



International Year of the  
**POTATO**

# Sustainable potato production

**GUIDELINES** FOR DEVELOPING COUNTRIES



During the International Year of the Potato, celebrated in 2008, FAO and CIP helped forge partnerships worldwide to address critical aspects of sustainable potato production. This technical guide collates that experience to review technical, socio-economic, policy and institutional factors that currently constrain increased potato production and productivity in tropical and subtropical countries. It presents Good Agriculture Practices relevant to potato production, and indicators and recommendations for action in key areas, from the utilization of potato biodiversity and improvements in seed systems, to soil management, insect pest and disease control and opportunities for value addition. It outlines a new policy and research agenda for the potato subsector that aims at making a real contribution to the eradication of hunger and poverty.

McCain





# Sustainable potato production

**GUIDELINES** FOR DEVELOPING COUNTRIES

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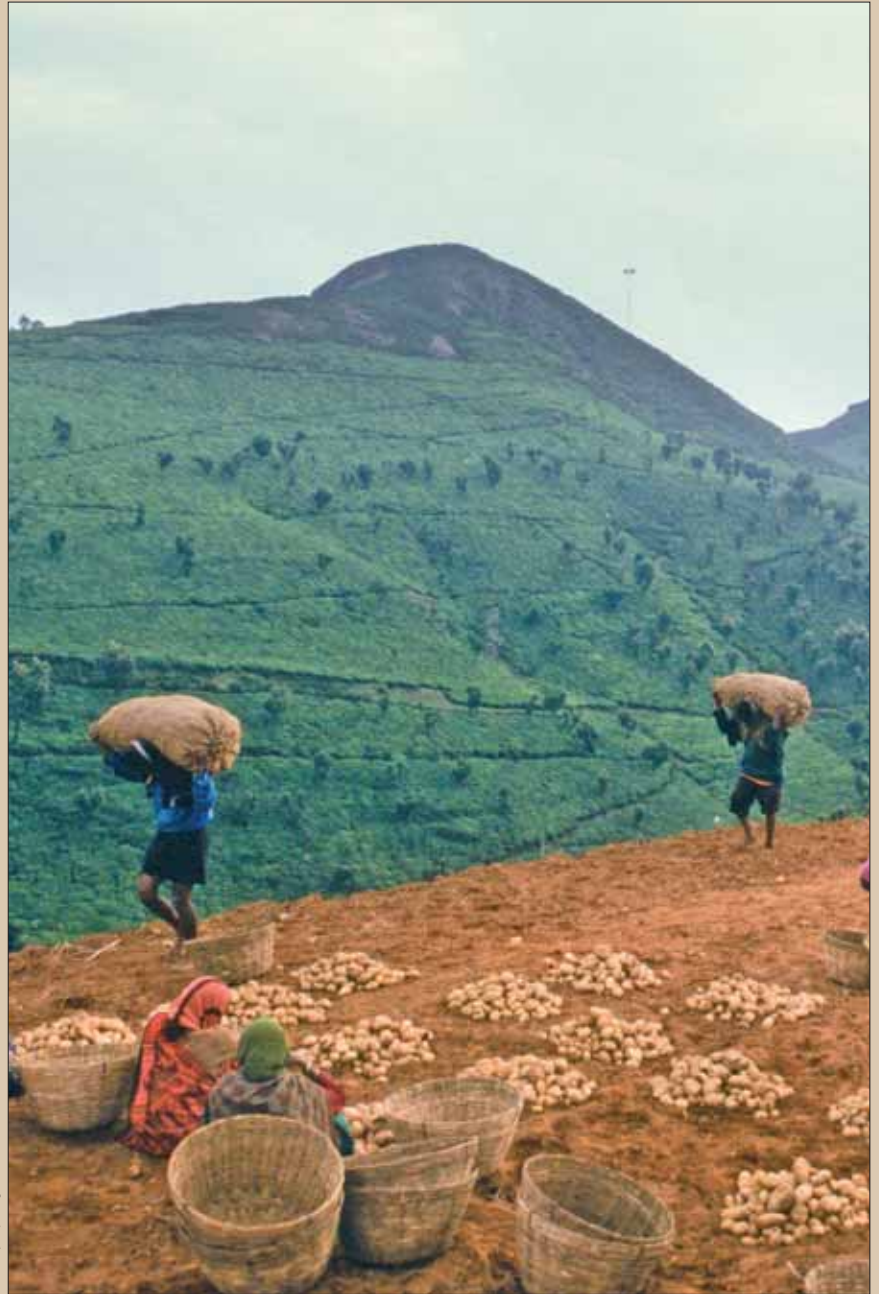
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**POTATO HARVEST  
IN TAMIL NADU,  
SOUTHERN INDIA**  
(PHOTO: JONATHAN  
KINGSTON)

# Foreword

**C**elebrated in 2008, the United Nations International Year of the Potato (IYP) highlighted the important role of the potato in agriculture, the economy and world food security. IYP also had a very practical aim: to promote the development of sustainable potato-based systems that enhance the well-being of potato producers and consumers, especially in developing countries.

This technical guide is a contribution to achievement of the International Year's broader development objective. Today, potato production and consumption is booming worldwide, with ever greater quantities being processed for the convenience food and snack industries, while its importance as a subsistence crop continues to expand. Many developing countries wish to enter lucrative emerging markets for potatoes and potato products, but to do so need to make major improvements in the productivity, profitability and sustainability of their potato subsectors. For example, potato yields in the developing world average around 10 to 15 tonnes per hectare, less than half of average yields achieved by farmers in Western Europe and North America.

The present guide builds on experience gained through partnerships forged during IYP implementation to address critical aspects of sustainable potato production. It represents the first inter-partner effort, post-2008, aimed at producing technical guidelines that can be used by decision makers in developing countries to improve the sustainability of potato production and

boost the potato subsector's contribution to social and economic development.

The guide presents a summary review of factors that constrain the potato subsector in tropical and subtropical countries, principles of Good Agriculture Practices, and GAPs relevant to potato production. It provides indicators and recommendations for action in key areas – from the conservation and utilization of potato biodiversity and improvements in seed systems, to management of soil fertility, insect pest and diseases, water use, the importance of storage, and the opportunities created by value addition. It also provides “snapshots” of selected best practices and examples of successful approaches in developing countries. It concludes with a series of useful fact sheets on key issues in potato development.

While aimed primarily at decision makers at institutional level, the guide will also be of use to technicians, potato growers and processors. We trust that it will help further IYP's goal of helping to realize the potato's full potential as a “food of the future”.

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## Abbreviations and acronyms

CIP	International Potato Center
DLS	Diffuse light stores
FAO	Food and Agriculture Organization of the United Nations
GAP	Good Agricultural Practices
FFS	Farmers' Field Schools
ICM	Integrated Crop Management
IDM	Integrated Disease Management
IPM	Integrated Pest Management
IPPM	Integrated Potato Pest Management
NGO	Non-Governmental Organizations
NSI	Nutrient Supplementation Index
PMCA	Participatory Market Chain Approach
PRSP	Poverty Reduction Strategy Papers

# Acknowledgements

**D**evelopment of this guide was initiated as part of the International Year of the Potato 2008, which was facilitated by FAO's Plant Production and Protection Division (AGP), in partnership with the International Potato Center (CIP). The International Year helped raise awareness of the potato subsector and support for its development, and served as a catalyst for the initiatives aimed at overcoming policy constraints to potato development.

This manual was conceived, initiated, guided and edited by NeBambi Lutaladio of AGP. He benefited from the collaboration of colleagues in partner institutions, in particular the International Potato Center (CIP), Wageningen University Research Center (WUR) and McCain Foods Ltd of Canada.

Special thanks for their technical inputs are due to Jean Pierre Anota and Amir Kassam (consultants), to Anne Sophie Poisot, Mike Robson, Tom Osborn, Michael Larinde and Marjon Fredrix of AGP, and to Andreas Oswald, Carlo Carli, Fernando Ezeta, Graham Thiele, Merideth Bonierbale, Roberto Quiroz and Victor Mares of CIP.

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AT A POTATO  
SORTING FACTORY  
IN THE NILE DELTA,  
EGYPT.  
(PHOTO:  
MOSTAFA MOFTAH)

# Introduction

**T**he potato is the world's most important root and tuber crop worldwide. It is grown in more than 125 countries and consumed almost daily by more than a billion people. Hundreds of millions of people in developing countries depend on potatoes for their survival. Potato cultivation is expanding strongly in the developing world, where the potato's ease of cultivation and nutritive content have made it a valuable food security and cash crop for millions of farmers. Developing countries are now the world's biggest producers – and importers – of potatoes and potato products.

Once harvested, potatoes can be used for a variety of purposes: as a fresh vegetable for cooking at home, as raw material for processing into food products, food ingredients, starch and alcohol, as feed for animals, and as seed tubers for growing the next season's crop.

Around the world, consumer demand is shifting from fresh tubers to processed products and ever greater quantities of potatoes are being processed to meet rising demand for convenience food and snacks. The major drivers behind this trend include expanding urban populations, rising incomes, diversification of diets, and lifestyles that leave less time for preparing the fresh product for consumption.

The development of a vibrant, profitable and sustainable potato subsector in developing countries depends on measures to overcome a number of persistent constraints. Those measures include

improvements in the quality of planting material, potato varieties that have reduced water needs, greater resistance to insect pests and diseases, and resilience in the face of climate changes, and farming systems that make more sustainable use of natural resources. Not least, potato development – and agricultural development in general – requires empowerment of small farmers through improved access to production inputs, credit and markets.

These guidelines present a compilation of potato management practices in use in tropical and subtropical developing countries that have helped increase potato production and productivity. They can be refined to address particular conditions in specific locations. The publication provides indicators of sustainability, and highlights potential areas of improvement for potato development. While aimed primarily at decision makers, the manual tries as much as possible to use language familiar to farmers.

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**POTATO FIELDS  
IN CENTRAL JAVA,  
INDONESIA.**  
(PHOTO: HARJONO  
DJOYOBISONO)





## SECTION 1

# Factors constraining the potato subsector

*In the years ahead, world potato production is expected to grow at a rate of 2.5 per cent a year, presenting opportunities for expanded utilization and opening up new market segments. To realize the full potential of this crop, developing countries must address both supply- and demand-side constraints.*





**POTATO MARKET  
IN KASUNGU, MALAWI.**  
(PHOTO: ANNE LI)

# Technical factors

## **The potato's biological characteristics**

Many constraints derive from the biological characteristics of the potato itself. These include the low multiplication rates of seed tubers, and the technical difficulties and costs associated with maintaining seed quality through successive multiplications, owing to the potato's susceptibility to soil and seed-borne insect pests and diseases. Seed tubers are also bulky: two to three tonnes per hectare is the typical seed requirement. Stringent phytosanitary restrictions limit the movement of potato germplasm, seed tubers and fresh ware potatoes. Potatoes have high fertilizer requirements but low utilization efficiency. Post-harvest, fresh potato tubers deteriorate quickly in tropical and subtropical environments, especially in the lowlands.

## **Lack of efficient seed systems**

Many developing countries lack efficient systems for the regular multiplication and distribution of certified seed tubers and the rapid deployment of new, improved varieties. Causal factors include the limited technical capacity of human resources, lack of managerial expertise and inadequate resource allocations to seed systems and the potato subsector in general. As a result, farmer-based seed systems are still common, and have managed to supply planting material of limited quality over the years, and contributed to expanding cultivation of the crop. Farmer seed systems face many challenges, but also offer an opportunity to

improve seed supply, provided suitable training is available and links with the formal sector are established.

## **Diseases and insect pests**

Diseases and insect pests are another major constraint. New strains of late blight have reached many developing countries and continue to spread. Late blight constitutes the most serious threat to increased potato production. Second to late blight in importance, particularly in warmer, more tropical regions, is bacterial wilt. The impact of insect pests varies between regions. Major insect pests include aphids, tuber moths, leaf miners, Colorado potato beetle and Andean potato weevil.

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## Export markets open in USA and Europe

The US government's African Growth and Opportunity Act (AGOA) provides preferential access for more than 1,800 tariff

lines, including agricultural commodities, from designated sub-Saharan African countries. The Everything But Arms (EBA)

initiative of the European Union (EU) eliminates import tariffs and restrictions on numerous goods, including agricultural products, from least developed countries provided that plant health regulations are met. EBA grants duty-free access for imports from most Less Developed Countries, except for a few sensitive commodities (e.g. bananas, sugar and rice) that will be liberalized gradually. Most of the commodities included in EBA previously received duty-free access to the EU under preferential programmes such as the Lomé/Cotonou Agreement.



**LOCAL TRANSPORTATION  
OF POTATOES TO MARKET  
IN MYANMAR.**  
(PHOTO: ZIN MIN)



# Socio-economic factors

## High production costs and lack of credit

Compared to other food crops, production of potatoes is capital-intensive, requiring the purchase of large quantities of bulky seed and the application of high-cost inputs such as fertilizers and pesticides. With limited access to credit and few means of mitigating the risks of taking out loans, small-scale farmers find it difficult to compete in potato production. The current global financial crisis could leave a great number of farmers with little money and no credit to invest in production.

## Price instability

With potato becoming increasingly a cash crop, small-scale potato growers are vulnerable to abrupt changes in input and output prices. Seasonal and year-to-year price movements can affect individual small growers who lack the financial resources and resilience of larger producers and cooperatives.

## Inefficiency of local markets

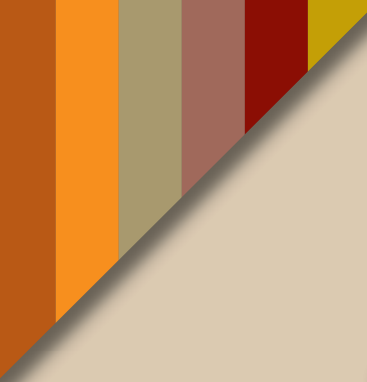
Potato prices are usually determined by supply and demand, not the vagaries of international markets as in the case of cereals. It is, therefore, a crop that can help low-income farmers and consumers to ride out episodes of food price inflation, such as that experienced worldwide in 2007-08. However, the profitability of potato depends on efficient local markets and measures to control overproduction.

## Limited access to higher value markets

To be successful, small-scale potato growers need access to profitable emerging domestic markets – such as the rapidly growing processing segment – as well as to potato export markets. However, access to domestic markets is often restricted by the marketing power of foreign suppliers, while exports are constrained by trade barriers in developed countries to processed products from the developing world. However, there are encouraging “success stories” that illustrate how small-scale producers can increase production and expand their market share. In India, potato growers who adapted new technology with the support of McCain Foods Ltd more than doubled their yields and incomes. Other private industries, including small businesses, have launched potato chips made from coloured native potatoes that were prototyped by CIP in order to promote the sustainable use of biodiversity in the Andean Region. Recent legislation in the USA and Europe provide greater access to agricultural products from the developing world.

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# Policy and institutional factors

## **Neglect of the potato subsector**

With a few notable exceptions – such as Ethiopia – most developing countries have policies toward the potato subsector, and especially small-scale producers, that can be best characterized as “benign neglect”. Little or no public investment is targeted at integrated strategies for crop improvement, value addition and marketing schemes or the potato production-processing-marketing chain. Many countries lack adequate seed production systems backed by certification and seed laws. Breeding rights are often not respected, reducing incentives to breeders to create new adapted and resistant varieties. In many areas, poor infrastructural facilities and poor access to markets are also major challenges to expansion of potato production and its profitability.

## **Inadequate capacity building initiatives**

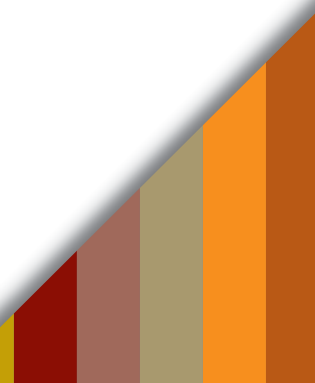
The potato has attracted private sector investment in the crucial area of seed multiplication and seed systems in only a few countries. Support for programmes for the diffusion of new varieties and for the scaling up of existing integrated disease and insect pest management technologies and methodologies is generally inadequate. Programmes to upgrade the skills of potato growers need to be matched by government efforts to create, monitor and enforce regulations on pesticide use and the spread of pesticide or fertilizer residues into water supplies, which are major constraints to the sustainability of potato production systems.

## **Lack of support to farmer organizations and entrepreneurs**

Support for potato farmer groups and associations and for local entrepreneurship is lacking in many countries. In Bangladesh and Pakistan, powerful lobbies represent the most serious obstacle to the development of a local seed potato industry. One notable exception is Argentina, where efforts are being made by public and private sector to improve seed quality and promote variety development, and to transfer technology for integrated crop management to its contract growers.

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**POTATO PLOTS IN SRI LANKA.**  
(PHOTO: ALEFIYA AKBARALLY)

An aerial photograph of a terraced potato field in a mountainous region. The field is divided into numerous rectangular plots, each with rows of young potato plants. The terraces are built into the side of a hill, with a dense forest of tall trees in the background. Several people can be seen working in the field, and there are some small structures or huts scattered throughout the landscape. The overall scene depicts a well-organized agricultural system in a rural, mountainous setting.

## SECTION 2

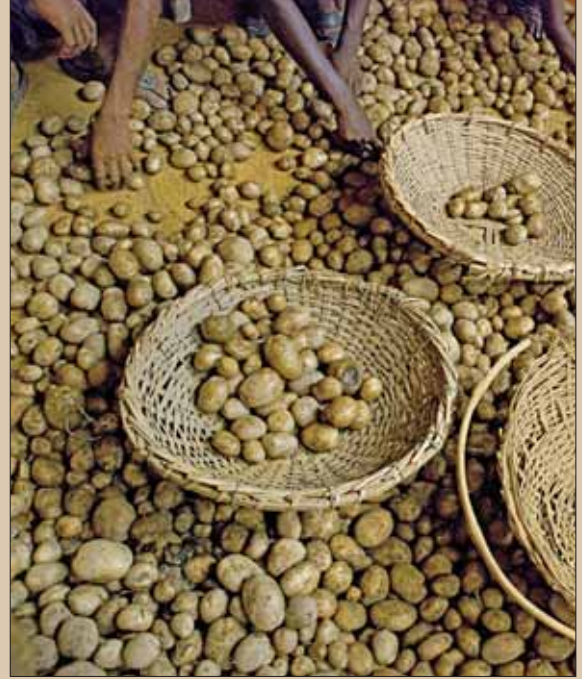
# Good Agricultural Practices and potato production

*The term Good Agricultural Practices (GAPs) refers to principles and codes of practice that are applied to on-farm production and post-production processes and aim at ensuring safe and healthy food and non-food agricultural products, while taking into account economical, social and environmental sustainability.*



## The cost of GAPs

With most GAP applications, production costs are lower, losses reduced, and use of inputs rationalized as a better management system is put in place. The cost of private GAP standard certification (e.g. for GlobalGAP or Tesco Nature's Choice) may be higher owing to stricter requirements. However, this does not necessarily have to be the case with adoption of good practices per se. Generally, there is no higher cost to the consumer – that is why retailers and commercial farming are rapidly adopting GAPs. Where adoption of GAPs entails additional costs, the benefits in economic, social or environmental terms are usually higher.



**SORTING OF POTATO IN INDIA.**  
(PHOTO: RINI MAJUMDAR)

# GAP concepts and principles

**G**APs may be applied to a wide range of farming systems and at different scales. They are applied through sustainable agricultural methods, such as integrated pest management, integrated water and fertilizer management, and conservation agriculture. GAPs are based on four principles:

1. to economically and efficiently produce sufficient quantities of safe and nutritious food;
2. to sustain and enhance ;
3. to maintain viable farming enterprises and contribute to livelihoods;
4. to meet the cultural and social needs of society.

GAP applications are being developed by governments, NGOs and the private sector to meet the needs of growers and processors and for other specific purposes. They provide the opportunity to assess and decide on which to follow at each step of the production process.

It is important that GAPs are applied in a coordinated way. For each agricultural production system, GAPs should be part of a comprehensive management strategy, providing for adjustments when needed in response to changing conditions. The implementation of such a management strategy requires knowledge, planning, measuring, monitoring and record-keeping at each step of the production process. Adoption of GAPs may sometimes result in higher production, processing and marketing costs, and higher prices for the

consumer. To minimize costs, while maintaining the quality and safety of food products, participatory technical training and advice can be used to inform farmers of new technologies that will benefit them.

Information on options for GAP adoption would be facilitated through the use of common databases and information exchange platforms on available enabling technologies and integrated production techniques for different major agro-ecological areas.

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## Examples of GAPs

### Soil management

- \* Reduce wind and water erosion through hedging and ditching.
- \* Apply fertilizers at appropriate moments in adequate doses (e.g. based on soil analysis and crop requirement) to avoid extra costs and possible run-off and leaching.
- \* Maintain or restore soil organic content through application of manure, use of grazing and/or crop rotation .
- \* Reduce soil compaction by avoiding use of heavy machinery.
- \* Maintain soil structure by limiting heavy and sometimes unnecessary tillage practices, and through use of cover crops such as pulses.

### Water use efficiency

- \* Use minimum or zero-tillage and maintain soil cover to reduce soil evaporation and improve soil structure and water infiltration.
- \* To avoid water loss by drainage, schedule irrigation and monitor plant needs and soil water reserve status.
- \* Prevent soil salinization by matching water input to needs, allowing some drainage and recycling water whenever possible.
- \* Avoid excessive drainage and fertilizer run-off.
- \* Maintain permanent soil cover in winter to avoid nitrogen run-off and wind erosion that contributes to soil degradation.
- \* Carefully manage the water table by limiting withdrawals.
- \* Avoid soil compaction (e.g., caused by too many passes of farm machinery) which can cause water logging and lead to emergence of potato diseases during storage.

# GAPs in the potato subsector

**A**ppplied to the potato subsector, GAP principles imply that potato production:

1. takes place in an economically efficient way;
2. contributes to food security by providing quantity and nutritional quality for a balanced food supply;
3. along with post-harvest handling and processing, ensures a safe food supply to consumers;
4. conserves the natural resource base;
5. does not lead to emissions that endanger the environment and biodiversity;
6. enhances potato biodiversity and ensures a sufficient genetic base for varietal adaptation and resistance;
7. supports viable farming enterprises and contributes to livelihoods;
8. meets the cultural and social needs of society.

Several approaches can be utilized to operationalize GAP principles in potato production. The most stringent one attaches criteria to each principle, with indicators and indicator values. For example, the following table summarizes criteria, indicators, indicator values and GAPs that could be used in implementing principle 4 above:

## Conserving the natural resource base

<i>Criteria</i>	<i>Indicators</i>	<i>Indicator values</i>	<i>GAPs</i>
conserve soil organic matter	percentage of soil organic matter	5% organic matter	apply compost, manure or green manure to keep soil organic matter at the desired level
ensure replenishment of groundwater used by irrigation	depth of the water table	5 m below topsoil level	do not over-irrigate from deep wells and tap other water sources or grow potatoes during a wetter period of the year if the threat of disease is not high.
avoid soil erosion	surface run-off of soil particles	0 kg soil loss per square meter per year	apply contour farming, make terraces and use minimum or zero-tillage implements

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“PACHAMAMA HUELLA” -  
LAND PREPARATION  
FOR POTATO IN BOLIVIA.  
(PHOTO: MANUEL SEOANE  
SALAZAR)



# Production decision factors

In potato-based systems in developing countries, the GAP concept can be associated with critical production decision factors and recommendations.

## Environment and production zones

The potato is essentially a “cool weather crop”, with temperature being the main limiting factor. In tropical areas, potato should be grown where the climate is tempered by altitude (1 500 – 4 200 m) or at lower altitudes provided the crop is grown during the cool season.

The ideal condition for tuberization is a night temperature of around 16°C, while optimum yields are obtained where mean daily temperatures are in the 18-20°C range. Loose, moist and well-drained slightly acid soil (with pH of 5.0-5.5) or volcanic upland soils are preferred. The water supply for the potato crop should be regular, especially from the stage of tuber initiation until the end of tuber enlargement.

## Cultivation methods

A successful potato crop depends on judicious cultural practices. These include good knowledge of variety purity and characteristics such as dormancy duration, the physiological condition of seed potato tubers (well sprouted and 30-80 g in weight, depending on variety) and resistance to the main transmissible potato diseases and nematodes.

Potatoes are best grown in rotation. In the Andes, it is usually the first crop in the

rotation. In other regions, it can be planted after cereals and before legumes, but not with crops (e.g. tomato and other solanaceae) that are susceptible to the same pathogens as the potato. Sometimes natural fallow is necessary to prevent soil impoverishment and the build-up of potato-specific diseases and insect pests.

Soil preparation for the potato crop should be adequate with minimum soil disturbance. Naturally loose soils, and loamy and sandy loam soils that are rich in organic matter with good drainage and aeration, are the most suitable.

Planting depth, density and spacing depend on the variety chosen and tuber size, and should allow for shallow inter-row ridging, when required. Usually, about two tonnes of seed tubers are planted per hectare.

To give the crop a competitive advantage, weeding should be performed after full crop emergence (about 4 weeks after planting) and after the plants have reached a height of about 20 cm. Shallow ridging is done subsequently to prevent the stolons becoming aerials, and to protect tubers against insect pests, disease infection and greening. Crop rotation and careful chemical control with herbicides, applied at minimum lethal doses, may be part of an integrated weed management system, although in most developing countries weed management is usually carried out manually.

A few basic precautions against insect pests and diseases can help avoid great yield

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**POTATO HARVESTING  
IN PANUTY DISTRICT,  
NEPAL.**  
(PHOTO: G.M. BAKASH)

and quality losses. They include crop rotation, use of resistant varieties and healthy, certified seed tubers (if available or at least seed from a reputed source or through positive selection), and integrated disease and insect pest management, which involves regular monitoring of aphid and thrips vectors, other insects and natural enemy populations, and chemical spraying only when necessary.

Fertilizer application during the stages of pre-planting, planting or crop growth should be determined by soil nutrient availability, taking into account the potato's high demand for potassium, phosphorus and magnesium deficiencies in acid soils. The NPK ratio 1-1-1 is usually a wise choice to avoid spoiling tuber quality. The potato can benefit from the application of organic manure at the start of a new rotation as it provides a good nutrient balance and protects soil structure from compaction and erosion.

As soil moisture must be maintained at a relatively high level in production of potatoes, compared to other crops, irrigation may be required where rainfall is limited.

## Harvesting

For most commercial varieties, yellowing of the potato plant's leaves and easy separation of tubers from stolons indicate that the potato crop has reached maturity. If the potatoes are to be stored rather than consumed immediately, they are left in the soil to allow their skin to harden – hard skin also help seed potatoes to resist storage diseases. However, leaving tubers for too long in the ground increases their exposure to the fungal disease black scurf and increases the risk of losing quality and marketable yield.

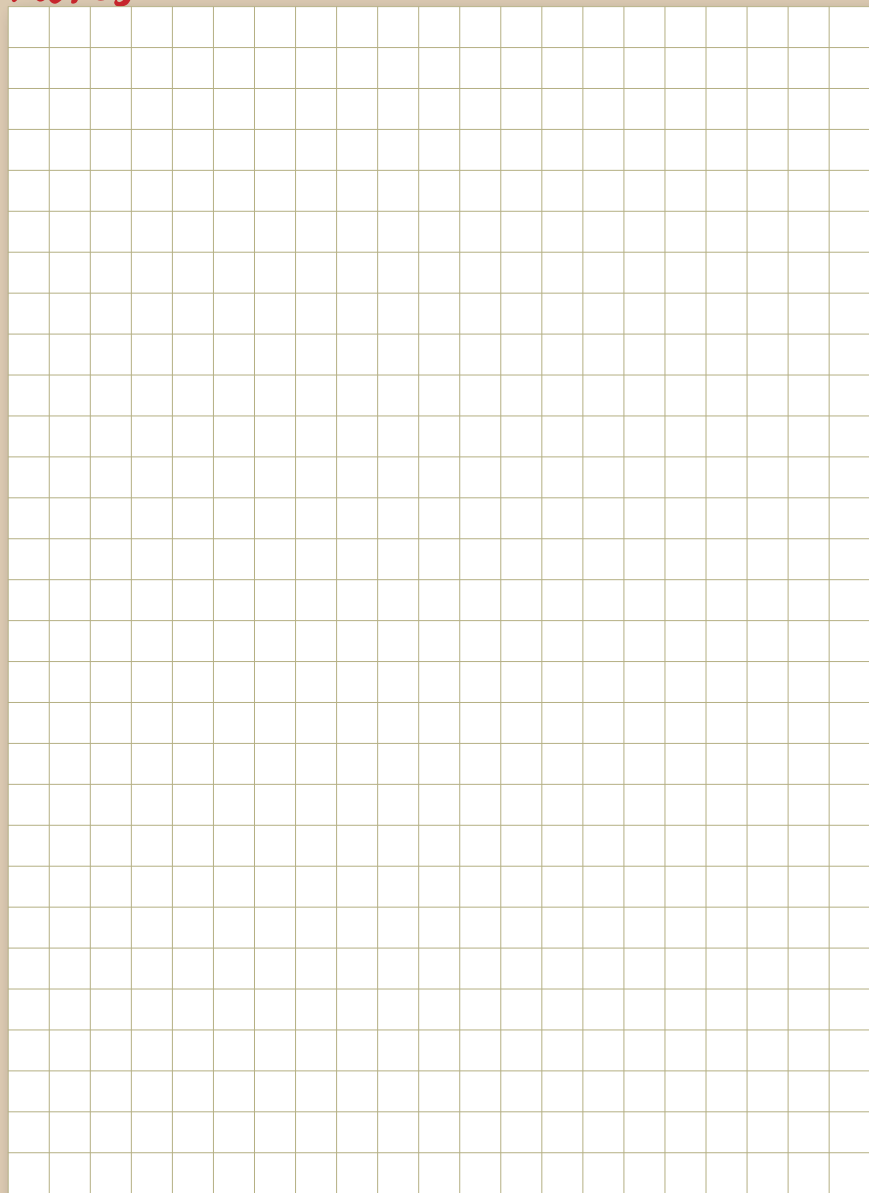
To facilitate harvesting and stop tuber growth, potato vines should be removed two weeks before the potatoes are dug up. Depending on the scale of the production, potatoes are harvested using a spading fork, a plough or commercial potato harvesters that unearth the plant and shake or blow the soil from the tubers. During harvesting, especially if it is done mechanically, it is important to avoid bruising or other injuries, which provide entry points for storage diseases and reduce the commercial, processing quality and storability of the tubers.

In suitable environments and where growing conditions are adequate, commercial yields are in the range of 40–60 tonnes per hectare. In many developing countries, however, they are far below this figure, with national averages of about 10-20 tonnes per hectare.

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## Storage and transport

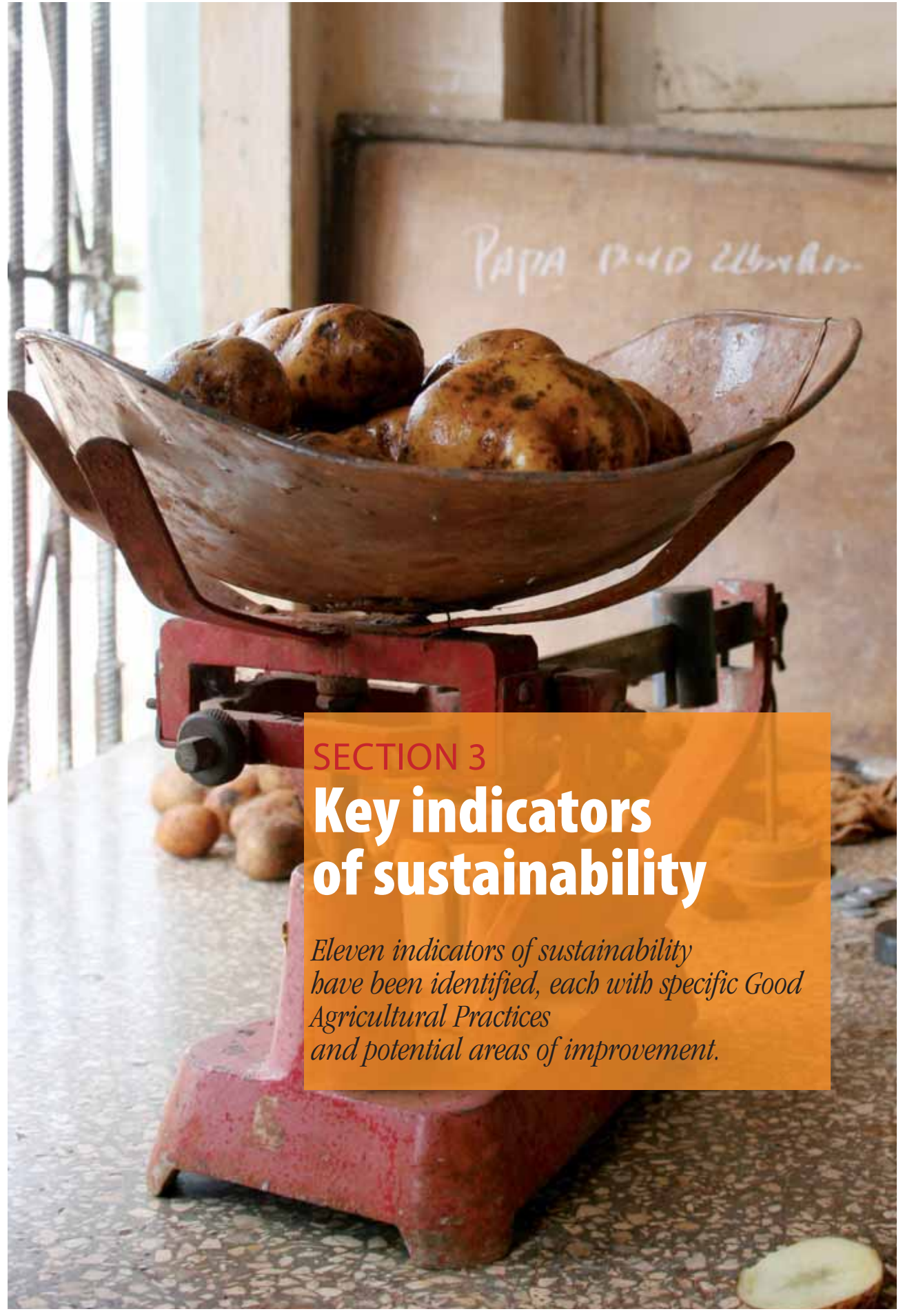
In the tropics and where refrigerated storage is not available, seed tubers should be stored under diffuse light in order to maintain their sprouting capacity and to encourage development of vigorous sprouts. In regions with only one cropping season per year and where storage of tubers from one season to the next is difficult without the use of costly refrigeration equipment, off-season planting may offer a solution. Importation of seed tubers is common in these regions, but may entail higher costs and risks of late delivery and deterioration in tuber quality along the marketing chain.

Ware potatoes should be kept at a temperature of about 6 to 8°C, in a dark, well ventilated environment with high

relative humidity (85 to 90 percent). For processing purposes, such as the production of french fries, storage temperatures may range up to 10°C to reduce the risk of increasing sugar levels, which are responsible for a dark colour during frying. Potato darkening can also be caused by an excess of nitrogen in the fertilization formula.

During transport of seed tubers and ware and processing potatoes, it is important to avoid bruising by reducing drop height, lining containers with rubber or other soft material, and avoiding extreme temperatures. Tubers should be protected against unexpected rainfall and snow, which can occur at high altitudes.

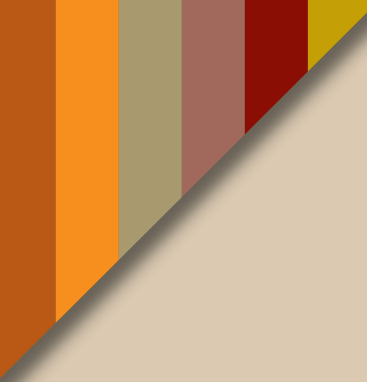
**PAPA,  
ALIMENTO  
DEL PUEBLO,  
CUBA.**  
(PHOTO:  
YANDER ALBERTO  
ZAMORA  
DE LOS REYES)



### SECTION 3

## Key indicators of sustainability

*Eleven indicators of sustainability have been identified, each with specific Good Agricultural Practices and potential areas of improvement.*



## A potato park in the Andes

PAPA HALLAY, PERU  
(PHOTO: O.S. BUTRON RIOS)

The 12 000 hectare Potato Park located in the Andes near Cusco is one of the few conservation initiatives in which local communities are managing and protecting their potato genetic resources and traditional knowledge of cultivation, plant protection and breeding. CIP has repatriated to the park hundreds of virus-free varieties of native potatoes which are now in full production and yielding 30 percent more than potatoes that have not been cleaned of viruses. The Potato Park helps preserve indigenous knowledge and ancient technologies, while



ensuring that the production of native varieties remains under local control. The approach could serve as a model for other indigenous communities

because biological diversity is best rooted in its natural environment and managed by indigenous peoples who know it best.

# Biodiversity and varieties

**T**he potato has the richest genetic diversity of any cultivated plant. Potato genetic resources in South American include wild relatives, native cultivar groups, local farmer-developed varieties (“landraces”), and hybrids of cultivated and wild plants. These varieties contain a wealth of valuable traits, such as resistance to insect pests and diseases, nutrition value, taste and adaptation to extreme climatic conditions. To control insect pests and diseases, increase yield and sustain production, especially on marginal lands, today’s potato-based agricultural systems need a continuous supply of new, improved varieties, a process that requires access to the entire potato gene pool.

Also at national level in regions outside the Andes, maintenance of and increase in the genetic variability of available potato varieties are needed in order to ensure there is a sufficient broad genetic base for adaptation of the plant to local environmental conditions, such as temperature, day-length, moisture availability, and insect pest and disease pressures.

## Good practices

### ***Crop genetic diversity***

- ✿ Facilitate efforts to conserve and sustainably use potato germplasm.
- ✿ Support breeding programmes and ensure conservation of breeding stocks.
- ✿ Breed varieties with high yield, high nutritional value, resistance to main diseases and high adaptability to less-favoured conditions.

### ***Choice of potato variety***

- ✿ Promote varieties adapted to the range of existing climatic conditions to ensure wide adaptability and stable production.
- ✿ Abandon varieties with poor storage characteristics and low levels of resistance to major diseases.
- ✿ Promote varieties that are already grown in the country and are accepted by farmers and markets.
- ✿ Support participatory evaluation of candidate varieties from breeding programmes and other countries for local testing and release.

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**KEY INDICATORS  
OF  
SUSTAINABILITY**



FROM THE ESSAY,  
"HARVEST OF  
NATIVE POTATOES,  
PERU."  
(PHOTO:  
EITAN ABRAMOVICH  
SAMESAS)

### Potential areas of improvement

- ✿ More effective national potato breeding programmes.
- ✿ Adaptation of breeding objectives and targets based on local expected results and needs.
- ✿ Focus breeding programmes on achieving long term benefits, including not only resistance to insect pests and diseases but also high, stable yield, greater resource-use efficiency, nutritional quality, and good storability.
- ✿ Disseminate complementary conservation methods, especially the conservation of biodiversity carried out by farmers (in situ/on-farm conservation).
- ✿ Reinforce “potato park” initiatives through repatriation of biological diversity to farmers’ communities.



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SUSTAINABLE  
POTATO  
PRODUCTION



TAKING TIME  
TO CLEAN HARVESTED  
POTATOES,  
THE PHILIPPINES.  
(PHOTO: ARTEMIO LAYNO)

# Seed production and seed quality

**A** reliable supply of good quality seed is crucial to the development of the potato subsector. Availability of seed remains one of the main constraints to the large scale adoption of research-bred or research-derived improved varieties.

Good quality seed is essential to high yields and is usually the most costly input to potato cultivation, accounting for 30-50 percent of production costs. The improvement of seed quality will contribute to enhancing farmer efficiency and competitiveness. The most important seed quality characteristics are variety purity, physiological stage, seed size, seed health and physical aspect.

## Good practices

### Seed production

- ✳ Supply seeds that meet strict quantity, timing, and quality-control requirements.
- ✳ Grow seed in the best and coolest areas or time of the year in order to avoid insect populations that can transmit diseases.
- ✳ Where potatoes can be grown year-round, encourage farmers in a seed production area to include a “potato-free” period in the farming calendar in order to break cycles of insects that act as vector for virus diseases.

### Purity of variety

The use of varieties with better quality and greater adaptability to marginal environments will help to enhance potato

production and ensure the sustainability and competitiveness of potato-based farming and utilization systems.

- ✳ Seed should be of the same variety as that by which it is sold.
- ✳ Use varieties that are adapted and stable in term of yields.

Where appropriate and where farmers currently use mixes of different varieties, ensure the added benefits of such mixtures in terms of tolerance to diseases and ensure that farmers have adequate knowledge, infrastructure and guidelines to apply best practices for seed production.

### Physiological stage

Physiological development of a seed tuber is categorized as follows:

- ✳ Phase I = dormant period;
- ✳ Phase II = apical sprouting;
- ✳ Phase III = period of normal sprouting;
- ✳ Phase IV = period of thin sprouts;
- ✳ Phase V = incubated – too old seed tubers.

As the physiology of the seed is a major factor in seed quality, storage systems and storage duration are critical aspects to be considered. To obtain a high yielding crop, seed should be at the correct physiological age and sprouting stage at planting, depending on the purpose of the crop. In principle, seed should be at least three months old before it is planted, and no older than 5-11 months (depending on variety, storage system and temperature).

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KEY INDICATORS  
OF  
SUSTAINABILITY

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SUSTAINABLE  
POTATO  
PRODUCTION



POTATO  
HARVESTING  
IN NEPAL.  
(PHOTO:  
G.M. BAKASH)

- ☼ Provide a storage area with good air circulation and adjustable lighting.
- ☼ Store only seed tubers taken from healthy plants and ensure they are devoid of storage diseases such as late blight, bacterial rot and silver scurf.
- ☼ About one month before planting, pre-sprouting of seed potatoes should favour quick emergence at planting time.
- ☼ In the tropics, if no refrigerated storage capacity is available, store seed potatoes under diffuse light in order to maintain their sprouting capacity (i.e. help tubers stay physiologically young for longer) and to encourage development of vigorous sprouts.

Direct sunlight on potato seed should be avoided. Therefore:

- ☼ For long-term storage, store seed potatoes either at 2–4°C or, when stored at higher temperatures, in diffused light.
- ☼ The period between planting and emergence should be kept as short as possible in order to make best use of the available growing season. Therefore, at planting time the seed should be at a physiological stage that allows a quick emergence.
- ☼ For planting, the best stage is phase III (robust sprouts having their typical varietal colour), the “normal multi-sprouting” phase.
- ☼ Put bulked seed potatoes in trays to stimulate more uniform sprouting.

### **Seed size**

- ☼ Use seed of uniform size, ranging from 25 to 50 mm or weighing between 30 to 80 g, depending on tuber size and shape.
- ☼ Plant tubers which have little variation in size. Using seed with a wide variation in size will not produce a uniform crop and makes it more difficult to predict the plant density and properly manage the crop.
- ☼ Use large tuber seed when soil and weather conditions at planting are unfavourable, the growing season is short, or where there is the risk that during the first part of the growing season, the crop may be damaged by night frost, hail or drought.
- ☼ Large tubers may be cut into smaller pieces for planting to reduce seed costs and favour a more uniform crop. This should be done at least two weeks before planting in temperature conditions of between 10 and 22°C to allow wound healing prior to planting. However, precautions are needed to avoid transmission of viruses via the cutting blades.

### **Seed health**

Seed potato is generally the main source of insect pest and disease infection, because most seed-borne diseases are systemic, thus favouring disease transmission to the next tuber generation. Seed treatment with chemicals can never replace the use of high quality seed or proper handling, storage and sprouting. Therefore:

- ☼ Use only disease-free seed.
- ☼ Produce seed tubers in disease-free areas



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SUSTAINABLE  
POTATO  
PRODUCTION



FROM  
THE PHOTO ESSAY,  
"BELARUS SOLDIERS  
EAT POTATOES."  
(PHOTO:  
VIKTOR DRACHEV)



and on land not infested with soil-borne diseases or insect pests.

- ✿ Ensure proper sanitation by using clean tools when cutting seed to avoid diseases transmitted mechanically.
  - ✿ Practice crop rotation and remove potato volunteers when cultivation and weeding are implemented.
  - ✿ Adopt strict rotation procedures, and never use the same field more than once in a 3-4 year period.
  - ✿ Rogue out diseased plants, including tubers, stolons and roots, being careful to avoid spilling soil on healthy plants, and bury them in a pit outside the field.
  - ✿ In the tropics, use storage areas with good air circulation and adjustable lighting.
- ✿ Disinfect storage structures every year by spreading lime (use of dangerous chemicals such as formalin is not necessary).
  - ✿ Clear away potato residues, sacks and other waste, as these can be breeding grounds for potato tuber moths and diseases.
  - ✿ Remove and destroy seed tubers infected by diseases or insect pests during storage.
  - ✿ Make routine observations to identify insect pest- and disease-infected tubers in storage.
  - ✿ Routinely control the temperature in the potato heap (bulk) to ensure that no rotting occurs. Rot processes are likely to emerge when bulk temperature suddenly increases.

## Diffuse light storage for seed potato tubers

In tropical areas such as the Central African highlands, where cold storage is unavailable or too costly, smallholder growers store their seeds on the farm. The efficiency of their simple home storage facilities could be dramatically improved with use of diffuse light technology. Diffuse light stores (DLS) are most suitable where temperatures are moderate (no frost or extreme high temperatures) and seed has to be

stored for more than four months. By using DLS, farmers are able to store their own seed stocks, instead of buying them from distant suppliers. However, the loading capacity of DLS is limited since all tubers must be exposed to the diffuse light. These stores are suitable generally for small seed units and not for large scale seed production schemes. Seed potatoes stored in diffuse light give a more vigorous crop than

seed that has been stored for relatively long periods in the dark at higher temperatures. However, the DLS must be protected against aphids (e.g. with an aphid proof screen) to avoid the risk of infection and transmission of viruses such as potato virus Y and potato leaf roll virus. Since the aphid population increases throughout the storage phase, stringent control measures need to be put in place to reduce seed degeneration.

## Capacity-building for seed potato selection

A technique known as “positive selection” was pilot-tested by smallholder potato farmers in the Narok district of Kenya as a way of improving the quality of their seed potatoes. Positive selection involves marking healthy-looking mother plants for later seed collection. More than 100 extension workers and farmer-trainers were trained in all aspects of positive selection, and then assigned to work with some 1 200 farmers organized in 70 farmer groups. A participatory

research approach was used, with a demonstration experiment forming the core of the training curriculum. All activities took place in the potato field, and the mode of teaching was “learning by doing”. The farmer groups met regularly, learning first how to distinguish between sick and healthy-looking plants in the potato field. Next, a comparative study divided the potato field was into two parts: one where positive selection was used and one where the farmers used their

traditional methods. Tubers from the two different selection methods were planted separately the next season, and the group analysed the results. Within the positive selection field, potato yields increased on average by about 30 percent. A survey two years afterwards showed that more than one quarter of the farmers trained had adopted the positive selection method. These farmers reported that their yields had doubled.

# Seed systems

In most developing countries, the vast majority of smallholder farmers use farm-saved seed potato obtained from non-specialized seed growers, owing to the lack of commercial seed production systems or, where they exist, to the high price of certified seed. Farmer-based informal seed systems are generally unable to maintain seed quality or eliminate diseases such as bacterial wilt or viruses. Poor functioning seed systems are consistently ranked by CIP as being among the major constraints to improved potato production.

## Good practices

- ✳️ Train seed growers in seed quality maintenance and managing bacterial wilt and viruses.
- ✳️ In order to avoid multiplying different categories of seed in the same locality and to sustain the replenishment of quality planting stock, promote a permanent “flush-out” system that prevents multiplication of lower categories of seed.

## Potential areas of improvement

Much effort has been made in the past to improve seed potato production in developing countries, usually through specialized seed companies. However, commercially produced seed potatoes remain beyond the reach of many smallholder producers, especially in sub-Saharan Africa, where producers rely on farm-saved seed. Simple, low-cost

technologies are therefore needed to help developing countries produce and distribute the healthy and high quality seed tubers needed for sustainable and profitable potato production.

- ✳️ Develop participatory research and promote appropriate technologies to improve the quality of farm-saved seed in sub-Saharan Africa and other parts of the world.
- ✳️ Identify localities with low vector pressure and communicate the value of positive and/or negative selection (rouging) practice for the production of potato seed
- ✳️ Determine the degeneration rate of seed potatoes, by variety and location, so as to determine how much basic seed needs to be produced annually.
- ✳️ Introduce laboratories for disease diagnostics to identify seed-borne viruses, bacteria and fungi.
- ✳️ Introduce rapid multiplication techniques and encourage small enterprises to produce healthy material.
- ✳️ Develop new methods to ensure the production and delivery of high quality potato planting material and improve formal and farmer-based seed systems.
- ✳️ Develop legislation and accreditation systems for seed certification adapted to local conditions.

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KEY INDICATORS  
OF  
SUSTAINABILITY

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SUSTAINABLE  
POTATO  
PRODUCTION



FROM  
THE PHOTO ESSAY,  
"BELARUS SOLDIERS  
EAT POTATOES."  
(PHOTO:  
VIKTOR DRACHEV)

# Soil health and fertility management

**M**aintaining a high yielding potential in potatoes requires soil health and fertility management. Soil health depends on physical and chemical properties and functions, organic matter and biological activity, which are fundamental to sustaining agricultural production and determine, in their complexity, soil fertility and productivity.

Crop fertilization requirements need to be correctly estimated according to the expected yield, the potential of the variety planted and the intended use of the harvested crop. Before application of fertilizers, farmers should perform, where possible, a soil test to identify soil characteristics, nutrient content and soil contaminants. Soil tests help assess fertility and indicate deficiencies that need to be addressed.

## Good practices

Potato should be planted with organic fertilizer, such as farmyard manure where possible and as appropriate. As well as supplying nutrients to the crop, organic fertilizer often increases the efficiency of inorganic fertilizers, improving crop yields substantially, and also improving soil health, which could have a positive effect by helping to reduce soil borne diseases.

## Farmyard manure

☛ Of all field crops, potato has the best response to farmyard manure. Use well-decomposed farmyard manure at a rate of 10 tonnes per hectare or more, if available.

- ☛ Precautions should be taken to reduce nitrogen applications by 30 percent, if inorganic fertilizers are applied at the same time.
- ☛ Avoid using fresh, incompletely decomposed manure because it will become active too late in the season and may reduce dry matter content, delay maturity and transmit diseases (e.g. *Rhizoctonia solani*).

## Fertilizers

- ☛ Prior to planting, make a planting bed with some 20 cm of loose soil mixed with fertilizer and/or manure to allow proper rooting and hilling.
- ☛ In moist soil, apply fertilizers at the root zone (25-28 cm) where they are most effective.
- ☛ To be more effective, place phosphates in the root area because, unlike nitrogen and to some extent potassium, phosphates have limited movement in the soil and within plants.
- ☛ Use of fertilizers is advantageous when levels of soil fertility are low.

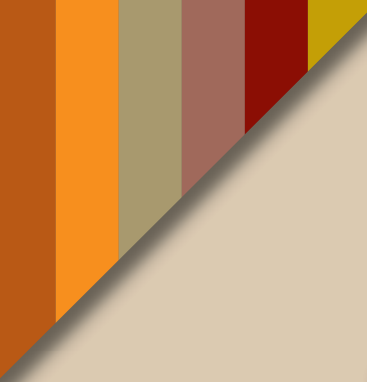
## Potential areas of improvement

- ☛ Promote conservation agriculture approaches to soil health and fertility management.
- ☛ Support integrated crop, soil health and fertility management programmes.
- ☛ Conduct research and development based on adequate use and conservation of natural resources.

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KEY INDICATORS  
OF  
SUSTAINABILITY





*notes*

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**SUSTAINABLE  
POTATO  
PRODUCTION**

# Nutrient management

**S**ustainable nutrient management involves a set of management practices designed to conserve soil resources, maintain or enhance productivity, and help reduce growers' reliance on chemical fertilizers. Due to its relatively poorly developed and shallow root system, the potato demands a high level of soil nutrients. Without balanced fertilization management, growth and development of the crop are poor and both yield and quality of tubers are diminished.

The type and extent of nutrient management depends on the production potential of the area in which potatoes are cultivated and farmers' productivity objectives. Farmers should be advised to perform a soil test before application of fertilizers – fertilization is highly dependent on location and blanket recommendations are not applicable. They should also be aware of the effect of the soil pH on nutrient supply and the type of fertilizer to be used.

## Good practices

Crop response to fertilizers varies from field to field. The fertilizer ratio of N-P-K often recommended and practiced is usually 1:1:1. However, high yields and enhanced quality of tubers can only be sustained through the application of optimal nutrient doses in balanced proportions.

**Nitrogen.** The amount of nitrogen applied to a potato crop varies from 100 to as much

as 300 kg/ha depending on the purpose of the crop and soil characteristics.

- ✳️ Avoid high or excessive nitrogen dressing as it stimulates haulm growth, delays tuber formation and affects tuber quality (low dry matter content, high reducing sugar content and high protein and nitrate content).
- ✳️ Apply nitrogen shortly before, or at, planting time. However, if there is a risk of leaching (e.g. with heavy watering on light soils), or if the application of large quantities of fertilizer under dry conditions may cause scorching, a split application may be better. The second nitrogen application should, in general, be given no later than three to five weeks after crop emergence.

**Phosphorus.** Phosphorus contributes to the early development of the crop and early tuberization. It increases the crop's dry matter content and improves the tuber's storage quality. Often more than 100 kg/ha is applied, while on phosphorus-fixing soils much higher doses are used.

- ✳️ Apply the total amount of phosphorus before or during planting.
- ✳️ Apply phosphorus in the planting furrow in P-fixing soils.

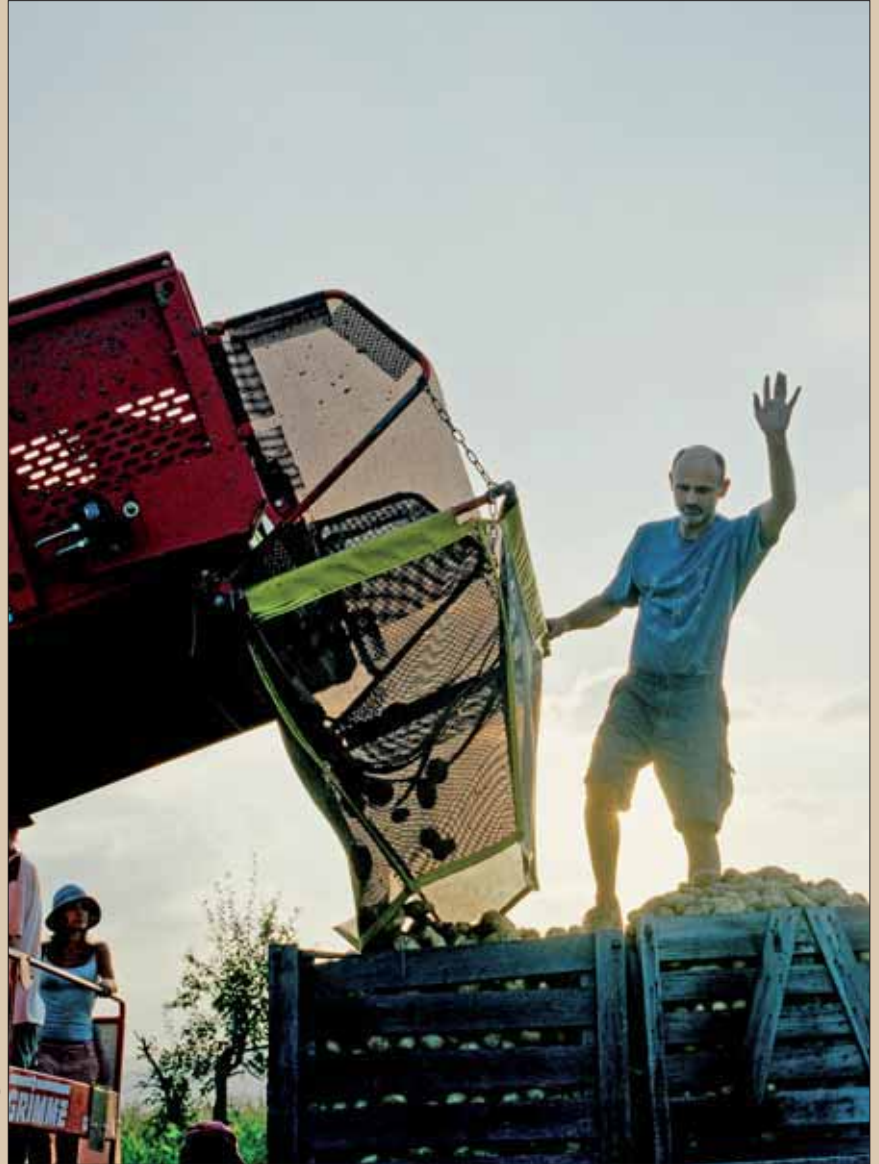
**Potassium.** Potassium not only improves yields but also improves tuber quality (size, starch content and storability). An adequate supply of potassium can help reduce internal blackening and mechanical damage, and has been

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KEY INDICATORS  
OF  
SUSTAINABILITY

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SUSTAINABLE  
POTATO  
PRODUCTION



HARVESTED  
POTATOES BEING  
LOADED INTO CRATES.  
(PHOTO: PASCAL BASTIEN)

associated with increased stress tolerance.

- ☛ Apply the total amount of potassium before or during planting.

### **Magnesium**

- ☛ Close attention should be paid to magnesium requirements, particularly when potatoes are grown on light acid soils. High rates of potassium, and nitrogen application in the form of ammonium, reduce the uptake of magnesium.

### **Calcium**

- ☛ Potatoes are tolerant to soil acidity. Below pH 4.8, however, the crop may fail due to calcium deficiency. Liming may be necessary.
- ☛ Seed potatoes, in particular, need to be grown in soils with sufficient calcium. Calcium deficient seed tubers may fail to sprout properly.

### **Foliar fertilizers**

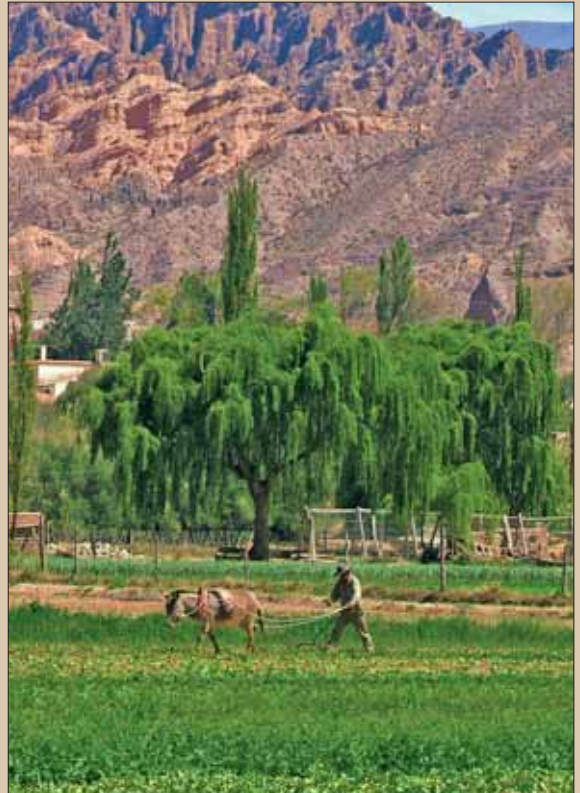
- ☛ Foliar fertilizers contain major nutrients and also micronutrients. They are applied to and absorbed by the leaves and have therefore an immediate effect on plant growth. They may help to overcome apparent nutrient deficiencies, especially of micronutrients, and support plant recovery following stress events, such as frost and drought.

### **Potential areas of improvement**

- ☛ Promote the establishment of laboratories where soil mineral content can be assessed prior to planting. Laboratories can also verify the claimed concentrations of N-P-K in commercial products.
- ☛ Promote the development and use of decision support systems that help growers apply fertilizers according to soil mineral content and crop needs.
- ☛ Encourage fertilizer companies to market compound fertilizers with compositions of N, P and K tailored to different soil types.
- ☛ Support integrated crop management (ICM) programmes and integrated nutrient management systems for potatoes.
- ☛ For the fertilization of crop mixtures that include potato, the Nutrient Supplementation Index (NSI) concept can help estimate the additional percentage of N, P, K and Ca needed to satisfy the needs of a 1:1 row intercrop (e.g. potato-corn). NSI estimates total fertility input needs for the multiple cropping system based on the nutrient uptake of each crop component relative to their monoculture uptake. With NSI, intercrop fertilizer needs can be estimated from established sole crop response curves for the component species. Alternatively, fertilizer needs for the multiple crop system can be estimated for a given planting pattern using the response equations of one or more of the component crops.
- ☛ Develop nutrient management practices for potato production under conservation agriculture.

## The advantages of conservation agriculture

Conservation agriculture (CA) aims at enhancing natural biological processes both above and below ground. It is based on three principles: minimum mechanical soil disturbance, permanent organic soil cover, and diversified crop rotations for annual crops and plant associations for perennial crops. By minimizing soil disturbance, CA creates a vertical macro-pore structure in the soil, which facilitates the infiltration of excess rainwater into the subsoil, improves the aeration of deeper soil layers, and facilitates root penetration.



**POTATO FARMING IN ARGENTINA.**  
(PHOTO: H.C. CUEVAS)



# Soil conservation

**S**oil erosion on tillage-based cultivated lands is a problem that continues to threaten the sustainability of both subsistence and commercial agriculture in potato growing areas around the world. Potato cultivation usually involves intensive soil tillage throughout the cropping period, which often leads to soil degradation, erosion and leaching of nitrates. During soil preparation, the entire topsoil is loosened and – particularly on sticky clay soils – pulverized into small aggregates to avoid the formation of clods in the potato beds. Mechanical weeding and mechanized harvesting also entail intensive soil disturbance.

## Good practices

The use of mulch at planting and the “no-till” land preparation method are recommended to reduce soil degradation, erosion and nitrate pollution and to restore degraded soils and achieve good potato yields with reduced need for fertilizer. The mulch protects the soil from erosion during the first weeks of the crop.

A green manure crop can be seeded towards the end of the crop, as the potato plants are drying off. The cover crop will help to dry out the potato beds, contributing to healthier tubers with reduced risk of damage during harvest. Nevertheless, while mulch planting of potatoes reduces the risk of erosion and nitrate leaching, it may have some disadvantages (e.g. excessive moisture and reduced soil temperature leading to

retarded plant emergence). Hence it should not be a blanket recommendation.

The “no-till” potato is pressed into the soil surface, and then covered with a thick layer of mulch, preferably straw, which is fairly stable and does not rot quickly. The young potato tubers form under the mulch but above the soil surface. In some cases – for example in dry areas under drip irrigation – black plastic sheets can also be used as mulch. Holes are punched in the plastic to allow the potato plant to grow through it. During harvesting, the sheets are removed and the potatoes are simply “collected”. Currently, the “no-till” potato is only grown in small fields using manual labour.

## Potential areas of improvement

- ✳ Promote conservation agriculture approaches as a resource-saving crop production system.

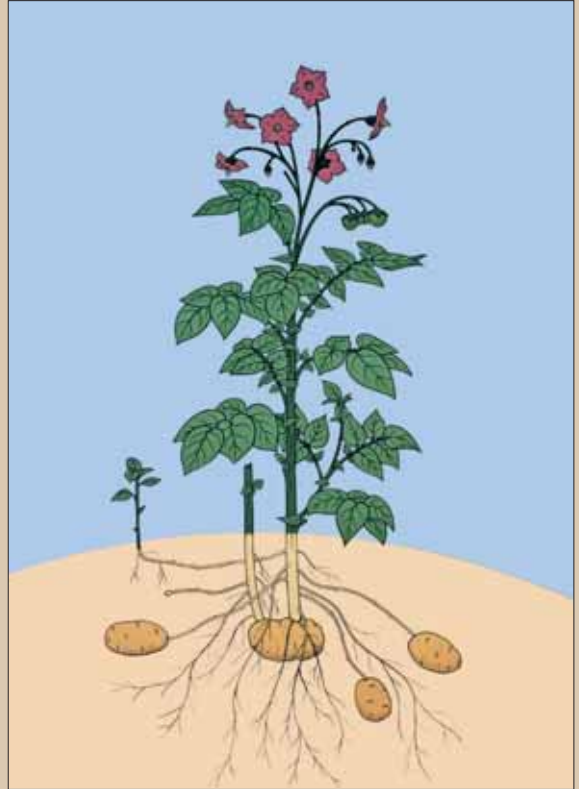
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KEY INDICATORS  
OF  
SUSTAINABILITY

## Principles of potato plant health management

Incorporation of the following practices into the production scheme should result in optimal health of the potato crop:

- \* Plant healthy seed tubers from reliable sources.
- \* Select and prepare planting site, and choose cultivars, planting and harvest dates with disease and insect pest management in mind.
- \* Handle and plant seed potatoes to ensure rapid emergence, and protect foliage using a holistic crop protection approach or integrated production and pest management.
- \* Minimize tuber infection by timely killing or removal of vines before harvest; avoid tuber injury and cure tubers before long term storage.
- \* Manage storage conditions to minimize post-harvest deterioration.



POTATO PLANT  
(CIP)

# Pest management

**P**otato diseases are spread by insect vectors, seed and wind, running water, soil, sacks and implements. Seed is generally the main source of infection. Combating insect pests, diseases and weeds with intensive use of insecticides, fungicides and herbicides can harm the environment and pose a serious threat to the health of producers and consumers.

Regular field monitoring for pests and the broader agro-ecosystem is the basis for ecological-based plant protection and pest management. For example, aphid monitoring and consequent adjustment of planting and harvest dates would deserve special attention as a feasible knowledge-based practice in the context of insect pest management. However, the management of potato late blight is difficult without fungicides. Therefore, the use of biocides is acceptable, and often considered as a component of integrated insect pest and disease management schemes.

## Good practices

- ✿ To increase potato production while protecting producers, consumers and the environment, use insect pest and disease management strategies that encourage biological control of insect pests, varieties with insect pest and/or disease resistance, planting of healthy seed potatoes, the growing of potatoes in rotation with other crops, and organic composting to improve soil quality.
- ✿ Whenever possible, use rotations that reduce insect pest and disease problems and avoid those that may increase them. In general, avoid solanaceous crops as rotation choices.
- ✿ Control volunteer potato plants and weeds in the rotation crop.
- ✿ Avoid build up of weed seeds in the soil by removing weeds before they flower and set seeds.
- ✿ Reduce or eliminate weed seeds in soil through conservation agriculture approaches to weed management.

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KEY INDICATORS  
OF  
SUSTAINABILITY

## Fighting potato late blight

In developing countries, farmers generally lack knowledge of late blight (LB) control measures, and have limited or no access to resistant varieties and agricultural inputs needed to control potato LB effectively. CIP is working on different fronts to develop alternatives to control LB. In recent decades, its breeding programme has developed LB-resistant varieties adapted to smallholder farming conditions in tropical

environments. Some of these varieties are already being cultivated in several countries in Latin America (Bolivia, Colombia, Ecuador, Peru), in Africa (Ethiopia, Uganda, Rwanda, Tanzania) and in Asia (China, India). CIP has also developed technical principles for optimizing fungicide use, and for designing and adapting participatory research and training methods to deal with the complexities of LB management. The experience in LB

management accumulated so far has shown that returns on investment in controlling the disease are high, with marginal rates of return ranging from 260 percent to 1360 percent. These are especially significant for resource-poor farmers for whom potato cultivation represents an important coping strategy. Support is needed to help optimize this impact by scaling up and out the technologies and methodologies developed by CIP.

## Pesticides and the environment

Improper use of pesticides in potato cultivation is a major environmental concern. The most widespread and intensive use of pesticides in developing countries is for control of late blight (LB) potato disease. Farmers in some countries spray their potato fields more than 10 times during a single growing season of 4 to 6 months to combat this disease. Biocides are a health risk to farm families and farm workers engaged in potato

production. With the emergence of new and more virulent strains of LB, even more frequent (and increasingly ineffective) applications of pesticides are being made, raising the risk to human health and the environment. The spread of pesticides or fertilizer residues into water supplies through irrigation systems or field runoff contribute to water pollution that damages plants, insects and livestock, and poses a serious

threat to drinking water and to water used for post-harvest activities. Concern over environmental and health impacts, combined with the better appreciation of the damage different diseases and insects cause to the potato, have led to the development and diffusion of alternative technologies including disease-resistant varieties and integrated management (IDM/IPM) techniques.

### Potential areas of improvement

- ✿ Develop approaches that are specific to the target pests and have the least harmful effect on other organisms, human health or the environment.
- ✿ Develop decision support systems that assess disease or insect pest pressure and identify the most appropriate timing and dosage of chemical interventions.
- ✿ Ensure that when there is a need to apply pesticides, appropriate equipment is used and measures are taken to reduce risks during handling of the pesticides.
- ✿ Establish laboratories to verify compounds and concentration of the active ingredients in pesticides.
- ✿ Support facilitation of CIP's integrated pest/disease management (IPM/IDM) programme, FAO's IPM and any other IPPM approach through Farmer Field Schools or other formal or informal extension programmes.
- ✿ Always aim for reduced use of pesticides by applying IPM practices. If pesticides must be applied, use only products registered in the country, give preference to comparatively less toxic pesticides strictly follow usage recommendations and ensure that farmers and farm workers use properly functioning protective equipment.
- ✿ Promote conservation agriculture approaches to crop health management.



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SUSTAINABLE  
POTATO  
PRODUCTION



AN IRRIGATED POTATO  
FIELD IN CAPE VERDE.  
(PHOTO: MARZIO MARZOT)

# Water management

In potato production, shortages of water are usually one of the most important constraints to higher yields. Achieving better yields requires an adequate water supply from planting until maturity. The main effect of drought or water stress on potato is yield and size reduction.

Frequent irrigation reduces the occurrence of tuber malformation. For the potato, the critical period for water deficit is during tuber development. Water deficit in the early phase of yield formation increases the occurrence of spindled tubers (more noticeable in oval than in round tuber varieties) and, when followed by irrigation, may result in tuber cracking or tubers with “hollow hearts”. Therefore, water supply and scheduling have important impacts on potato growth, yield and tuber quality.

## Good practices

- ✿ Match water application to the potato crop's water requirements and maintain adequate soil moisture to maximize yield. For best yields, a 120 to 150 day crop requires from 500 to 700 mm (20 to 27.5 inches) of water.
- ✿ Avoid water deficits in the middle to late part of the growing period – deficits during stolonization, tuber initiation and bulking tend to reduce yield.
- ✿ Allow higher depletion toward the ripening period (a practice that may also hasten maturity and increase dry matter content).

- ✿ Where water supply is limited and salinity might become a problem, use of a technique known as “partial root-zone drying” increases water use efficiency. Potatoes are planted in furrows so that one side can be irrigated and the other kept dry in one watering cycle; the opposite furrows are watered in the following cycle.
- ✿ Use no-till and soil cover to minimize soil evaporation.

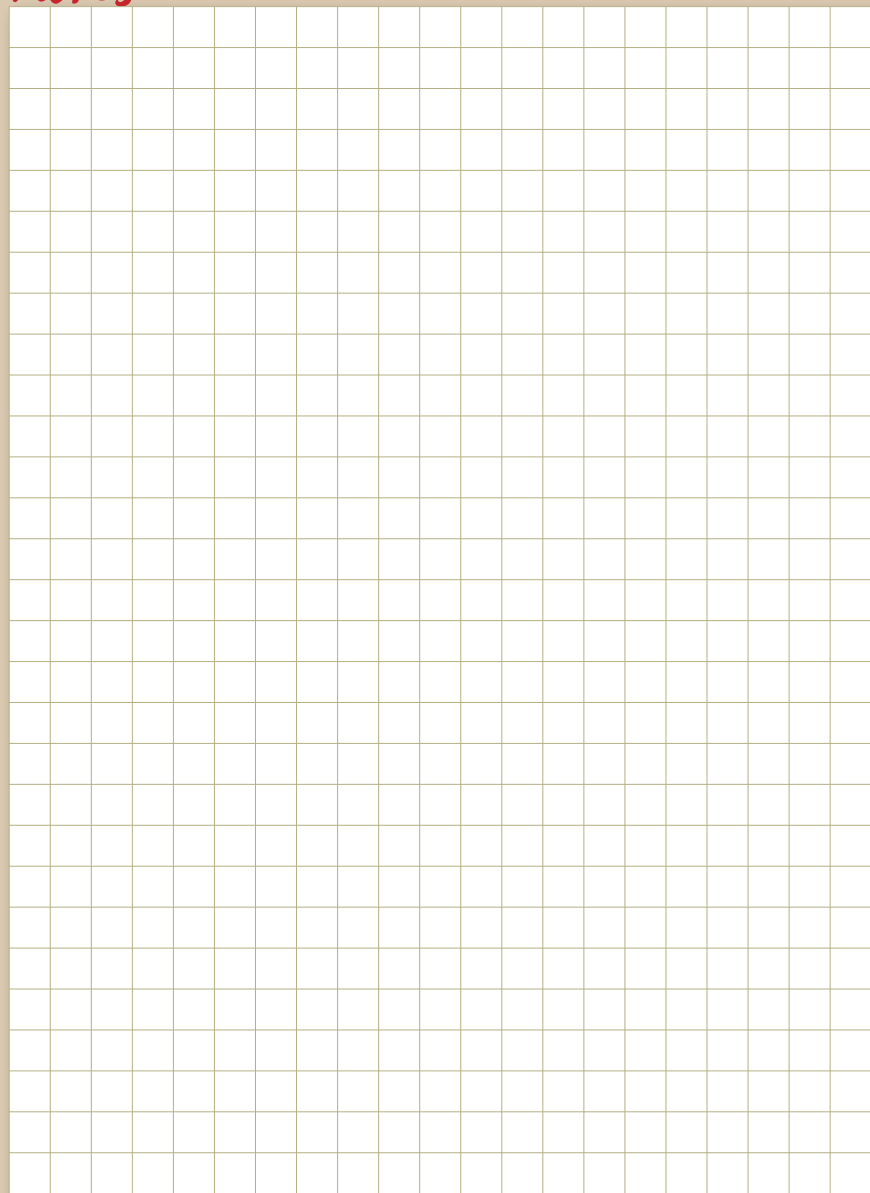
## Potential areas of improvement

- ✿ Support research aiming at developing drought tolerant and resistant varieties.
- ✿ Improve irrigation and fertilization techniques using conservation agriculture approaches.

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KEY INDICATORS  
OF  
SUSTAINABILITY

*notes*



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**SUSTAINABLE  
POTATO  
PRODUCTION**

# Post-harvest management

**S**ince harvested tubers are living tissues and therefore subject to deterioration, proper storage is essential, both to prevent post-harvest losses of potatoes destined for fresh consumption or processing, and to guarantee an adequate supply of seed tubers. The storage of potatoes is intended:

- to preserve them in first class condition for consumption by the grower and customers;
- to add value and increase profit through off-season sales or during the more lucrative high-price season;
- to preserve tubers for planting in the next season.

For ware and processing potatoes, storage aims at preventing “greening” and losses in weight and quality. In potato storage, the two critical environmental factors are temperature and humidity. Adequate and unrestricted air movement is necessary to maintain constant temperature and humidity throughout the storage pile, and to prevent excessive shrinkage from moisture loss and decay. The storage temperature affects curing and wound healing processes, the spread and severity of disease, sugar-starch balances, and respiration. Respiration, in turn, influences dormancy or sprouting, and weight loss. High humidity is essential for optimum wound healing during the curing period.

It is also essential throughout the storage period in order to minimize tuber weight loss – weight loss rapidly increases at relative humidity levels below 90 percent.

Depending on variety and conditions during growth, at 10–13°C and 93 percent humidity, potatoes store for 1–3 months; at 8–10°C and 93 percent humidity for 2–5 months; at 5–8°C and 93 percent for 4–8 months; at 2–5°C and 93 percent humidity for 7 months.

## Good practices

- ☼ Store well cured potatoes that were harvested when ripe (2 weeks after foliage death) in a well-ventilated, dark, cool place at about 4°C (where refrigeration is an option) with humidity around 90 percent. The potatoes will store for roughly three to six months.
- ☼ Store only tubers that are mature and free of diseases, insect pest and physical damage such as bruising. Research has demonstrated that potatoes from healthy plants are much more resistant to storage decay than potatoes from plants that have been weakened from physiological stresses.
- ☼ Handle the tubers carefully throughout the harvesting and pre-storage operations in order to minimize bruising, skinning and cutting. Ideally, the harvest should be carried out in temperatures of between 10–18°C. Do not harvest when tuber pulp temperature is less than 8°C or more than 20°C.
- ☼ Remove soil and plant residues before placing potatoes in storage.
- ☼ A wound healing or curing period is

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KEY INDICATORS  
OF  
SUSTAINABILITY

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**SUSTAINABLE  
POTATO  
PRODUCTION**



**COLLECTING  
POTATOES  
IN DIENG PLATEAU,  
INDONESIA.**  
(PHOTO: HARJONO  
DJOYOBISONO)



necessary to prevent the entry of rot organisms and to reduce water loss. Wound healing occurs most rapidly at 15-18°C, with 95 percent humidity, and requires 5-20 days.

- ✿ Pile potatoes without refrigeration in several small piles rather than in one large heap. Large amounts tend to heat because ventilation cannot reach the centre of the pile, thus lowering quality and shortening storage life.
- ✿ Never store potatoes in close proximity to fruit – hormones produced by ripening fruits will cause the potatoes to sprout or rot prematurely.
- ✿ Storing ware potatoes at a temperature of less than 6°C stimulates the conversion of starch into sugars, giving the tubers an unnaturally sweet taste. Moreover, sugars will interact with free amino acids during frying, producing dark products with poor taste.

### Potential areas of improvement

- ✿ Promote improvements in harvest technologies to minimize bruising, improve tuber quality and storability.
- ✿ Develop and promote low-cost storage technologies suitable to small-scale farms in the tropics and subtropics.
- ✿ Carry out ex-ante cost-benefit studies on small or large scale refrigerated storage capacity.

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**KEY INDICATORS  
OF  
SUSTAINABILITY**



## Adding value in East Africa

A study was conducted recently across the East African region to estimate the potential size of the market for fresh and processed potato in selected cities in Burundi, Ethiopia, Kenya, Rwanda, Tanzania and Uganda. Findings show

that establishment of a viable industry for processed potato hinges on improvements in quality standards and packaging and premium prices for quality produce. The study said that expanded potato processing would

increase employment opportunities in city areas. With half of East Africans expected to live in urban areas by 2015, the boom in demand for potato chips and French fries looks set to continue.

## Enhancing the value chain and markets

Learning to innovate and engage with markets, and to become more competitive are main challenges facing small-scale farmers. However, in many low-income developing countries, potatoes are typically marketed through fragmented chains with little coordination and poor information flows, giving rise to high supply risks and high transaction costs. Average yields

remain far too low to enable small-scale potato growers to produce a marketable surplus, preventing them from increasing their participation in potato marketing systems. In addition, limited storage and transport facilities can adversely affect the quality of tubers after harvest. Efforts to enhance the value chain will only be successful provided there are substantial levels of

public and private investment in the subsector, such as in breeding programmes, infrastructural improvements and initiatives to support and coordinate activities along the chain. Policy-makers should increase support to the subsector, by – for example – extending to the potato sub-sector policies and resources traditionally focused on cereals and on cash crops for export.

## The Participatory Market Chain Approach

The Participatory Market Chain Approach (PMCA) was developed by the Papa Andina Regional Initiative conducted in Bolivia, Ecuador and Peru by the International Potato Center (CIP). The aim of Papa Andina is to improve the competitiveness of potato market chains and small potato producers. PMCA has

proven effective in strengthening innovation capacity and developing market chain innovations that benefit small farmers as well as processors and distributors. Valuable capacities for innovation have been developed, particularly in the realms of knowledge, attitudes,

skills, and social capital. These new capacities are potentially valuable assets for stimulating future innovations in market chains. The benefits of the PMCA have stimulated considerable interest in the approach among R&D organizations, policy makers and market chain actors.

# Value addition and markets

**W**ith its adaptability to a wide range of uses, the potato has a potentially important role to play in the food systems of developing countries. In fact, in many countries, growth in urban populations, rising incomes and dietary diversification have led to rapidly increasing demand for potatoes from the fresh market, fast food, snack and convenience food industries. The structural transformation of agriculture-based economies into more urbanized societies opens up new market opportunities for potato growers and to their trading and processing partners in the value chain. In order to tap such potential, an efficient value chain for potato needs to be established.

Often potatoes are purchased in the countryside by traders from cities, with very limited negotiation and with prices decided at the farm gate, resulting in an uneven distribution of income along the value creation chain. This leads to insufficient buying power among potato growers and the draining away of capital that could be invested in rural areas to build infrastructure such as roads and improve education.

## Good practices

- ✳️ Carry out consumer surveys to identify growing market segments and types of products likely to be in demand in the near future.

- ✳️ Develop and select cultivars that are preferred by consumers, processing industries or local exporters.
- ✳️ Use appropriate post-harvest practices and storage facilities to keep tubers in their most edible and marketable condition.
- ✳️ To increase value, provide high quality ware potatoes or potato products to consumers.
- ✳️ Use simple market-oriented technologies that transform potato tubers into stable high quality products.
- ✳️ Encourage farmer participation in producer groups and organizations in order to increase their market competitiveness and bargaining capacity and strengthen their position within the potato value chain.

## Potential areas of improvement

- ✳️ Support participatory market chain approaches for potato (see box).
- ✳️ Develop innovative marketing and utilization techniques linking small scale potato producers to new market opportunities.
- ✳️ Promote mechanisms and approaches to link technology suppliers with farmers' needs, based on opportunities identified within a market chain framework.
- ✳️ Organize growers in cooperatives for joint purchase of inputs such as fertilizers and for joint processing and trading so that a greater proportion of the potato value chain remains in the hands of producers.

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KEY INDICATORS  
OF  
SUSTAINABILITY



POTATO HARVESTING.  
(PHOTO: FAO)

# Farmers' health, safety and welfare

**T**he health, safety and welfare of farmers and consumers are vital assets for the sustainable development of the potato subsector and agriculture throughout the world. Particular attention must be paid to reducing risks associated with the use of pesticides, tools and machinery, and to ensuring that potatoes are produced and handled in a manner that does not harm the environment and the health, and safety of farmers and consumers.

## Good practices

- ✳ Creating awareness of food safety and environmental issues should be part of community education programmes in rural areas.
- ✳ Train farmers in the efficient and safe use of pesticides, fertilizers, tools and machinery
- ✳ Encourage them to invest in potato farming, and in improving their living standards.
- ✳ Use decision support tools to reduce the amounts of biocides used in potato production and thus reduce the risks of dangerous levels of residues in harvested or stored produce.
- ✳ Ensure that medical doctors and hospitals in rural areas are able to recognize symptoms of agrochemical poisoning and treat it.

## Potential areas of improvement

- ✳ Farmers groups should consider developing partnerships with public sector and development organizations to address health and safety issues.
- ✳ Create services that collect pesticide packing material and unused redundant stocks for centrally organized destruction.
- ✳ Inform farmers and households about proper pesticide labelling and the designation of containers used to mix pesticides, and the use of properly functioning protective equipment and clothing.
- ✳ Establish a list of chemicals that are generally safe for various crops and a “black list” of chemicals that are dangerous and are forbidden.
- ✳ Set maximum residue levels for agrochemicals that are permitted for use in the country.
- ✳ Organize farmers groups in cooperatives to promote their interests and call for positive marketing regulations, lower duties and taxes on imported tools and equipment, and better access to credit to improve their self-reliance and welfare.

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KEY INDICATORS  
OF  
SUSTAINABILITY

**POTATO BAGS WAITING  
TO BE SENT BY TRAIN  
FROM SHIMLA, INDIA.  
(PHOTO: S. PAUL)**



A black and white photograph of a person walking along a high stone wall. The wall is made of large, rounded stones and runs across the middle of the frame. In the background, there are rolling hills and mountains under a clear sky. The person is on the left side of the wall, walking towards the right. The overall scene is rural and mountainous.

## SECTION 4

# Implications for policy and research

*Potato production in the developing world grew from 85 million tonnes in 1991 to 165 million tonnes in 2007. To sustain that exceptional growth, policy and research must shift from the traditional focus on raising production to a broader approach aimed improving rural incomes, livelihoods, nutrition and health, while conserving the natural resource base.*



## “Papa pan”, a pro-potato policy solution

Although the potato has been a staple food for Andean peoples for millennia, many modern Peruvians prefer rice or bread made from imported wheat. To support domestic potato production, the Government of Peru has offered low-income potato farmers emergency credit to maintain production and encourages Peruvians to eat a greater proportion of potatoes, thus boosting demand and prices. The government is also promoting the use of potatoes to make bread. A government-run food company produces each day more than 12 000 loaves made from one-third boiled and mashed potatoes and two-thirds wheat flour. Replacing a third of the wheat flour with mashed

potatoes or potato flour results in a soft, tasty bread that keeps well, and is more nutritious and cheaper than bread made from wheat only. Since January 2008, Peru’s prisons and many public schools have been serving potato bread (papa pan). It is also sold by Plaza Vea, a Peruvian supermarket

chain. More recently, the chief of Peru’s Sierra Exportadora, which supports farmer co-operatives, has called on Ministers to approve the construction of 100 potato flour production plants to supply small and medium bakeries and even to export potato flour to Europe, Japan and the USA.



**POTATO STARCH.**  
(PHOTO: JANGSU CORP.)

# Building support at policy level

**G**lobally, potato production is growing at a rate of 2 percent annually while in developing countries, growth is estimated at around 5 percent.

Sustaining the exceptional growth in potato production of the past two decades – from 268 million tonnes in the early 1990s to 325 million tonnes in 2007 – and the expansion of potato domestic trading in developing countries depends on choosing the right policy and research options for development of the agricultural sector and potato-based farming systems. The policy and research agenda is expected to shift from the traditional focus on raising productivity to a broader approach that makes a real contribution to the fight against hunger, poverty and environmental degradation by improving rural income, livelihoods, nutrition, health, and conserves the natural resource base.

Policy reforms are a needed if developing countries wish to develop and promote a sustainable potato industry and agricultural sector. This implies overcoming current trade barriers, including the lack of harmonized transit charges and customs documentation. It also implies overcoming current barriers to sustainable production intensification based on good agricultural practices.

Policy makers need to be more aware of the contribution that the potato is already making to development and food security, and of its importance as a staple food and cash crop in developing countries. In the process of revising poverty reduction strategy papers (PRSPs), and in formulating strategies for agricultural development, they should take into account the needs and potentials of the potato subsector and support its more active engagement in the

development process.

One important policy aim in developing countries should be to enhance the value of potato production by establishing links between farmers and food processors, improving credit availability, and fostering public-private partnerships for technology innovation. By engaging interested partners from the public and private sectors and civil society, policy can facilitate the development of focused country-level programmes, projects and activities to support a sustainable potato subsector.

Policy should also create a regulatory environment conducive to sustainable potato development through support for knowledge enhancement and research, application of best management practices, and sharing and promotion of proven and advanced potato technologies through education, extension and training.

Policy should address constraints on potato-based production systems by favouring the introduction of good quality planting material and potato varieties more resistant to insect pests, diseases, water scarcity and climate change, farming systems that can make optimum use of natural resources, seed certification schemes and soil testing laboratories.

Policy will also have to secure financial commitments from national governments, donors and the private sector to invest in potato-based systems and value chains. In doing so, policy makers should encourage a stronger commitment by the potato community to potato subsector development.

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**IMPLICATIONS  
FOR POLICY  
AND RESEARCH**

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**SUSTAINABLE  
POTATO  
PRODUCTION**



**IN VITRO PLANTS  
OF POTATO.**  
(PHOTO:  
YOAV FRIDLANDER)

# Research for development agenda

**A**ccelerated and sustainable development of the potato subsector in developing countries requires increases in the productivity, profitability and sustainability of potato-based farming systems. This implies a new and vigorous research for development agenda.

The way forward for potato research in developing countries will include a number of priority areas. First, the lack of adequate quantities of clean seed is a major bottleneck to improved productivity. Promising results have been obtained through extension efforts that promote the use of “positive selection” and small-scale seed plots. Other research work aimed at improving the quality of farmers’ seed through novel technologies such as aeroponic production of clean seed tubers has yielded positive results. Strong consideration should be given to fostering public-private sector partnerships as a strategy for getting potato seed systems moving in developing countries. Also recommended are ex-ante assessments of the potential return on investments by calculating the impact of new adapted varieties and cleaner seed.

In many countries, investments are needed in laboratories for the diagnosis of potato diseases, for measuring mineral concentrations in soils, manure and fertilizers, and for determining the composition and concentration of active compounds in herbicides, pesticides, fungicides and nematicides.

Legislation is needed in many countries to set quality standards for seed and to introduce or enforce mechanisms for certification through accredited laboratories. Legislation may also be needed to protect potato breeders’ rights.

The potential effects of climate change pose a threat to the levels and stability of potato yields. Heat and drought resistance should be considered in breeding programmes along with other key traits such as late-blight resistance, virus resistance, earliness and culinary qualities. Hence, research needs to provide a broader range of genetic material that meets site-specific criteria, is adaptable to changing environments, and meets new demands from emerging markets for processed food products, non-food ingredients and starch for industry. The growing demand for potato with specific characteristics for a particular processed product must be taken into consideration, but should only be pursued after a careful analysis of market prospects.

The potato subsector faces a growing challenge from more aggressive strains of late blight and many developing countries have a limited capacity to control the disease through fungicide application. Continued research on resistance breeding and integrated management strategies is essential, while support is needed for scaling up LB control technologies and methodologies developed by CIP.

It is unlikely that resistance to latent bacterial wilt infection will be available through conventional breeding in the near

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**IMPLICATIONS  
FOR POLICY  
AND RESEARCH**

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SUSTAINABLE  
POTATO  
PRODUCTION



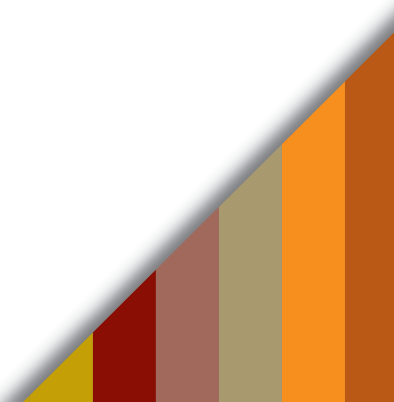
FROM THE ESSAY,  
"HARVEST OF NATIVE  
POTATOES, PERU."  
(PHOTO: EITAN  
ABRAMOVICH SAMESAS)

future. Research on integrated management to control bacterial wilt needs to focus on designing improved detection technologies, developing recommendations that farmers are willing and able to adopt, and exploring options for suppressing the disease through improved soil fertility and health management (e.g. sanitation measures and clean seed). Participatory approaches to farmer empowerment and learning, such as Farmers' Field Schools (FFS) for IPM and IDM, are required in order to reach a significant number of potato growers. Progress in the sequencing of the bacterial wilt genome might lead to new ways of controlling the disease in the long term.

The development of conservation agriculture technologies and practices for potato-based systems presents opportunities

for both public and private sector research. All aspects require increased research support.

Finally, improving the incomes of small-scale potato growers depends on increasing demand-driven opportunities and developing value-chains which include all market chain actors, from input suppliers to consumers. Linking farmers to markets, especially high-value supermarkets and restaurant chains, can substantially increase the profitability of the potato cultivation. This requires technological innovation at many points in the value chain, including introduction of improved varieties and more efficient post-harvest processes, as well as technical assistance to ensure timely production and supply of adequate quantities of high quality potato products.





## Challenge of a better functioning value chain

Potato seed producers arguably constitute the most critical link in the potato chain. For it is their role to ensure that the chain has access to sufficient quantities and qualities of planting material to meet the needs of potato growers, processors and traders. In order for this group to successfully participate in the value chain, they need yield-improving and input-saving technologies to help close the persistent potato “yield gap” and to reduce per tonne production costs. Production initiatives can be strengthened greatly by germplasm research focused on specific end uses, tissue culture, rapid multiplication of planting material, insect pest and disease resistance (including enhancing resistance to prevalent diseases such as late blight by

combining conventional plant breeding techniques with biotechnology) and the formation of producer groups to share expertise and to strengthen bargaining power. The continuous generation and diffusion of improved varieties is important if the potato subsector is to flourish. The expansion of potato cultivation will also be facilitated by improved irrigation supply, chemical fertilizers, cold storage

facilities, and transport infrastructure. In addition, the market price of potato is often subject to very limited negotiation and is often decided at the farm gate. Inefficient and unfair pricing often results in producers failing to respond to market incentives, stifling efforts to increase productivity and undermining the necessary on-farm investments in production.



ASSEMBLING  
THE POTATO  
HARVEST, INDONESIA.  
(PHOTO:  
FERNADIE LILI)

# Partnerships for policy and research

**E**xtending the benefits of potato subsector in developing countries requires action on a wider front. The best strategy for achieving this is to engage the international community in agricultural development that benefits small-scale farmers, who make up the majority of the world's most poor and hungry. Such commitment will make a strong contribution to achievement of the first of the United Nations Millennium Development Goals, to half the proportion of those living in extreme poverty and hunger.

As a lead UN agency for agriculture and rural development, FAO will be a key partner in that process, by advising on policies and strategies to modernize the potato subsector, sharing its extensive knowledge of potato farming systems, promoting appropriate technology for sustainable intensification of

production, and forging links among decision makers, producers, processors and marketing chains.

CIP will play a key role through its campaign for a new research for development agenda that puts potato science at the service of the poor. The new agenda seeks to boost potato yields in developing countries by working with them to provide higher quality planting material, better varieties drawn from a broader base of potato genetic resources (including the rich storehouse of Andean varieties), and improved crop management practices. CIP is calling for a renewed sense of responsibility for conservation of the potato gene pool and take concrete steps to ensure that developing countries acquire the capacity to utilize it in a sustainable manner.

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**IMPLICATIONS  
FOR POLICY  
AND RESEARCH**

**BAMBOO BOAT,  
THE PHILIPPINES.**  
(PHOTO:  
MARLENE SINGH)



## SECTION 5

# Potato fact sheets

*To deepen understanding of the potato's role in world agriculture, the economy and global food security, FAO specialists compiled a series of factsheets on key issues in potato development.*

## Potato and biodiversity

**By conserving – and utilizing – the potato genetic diversity developed by their ancestors, small farmers in the Andes are helping ensure world food security**



### Key points

Potato farming systems need a continuous supply of new varieties drawn from the entire potato gene pool.

Potato biodiversity is under threat – ancient varieties cultivated for millennia have been lost and wild species are threatened by climate changes.

Smallholder farming systems in the Andes encourage cross-pollination of potato flowers, vital to sustaining the diversity of local, farmer-developed varieties.

With CIP support, Andean communities have created a “potato park” holding some 1 200 traditional varieties of potato.

The history of the potato provides a grim warning of the need to maintain genetic diversity in our staple food crops. In the 19th century, Ireland was heavily reliant on only a few varieties of potato, and those types contained no resistance to the devastating disease known as late blight. When late blight destroyed the 1845-1846 potato crop, widespread famine followed. An estimated one million people starved to death and more than a million were forced to migrate abroad.

To combat pests and diseases, increase yields, and sustain production on marginal lands, today's potato-based agricultural systems need a continuous supply of new varieties. That requires access to the entire potato gene pool. But potato biodiversity is under threat: ancient varieties cultivated by Andean peoples for millennia have been lost to diseases, climate change and social upheaval.

### Species and crop-associated diversity

While most varieties of potatoes belong to a single species, *Solanum tuberosum*, about 10 other *Solanum* species have been cultivated, and 200 wild species have been recorded. Climate change may threaten the survival of those wild relatives: it is forecast that as many as 12 percent will become extinct as their growing conditions deteriorate. If climate



Farmers sort varieties at Peru's "potato park".  
Photo: © CIP

### Centre of origin

In the Andean region, generations of farmers have domesticated thousands of potato varieties. Even today, farmers cultivate up to 50 varieties on their farms. In the biodiversity reserve of the Chiloé archipelago in Chile, local people cultivate about 200 varieties of native potato. They use farming practices transmitted orally by generations of mainly women farmers.

changes drastically, the area where wild potatoes grow naturally could be reduced by as much as 70 percent.

Since potatoes mostly propagate vegetatively, most commercial varieties of potato have a reduced ability to flower and breeders do not select for traits that make the flower attractive to pollinators. However, natural potato pollination remains important to sustaining the diversity of land races (farmer-developed varieties that are adapted to local environmental conditions). Fortunately, the diverse smallholder farming systems in the Andes harbour a variety of flowering plants that do attract pollinators, such as honeybees and bumblebees, which promote cross-pollination of potato flowers, thus increasing seed production and sustaining diversity.

### International Treaty

The potato is included in the multilateral system established under FAO's International Treaty on Plant Genetic Resources for Food and Agriculture.

The Treaty, which entered into force in 2004, aims at the conservation and sustainable use of crop plant diversity and the fair and equitable sharing of benefits derived from their use.



### Conserving potato biodiversity in the Andes

Having lost many of their traditional potato varieties, Peruvian farmers in the Andes are now taking measures to conserve and sustainably use those that remain. A pact has been signed by six Quechua communities with the International Potato Center that recognizes the rights of the communities over potato strains they have developed.

Under the agreement, the Center's genebank returns potato genetic resources – and knowledge associated with them – to the communities, which have established a "potato park" (*Parque de la papa*) in a conservation area where they grow and manage the plants. This repatriation of biological diversity effectively keeps control of genetic resources local. The 15 000 ha park is a "living library" of potato genetic diversity, holding some 1 200 varieties of potato cultivated in the highlands. A long-term goal is to re-establish all the world's 4 000 known potato varieties in the valley, allowing the park to function as a second centre of origin for this vital staple crop.



Inside CIP's gene bank. Photo: © CIP

#### Diversity conserved in trust

The International Potato Centre in Peru maintains the world's largest bank of potato germplasm, including some 1 500 samples of about 100 wild species collected in eight Latin American countries, and 3 800 traditional Andean cultivated potatoes. The collection is maintained and managed under the terms of an agreement with the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture and, like all collections eligible for funding from the Global Crop Diversity Trust, is available to plant breeders worldwide upon request.

#### Credits:

Information provided by the Global Crop Diversity Trust and the Plant Production and Protection Division, FAO.

#### About IYP 2008

The **International Year of the Potato**, to be celebrated throughout 2008, aims at raising global awareness of the potato's key role in agriculture, the economy and world food security.

[www.potato2008.org](http://www.potato2008.org)



HIDDEN  
TREASURE



[www.potato2008.org](http://www.potato2008.org)

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A simple, low-cost technology can help developing countries produce the healthy seed tubers farmers need for sustainable potato production

**A low-cost alternative: small cuttings**

While the above process does deliver healthy seed tubers, micropropagation of plantlets is costly, requiring sophisticated technology and well-trained staff. In many developing countries, simpler and less expensive ways of propagation are needed. FAO is promoting a promising, low-cost alternative: the use of very small

**Key Points**

Potato diseases can dramatically reduce both tuber yields and quality.

Tissue culture of plantlets *in vitro* for production of disease-free seed tuber requires expensive technology and highly trained staff.

A low cost alternative is the use of cuttings - a single-node, leaf-bud or other type of very small plant cutting - for propagation of plantlets under non-sterile conditions.

The cuttings root easily and produce plantlets as efficiently as *in vitro* propagation - each cutting can yield up to 100,000 progeny within six months.

**Tissue culture and micropropagation**

Elementary methods of tissue culture were developed in the 1950s, and micropropagation has been used commercially for multiplying stock plant material since the late 1960s.

The annual volume of plants micropropagated from tissue culture is estimated at hundreds of millions of plants, representing tens of thousands of varieties.

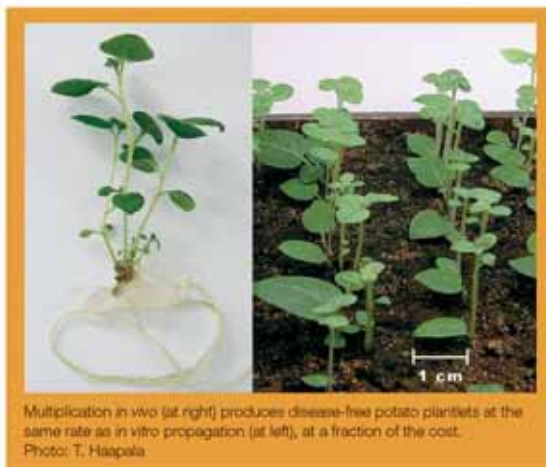
Commonly micropropagated plants include flowers, strawberry, ornamental shrubs and forestry trees.

Potatoes are susceptible to a variety of diseases that lower yields and tuber quality. What's more, pathogens accumulate in successive clonings of tubers and in the soil used to grow them. That is why sustainable potato production depends on a constantly renewed supply of disease-free planting material.

A major innovation for the potato industry in developed countries was the widespread adoption in the 1970s of tissue culture - or micropropagation - as a means of multiplying disease-free plants that can then be used to produce healthy seed tubers for farmers. First, viruses and other pathogens are eliminated by growing potato plants in a controlled environment at high temperature.

The disease-free shoot tips of the plants are then placed on a standard nutrient medium in glass containers (*in vitro*) in a completely sterile laboratory environment. The tips develop into plantlets that are then transferred to either a greenhouse or a field protected from insect pests, where they grow at the same rate as normal potato plants but produce smaller tubers (called "mini-tubers").

After harvesting, mini-tubers need to be stored at low temperature. After about 45 days - and for a period of up to seven months thereafter - they can be moved to a warmer environment to induce sprouting. Once planted, they go on to produce normal-size, disease-free seed tubers ready for delivery to farmers. (While growing, the plants need to be protected from insect pests to avoid new disease infections.)



Multiplication *in vivo* (at right) produces disease-free potato plantlets at the same rate as *in vitro* propagation (at left), at a fraction of the cost. Photo: T. Haapala

cuttings, i.e. a single-node, leaf-bud or other type of plant cutting of about 1.5 cm, which can be grown to produce plantlets on a commercial scale.

The starter plant material remains a small number of disease-free micropropagated plantlets, which, in regions such as sub-Saharan Africa, are often imported from developed countries. However, they are multiplied not *in vitro* but *in vivo* (i.e. in non-sterile, natural conditions). Cuttings are propagated in a growing room or a shaded greenhouse in a mixture of peat and sand (or other rooting media) in plastic trays placed on metal stands.

The cutting technique takes advantage of etiolation - i.e. growing the plantlets under low light intensity. Etiolated plants retain their juvenile characteristics, producing new shoots for further cuttings that root easily. In addition, the plants remain small, so many can be grown in a limited space.

- each tray can hold up to 500 cuttings per square metre. The cuttings grow into new plantlets within three weeks, providing a source for further cuttings. Within six months, a single cutting can yield up to 100 000 progeny.

Once the plant material is multiplied to the quantity needed, plantlets can be transferred to an environment free of insect pests (in a greenhouse or an open field under shade). Planted in deep soil, the plantlets root easily within a week, grow into perfectly normal potato plants and produce mini-tubers.

The technique produces plantlets at the same rate as *in vitro* propagation at a fraction of the cost. However, it is essential that the disease-free starting plant material is kept *in vitro* and all standard phytosanitary measures are followed throughout the propagation process.

### The importance of timing



Potato plantlets in a greenhouse, soon to be planted outdoors. Photo: CIP

The cutting technique is suited to developing countries that need simpler and less expensive ways of propagating seed tubers. However, producing good quality starter planting material is only one element in the process of potato seed tuber production. Seed supply schemes can fail because propagation from cuttings and storage of mini-tubers is not coordinated with farmers' cropping calendars. Unless the field and storage phases are well planned and implemented, the benefits of micropropagation may be lost.

#### About IYP 2008

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This fact sheet was written by FAO's Plant Production and Protection Division. The International Potato Center also contributed.



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## Potato pest and disease management

Combating pests and diseases with intensive use of insecticides and fungicides often does more harm than good. An array of alternatives is available...



### Key points

Intensive potato cultivation tends to increase pest and disease pressure, which often leads to intensive use of harmful pesticides.

Resistant potato varieties and improved cultural practices can reduce or eliminate many common pests and diseases.

Integrated pest management has helped farmers drastically reduce the need for chemical controls while increasing production.

The use of chemical pesticides on potato is increasing in developing countries, as farmers intensify production and expand cultivation into areas and planting seasons beyond the crop's traditional range. The chemicals used are frequently highly toxic and applied with little or no protective equipment.

The result is alarming levels of pesticide poisoning in farming communities. Insecticide absorbed by soil often penetrates subsequent crops and runs off to contaminate water supplies. Overuse of pesticides even compounds pest and disease problems: in Colombia, outbreaks of a viral disease have been linked to insecticides that wiped out natural predators of the disease's vector.

Increasing potato production while protecting producers, consumers and the environment requires a holistic crop protection approach encompassing a range of strategies – encouraging natural pest predators, breeding varieties with pest/disease resistance, planting certified seed potatoes, growing tubers in rotation with other crops, and organic composting to improve soil quality.

### Some of potato's main enemies

#### Diseases

**Late blight:** the most serious potato disease worldwide, is caused by a water mould, *Phytophthora infestans*, that destroys leaves, stems and tubers.

**Bacterial wilt:** caused by the bacterial pathogen, leads to severe losses in tropical, subtropical and temperate regions.

**Potato blackleg:** a bacterial infection, causes tubers to rot in the ground and in storage.

**Viruses:** disseminated in tubers, can cut yields by 50 percent.



Photo: © FAO

### Ecuador: training reduces pesticide poisoning

In Ecuador's Carchi province, a programme supported by CIP and FAO used Farmer Field Schools to drastically reduce high rates of pesticide poisoning. Continuous cropping of potato had produced not only high yields, but highly favourable conditions for insects and fungal diseases, leading to massive applications of insecticides and fungicides. As a result of pesticide exposure, CIP scientists say, 60 percent of people in the area showed reduced neuro-behavioural functions. IPM training enabled farmers to reduce agrochemical application costs – including fertilizer, pesticide and labour costs – by an average of 75 percent with no effect on productivity. Follow-up studies show that the reduced exposure to pesticides was associated with recovery of previously suppressed nervous system functions.

There is no effective chemical control, for example, against bacterial wilt. But planting healthy seed in clean soil, using

#### Pests

**Colorado potato beetle** (*Leptinotarsa decemlineata*): a serious pest with strong resistance to insecticides.

**Potato tuber moth:** most commonly *Phthorimaea operculella*, is the most damaging pest of planted and stored potatoes in warm, dry areas.

**Leafminer fly** (*Liriomyza huidobrensis*): A South American native common in areas where insecticides are used intensively.

**Cyst nematodes** (*Globodera pallida* and *G. rostochiensis*): serious soil pests in temperate regions, the Andes and other highland areas.

tolerant varieties in rotation with non-susceptible crops, and other sanitation and cultivation practices can lead to significant reduction of the disease. Incidence of potato tuber moth can also be reduced by preventing soil cracking that allows moths to reach the tubers.

Both the International Potato Center (CIP) and FAO advocate Integrated Pest Management (IPM) as the preferred pest control strategy during production. IPM aims at maintaining pest populations at acceptable levels and keeping pesticides and other interventions to levels that are economically justified and safe for human health and the environment.

FAO has promoted IPM in many developing countries using Farmer Field Schools, which centre around a "living laboratory" where farmers are trained to identify insects and diseases and compare results on two subplots – one using conventional chemical pest control and the other using IPM. On the improved management plot, participants strive to improve ecosystem health by cutting pesticide use while increasing productivity through management intensification. Farmers experiment with a variety of techniques, such as weevil traps,

### Virus control

Because virus-infected potato plants cannot be cured, CIP is working to incorporate into new varieties resistance to the three most common potato viruses. Some virus resistance is now available in about a quarter of CIP-bred genotypes.

### Beating late blight

The mould responsible for late blight has consistently overcome resistant cultivars and mutated into strains that survive spraying with powerful fungicides. The Global Initiative on Late Blight, a network of scientists, technologists and agricultural knowledge agents in 72 countries, is exploring new control strategies, including "organic management" using improved sanitation in storage, risk forecasting and genetic resistance.



different strains of potatoes and targeted applications of lower toxicity pesticides.

In Peru's Cañete River valley, CIP entomologists designed an IPM package to help growers protect their crops against the leafminer fly, which had become a major problem after massive use of insecticides exterminated its natural enemies. The IPM

programme included traps to lure and kill adult flies and reintroduction to the valley of parasitic wasps. Participating growers were able to reduce spraying from 12 times per season to only one or two carefully timed applications of insect growth regulators.



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## Potato and soil conservation

**Mulch planting and the "no-till" potato can help reduce the soil degradation, erosion and nitrate pollution often associated with potato production**

### Key Points

Land preparation, weeding and harvesting of potato often involve intensive soil disturbance.

Cover crops sown before planting and as the crop matures protect the soil and facilitate harvesting.

Cultivation of potato without tillage helps restore soil, produces good yields and reduces the need for fertilizer and fuel.

Potato cultivation usually involves intensive soil tillage throughout the cropping period, which often leads to soil degradation, erosion and leaching of nitrates. During soil preparation, the entire topsoil is loosened and - particularly on sticky soils - pulverized into small aggregates to avoid the formation of clods in the potato beds. Mechanical weeding and mechanized harvesting also involve intensive soil movement. Conservation agriculture - a resource-saving crop production system - offers several useful techniques for soil conservation in potato production.

### Mulch planting for potatoes

In conventional, tillage-based potato cropping systems, the risk of soil erosion and nitrate leaching can be reduced using the mulch planting technique. The potato beds are prepared well in advance of planting - if potato is to be planted in spring, the beds would be prepared before winter - and seeded

with a green manure cover crop. The potato is later planted into the beds which, by then, are covered by the dead mulch of the manure crop.

For mechanical planting, planters are equipped with special discs that cut through the mulch and split the potato beds. The mulch protects the soil from erosion during the first weeks of the crop. As the potato plants grow, the reshaping of the beds incorporates the mulch. A second green manure crop can be seeded towards the end of the potato crop, as the potato plants are drying off. The cover crop helps to dry out the potato beds, contributing to healthier tubers with reduced risk of damage during harvest. The green manure is separated from the potato by a mechanical potato harvester and is left as a mulch cover after harvest, protecting the soil from erosion.

Mulch planting is being used for potatoes in parts of Germany and Switzerland, particularly in watersheds where drinking water sources might be prone to nitrate pollution from conventional cultivation methods. Nevertheless, while mulch planting of potatoes reduces the risk of erosion and nitrate leaching, it still involves major soil movement.

### The 'no-till potato'

Soil conservation can be enhanced further using a basic CA technique, "no-till" cultivation. The "no-till" potato is pressed into the soil surface, then covered with a thick layer of mulch - preferably straw, which is fairly stable and does not rot quickly. (Potatoes need to be kept in the dark to avoid the formation of chlorophyll, which renders the tubers green, bitter and toxic.)

### The advantages of conservation agriculture



Conservation agriculture (CA) aims at enhancing natural biological processes both above and below ground. It is based on three principles: minimum mechanical soil disturbance, permanent organic soil cover, and diversified crop rotations for annual crops and plant associations for perennial crops. By minimizing soil disturbance, CA creates a vertical macro-pore structure in the soil, which facilitates the infiltration of excess rainwater into the subsoil, improves the aeration of deeper soil layers, and facilitates root penetration.

In some cases - for example in dry areas under drip irrigation - black plastic sheets can also be used as mulch. Holes are punched in the plastic to allow the potato plant to grow through it. The young potato tubers form under the mulch but above the soil surface. During harvesting, the sheets are removed and the potatoes are simply "collected". Currently, the "no-till" potato is only grown in small fields using manual labour - for example, in Peru under plastic covers and in the Democratic People's Republic of Korea under rice straw.

### No-till potato in the Democratic People's Republic of Korea



Farmers in the Democratic People's Republic of Korea are using conservation agriculture in rice and potato production in order to restore degraded soils and achieve good potato yields with reduced need for fertilizer and fuel. The potato-rice crop rotation system produces two crops in a relatively short growing season, resulting in higher overall food production when compared to output from a single main crop. The seed potato is inserted into the soil under a mulch cover formed by the residues of the preceding rice crop. The potatoes grow through the rice straw and are harvested within three months. Immediately afterward, "no-till" rice is transplanted as the main summer crop. Per hectare, the system can produce 25 tonnes of potatoes and 7.5 tonnes of rice, and in cold storage and transport infrastructure.

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## Potato and water resources

**Agriculture faces a double challenge: to grow enough food for the world's expanding population while reducing its share of the Earth's freshwater resources. The potato can help...**

### Key Points

Agriculture must significantly improve its volume of production per unit of water used.

The potato produces more food per unit of water than any other major crop.

From the same amount of water, the potato produces more dietary energy than rice, wheat and maize.

Tailoring the timing and depth of water applications to specific stages of the potato's growth cycle can help reduce water usage.



To reduce potato's water needs, scientists are developing varieties that are drought-resistant with longer root systems. Drawing: CIP

Over the past century, human appropriation of fresh water has expanded at more than twice the rate of population increase. An estimated 3 830 cubic km (or 3 830 trillion litres) of water are now withdrawn for human use each year, with the lion's share – some 70 percent – being taken by the agricultural sector.

But agriculture's thirst is not sustainable in the long term. Facing intense competition from urban and industrial users, and mounting evidence that human use of water is jeopardizing the efficiency of the Earth's ecosystems, the sector must significantly improve the volume of production per unit of water used.

### Nutritional productivity

The potato stands out for its productive water use, yielding more food per unit of water than any other major crop. Along with groundnut, onion and carrots, its "nutritional productivity" is especially high: for every cubic metre of water applied in cultivation, the potato produces 5 600 calories of dietary energy, compared to 3 860 in maize, 2 300 in wheat and just 2 000 in rice. For the same cubic metre, the potato yields 150 g of protein, double that of wheat and maize, and 540 mg of calcium, double that of wheat and four times that of rice.

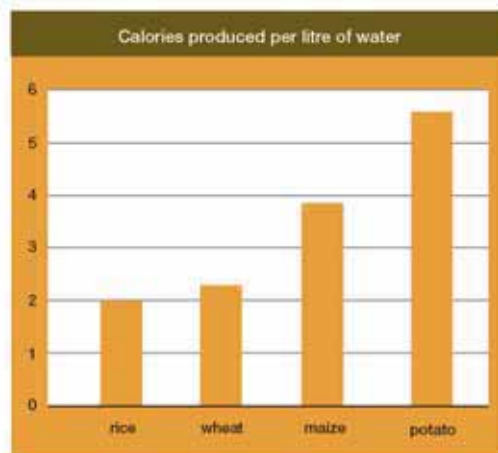
An increase in the proportion of potato in the diet would alleviate pressure on water resources. Currently, producing the foods – especially animal



An irrigated potato field in Cape Verde. Photo: ©FAO/Marzo Marzot

products – consumed in the average diet in the developed world requires water withdrawals estimated at 4 000 litres per capita per day (it takes, for example, around 13 000 to 15 000 litres of water to produce 1 kg of grain-fed beef). But one recent study estimated that a balanced diet based on potato, groundnut, onion and carrot would require per capita water consumption of just 1 000 litres per day.

While a potato-based diet is impractical – 4 kg would be needed to cover per capita daily energy and protein requirements – increased consumption of processed potato products and extraction of potato's nutrients offer a water-efficient means of meeting nutritional needs.



## Potato's water requirements

Modern potato varieties are sensitive to soil water deficits and need frequent, shallow irrigation. A 120 to 150 day potato crop consumes from 500 to 700 mm of water, and depletion of more than 50 percent of the total available soil water during the growing period results in lower yields.

To reduce potato's water needs, scientists are developing varieties that are drought-resistant with longer root systems. But significant water savings can be made in cultivation of today's commercial varieties by tailoring the timing and depth of water applications to specific stages of the plant's growth cycle.

In general, water deficits in the middle to late part of the growing period – during stolonization and tuber initiation and bulking – tend to reduce yield, while the crop is less sensitive during early vegetative growth. Water savings can also be achieved by allowing higher depletion toward the ripening period so that the crop uses all available water stored in the root zone, a practice that may also hasten maturity and increase dry matter content.

Some varieties respond better to irrigation in the earlier part of tuber bulking, while others show a better response in the latter part. Varieties with few tubers are usually less sensitive to water deficit than those with many tubers.

While soil should be maintained at a relatively high moisture content to maximize yield, frequent irrigation with relatively cold water may reduce the soil temperature below the optimum value for tuber formation (15 to 16°C), thus affecting yields. Also, wet and heavy soils can create soil aeration problems.

The most common irrigation methods for potato use furrow or sprinkler systems. Furrow irrigation has relatively low water use efficiency and is suitable when water supply is ample. In



For every unit of water, the potato produces twice as much protein as wheat and maize. Photo: ©FAO/Giulo Napolitano

areas with water scarcity, sprinkler or drip irrigation is preferred, especially on soils with low water retention capacity.

### Tuber quality and yield

Water supply and scheduling have important impacts on tuber quality – frequent irrigation reduces the occurrence of tuber malformation. Water deficit in the early phase of yield formation increases the occurrence of spindled tubers (more noticeable in oval than in round tuber varieties) and, when followed by irrigation, may result in tuber cracking or tubers with "black hearts".

Using good agricultural practices, including irrigation when necessary, a crop of about 120 days in temperate and subtropical climates can yield 25 to 40 tonnes of fresh tubers per hectare.

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## Potato and food price inflation

**The potato is a highly recommended food security crop that can help shield low-income countries from the risks posed by rising international food prices**

### Key Points



Prices of cereals are rising faster than those of potato and other root crops.

Countries with low levels of dietary diversity and high dependency on cereal imports could benefit greatly from expanded potato cultivation.

Potato flour can be blended easily with wheat flour, providing countries with a means of reducing costly wheat imports.

Potato is increasingly a valuable source of cash income for low-income farm households

Intense competition for reduced international supplies of cereals and other agricultural commodities is driving worldwide food price inflation, which brings with it the risk of food shortages and social unrest in low-income countries. One strategy that could help reduce the risk is diversification of food production to nutritious and versatile staple crops that are less susceptible to the vagaries of international markets. One such crop is potato.

Unlike rice, wheat and maize, the potato is not a globally traded commodity and its prices are determined usually by local supply and demand. A recent FAO survey in more than 70 of the world's most vulnerable countries found that inflation in potato prices is much lower than that for cereals. The potato is, therefore, a highly recommended food security crop that can help low-income countries ride out turmoil created by food price increases.

### Potato for nutrition – and income

In many developing countries, the poorest and most undernourished farm households depend on potatoes as a primary or secondary source of food and

nutrition. These households value potato because it produces large quantities of dietary energy and has relatively stable yields under conditions in which other crops might fail.

The potato is highly adaptable to a wide variety of farming systems. With its short vegetative cycle – high yields within 100 days – it fits well into double cropping systems with rice, and is also suitable for intercropping with maize and soybeans. Potatoes can be grown at altitudes of up to 4 300 m and in a variety of climates, from the barren highlands of the Andes to the tropical lowlands of Africa and Asia.

Potato is also rapidly becoming a valuable source of cash income – a primary requisite of food security – for many small scale producers. In many developing countries, growth in urban populations and incomes and the diversification of diets have led to rising demand for potatoes from the fast food, snack and convenience food industries. The structural transformation of agriculture-based economies into more urbanized societies opens up new market opportunities for potato growers

### FAO Cereal Price Index

1998-2000=100



Rising prices of maize, wheat and rice pose a threat to low-income countries

and to their trading and processing partners in the value chain.

### Investing in potato production

With its adaptability to a wide range of uses, the potato has a potentially important role to play in the food systems of developing countries. However, policy makers have traditionally focused on cash crops for export and on cereals, leaving potato and other root crops at the periphery of agricultural development efforts. Redressing this imbalance is important if potato sectors are to thrive.

Investment in potato production should be considered as insurance against international market turbulence and as a food security safeguard. In the current climate of high food prices, it is often forgotten that until recently international prices for cereals had reached historic lows when adjusted for inflation. A boom followed by bust in cereal prices could easily undermine investments in the potato sector if consumers revert back to purchasing cheap, subsidized imported cereals.

### Strengthening the potato 'value chain'

In developing countries, potatoes are often sold through fragmented marketing chains with little co-ordination and a lack of market information, giving rise to supply disruptions and high transactions costs. Many small scale farmers are excluded from markets owing to their low yields, and inadequate storage and transport. Inefficient and unfair pricing discourages them from making on-farm investments in production.

Enhancing the value chain requires substantial public and private investment, especially in breeding programmes and in infrastructure to support and co-ordinate activities along the chain.

Production initiatives can be strengthened by research focused on specific end uses, rapid multiplication of good quality planting material, and varieties with pest and disease resistance. Producers of potato seed tubers need to offer yield-improving and input-saving technologies that boost yields and



reduce costs. The formation of producer groups would help farmers share expertise and strengthen their bargaining power. Production would also benefit from improvements in the supply of irrigation water and chemical fertilizers, and in cold storage and transport infrastructure.

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