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Potato Production Systems

Springer

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Preface

There have been significant technological advancements in potato production in recent years that have remarkably improved potato yields in North America and throughout the world. However, substantial increases in transportation, fuel, fertilizer, pesticide, and processing costs, as well as changing consumer preferences, have created an even greater need for information that can be used to improve potato production efficiency and sustainability. The successful development and implementation of sustainable potato production systems requires the integration of a wide array of cultural and pest management practices that are well adapted to local environments. This is a process that is both challenging and rewarding, given the importance of the potato crop in the world's food systems.

With this goal in mind, we have endeavored to bring together the latest information on the science and practice of potato production with emphasis on North American production systems. Obviously, management recommendations vary across production regions and environments, and it is not practical to include all of them in a single book. However, we have tried to present representative management approaches that have broad application across the major production regions in North America, which, in turn, can be adapted to local production environments.

The second edition of *Potato Production Systems* represents the combined efforts of over 39 potato scientists from the USA and Canada. We have endeavored to make this new edition as comprehensive as possible, covering all aspects of potato production from field preparation, varietal selection, seed production, and planting, through pest management, fertilization, irrigation, harvesting, and storage. There are chapters focusing specifically on disease, nematode, weed, and insect management, as well as chapters on marketing and economics.

The editors express their appreciation to all of those who contributed information, insight, and images to this effort. This book would not have been possible without their participation.

We also thank Barbara Gronstrom-Smith for the outstanding job she did reviewing and editing this book and helping us manage the many details associated with its development. Her advice, guidance, and support have made an immeasurable contribution to the success of this effort.

For those seeking more information on potato production systems, we have included suggestions for further reading for most chapters at the end of the book.

Idaho Falls, ID, USA Jeffrey C. Stark
Parma, ID, USA Mike Thornton
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Contents

1 **A Short History of Potato Production Systems** 1
Stephen L. Love, Kurt Manrique-Klinge, Jeffrey C. Stark, and Edgar Quispe-Mamani

2 **Potato Growth and Development**. 19
Mike Thornton

3 **Variety Selection and Management**. 35
Jeffrey C. Stark, Asunta (Susie) L. Thompson, Richard Novy, and Stephen L. Love

4 **Seed Potato Production and Certification** 65
Alan Westra, Phillip Nolte, Jonathan L. Whitworth, and Jenny Durrin

5 **Field Selection, Crop Rotations, and Soil Management** 87
Jeffrey C. Stark and Mike Thornton

6 **Organic Potato Production**. 101
Amber Moore, Dan M. Sullivan, Nora Olsen, Pamela J. S. Hutchinson, Phillip Wharton, and Erik J. Wenninger

7 **Seed and Planting Management** 135
Phillip Nolte, Nora Olsen, William H. Bohl, and Stephen L. Love

8 **Nutrient Management** 155
Bryan G. Hopkins, Jeffrey C. Stark, and Keith A. Kelling

9 **Disease Management** 203
Phillip Nolte, Jeff Miller, Kasia M. Duellman, Amanda J. Gevens, and Eugenia Banks

10 **Nematode Management** 259
Saad L. Hafez, Sundararaj Palanisamy, and Ann E. MacGuidwin

11 Insect Pests and Their Management 283
Erik J. Wenninger, Arash Rashed, Silvia I. Rondon, Andrei Alyokhin, and Juan Manuel Alvarez

12 Weed Management 347
Pamela J. S. Hutchinson

13 Potato Irrigation Management 417
Bradley A. King, Jeffrey C. Stark, and Howard Neibling

14 Physiological Disorders 447
Mike Thornton, Nora Olsen, and Xi Liang

15 Tuber Quality 479
Jeffrey C. Stark, Stephen L. Love, and N. Richard Knowles

16 Harvest Management 499
Mike Thornton, Pamela J. S. Hutchinson, and Nora Olsen

17 Storage Management 523
Nora Olsen and Gale Kleinkopf

18 Principles of Economics and Marketing 547
Joseph F. Guenthner

19 Cost of Production 573
Paul E. Patterson and Ben Eborn

20 Potato Nutrition 595
Martha A. Raidl

Further Reading 607

Index 619

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Mike Thornton is a professor of plant science working on potatoes for the University of Idaho at the Parma Research and Extension Center. His research program focuses on sustainable production of new varieties, management of in-season pest problems, and reduction of losses during storage. He has worked closely with key influencers in the potato industry (growers, commodity commissions, and processors) to document and address the most important issues they face. Mike has over 35 years' experience in the potato industry in North America and has worked both in academia and industry. This allows him to see problems from several perspectives and develop effective research and extension programs.

Phillip Nolte is an extension seed potato specialist, University of Idaho (emeritus). His programs not only focused on seed potatoes but also included seed-related problems in commercial production and general potato disease diagnosis and management. His areas of study included investigations on the potato mosaic virus complex (PVY and PVA), management of potato late blight, fungicide resistance studies in Fusarium dry rot, and the effect of chemical application on wound healing (suberization) in cut seed. He served as the technical editor for *Potato Grower* magazine and as a contributing editor for *American Vegetable Grower* magazine. He was also president of The Potato Association of America 2009–2010. He began working on potatoes in 1979.

Chapter 1
A Short History of Potato Production Systems

Stephen L. Love, Kurt Manrique-Klinge, Jeffrey C. Stark, and Edgar Quispe-Mamani

Contents

Introduction 2
History 2
Production Principles 8
Crop Rotation 8
Soil Fertility 8
Soil Preparation 8
Irrigation 8
Hilling 9
Cultivar Improvement and Selection 10
Seed Management 11
Pest Control 11
Harvest 12
Storage 12
Processing 12
Exchange 14
References 17

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Introduction

In the early 1500s when Spanish explorers stepped onto the continent of South America, they discovered a civilization consisting of 10 million people spread along 2000 miles of the Andes. They also discovered that this relatively advanced culture subsisted largely on a previously unknown crop that came to be known as the potato. Far beyond being just something to eat, explorers recorded that potatoes infused every aspect of Andean culture. This crop was incorporated into many local creation myths, served a central role in religious rites, became a common subject of artwork, and was central in daily and seasonal rituals. Over an undefined period of history, potato production in the Andes evolved in sophistication and productivity. Thousands of years before this crop became a staple in Europe, the Andean culture had developed a complex, efficient potato production system. All aspects of what we commonly assume are modern agricultural principles were addressed within this system: crop rotation, soil fertility, soil preparation, irrigation, cultivar improvement, seed management, pest control, judicious harvest protocols, long-term storage, production of processed products, and complex marketing schemes. Evidence suggests that efficacious potato production gave rise to the Incan Empire and vastly improved quality of life for its citizens. As modern producers consider options for improving potato production practices, comparison of ancient Andean potato production methodologies may be both enlightening and constructive.

History

Spanish conquerors traveling into the Andean highlands in the early 1500s recorded observations about the production and consumption of a previously unknown crop, the potato (Fig. 1.1). Chronicler Pedro Cieza de León wrote, "Of the natural resources that the Indians use for sustenance, apart from corn, there are two principle foodstuffs; one of these is called the potato, which is somewhat like a truffle, yet after cooking it becomes soft on the inside like a roasted chestnut; like a truffle, it does not have a shell or bone, because it grows beneath the earth." At the time, Spaniards were not particularly impressed with this lowly underground crop. Little did they know that potatoes would become vastly more important to world economics than the tons of gold they transported out of South America. Writing about the potato in Scotland during the 1700s, Thomas Garnett claimed that, "…this useful root, for which we are indebted to America,… is more valuable than all the gold of Mexico, all the diamonds of Golconda, or all the tea of China."

When the first Spanish explorers stepped onto the South American continent, the Inca Empire comprised 10 million people and was spread along 2000 miles of the Andes Mountains. This Empire was a complex culture that incorporated extensive trade and incredible advancements in agriculture, music and the arts, mathematics, and medicine. Potatoes were central to the food security of the region, and many historians express the opinion that this vast and sophisticated Inca Empire was

Fig. 1.1 High-elevation Andean agriculture in Ayacucho, Peru, in the region where potato production had its beginnings. This modern scene is little changed from the terraced agricultural systems discovered by the Spanish conquerors. (Photo credit: Kurt Manrique-Klinge)

raised on the back of this humble crop. Adoption of potato agriculture ensured a constant supply of nutrient-rich food that could be produced on relatively small amounts of land, while giving people time and energy to pursue other interests. It was the primary source of nutrition for noblemen and peasants alike. Freeze-dried potatoes, known as chuño, provided sustenance during times of famine and were the food of choice for mobile Incan armies.

Far beyond being just something to eat, potatoes made their way into every aspect of Andean culture. They were incorporated into many local creation myths, served a central role in religious rites, became the subject of artwork (Fig. 1.2), and were integrated into many of the activities of everyday life. According to Incan lore, the universe was divided into three worlds: the upper world (Hanan Pacha) inhabited by the primary gods such as the sun, moon, stars, lightning, and the rainbow; the underworld (Uku Pacha) inhabited by death, spirits, diseases, and minor Gods, such as Huatiacuri (personification of the potato); and the world that makes up the zone of life (Kay Pacha) where men, animals, and plants exist. These three worlds coexist and their natural and spiritual entities interact. The potato belongs to Uku Pacha because it grows and lives in darkness beneath earth. Huatiacuri was a lowly God in that he lived below the Earth's surface, wore ragged clothes, and was covered with dirt and purple flowers. Yet, he possessed the hidden power to protect the entire Incan universe. The Andean culture celebrated ceremonies to mitigate the Gods, including Huatiacuri, where an early potato planting was completed in late August to awaken the Uku Pacha. At harvest, if double or coalescent tubers were found, they were kept and revered as a sign of fertility and a profitable future. Such was the reverence Andean cultures had for the potato.

Fig. 1.2 An Andean pottery artifact, approximately 2000 years old, modeled after a potato tuber. (Photo credit: Stephen Love)

Fig. 1.3 Homes amidst agricultural terraces on the Island of Taquile in Lake Titicaca. This region is the proposed center of origin and earliest known site of potato production. (Photo credit: Stephen Love)

Based on evidence from modern genetic studies, it is now accepted that the center of origin and site of domestication of potatoes is the high Altiplano region (11,000–13,000 ft. elevation) of Peru near Lake Titicaca (Fig. 1.3). Recent archeological evidence suggests a history of potato production and use in this area that dates back at least 7000, and possibly as many as 13,000, years. Rich genetic resources, in the form of wild relatives, are common in the region. Native cultures took advantage of these resources and began a process of adapting these naturally occurring species into something of greater societal value. As the value of potatoes increased, the amount of effort dedicated to their improvement also grew. The rich local gene pool, derived primarily from eight local species of the genus *Solanum*, evolved into over 4000 unique, locally produced potato cultivars. The incredible diversity infused into this crop can still be observed as a kaleidoscope of colors and multitude of shapes found in any modern Peruvian marketplace. Conservationist Andean farmers in Peru hold a collection of potato cultivars estimated at more than 2800 native landraces. The International Potato Center (CIP) preserves the world potato collection with almost 5000 cultivars.

Indigenous people in the Andes continue to maintain a close relationship with potato genetic diversity. Stephen Brush, professor at the University of California at Davis, wrote that in a single valley in the Peruvian Andes, peasant communities may grow between 70 and 100 distinct potato cultivars, and a typical Andean household may keep up to 50 cultivars from several potato species for home consumption and eventual exchange (Brush et al. 1990) (Fig. 1.4). This diversity contributes to potato

Fig. 1.4 Potato harvest in the uplands of Peru, with an example in the foreground of the diversity of potato cultivars grown on this farm. (Photo credit: Kurt Manrique-Klinge)

Fig. 1.5 Artwork of the native Peruvian chronicler, Guaman Poma, depicting the practice of planting potatoes as recorded in the year 1615. (Public domain image from Wikimedia Commons)

utilization by providing adaptation to a wide range of production conditions and conversion to a wide range of culinary uses, although most of these native potato cultivars are conditioned to grow in the high Andes and don't adapt easily to areas of lower elevation.

Sixteenth century drawings created by Guaman Poma, a native Peruvian chronicler, depict scenes of potato production systems and technology developed by the Incas (Figs. 1.5 and 1.6). In many regions, Andean potato production has changed very little in the intervening years. From a modern point of view, both historical and current methods superficially appear primitive. On closer inspection, it becomes clear that the culture that contributed the potato to the human family also developed many of the productions systems used in modern agriculture. Ancient Andean

Fig. 1.6 Artwork of the native Peruvian chronicler, Guaman Poma, depicting the practice of harvesting potatoes as recorded in the year 1615. (Public domain image from Wikimedia Commons)

potato growers understood their environment, the demands of the crop, and the available resources. They also learned to use these factors to their advantage. A closer look will reveal how sophisticated Andean potato production systems became prior to the destruction that accompanied the Spanish intervention.

The one thing early Andean potato producers lacked, and often still lack, is a source of inexpensive energy. As a result, hand labor substituted for the mechanical aids that have become synonymous with modern potato production. If we look past this one element of agricultural advancement, the sophistication of Andean production systems becomes much more evident. For example, below are some of the production principles developed by primitive Andean potato growers.

Production Principles

Crop Rotation

Although lacking an understanding of the biological imperatives for crop rotation practices, the necessity of proper farm management was fully accepted. A typical crop rotation for highland-grown potatoes was 1 year of potatoes; 1 year of another endemic root crop, such as isaño, oca, olluco, maca, or mashua; 1 year of the grain crop quinoa, maize, or kiwicha; followed by 2–9 years of fallow, depending on personal need or market demand.

Soil Fertility

Without modern fertilizer products, many primitive cultures worldwide relied on the use of legume-based green manures to manage soil fertility and replace nutrients lost with crop removal. Lacking even this resource, Andean growers developed unique procedures that included pasturing animals on fallow ground to provide manure, adding additional manure taken from animal enclosures, burning weeds and plant refuse on the fields to provide phosphorus and potassium, and adding nutrient-rich bog soils to their fields. In coastal areas, fertility practices included the burial of fish carcasses near plants and application of *guano*, which is the dried remains of birds' semisolid urine. It makes an excellent fertilizer, a mechanism for giving plants nitrogen.

Soil Preparation

One of the greatest agricultural achievements of Andean farmers was the development of extensive terracing systems that not only allowed production on steep land, but also alleviated erosion and permitted water capture. Additionally, proper seedbed preparation was understood and practiced. Rather than using a modern moldboard plow or ripper, ancient Peruvians used a foot plow (*chakitaqlla*), and rather than a harrow, they used a hand-held clodbuster (*waqtana*). Regardless, the result was a mellow, aerated planting medium (Fig. 1.7).

Irrigation

Prior to the Spanish invasion, Andean farmers in sloped regions built the amazing *qocha* (reservoir) irrigation systems consisting of channels, aqueducts, and cisterns to deliver and store rainwater for use in their terraced fields. Most of these delivery

Fig. 1.7 Peruvian farmer on the Island of Taquile plowing a field with a traditional foot plow (*chakitaqlla*) in preparation for planting potatoes. (Photo credit: Stephen Love)

systems were destroyed by the Spaniards, and only a small portion of them have been restored to full function. We are just now beginning to understand the incredible ingenuity behind these systems. To meet a different set of conditions in the flat, lowland areas around Lake Titicaca, the *waru-waru* irrigation system was developed. Long beds, 10 or more ft. wide, were raised above the natural ground level by excavating adjacent soil. Due to a high water table, the result was a series of mounded planting beds interspersed with water channels up to 4-ft deep. The channels served not only to provide water during dry periods through soil wicking, but also helped drain excess water after heavy storms, served as a source of nutrient-rich silt, and eliminated or reduced frost damage by serving as a heat reservoir. Additionally, the channels were often used to farm fish.

Hilling

Ancient Andean farmers developed methods for row planting and hilling for potatoes very similar to what is used in modern production (Fig. 1.8). The primary objective was to improve soil drainage and keep the tubers from becoming water logged. Further, they also recognized soil temperature advantages that result from furrow orientation. Farmers living in drier regions pushed up small hills, hoping to conserve water. Those living in areas with greater rainfall or high water tables

Fig. 1.8 Potatoes near Huancayo, Peru, planted in a linear hill arrangement to provide appropriate drainage. (Photo credit: Jeffrey Stark)

pushed up very high hills, sometimes creating furrows up to 2-ft deep, to drain excess water from the fields.

Cultivar Improvement and Selection

Farming in a period prior to the advent of modern breeding did not prevent Andean farmers from taking advantage of genetic diversity. Each farm served as an on-going experimental cultivar evaluation site. At the end of every season, each grower, often in consultation with local residents, reviewed the performance of each cultivar and determined which ones to grow the following year. In antiquity, cultivar choice was closely related to culinary use, and Peruvian farmers developed classes of potatoes for very specific purposes. They created *chaucha* for early fresh table use; *hatum* for main crop fresh table use; *siri*, a bitter potato used for making chuño; *moraya* for making tunta; and cultivars intended solely for boiling or baking. Beyond local selection of landraces, there is evidence Incan "scientists" (known as *amautas*) devised evaluation procedures to improve potatoes. John Earls, in a study published in 1998, concluded that concentric terraces at an archeological site in Moray served as an experimental center for improving crop production on the Inca state terraces (Fig. 1.9). One line of thought is that the site was used to acclimatize crops to new eco-climatic conditions and create new cultivars and sub-cultivars of adapted crops (Earls 1998).

Fig. 1.9 Archeological site near Moray, Peru, showing the concentric ring terraces thought to be an Incan agronomic research site. (Photo credit: Kurt Manrique-Klinge)

Seed Management

Although lacking complex seed certification procedures, Andean potato farmers understood the need for high-quality seed. At the end of each growing season, before consuming or selling the crop, they selected the best tubers from the previous crop to serve as seed for the subsequent year. Seed tubers were stored carefully and strictly reserved for production the following year.

Pest Control

It cannot be argued that advancements in insect and disease management are mostly modern. However, ancient Andean producers recognized pest issues and developed more or less effective management strategies. The most important approach was to mix and grow multiple cultivars with a range of resistance responses to ensure that infestation by a destructive insect or disease pest would not destroy an entire crop. The unique practice of encouraging frogs to live and proliferate in fields was used to control the destructive tuber worm by their consumption of adult moths. In storage, the Incas utilized the deterrent effect of certain Andean herbs; e.g., muña

(*Minthostachis mollis*) and aya manchana (*Lantana camara*) that have active, fragrant essential oils to deter damaging insects.

Harvest

Rather than using a six-row, self-propelled mechanical harvester, Andean farmers historically (and many still do) used manual labor and the native version of the mattock (raucana) to harvest potatoes. Regardless of tools, they understood principles and developed practices to optimize maturity and reduce handling injury.

Storage

Ground storage (simply leaving the potatoes in the ground during the dry season) was possible and often practiced in the climatic conditions of the high Andes where cool conditions prevailed but ground frost was rare. However, more sophisticated storage facilities were commonly built and utilized. Ancient potato cellars found in Huanuco Pampa provide an example of the astounding storage technology of the Inca civilization. Control of storage temperature was accomplished by manipulating three factors in the storage environment: ventilation, insulation, and the selection of adequate warehouse locations. Morris and Thompson (1985) described these ancient buildings as being located in cool locations at the top of cliffs and mountains. They were built with thick walls and thatched roofs to insulate against heat during warm days and excessive cold at night. Ventilation was provided either by construction of windows placed on opposite sides of the storage or by construction of crevices in the stone floors connected to the outside by ducts or vents (Fig. 1.10).

Processing

Andean potato farmers developed a range of useful, and more importantly, storable, potato products (Fig. 1.11). The most widespread and important of the processed products was—and still is—chuño. Ancient growers took advantage of natural climatic conditions of the high mountainous regions to produce a natural lyophylization process. Chuño was made by placing dark-skinned, bitter, small potatoes in a single layer on the ground and allowing them to alternately freeze at night and thaw during the day. As the potatoes began to weep, people walked on them to press out the moisture. Within a few weeks, the potatoes were completely freeze-dried (the first dehydrated potato products). Another freeze-dried product, *tunta*, was made using a more complex procedure. Potatoes tubers were spread out on the ground to freeze but covered during the day to keep them in the dark. After 2 days of alternate freezing and drying, the tubers were immersed in frequently changed water for 6–8 weeks and ultimately dried to create a product that retained its bright white

Fig. 1.10 Ruins of an ancient Peruvian potato storage building located near the top of a steep slope where climatic conditions are cool. (Photo credit: Kurt Manrique-Klinge)

Fig. 1.11 Examples of freeze-dried potato processing products known as chuño (left) and tunta (right). (Photo credit: Stephen Love)

color. Anciently, *tunta*, also referred to as *moraya*, was considered to be a superior product and was made specifically for nobility. Another processed product, called tocosh (CIP 2003), was made by soaking freshly harvested tubers until they fermented, then drying the softened tubers in the sun. Tocosh is still produced and utilized nowadays as a natural antibiotic because penicillin is produced during the fermentation process. Simply drying pre-baked tubers was also a common practice. Processing supplied food through the dry season, during times of famine and war, and in cases of crop failures.

Exchange

The majority of potatoes grown by Andean farmers was used for subsistence or for paying homage to nobility. The Incas didn't know the concept of money; however, they had a good understanding of food availability for social welfare. Therefore, barter was a common practice among regions and communities to exchange a diversity of food products. Food distribution in the Inca Empire was a mandatory cooperative system based on community work (*ayni, minka*) and on work dedicated to the Inca state terraces and fields (*mita*). This system, still practiced by native communities, ensured that every subject in the empire (including elderly and ill people, children, widows, and the disabled) received sufficient food. Thus, famine never occurred at that time.

As people began to understand the value of potatoes, they spread throughout the world. Initially, they were adopted into the cultures of nearby regions of South America, then into Central America and Mexico. We used to think this was the limit of potato dissemination, until European explorers took them across the Atlantic. However, more recent evidence suggests a much wider ancient distribution. People of the Navajo Nation in the southwestern U.S. still occasionally cultivate and eat tubers from a naturalized species. This is obviously not a part of European potato succession. One tribe of Native Americans in Alaska retains two very old cultivars accompanied by traditions that one came from South America and the other from Hawaii. The Maori of New Zealand claim to have grown potatoes long before the arrival of the first European explorers.

The potato began its journey into the old world as Spanish explorers returned home with the spoils of war. There is still some argument as to when potatoes made their way into Europe, but we have record of a shipment of potatoes from the Canary Islands into most likely Belgium around 1567, suggesting production on the islands began several years earlier. We have written records of potatoes being present in Spain by 1570 and England by 1580.

For many years, the European populace failed to see the value in potatoes, and they were usually collected and transported as botanical oddities rather than foodstuffs. They did not become economically and nutritionally important for almost two additional centuries. People were suspicious of any plant from the generally poisonous nightshade family and were put off by something that came out of the dirt. However, potatoes had their occasional supporters among the European elite. In 1586, Diego Dávila Briceño, a Spanish official living in Huarochiri, Peru, wrote that, "…if in our Spain, these [potatoes] were to be grown as they are here, they would be a great solution in the years of famine." Over time, this opinion was held by nobility and common folk alike, but only after time broke down the barriers of neglect. After adoption by nobility in France, followed by a rapid shift in public image, the potato became a staple of European diets. This had an immediate impact on many cultures, as potato crops provided greater food security and better nutrition. Since then, the potato crop has saved the lives of millions around the world during times of human tragedies and natural disasters. After WWII refugees and

Fig. 1.12 Post-WWII refugees planting potatoes as a subsistence crop. (Public domain image from Wikimedia Commons)

displaced populations in Europe depended on the potato to survive (Fig. 1.12). This enabled populations to increase, and people found more time for activities beyond basic survival.

The influence of potatoes went far beyond simple nutrition; it changed cultures and shifted world politics, as evidenced by the potato famine of Ireland. The introduction of late blight, a devastating disease of potatoes, combined with an unstable political situation, led to mass starvation and upheaval. One million Irish residents died of starvation, and another 2 million migrated to other countries during this devastating period in 1852; the majority to the U.S. On the positive side, the potato is often credited with advancing the industrial revolution. It is currently grown in at least 148 countries, more than any other crop, except corn. It is the fourth most important food crop worldwide. It is a critical nutrient and energy source in nearly every temperate country, has been adapted to the highlands of the tropics, and most recently has been found to be a suitable crop for the dry season in tropical lowlands.

As potatoes made their way around the world, the knowledge concerning production systems followed. Soil preparation, fertility management, seed management, and hilling practices developed by the ancient Andean farmers were, for the most part, duplicated. But some important practical management differences emerged. Rather than using genetic diversity to manage pests and environmental issues, single cultivars were grown. Individual fields became larger. Crop rotations were shortened or eliminated. Many of these practices have been retained in the modern era. The consequence is a need for more intensive practices to manage pests

Fig. 1.13 Early generation tractor and single row potato harvester. (Public domain image from Wikimedia Commons)

and problems. Widespread devastation caused by late blight and subsequently the Colorado potato beetle led to the evolution of the modern crop protection industry. The industrial revolution led to the design and manufacture of equipment that mechanized many of the drudgery aspects of potato production. The discovery of fossil fuels and the combustion engine provided the power to operate these mechanical wonders (Figs. 1.13 and 1.14). Farms grew in size and complexity. Agriculture, in general, and potato production in particular, quickly changed.

And the end is not in sight. As time passes, potato growers will be required to adapt to new situations and challenges, such as climate change. Imminent concerns include the loss of fertilizers and protection products as a result of ever-increasing concern over safety and environmental issues. As temperature increases, water supply will become more and more limited. Improved, but very different, potato cultivars will become major components of production. Market specifications will become more stringent. The need for fiscal sustainability will dictate that farming operations become even larger and more intensely managed. Problems we have not yet encountered will become significant barriers to profitable production. Advancements in our understanding of basic agricultural principles will produce new tools, but only for those with the knowledge to use them.

The purpose of this book is to detail the current status of potato production science and technology. It will serve as an educational tool to help producers, consultants, educators, students, and anyone else involved in making efficacious potato production decisions. As the production environment rapidly evolves, finding balance on the cusp of potato science will be critical to its continued success. But as things change, they, in many ways, remain the same. Just like our Andean forefarmers, success will come as we gain understanding of our environment, the demands of the crop, and the available resources. We then must learn to use these factors to

Fig. 1.14 Modern four-row potato harvester. (Photo credit: William Bohl)

our advantage. The details will change, the tools will evolve, but the overarching principles will remain the same.

Acknowledgement Unless otherwise noted, photographs, graphics, and data were adapted from collections of University of Idaho Extension educators, scientists, and researchers, who wrote the chapters of the first edition of this textbook.

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Chapter 2
Potato Growth and Development

Mike Thornton

Contents

Introduction.... 19
Characteristics.... 19
  Below-Ground Structures.... 21
  Above-Ground Structures.... 23
  Growth Stages.... 25
  Growth Habit.... 30
  Impact of Management at Each Growth Stage.... 31
References.... 33

Introduction

This chapter describes the somewhat unique characteristics, structures, and growth patterns of the potato plant and is designed to enhance the understanding of management strategies described in later chapters

Characteristics

The potato plant is distinct among major food crops in that it is almost always propagated by planting whole or cut pieces of the tuber (i.e., seed pieces) instead of true seeds. This form of propagation is called "vegetative." Vegetative propagation means that new growth must arise from axial buds (commonly called the "eyes"), as opposed to a fully formed embryo as occurs with seeded crops. As a result, potato crops often emerge slower than seeded crops, but subsequent development is faster due to the relatively large energy reserves contained within the seed piece in the form of carbohydrates.

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Sidebar 2.1: The Potato Fruit

Most commercial potato varieties will drop their flowers after a few days. However, under proper environmental conditions, flowers can pollinate and develop into a mature fruit or seed ball (Fig. 2.1). These fruits look like small, green tomatoes, and they can develop tiny seeds that are about one-fourth the size of tomato seeds (Fig. 2.2). Under field conditions, these fruits are rarely seen on varieties such as Russet Burbank, but occasionally a few plants will form potato fruits.

Fig. 2.1 Potato fruit resembles small, green tomatoes

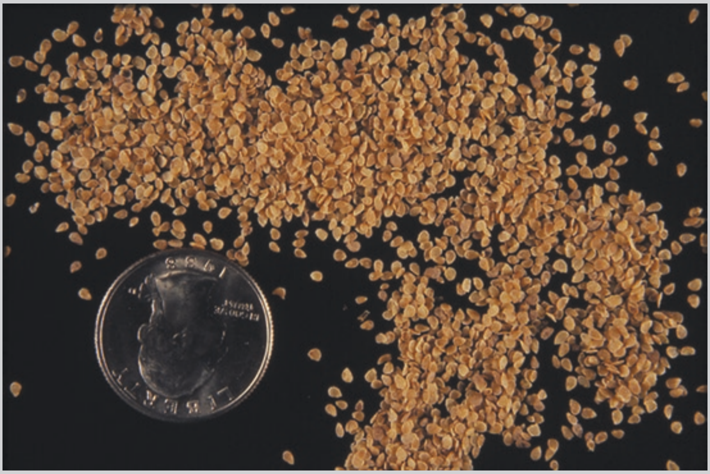

Fig. 2.2 True potato seed is small and similar in size to tomato seed

Each seed inside of a potato fruit is genetically different, and each seed is potentially a new potato variety. Potato breeders use these fruits to produce new varieties, and they're often frustrated when the flowers drop before they can be pollinated. To improve the retention of flowers, potato breeders spray the plants at flowering time with a plant hormone called gibberellic acid, which improves fruit set. Another frustration for the potato breeder is that some varieties, such as Russet Burbank, are male sterile, meaning that they do not produce useable pollen. As a result, the Russet Burbank variety can be used only as a female parent for genetic crosses.

Potatoes also produce a fruit that contains true seeds that can be used in propagation. See Sidebar 2.1. However, each seed is genetically unique, and tubers produced from true-seeded crops are not uniform enough to meet requirements of most markets. However, breeding of new varieties relies on this genetic variation to introduce new traits.

Below-Ground Structures

Sprouts

The first visible growth after seed pieces are planted is a swelling in the axial nodes, or eyes. These structures are called "sprouts," and consist of stem tissue and meristems where growth occurs. Under dark conditions the sprouts elongate until light is reached, then leaves form. When sprouts begin to grow while exposed to light, they generally form short stems with leaves.

Roots

Root development begins shortly after sprouting in the nodes that develop above the seed piece. Potatoes have a relatively shallow, sparse root system, with up to 70% of the root system developing in the upper 12 in. of soil. Compared to sugar beets and cereal crops, potatoes produce 25–50% less total root length, and the root system contains a smaller portion of root hairs. This has major consequences in terms of managing nutrients and soil moisture, as outlined in Chaps. 8 and 13.

Stolons

Stolons are modified stems that grow horizontally. Within the first 3 weeks after emergence, plants will generally begin producing stolons at the underground nodes above the seed piece. A common cultural practice with potatoes is the process of "hilling" or mounding soil at the base of the plants so that stolons will form underground. In

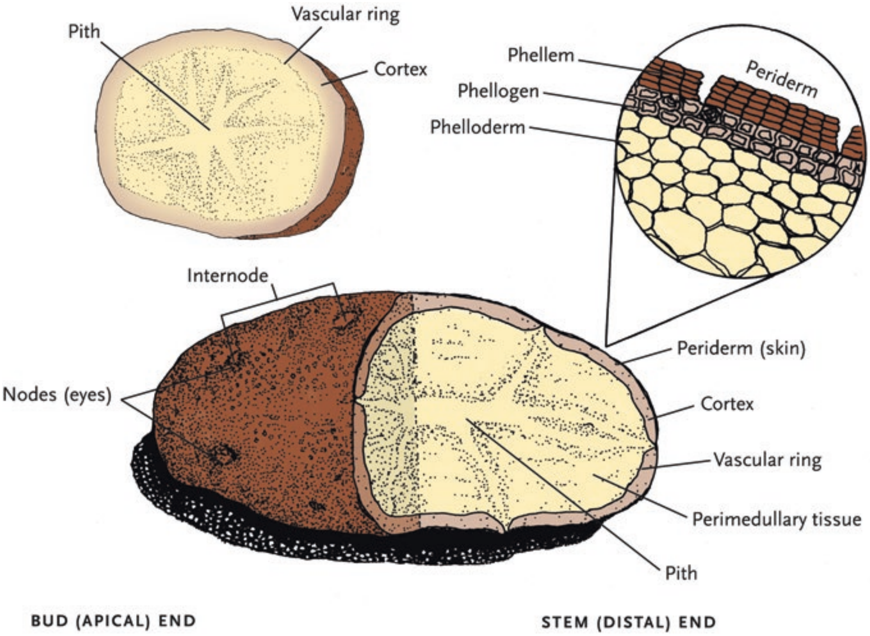

Fig. 2.3 The anatomy of a potato tuber. (Adapted from Dean 1994)

some instances, stolons will continue to elongate, emerge through the soil surface, and develop into a leafy stem (see discussion of heat runners in Chap. 14). However, with appropriate conditions the tips of the stolons will soon "hook" and begin to swell, resulting in the initiation of new tubers.

Tubers

A potato tuber is actually a modified stem that has all of the internal and external structures that are characteristic of stem tissue. The primary function of a potato tuber is to store chemical energy produced by the leaves in the form of carbohydrates. Once the tuber starts to sprout, these energy reserves are mobilized to drive plant growth.

Internal Structures

A cross section through a tuber shows an outer region of storage tissue (the cortex), a ring of vascular tissue, a region of inner storage tissue (perimedullary), and a somewhat translucent or light-colored inner ring (the pith) (Fig. 2.3). Each of these structures has different characteristics, such as starch and nutrient content, as well as cell size.