowcharts, have them present their findings and discuss their approaches.

Extension activity: Instruct students to read the section 'Genetic improvements in cotton: producing BT cotton', and ask them to create a flow chart to show how was BT cotton produced using recombinant DNA technology.

What does this question make students do?
This activity promotes critical thinking and problem-solving skills. This activity will enhance their understanding of genetic engineering by visualizing the process.

C2.6 Impact of Bt Cotton in India

Building Capacity: Scientific process; Reading and interpreting; Bridging Science, society and the Environment

Question
What are the potential benefits and risks of genetically modified (GM) plants?

Hint

The answer to this question is not simple, it is a complex issue that needs to be understood from multiple perspectives.

Suggested Activity -1

Title: Debate on GMOs

Part-1

Suggested time - 25 mins.

Introduction

To introduce students to *how GM plants are created*, we recommend showing one of these short videos in the class:

1. https://www.youtube.com/watch?v=2G-yUuiqIZ0&t=95s
2. https://www.youtube.com/watch?v=QRLY_aNAsOE

Thinking critically

To engage students in critical thinking, provide them with the following scenarios and ask what they would do in this situation:

- *Situation-1:* You are a medical practitioner and some of your patients are small children suffering from infectious diseases. Many of these diseases can be prevented through vaccination, however, these families cannot bear the cost of vaccination. You learned about genetically modified fruits containing vaccines. Many cereals such as rice, maize, etc. or fruits like tomato, banana, etc. have been used to develop these edible vaccines. By eating a banana with an edible vaccine, your patient can be vaccinated without paying a hefty amount for vaccine shots! Would you recommend your patients go for edible vaccines? If yes, how would you address the concern of parents about its safety and effectiveness?
- *Situation-2*: You are the leader of a country that is faced with the challenge of resource depletion and climate change due to the increasing use of fossil fuels. You learned about sustainable biofuel alternative which involves genetically engineering algae that are rich in oils. This allows producing a large amount of biofuel while minimizing land use. As a leader of the country, you must consider the socio-economic and environmental impact of this approach. What information would you gather to make an informed decision to implement this technology? How would you address concerns related to potential risks, ethical implications, and long-term sustainability?
- *Situation-3*: You are a farmer who has been struggling to grow a rice crop due to pest infestation. You have spent a huge sum of money on different pesticides to get rid of the pest but none of them have been successful. You learn about a new strain of rice that has been genetically modified to confer pest resistance. By using this strain, you can avoid pests destroying your crops and also save money on pesticides. As a farmer, what factors would you consider in shifting to GM rice?

  (*adapted from - Learn.Genetics*)

With recent technology, we can manipulate plants by introducing genes which help solve many real-world issues. However, there is substantial opposition to the use of genetically modified plants. These oppositions revolve around changing the natural genetic makeup of a plant, and the risk of these plants to human health. What would be the environmental impact of such plants? Humans have been manipulating the genetic makeup of plants for millennia, how does genetic modification differ from other forms of plant breeding? Is there any difference between the food we get from GM crops and non-GM crops?

After introducing the students to GM plants and the critical thinking exercise, assign students the task to prepare for a debate on GM plants in the next class. Instruct them to research on environmental impact, public health and socio-economic impact of GM plants.

Part-2
Suggested time - 1-hour.

Topic: Debating Genetically Modified Plants

Preparation

a. Divide the class into two teams: “For” and “Against” GMO crops. Further, divide students into groups of four within these teams.
b. Explain that each group will research and prepare arguments, evidence, and counterarguments to support their respective positions.
c. Allow students to conduct online research and cite references.
d. Give them instructions in the previous class, so that they come prepared for the debate.

Debate

a. Each group will get 5 minutes to present their arguments regarding the GM plants followed by Q&A. Let one group present their arguments without interruptions.
b. Ask students in the audience to write any questions they want to ask during the Q&A round.
c. Each group presents their arguments, supporting evidence, and counterarguments in favour of or against GM crops.
d. Encourage respectful and evidence-based arguments and ensure equal opportunities for participation.

Q&A and Rebuttal

a. After each group present their arguments, allow a period for questions from the opposing group and the audience.
b. Speakers from both sides can provide rebuttals to counter opposing arguments.

Reflection and Conclusion

a. Facilitate a brief class discussion on the debate.

b. Ask students to reflect on the process, their perspectives, and any changes or insights they gained from the debate.
c. Emphasize the importance of respectful dialogue, critical thinking, and considering multiple viewpoints when discussing complex topics like GMOs.

Teachers can share this handout with students to research and address the following questions in their arguments. Encourage students to share perspectives from scientific, environmental, agricultural, political, and socio-economic aspects.

What does this question make students do?
This activity will foster critical thinking and research skills in students. Conducting a debate will enhance the communication skills of students and they will learn to respectfully listen to counterarguments. They will learn multiple perspectives and would learn how to make an informed decision.

Suggested Activity -2

Title: Exploring GM Plants and understanding common misconceptions: A documentary analysis

Student Perspectives
For this activity, students will watch a documentary. Before introducing students to the documentary, ask them their perspectives on GM plants. Ask them the following questions:

- What is their opinion on growing genetically modified crops?
- What concerns do they have about GMOs? Discuss the origins of these concerns.
- What do they think is the difference between the food we get from GM crops and non-GM crops?
- Should GM plants be labelled? Why or why not?

Documentary viewing
Show the documentary Food Evolution in your class. This documentary will introduce students to the viewpoints of different stakeholders on GM plants. How misinformation can spread fear among people about new technology. This documentary examines the history of GMOs, their scientific development and the debates surrounding their use. It addresses common concerns and misconceptions about GMOs.

Reflective essay
After showing the documentary to the class, ask students to write a reflective essay. Ask them to reflect on and address the following questions in their essay:

- Which stakeholders are contributing to the discussions surrounding GMOs?
- Which stakeholders would you trust to share reliable information? Why?
- How did scientists use a scientific method to create rainbow papaya? How can you advocate for the scientific method in your daily life?

- What example did you come across in the documentary that demonstrates the concept of correlation? How does correlation differ from causation? Does correlation always imply causation?
- What kind of challenges in agriculture cannot be solved by organic farming?
- What new information did you learn from this documentary? How did this piece of information influence your perspective on GMOs?
- How businesses, such as Monsanto, can impact the public's distrust of science?
- Why do you think there is a huge gap between the scientific community and consumers' opinions?
- Reflect on your overall personal views on GMOs before and after watching this documentary. Discuss any shifts in perspective.

Discussion

In the next class, have a class discussion based on reflective essays submitted by the students. Discuss the common misconceptions about GMOs. Encourage students to share their insights and changes in their viewpoints on GMOs.

What does this question make students do?

This activity promotes critical thinking, research and writing skills. This activity will students an opportunity to reflect and challenge their initial opinions and keep an open mind to new information that may challenge their opinions.

Suggested reading - Gilbert, N. (2013). Case studies: A hard look at GM crops. Nature, 497(7447), 24–26. doi:10.1038/497024a

Suggested video: this video shows the journey of India's first genetically modified crop, Bt Cotton, from its initial stages of development to its eventual approval for commercialization. It shares the experiences, opportunities and challenges faced by farmers and other stakeholders.
https://www.youtube.com/watch?v=9k8FbJ9yFgQ

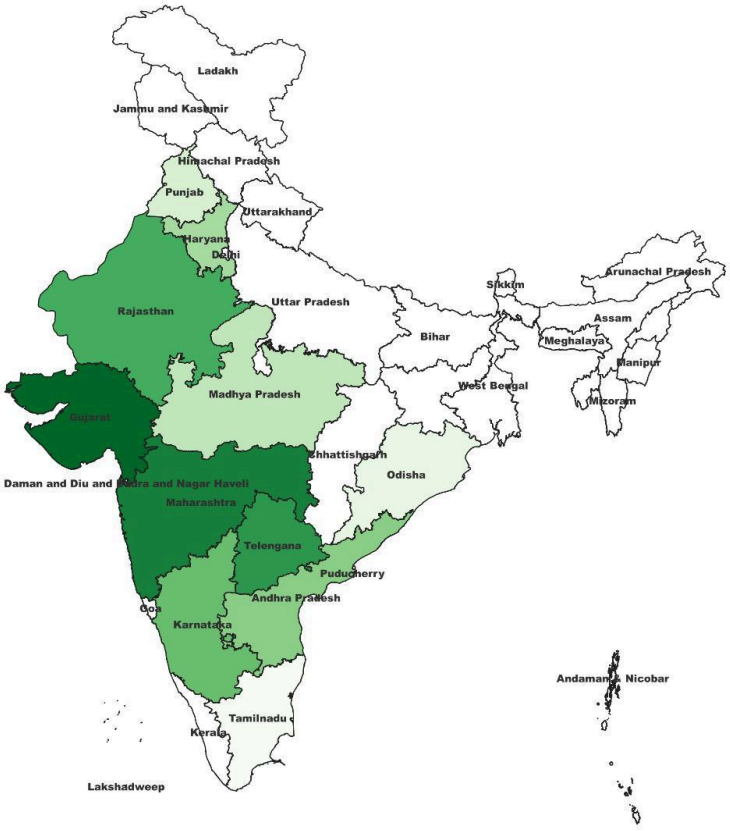
Annexure

Worksheet - 1

A. Study the map showing the top 10 Cotton Producing States of India.

Cotton Production (Lakh Bales)

Tamil Nadu	1.870
Odisha	6.820
Madhya Pradesh	9.220
Punjab	15.190
Haryana	17.210
Andhra Pradesh	17.850
Karnataka	21.040
Rajasthan	27.120
Telangana	53.250
Maharashtra	80.250
Gujarat	91.830
Others	0.26



1. Using the data for cotton production from the map, find the percentage of cotton produced by these 10 states.
2. Create a bar graph and a pie chart for the percentage of cotton production in different states of India.
3. Which graph is a better representation of the given data – bar graph or pie chart?

B. Study the table below carefully and answer the questions.

Table: The area under cotton cultivation and production in Lakh bales of cotton in the top 10 states of India.

State	Area under cotton cultivation in Lakh Hectares	Production in Lakh bales of 170 kg.

Punjab	2.84	11.5
Haryana	6.65	27
Rajasthan	4.96	22
Gujarat	27.09	92
Maharashtra	41.19	81
Madhya Pradesh	6.97	24
Telangana	17.94	53
Andhra Pradesh	5.51	20
Karnataka	5.75	18
Tamil Nadu	1.4	6
Odisha	1.58	4.5

Source: Cotton Advisory Board

Study the table carefully, and answer the following questions:

- Looking at the map, and area under cultivation in the table given above - does the state with the highest area has the highest area under cotton cultivation?
- What is the correlation between the area in lakh hectares and the production in lakh bales of cotton for the given states?
- Despite Maharashtra having a larger area under cotton cultivation compared to Gujarat, why does Gujarat still have higher cotton production than Maharashtra?
- Identify the state with the highest production-to-area ratio for cotton cultivation.
- Which state has disproportionately higher or lower production of cotton compared to its area under cultivation?

Worksheet - 2

Plant fibres are very commonly used in textile industries. Given below are some commonly used plant fibres. Research and find information about them and fill in the table.

Fibre	**Source of fibre**	**Plant part used for fibre**	**Characteristics**	**Uses**
Cotton				
Linen				
Hemp				
Jute				
Sisal				