The Science of Agriculture

A BIOLOGICAL APPROACH

5TH EDITION

RAY V. HERREN

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This book is dedicated to my mother, Ethel Herren.
She taught me from a very early age the value of an education.
Her philosophy, “Where there is a will, there is a way,”
set the foundation for all my achievements.

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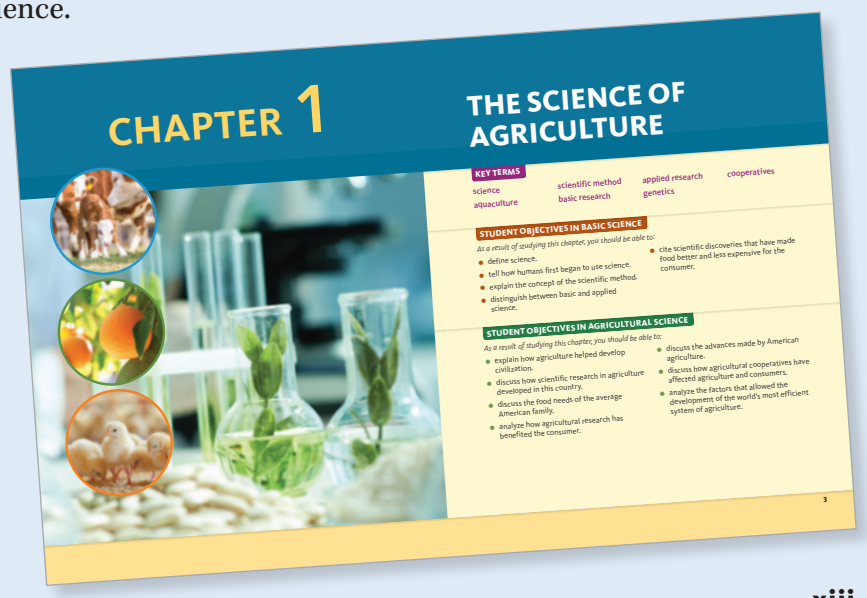
PREFACE

Constant change is a fact of our everyday lives. No segment of our society changes more rapidly than that of the sciences. In fact, it is *because* of the changes in science that many of the other changes in our lives occur. Perhaps the most sensational changes occur in the biological sciences. Our understanding of the life processes is continually expanding, and the rate of the understanding and change is increasing as new discoveries unlock the mysteries of life. All of the knowledge we have about biology has but three applications: medicine, ecology, and agriculture. By far, the widest application is that of agriculture. In fact, advances in medicine and ecology often come about as a result of agricultural research. *The Science of Agriculture: A Biological Approach* explains the scientific principles behind the production of food and fiber. All of modern agriculture is built on these principles, and it is through scientific inquiry that we progress.

Traditionally, agricultural texts have concentrated on the *how* of production. This text approaches the material from the *why* rather than the *how* perspective, allowing you to build and strengthen your understanding of agriculture as a science.

FEATURES OF THIS TEXT

- **Reader-friendly** narrative presents information in an interesting and engaging way
- **Full-color photos**, illustrations, and design bring key points to life and bridge the gap between the readings and real-world application.
- **Learning objectives**—one set for basic science and one set for


CHAPTER 1

THE SCIENCE OF AGRICULTURE

KEY TERMS

science
aquaculture
scientific method
basic research
applied research
genetics
cooperatives

STUDENT OBJECTIVES IN BASIC SCIENCE

As a result of studying this chapter, you should be able to:

- define science.
- tell how humans first began to use science.
- explain the concept of the scientific method.
- distinguish between basic and applied science.
- cite scientific discoveries that have made food better and less expensive for the consumer.

STUDENT OBJECTIVES IN AGRICULTURAL SCIENCE

As a result of studying this chapter, you should be able to:

- explain how agriculture helped develop civilization.
- discuss how scientific research in agriculture developed in this country.
- discuss the food needs of the average American family.
- analyze how agricultural research has benefitted the consumer.
- discuss the advances made by American agriculture.
- discuss how agricultural cooperatives have affected agriculture and consumers.
- analyze the factors that allowed the development of the world's most efficient system of agriculture.

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BIO BRIEF

Identifying Tiny Wasps

By Jan Suszkiw, Agricultural Research Service Information Staff; USDA, AgResearch Magazine, August 2015

Determining the identity of parasitic wasps—some measuring less than a millimeter long—can be a time-consuming process that includes comparing their features to descriptions in published works and disparate specimen collections. And correct identification is critical, as these parasitic wasps lay their eggs inside other insect species, killing the host insect in the process. As a result, these wasps are used extensively, worldwide, to control pest insect populations in agriculture.

Now, making such identifications could begin with the click of a mouse.

An international team of researchers, including a scientist from the Agricultural Research Service, has published a new, online document called a "monograph" that will make it easier to identify and study wasps belonging to a group called the "Cynipoidea." While these wasps are common worldwide, the monograph focuses on species from the Afrotropical region. This vast area, encompassing all of Africa south of the Sahara Desert, as well as the southern Arabian Peninsula, Madagascar, and surrounding islands, is ripe for entomological discovery.

The monograph uses pairs of interactive, image-based identification keys—including those of wing shape, body segmentation, and other characteristics—to help users navigate to the correct genus or species of the wasp of interest, along with available biological, geographic, and other information about the insect, including locations of existing specimens.

"These wasps are critical components of natural and agricultural ecosystems, attacking the larval stages of pest flies, such leaf-mining flies and fruit flies," says Matt Buffington, a team member and entomologist at the ARS Systematic Entomology Laboratory in Washington, D.C. "Within this monograph now published, for the first time, these wasps of agricultural importance will be reliably identified by researchers worldwide."

In the Afrotropical region, the superfamily Cynipoidea is represented by 306 described species and 54 genera, but there are hundreds more species yet to be described, adds Buffington, who coauthored a paper describing the monograph in the April 2015 issue of the Journal ZooKeys.

The resource, which brings together all that's currently known about the Afrotropical members of this wasp superfamily "under one roof," will make it easier to identify and categorize new species as they're discovered. It will also broaden scientific understanding of their taxonomic associations and biological diversity. One important use could be the identification of wasp species having potential as biological control agents, such as those that parasitize crop-damaging flies or that form galls in the tissues of invasive weeds in the United States.

Historically, the identification of cynipoid wasps has been rather piecemeal. Some specimens that were collected were not cross-checked with existing repositories of the wasps, or closely related species went ignored entirely, leading to a spotty taxonomic effort. So, Buffington and colleagues decided to pool their resources and expertise in conducting an exhaustive search and reexamination of specimens obtained from field sites and museum collections around the world.

"There are few regional keys to identification in the world that are useful, and we generated the first such key for the Afrotropical Region, with long-term plans to have keys such as these made available to other parts of the world over the next 10 years," said Buffington, who collaborated with Simon van Noort of the Natural History Department at the Iziko South African Museum and Mattias Forshage, with the Swedish Museum of Natural History.

The final product resulting from this long-term initiative will provide an unparalleled comprehensive identification resource to a diverse array of economically and agriculturally significant wasp, bee, and ant species in the Afrotropical region and elsewhere, adds van Noort. ■

This Diplazon wasp (about 2.5 millimeters long) is found worldwide. Source: USDA Agricultural Research Service (ARS) Photo by Stan Bechinski

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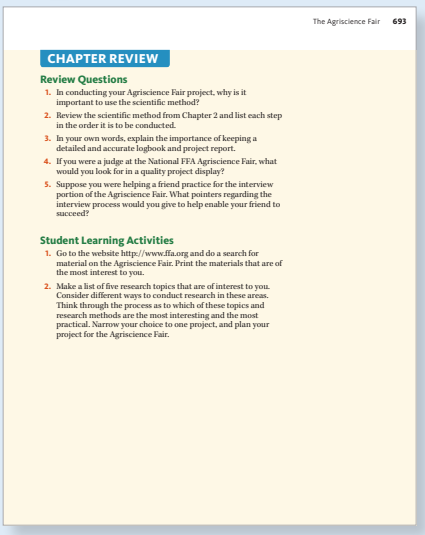

The Agriscience Fair 693

CHAPTER REVIEW

Review Questions

1. In conducting your Agriscience Fair project, why is it important to use the scientific method?
2. Review the scientific method from Chapter 2 and list each step in the order it is to be conducted.
3. In your own words, explain the importance of keeping a detailed and accurate logbook and project report.
4. If you were a judge at the National FFA Agriscience Fair, what would you look for in a quality project display?
5. Suppose you were helping a friend practice for the interview portion of the Agriscience Fair. What pointers regarding the interview process would you give to help enable your friend to succeed?

Student Learning Activities

1. Go to the website http://www.ffa.org and do a search for material on the Agriscience Fair. Print the materials that are of the most interest to you.
2. Make a list of five research topics that are of interest to you. Consider different ways to conduct research in these areas. Think through the process as to which of these topics and research methods are the most interesting and the most practical. Narrow your choice to one project, and plan your project for the Agriscience Fair.

agricultural science—open all applicable chapters and allow you to see the connection between the agriculture industry and the scientific concepts that uphold it and move it forward. Additionally, a successful understanding of these concepts can prepare you to receive a science credit for the course.

- ***Bio Brief* articles** are included in the chapters; these present actual scientific studies and discoveries that are happening throughout the world and that relate directly to what you are learning.
- ***Discussion Questions* and *Student Learning Activities*** encourage practical application of the content in each chapter.

NEW TO THIS EDITION

- Readings within each chapter are broken down further into smaller sections by new headings to help you easily learn new concepts and quickly locate specific topics
- All-new *Bio Briefs* reflect current news in the world of science and agriculture, placing a spotlight on exciting advancements in agriculture
- Current statistics reflect the latest U.S. and global trends in agriculture
- New, noteworthy topics, including:
  - histones, and their role in affecting genetic traits
  - quarantine measures for plant and animal diseases
  - no-till crops as a new method of cultivation for weed control
  - food labeling for consumer awareness
  - high pressure processing in food preservation
  - developing new foods through genetic engineering
  - fracking as a method for unlocking new sources of energy

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EXTENSIVE TEACHING/LEARNING PACKAGE

This supplement package was developed to achieve two goals:

1. To assist students in learning the essential information needed to continue their exploration into the exciting field of agriscience.
2. To assist instructors in planning and implementing their instructional program for the most efficient use of time and other resources.

COMPANION SITE

NEW! The Companion site to accompany ***The Science of Agriculture: A Biological Approach, 5th Edition*** features tools to support learning and facilitate teaching:

- *Answers to Review Questions* appearing at the end of each chapter allow teachers to track and validate student learning.
- *Answers to the Lab Manual* provide responses to the all the questions found in the exercises.
- *Lesson Plans* provide an outline of the key topics in each chapter, and correlate to the accompanying PowerPoint® presentations.
- *PowerPoint®* presentations align with the Lesson Plans and include photos and illustrations to visually reinforce the key points in each chapter.
- *Testing powered by Cognero,* a flexible online system, provides chapter-by chapter quizzes, and enables teachers to:
  - Author, edit, and manage test bank content from multiple sources
  - Create multiple test versions in an instant
  - Deliver tests from teacher/school-specific learning management system (LMS) or classrooms
- *Construction Plans*, including one for a greenhouse and another for an aquaculture unit, detail the construction of these units to provide a space for conducting research studies.
- *Developing Critical Career Skills* provides information on effective methods for cultivating leadership abilities, outlines specific technical, management, and teamwork skills required of a successful employee in the business, and offers advice on preparing for an interview.

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- *Image Gallery* offers full-color photos and illustrations from the text to enable teachers to further enhance classroom presentations.

For these instructor-specific resources, please visit CengageBrain.com at http://login.cengage.com and follow the prompts for obtaining access to this secure site.

LAB MANUAL

Thoroughly revised to align to the latest core curriculum math and science standards, the *Lab Manual to Accompany The Science of Agriculture: A Biological Approach, 5th Edition* provides engaging exercises, thought-provoking questions, and supporting information for the hands-on application experience in the lab environment.

MINDTAP FOR THE SCIENCE OF AGRICULTURE, 5E

NEW! The MindTap for ***The Science of Agriculture: A Biological Approach, 5th Edition*** features an integrated course offering a complete digital experience for the student and teacher. This MindTap is highly customizable and combines assignments, videos, interactivities, lab exercises, and quizzing along with the enhanced ebook to enable students to directly analyze and apply what they are learning and allow teachers to measure skills and outcomes with ease.

- **A Guide:** Relevant interactivities combined with prescribed readings, featured multimedia, and quizzing to evaluate progress will guide students from basic knowledge and comprehension to analysis and application.
- **Personalized Teaching:** Teachers are able to control course content—hiding, rearranging existing content, or adding and creating their own content to meet the needs of their specific program.
- **Promote Better Outcomes:** Through relevant and engaging content, assignments, and activities, students are able to build the confidence they need to ultimately lead them to success. Likewise, teachers are able to view analytics and reports that provide a snapshot of class progress, time in course, and engagement and completion rates.

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ABOUT THE AUTHOR

DR. RAY V. HERREN has been actively involved in agriculture for most of his life. He grew up on a diversified farm, where he played a major role in the production of livestock. He obtained a Bachelor of Science degree in Agricultural Education from Auburn University, a Master's degree in Agribusiness education from Alabama A & M, and a Doctorate in Vocational Education (with an emphasis in Agricultural Education) from Virginia Polytechnic Institute and State University. Dr. Herren has taught at Gaylesville High School, Virginia Tech, Oregon State University, and the University of Georgia in Athens, where he recently retired as head of the Department of Agriculture Leadership, Education, and Communication. In addition to serving as National President in the FFA Alumni organization, he has served on numerous committees from the local to international level, including a national task force to develop FFA programs for middle school and the National Committee for Career Development Events. His prolific scholarly activity includes 26 journal articles, 51 invited or refereed presentations, and 12 books and manuals. He has also earned several awards for his commitment to service, including induction into the Georgia Agricultural Teacher Hall of Fame and UGA's prestigious College of Education Outstanding Teaching Award.

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CHAPTER 1

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THE SCIENCE OF AGRICULTURE

KEY TERMS

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In modern times, science has rapidly changed the way we live. Just look around at all the new innovations that make our lives easier and more enjoyable. While all branches of science have made important impacts, the science of agriculture is the basis on which all civilization is built. Before humans began to devise ways to produce their own food, most of their lives were devoted to finding enough to eat (**Figure 1–1**). The only available food was the plants and animals that grew wild in the area. Hunting and gathering food was a process that was not only time-consuming but also prevented early humans from settling in one place. If a group of people stayed in one area very long, most of the wild game and wild plants that provided food would be exhausted. Because gathering food took so much time, these early humans had no time for such endeavors as building homes and cities, or even to develop inventions that might make their lives better.

The Basis of Civilization

The very first science was agriculture. **Science** is knowledge obtained through a systematic study of naturally occurring phenomena. The first systematic study by humans was probably devising ways to obtain food, clothing, and shelter.

The systematic study of anything begins with observation. Early humans likely began to notice that plants sprouted from seeds and that by putting seeds in the ground, they could make the seeds come up where they wanted them. They also observed where the edible plants grew and the environment surrounding the growing plants. They noticed the time of year when the seeds, nuts, and fruits matured and returned to that area to harvest. By further observing, they saw that the seeds had to be planted at the right time of year; the plants had to have water and sunlight; and they had to be protected from animals. These early humans probably noticed which plants grew bigger and better than others and used these for obtaining seeds.

Similarly, humans observed the way animals developed patterns in where they ate, slept, and moved. They noticed that some animals were not as wild as others and would tolerate the presence of humans. Rather than following the herds of animals, they began to raise the animals in captivity and to live in one place. This provided a ready supply of food that required less time than hunting.

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Figure 1–1 Early humans spent most of their time searching for food.

The Beginning of Agriculture

Most anthropologists agree that agriculture began about 10,000 years ago in what is now known as the Middle East. When humans began to grow their own food, they no longer needed to wander about in search of edible plants and animals. This allowed them to settle down in one place and to develop villages where they could live together as one society (**Figure 1–2**).

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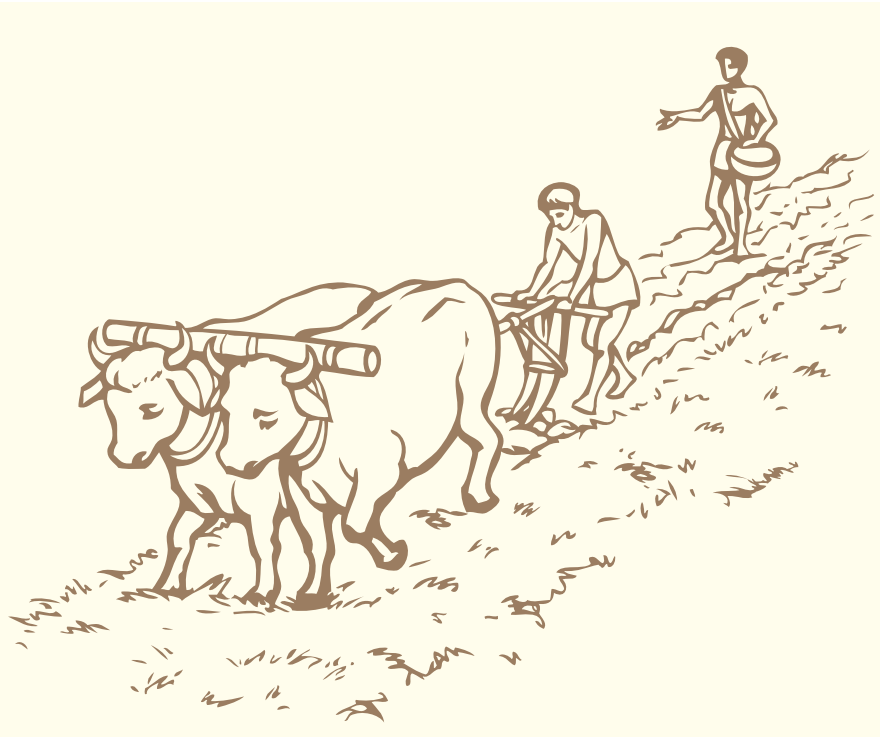

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Figure 1–2 Agriculture allowed people to settle down in one place and develop villages.

As humans grew more of their own plants and animals for food, they began to search for better ways to produce food. These ways were discovered through trial and error and passed down from parents to children. All modern agricultural crops and livestock were developed from the plants and animals tamed and cultured by early humans (**Figure 1–3**).

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Figure 1–3 All modern livestock was developed from animals tamed and cultured by early humans.

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As more efficient ways of growing plants and animals were developed, food could be produced in less time. As soon as people could supply enough to feed themselves and have some left over, the surplus food was traded to other people. Because food could be obtained through trading, time could then be spent developing skills in building, engineering, literature, and art that led to the great civilizations. When everyone had to find food every day, they had very little time and energy left to spend on inventions to improve their lives. Without the development of agriculture, humans would still be hunting and foraging for their food.

As people began to raise their own food, it became necessary to invent implements for opening the soil to plant seed or to dig out weeds. These first crude tools were made of wood or stone and later evolved into metal implements. The more tools people made, the more efficient they became at growing food. The more food people grew, the more time they had for inventing and making tools. After the technology was developed to make agricultural tools, humans discovered that these tools could also have other uses, such as carving stone for buildings or statues.

Some scientists think that counting and writing developed from agriculture. As people began to harvest crops and found that they had produced a surplus, ways to store the surplus had to be created and built. To indicate ownership, contents, and the amount in the containers, a system of marking had to be developed. As more and more containers needed to be marked, systems of written language developed (**Figure 1–4**). This allowed the expansion of trade and barter so that the excess food could be traded to other people.


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Figure 1–4 Some scientists think that counting and writing developed from agriculture.

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American Agriculture

When the first Europeans came to the New World, they found a system of agriculture already in existence. Native Americans in North America planted, cultivated, and harvested such crops as corn, squash, okra, and pumpkins. In Central and South America, civilizations such as the Incas, the Mayas, and the Aztecs had elaborate systems of fields and irrigation. They also developed tools of flint and wood to dig irrigation canals and drainage ditches and to plant, cultivate, and harvest crops. Their system of agriculture allowed them to feed their people and have enough time and energy to develop cities, roads, and works of art.

Historical accounts tell how Native Americans helped the settlers understand the methods used in the New World to produce food. Most of the Europeans who emigrated to America in the early years grew their own food. They learned from the Native Americans the plants and crops that grew best in the area, and also the techniques of planting, cultivating, and harvesting the crops. Until about 100 years ago, the vast majority of Americans were involved in growing crops and animals (**Figure 1–5**). Advancements in agriculture have increased production, allowing more people to leave the farm to pursue careers in other areas.

Modern American Agriculture

Today, the American agricultural system is the envy of the world. Each year this vast industry produces huge quantities of food and fiber (**Figure 1–6**). For example, annually we harvest about 881 billion pounds of grain, 91.2 million bales of cotton, and almost 48 billion pounds of chicken, 26.6 billion pounds of beef, 23.3 billion pounds of pork, and 11.3 billion eggs. A large portion of these products is shipped

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Figure 1–5 At one time the vast majority of Americans made their living through production agriculture.

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Figure 1–6 Annually we harvest about 68 million tons of wheat.

to other countries. We also import a lot of agricultural products such as fruit and vegetables that are produced in countries with growing seasons opposite from ours. This is why we can enjoy fresh grapes in January and cantaloupes year-round. According to the United States Department of Agriculture (USDA), one American farmer feeds more than 155 people. Not only do people in this country benefit from our agriculture, but much of the world is fed and clothed by American producers. Estimates are that of the more than 155 people each producer feeds, approximately half of them live in other countries.

Americans enjoy an abundance of food (**Figure 1–7**). According to the American Farm Bureau Federation, in one year the average American family consumes about 2.5 tons of food. Each of us consumes 196.9 pounds of flour and cereal products, 84.9 pounds of


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Figure 1–7 Americans enjoy an abundance of a wide array of foods.

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Figure 1–8 Americans spend a lower percentage of their income on food than citizens of any other country.

fats and oils, 20.7 gallons of beverage milk, 245 eggs, 116.9 pounds of red meat, 20.5 pounds of rice, 32.7 pounds of cheese, 73.7 pounds of poultry, 415 pounds of vegetables, and 202.2 pounds of fruit. If you multiply this by the number of people in the United States, it adds up to a tremendous amount of farm production!

Not only do Americans have a lot of food, but they can buy it at a relatively low cost (**Figure 1–8**). In fact, Americans spend a lower percent of their income on food than citizens of any other country in the world. People in many countries spend the bulk of their income on food. Even in advanced countries people may spend half of their paychecks at the grocery store. In the United States, the average family spends only 9.3 percent of its income for food. This compares with 11.5 percent in France, 25.7 percent in Italy, 14 percent in Japan, 34.3 percent in Venezuela, and 53.1 percent in India.

The American agricultural industry is the most efficient the world has ever seen. No one in the world can come even close to matching the United States in the power of our total agricultural output. This powerful, efficient system has evolved due to three basic reasons: climate and soil, the economic system, and scientific research.

The Climate and Soil

Crops and livestock are grown in all 50 states. Climate and soil conditions vary widely across the country, and this allows the cultivation of a tremendous variety of crops and animals. More than 200 different commodities are produced by American farmers, and this does not include some of the highly specialized crops. American agriculture produces such familiar crops as cotton, corn, soybeans, wheat, rice, apples, citrus fruits, green beans, grapes, and cherries. Think of all the sugar beets grown to sweeten our food or the mint grown to flavor our chewing gum. Thousands of acres of flowers are produced to brighten our lives (**Figure 1–9**). No other country in the world grows such a wide variety of agricultural products.

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