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Good Agricultural Practices in Potato Cultivation

A technical manual for

Maharashtra

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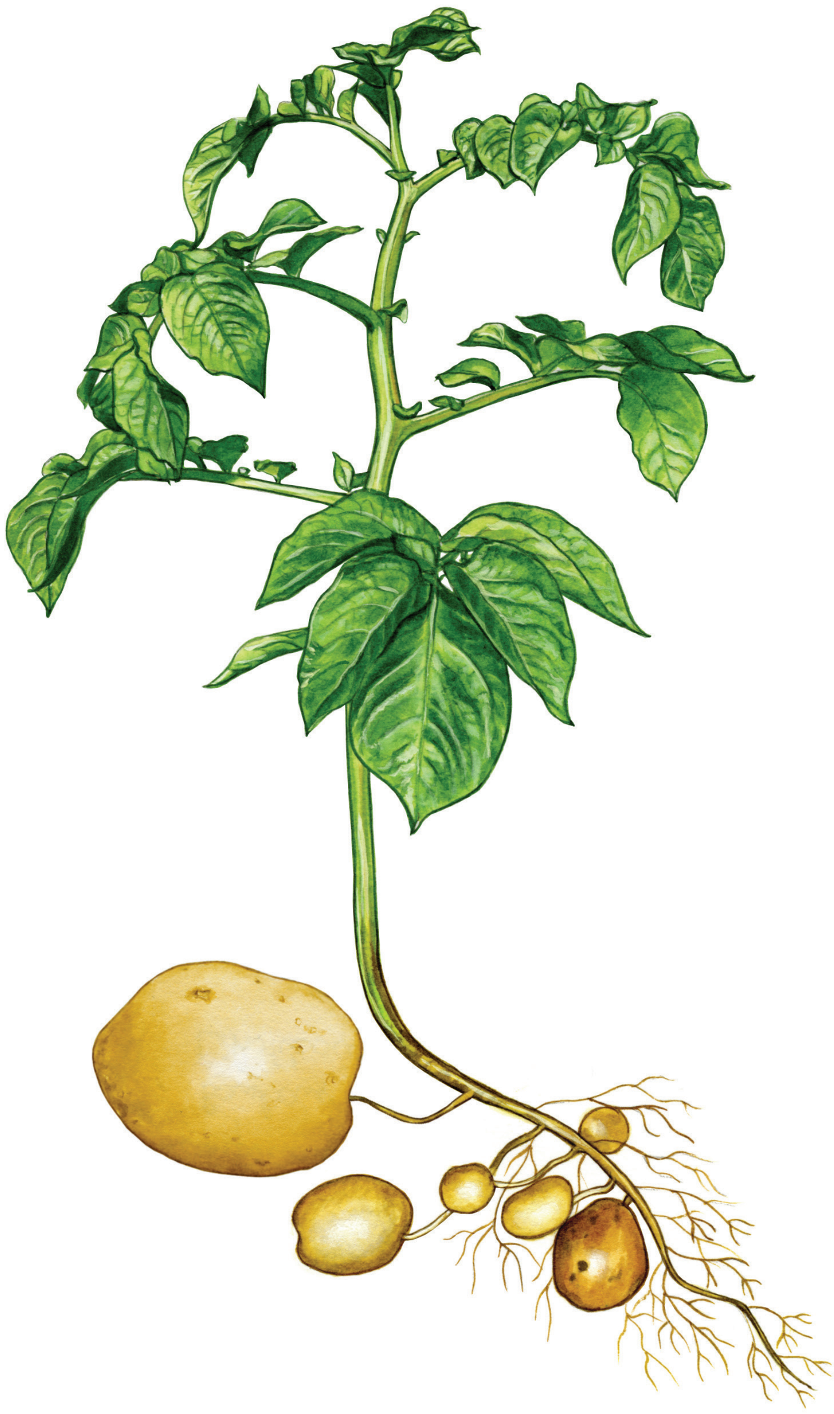
GOOD AGRICULTURAL PRACTICES IN POTATO CULTIVATION

A technical manual for Maharashtra



Foreword

The global programme "Green Innovation Centres for the Agriculture and Food Sector (GIC)" in India, commissioned by the German Federal Ministry of Economic Development and Cooperation (BMZ), has been working on the integrated development of the tomato, potato and apple value chain by identifying and scaling innovations that enhance the productivity and income of smallholder farmers and small-scale farming enterprises while creating employment opportunities in up-stream and down-stream businesses. The project is being implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, in cooperation with the Ministry of Agriculture & Farmers Welfare (MoA&FW).

In Maharashtra, the GIC project has been working on the potato and tomato value chains in Pune and Ahmednagar districts. This project is being implemented through a dedicated field team and in close cooperation with the Department of Agriculture, Government of Maharashtra, Mahatma Phule Krishi Vidyapeeth Rahuri (MKPV) and the University of Horticultural Sciences, Bagalkot. The project has successfully demonstrated several innovations to achieve the key objectives.

By applying the Participatory Technology Development (PTD) approach, the GIC project tested and implemented various innovative practices together with the farmers on the fields to address common challenges in the value chain.

Potato farmers are confronted with declining cultivations areas and yields. In addition, climatic shocks and diseases keep productivity at a low level which ultimately also influences the farmers' income. The lack of quality and early generation seed potatoes, a low mechanisation rate, and less focus on good agricultural practices further aggravate the problem. To address this, the project has introduced many innovations such as the introduction of the *Himalini* variety, adapted semi-automatic potato planters, blight management through preventive spray, etc. Overall, the project has adopted sustainable agriculture practices to protect the soil and environment.

As the GIC is now entering a new project phase, it documented all promoted good practices in the form of a technical manual which can serve as a ready reckoner for extension officers and farmers. This document is prepared with the involvement of the Department of Agriculture, Government of Maharashtra, Mahatma Phule Krishi Vidyapeeth Rahuri (MKPV) and the University of Horticultural Sciences, Bagalkot but most importantly with the constant involvement of the potato farmers in Maharashtra. I sincerely thank all these organisations for contributing their learnings.

I hope that this technical manual for good agricultural practices will help to scale up sustainable agricultural practices in potato cultivation in Maharashtra.

Mr Gerrit Qualitz
Project Director
Green Innovation Centres for the Agriculture and Food Sector – India

Message from Maharashtra State Horticulture And Medicinal Plant Board

Agriculture is an important sector of the Indian Economy as more than half of its population relies on agriculture sector. India is one of the major players in the agriculture sector worldwide. The Agriculture sector in India holds the record for second-largest agricultural land in the world, in recent data, agriculture is the primary source of income for half of the population that contributed 17-18 % to the country's GDP. Thus, farmers become an integral part of the sector to provide us with means of sustenance.
In India's rural areas, local food security is still based on smallholder structures.

India is the second-largest producer of vegetables in the world. Tomato and potato constitute almost half of the vegetable production in the country. The government is also focusing on TOP (tomato, onion and potato) crops under the Operation Greens scheme. The state of Maharashtra is endowed with different agro-climatic conditions, and has 8 agro-climatic zones with different types of soil and climate. This favours the farmers to grow different varieties of fruits and vegetables. Maharashtra has always taken an initiative in adopting new technologies in Horticulture. Onion, tomato, and potato are the three major grown vegetables in Maharashtra. Hence it is important to focus on these crops. The Green Innovations Centre for the Agriculture and Food Sector (GIC) - India project and Maharashtra State Horticulture and Medicinal Plant Board (MSHMPB) are closely working since 2016 on tomato and potato value chains in Maharashtra. The major focus of this collaboration is to provide farmers end to end knowledge of tomato and potato value chains.

Crop production depends upon crucial inputs such as good seeds, fertilizers, pesticides, irrigation, human labour, machinery, and management. However, there is a need for equipping the farmers with basic and advanced knowledge of crops for taking appropriate farm management decisions and adopt modern technologies. In view of this, the GIC India project and MSHMPB have jointly developed a field manual of tomato and potato crops which will provide detailed knowledge on production of tomato and potato crops. The Agricultural Technology Management Agency (ATMA) at district level is responsible for technology dissemination activities. It has linkages with all the line departments, research organisations, non-governmental organisations and is associated with the agricultural development in the district. The ATMA is working with the objective to strengthen research – extension - farmer linkages and to provide an effective mechanism for co-ordination and management of activities of different agencies involved in technology adaption/validation and dissemination at the district level and below.

The field manuals of tomato and potato crops developed by the GIC project and MSHMPB will help to enhance and update the knowledge of the extension workers and practitioners, and to disseminate this knowledge to the end users i. e., the farmers in Maharashtra. This will further enhance the capacities of farming communities, increase farm productivity, reduce input costs and increase income levels of farmers. We trust that these field manuals will benefit a maximum number of farmers to make farming economically and environmentally more sustainable.

Best regards

Dr. Kailas Mote
Director
Maharashtra State Horticulture And Medicinal Plant Board (MSHMPB)

Message from Agricultural Technology Management Agency

The Maharashtra agriculture sector is characterised by small and marginal landholders. There are 1.36 crore farmers in the state, of which 48.9% are marginal and 29.5% are small farmers. Hence it is important to provide technologies which are applicable for small and marginal farmers.

The Agricultural Technology Management Agency (ATMA) is a focal point for integrating Research and Extension activities. The ATMA plays a significant role in agriculture extension based on integrated farming system.

The field manuals for Tomato and Potato crops developed by the Green Innovations Centre for the Agriculture and Food Sector (GIC) - India project and the Maharashtra State Horticulture and Medicinal Plant Board (MSHMPB) are important tools for extension workers for disseminating improved technologies for tomato and potato crops. The manual focuses on reduction of input cost and increasing the productivity and production to increase the income of smallholder farmers in the state.

I strongly believe that these manuals will be helpful for extension workers and farmers to understand best practices in tomato and potato crops. These manuals will act as an important tool to improve extension services and dissemination of knowledge in the agriculture sector.

Mr Dashrath Tambhale
Director - Agriculture, ATMA, Maharashtra

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INTRODUCTION

Potato (*Solanum tuberosum*) is part of the genus tuberosum under the Solanaceae family.

It is a root vegetable plant native to America and domesticated in Peru about 6000 years ago. In the 16th century, it was introduced to Europe and became a staple food crop.

This herbaceous plant grows up to 1-2 m in height with a flexible fibre stem. It bears white, blue, red, and purple colours, depending on the varieties. There are close to 4000 varieties of potatoes. However, only about 100 varieties are being grown commercially.

In India the crop was introduced by the Portuguese in the 16th century and since then, this starch tuber has become an important and most familiar vegetable across India. Presently, India is the 2nd largest producer of potatoes in the world, with 44 million tons of production from 2.0 million hectares, amounting to a productivity of 22 tonnes per hectare. The higher productivity level confined to mainly the Indo-Gangetic plains and plateau regions producing about 90% of potatoes. However, towards Western and Southern regions the yield levels are comparatively smaller at below 10 tons per hectare mainly due to different agroclimatic characteristics and predominant rainfed farming.

In Maharashtra, potatoes are being grown mainly in Pune, Ahmednagar, Satara, Nashik, Beed and Aurangabad districts. Pune and Ahmednagar districts are major potato growing districts in Maharashtra state, which account for 70% of area and 76% of production. Total area under potato in Maharashtra was 21,950 hectares with 4,93,000 tonnes production.

Being a short duration crop of 3–3.5 months, this crop fits well in cropping system and for inter-cultivation. The potato varieties that are preferred for cultivation have early/medium maturity, are fast bulking, insensitive to photoperiod, have a slow rate of degeneration, high productivity, good storability at ambient temperature and are tolerant to late blight.

About 70% of the potatoes produced in Maharashtra are grown in the Kharif season, mostly under rain-fed conditions. Majority of farmers around Pune district grow processing type varieties in kharif season. The Rabi crop is concentrated around Pune and Ahmednagar districts and is mainly supported through irrigation. The Kharif season is changing due to the later arrival of the monsoon rains along with the expected periods of drought during the growing season. Kharif production is characterised by increasing temperatures during the growing season. Late planting is particularly at risk of high temperatures.

Another issue that has been a long-term concern for Indian farmers and policymakers alike is soil health. The carbon content of Indian soil has been gradually decreasing. Around 3.7 million hectares of soil in India have been found to have depleted organic matter levels. Historically, traditional farmyard manure was used to replenish carbon and nutrients in the soil. But, with decreasing livestock numbers, local availability of organic waste is declining. The planting time for potato is different for different parts of India, but potato is generally classified as Kharif or Rabi crop. The Rabi crop is usually cultivated from October to December and lasts up to March or April. Cultivation of the Rabi crop is mainly through irrigation due to the absence of predictable rainfall. The Kharif crop is grown in the monsoon season.

The Kharif season differs in every state of the country but is generally from mid-May to September. Farmers plant the crop at the beginning of the monsoon season, around June, and harvest by September or October. As the Kharif crop is rainfed and 70% of farmers grow potatoes in this season, the use of mechanisation may be difficult due to the wet soil and may delay planting. Most farmers tend to plant when there is excessive rain, which leads to higher losses through rotting.

The **Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH** is a public-benefit federal enterprise of the German Government. In its projects, GIZ works with partners in national governments as well as actors from the private sector, civil society and research institutions. GIZ's main commissioning party is Germany's **Federal Ministry for Economic Cooperation and Development (BMZ)**. Other commissioners include the European Union, the UN, the private sector, and governments of third countries. The global programme **"Green Innovations for the Agriculture and Food Sector (GIC)"** is funded through the Special Initiative "Transformation of Agricultural and Food Systems" of the BMZ. Since 2016, the project is implemented in India by GIZ in cooperation with the **Ministry of Agriculture & farmers Welfare (MoA&FW)**.

Working in Pune and Ahmednagar districts, the GIC project identified, tested and introduced various innovations in potato cultivation in a participatory manner involving the farmers. The project has adopted the **Participatory Technology Development (PTD)** process to identify the innovations and to work on those which are accepted by the farmers.

This report is a compilation of good agricultural practices and innovations introduced to the farmers to enhance their net productivity and income level. While preparing this report, inputs were taken from the Department of Agriculture of the Government of Maharashtra, Mahatma Phule Krishi Vidyapeeth Rahuri and the University of Horticultural Sciences, Bagalkot (UHSB). Scientists and officers from these institutions participated in a three-day writeshop to prepare this report.

The sustainable practices are documented in a simple and easy-to-read/understand manner. The target groups of this report are both extension workers and farmers. To make it more comprehensive, all stages of the crop production – right from potato seed tuber purchase and seed treatment to the field-level cultivation and post-harvest practices, will be discussed. Also, suitable agroecological approaches are included, especially for soil fertility management and integrated pest and disease management.

Hence, this report will act as a guiding tool at all stages for all the target groups and stakeholders.

List of Contributors

- **Mr. Ajit Bhor, Agriculture Advisor, GIC India Project, GIZ**
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- **Dr. Amruth Bhat, Assistant Professor, University of Horticultural Sciences Bagalkot**

Following are the broad sections of this report:

- Potato Seed and its preparation
- Land preparation and planting
- Water management
- Nutrient management
- Soil fertility management
- Weed management and Earthing up
- Pest and disease management
- Spraying techniques
- Harvesting, grading and transportation
- Lastly, an indicative cost of cultivation and case studies of nurseries and farmers are included.

While preparing this document, existing manuals, Packages of Practice of universities and other relevant knowledge products are referred to and acknowledged. Some of the key manuals/report referred are:

1	Package of Practices of Horticultural Crops, 2018, UHSB, Bagalkot
2	Krishidarshani 2022, Mahatma Phule Krishi Vidyapeeth, Rahuri
3	A Guide to Potato Production and Post-Harvest Management in Kenya, 2013
4	Good Agricultural Practices for Ware Potato Production in Cameroon, 2018, ProCiSA, GIZ
5	Good agricultural practices for ware potato production in Rwanda, 2021, CIP
6	AESA based IPM Package – Potato, 2014, Dept. of Agriculture and Cooperation, Ministry of Agriculture, New Delhi
7	A Guide to Good Agricultural Practices (GAP) for Crop Production, 2012, Ministry of Agriculture and Fisheries, Jamaica
8	The Potato Crop – Its Agricultural, Nutritional and Social Contribution to Humankind, 2020, Edited by Hugo Campos and Oscar Oritz, Springer Publication
9	Seed Potato Systems in Maharashtra and Karnataka and Options for the Future, 2018, CIP, GIC Project, GIZ
10	Best Fit Practice Manual for Potato Production and Utilization, 2015, BDU- CASCAPE Working Paper 8, Dutch Ministry of Foreign Affairs, Netherland
11	Various training handouts and presentation materials of AFC/ETC, GIC project, GIZ

SEED POTATO AND ITS PREPARATION

01

The quality of the seed is highly relevant for successful potato cultivation.

The planting material should be free of any seed-borne diseases. In potato cultivation, potato seeds are vital for high yields and account for 30-50 % of the production cost. Currently, seeds are procured from Punjab, which are normally of generation 6 and above, hence the quality will be low. The use of certified seeds reduces the risk of infection by tuber diseases. Therefore, certified seed potatoes should be used whenever possible. However, in Maharashtra, such certified planting material may not be available or may be too expensive. Instead, high-quality seeds with known history, e.g. from a known seed multiplier, may be used.

Variety selection

Farmers should go for resilient, nutritious, and high-yielding short to medium-duration potato varieties for table consumption and/or for processing or which have a good market demand. Additional desirable traits such as preferred flesh and skin colours, higher yield, early maturity and good processing quality are often also desired. Generally, varieties with the following characteristics should be promoted:

- Adapted to the range of existing climatic conditions to ensure wide adaptability and stable production
- Resistance to major diseases
- Good storage characteristics
- Commercially already available and accessible in the region.

The potato varieties recommended for Maharashtra by the Mahatma Phule Krishi Vidyapeeth are:

Variety	Key Characteristics
Kufri Jyoti	It is a medium-duration variety and comes to harvest in 95-100 days. The tubers are big in size, oval shape, flat surface and shining skin. It grows well in rainfed conditions too. In recent years, this variety has lost its resistance capacity to late blight diseases. Its yield level is about 25 tonnes per hectare.
Kufri Sindhuri	It is a long-duration variety and comes to harvest in 120-125 days. The tubers are of medium size with light red colour. It has a good keeping quality and medium resistance to late blight diseases.
Kufri Pukraj	It is a medium-duration variety (75-90 days) and bears white flowers. The plant produces brown big-sized tubers. It has a resistance to late blight disease and the yield level is 30-32 tonnes per hectare.
Kufri Jwahar	It is a short duration variety that matures in 75-80 days and is suitable to grow in Hassan and Chikkmagaluru. It is a dwarf variety and bears white flowers. The tubers are small to medium sized with white skin. It has resistance to late blight disease.
Kufri Lavkar	This is also a short-duration variety and matures in 75-80 days. It can be grown in high-temperature areas and gives good yield of 25-30 tonnes per hectare. It bears big-sized tubers with white flesh, hence suited for chip making.

Variety	Key Characteristics
Kufri Badashah	It is a medium-duration variety (95-100 days) suitable for plain and hilly regions. The tubers are tasty with good keeping quality. It has a resistance capacity to late blight disease and viral diseases.
Kufri Kubera	It is an early maturing variety with 75 days duration and bears medium-sized tubers in different shapes.
Kufri Surya	This variety is recommended for rainfed crop and matures in 75-90 days. It is a heat tolerant variety, and the tubers are of oval shaped. The yield level is 20-25 tonnes per hectare and suitable for processing.
Kufri Gourav	It is hybrid and recommended for transition zone (zone 4) of Maharashtra. Tubers are of medium to big size suitable for both processing and table purpose for cooking. It is resistance to late blight disease and for many pests. The yield level is 18-20 tonnes per hectare.
Kufri Chandramukhi	It is an early duration variety and comes to harvest in 85-95 days. Produces big sized oval shaped tubers but susceptible to late blight disease.
Varieties grown by farmers which have shown good results:	
Kufri Himalini	It is a recently introduced variety. It comes to harvest in 90-100 days. It has a good resistance capacity to late blight diseases, hence preferred for Kharif season. The tuber is of medium to big sizes, with a round shape. The skin is light brown without shining appearance. Its yield level is up to 25-30 tonnes per hectare.
FL 1533 (Processing Purpose, Fritolay)	It has high yields, nice chip color out of the field and from mid-season storage, and its tolerance of drought conditions in non-irrigated areas. This variety if stored in the evaporative cooled store at high temperature up to 90 days, produced chips of acceptable color.
Kufri Chipsona-4 (Processing Purpose)	Higher total and processing grade. Yield excellent chip colour and have high specific gravity and dry matter. Low level of reducing sugars. Moderately resistant to late blight in comparison to popular variety Kufri Jyoti and exotic Atlantic. Duration 90-110 days. Yield 30-35 tonnes per hectare.

Key Points for Seed Selection

Purchase Good Quality Seeds

In the market, available seed potatoes are usually of late generation (G5 or more) and infected with viruses (20% or more) and diseases. Hence, care should be taken to source good quality seed tubers from reputed traders or if possible, sourcing directly from Punjab/ Haryana through collective approach by the farmers.

Removal from Cold Storage One Month before Planting

Germination of whole seed potatoes is usually slow when they are coming from low temperatures (1-2°C) as dormancy is not broken. To break dormancy, farmers often cut potatoes and plant them immediately. This leads to infections and high mortality of plants (above 30%). Take seed potatoes out of cold storage one month before the expected planting date, immediately remove them from sacks, and dry potatoes in the shade.

Sorting and Grading

Only very limited sorting and grading is done by farmers; thus even, diseased potatoes are planted, leading to mortality and low yield. This can be avoided by proper sorting grading of the seed tubers.

Spreading of Seeds in One Layer in a Shaded Area for Three Weeks for Uniform and Good Sprouting

Generally, farmers dry the seeds after removal from the cold storage by stocking potatoes. As the temperature of seed potatoes is very low, water condensation on seeds takes place and results in rotting of the seeds.

Removal of Top Sprout

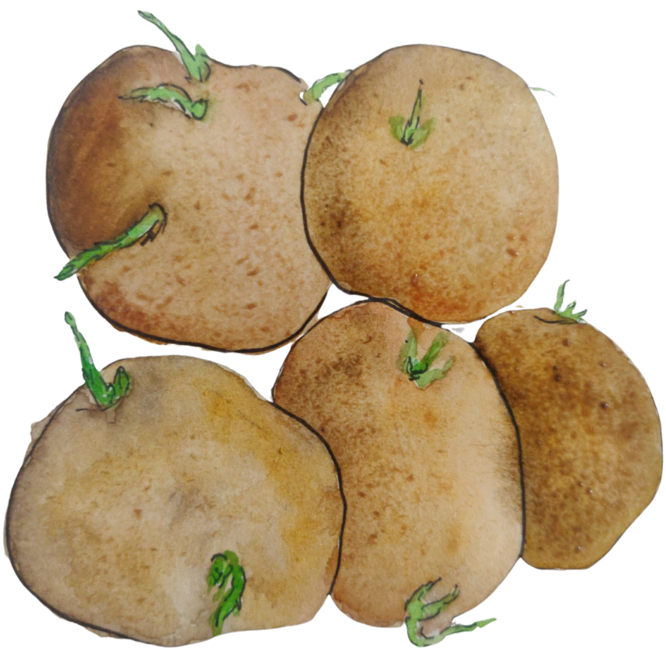
Farmers face the problem that whole potatoes only gave 2 or 3 sprouts when planted. By removing the top sprout, 4 to 5 sprouts are formed and thus increase potential yield. Hence, after about one week, inspect the seed potatoes and remove the top sprouts to induce more sprouts to emerge. Aim at 3 to 5 sprouts emerging per potato. If farmers cannot wait for three weeks for sprouting, cut the potato and treat with Mancozeb and then dry it for 3 days before planting. Cut potatoes using disinfected knife and dip the wound in Mancozeb. Dry in the shade for at least 24 hours before planting.

Pre-Germination of Seed Potato

The potato seed should be pre-germinated (or chitted) before planting. Pre-germination significantly increases the yield, as pre-germinated tubers emerge faster and are ready for harvesting 10-14 days sooner than non-pre-germinated tubers. This reduces the likelihood of infection of the sensitive sprouts with Rhizoctonia (Black scurf) or Erwinia (Blackleg) and reduces the risk of late blight. Moreover, pre-germination leads to fewer sprouts, and as a result, to fewer stems per unit area of foliage, hence reducing the number of tubers but increasing their size. The additional workload for pre-sprouting is reclaimed through higher yields and higher yield security.

Short and strong multiple sprouts are extremely important for a high yield. Seed tubers with short, firm sprouts can be transported to the field with a lower risk of sprout injury than tubers with longer sprouts.

The development of the sprouts is primarily affected by light intensity. If the tubers are well-exposed to diffuse light (but not direct sunlight), the sprouts will be slow in growth, coloured and sturdy. Seed tubers held in the dark will develop pale and long sprouts that easily break off. Long sprouts deplete the seed tuber and make it shrivel. Thus, for pre-germination the seed tubers should be placed in a cool and bright place, avoiding direct sunlight.



Seed Potato Treatment

There are two options for seed treatment, which are either chemical or biological:

Chemical Treatment

Mancozeb is a fungicide that controls seed-borne fungi. Use Mancozeb at the rate of 4 g/l of water. Spray it on the cut potato tubers. Avoid dipping all seed potatoes in the seed treatment chemical solution or moisten the potatoes by spraying water and then sprinkle Mancozeb at the rate of 4 g/kg seed over it. Mix the seeds and fungicide properly.

Biological Treatment

Trichoderma viridae, Trichoderma harzianum, Bacillus subtilis, and *Pseudomonas fluorescens* are biological disease control agents. Azotobacter is a free-living nitrogen-fixing bacterium in the soil. PSB solubilises phosphorus from insoluble compounds and makes it available to plants. Moisten the potatoes by spraying water. Sprinkle Trichoderma viridae at the rate of 5 g/kg seed. *Trichoderma harzianum* 5 g/kg seed, *Pseudomonas fluorescens* 2.5 g/kg seed, Bacillus subtilis 10 g/kg seed. Azotobacter 5 g/kg seed, PSB 5 g/kg seed and mix properly.

Precautions

- Seed treatment is to be done 4 - 5 hours before planting in case of whole tuber planting or immediately after cutting in case of cut tubers.
- If seeds are treated with chemical, dry the seed tubers in the shade
- If biological treatment is done, after seed treatment, the tubers should not be exposed to direct sunlight. Otherwise, their efficacy will be reduced.
- Biological agents should be stored in the shade before using them for seed treatment.
- Treat the seed with either chemical or biological treatment, but both should not be done for the same seed tubers.

The quality of seed potatoes differs a lot – rotting is a common problem, which can be caused by bacterial wilt or fungal infections transmitted through infected seed potatoes. Germination of seed potatoes can also be low when the tubers have been harvested too early or stored in very low temperatures (below 1°C) in cold storages. Seed potatoes with a very short period of sprouting before planting, and sometimes from very old generation (G5 and above), also have germination problems.

It is thus recommended to spread potatoes in semi-dark, well-ventilated room one month before planting – vegetable crates can also be used, and each crate can hold about 10 kg of seed potatoes. Planting of full potatoes after removal of top of the sprout is recommended.

If the farmer decides to cut the potatoes (to reduce the costs of planting material) then Formalin should be used to disinfect the knife and the wound treated within 1 hour with boric acid or with antagonists such as *Bacillus subtilis* and *Pseudomonas* species to reduce infection with Rhizoctonia and dry core. Keep the cut seed for at least one week to allow wound healing and sprouting.

Seed Replacement

The continuous use of the same seed stocks year after year without periodic replacement encourages infestation of the tubers with seed-borne diseases, particularly with viruses. Virus infestation considerably reduces the yield potential of potato plants. Frequent use of certified potato seeds produced by specialised growers contributes to higher yields and greater yield stability, especially when combined with disease resistance and the implementation of recommended cultivation measures such as a planned crop rotation, crop hygiene, regular monitoring of the crop, and appropriate pest and disease management.

A general recommendation is to replace the seed potatoes every second year. However, the better crop care measures are applied, the healthier the seed potato remains and the longer the interval for seed replacement can be.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LAND PREPARATION AND PLANTING

02

Proper Land Preparation is Important for Getting Good Yields.

Key points to be noted are:

- ### Application of Organic Matter at a Rate of More than 4 Tonnes per acre:
  Soil organic matter is seriously declining in sandy soils, which is negatively affecting the water holding capacity and Cation-Exchange Capacity (CEC) of soils. Additionally, it also gives rise to soil-borne diseases that attack the roots. Apply 4 tonnes of organic manure in form of compost or farmyard manure or plough in green manure (e.g Dhaincha, horse gram or Sunhemp) about 4 weeks before planting, which can happen during normal land preparation. In this way, the organic matter in the soil can increase.

- ### Deep Ploughing:
  Deep ploughing of land to create 30 cm of loose soil. This helps to make larger ridges. Fine tillage of the land by using a cultivator and rotavator should be done at least for three times. Make the soil fine and level using suitable implements. A field needs to be ploughed with a reversible mouldboard plough or a mouldboard plough behind a 45 HP or more tractor.

- ### Plant on Ridges or Beds:
  Farmers used to plant in an almost flat field. If rains are heavy, rotting of seed potatoes starts and many plants die. At harvest time, the same problems show up. Hence, planting on ridges should be done. When planted in ridges or on beds, water-saturated soil is below the place where tubers are growing, hence much less rotting occurs. The most important thing to achieve is that the seed potato is placed above the original soil surface and that drainage takes place below the level of the potato. Easiest realised with a potato planter, if not possible use a ridger.

- ### Plant Using Mechanised Planter:
  Access to labour is increasingly difficult and unpredictable, which leads to delays in planting and high costs. This turns to lower possible yields and profitability. Use potato planter after proper soil preparation.

- ### Plant Whole Tubers:
  Generally, farmers use cut tubers and plant them immediately to reduce the cost. However, this practice exposes the fresh wounds to diseases and as a result, many cut tubers rot before they can germinate. Planting whole tubers will increase the percentage of germination. If farmers want to use cut tubers, cut 3 days before planting, and treat with Mancozeb, if 3 days are not possible at least treat the cut tubers 24 hours before planting to protect against diseases and increase survival. Ideally, seed potatoes need to be cut with a knife, dipped in Formalin and treated for one hour with Mancozeb.

- ### Subsoiling Once in Five Years:
  Over the years, due to the compression by tractors, ploughs, rotovators, etc., the field becomes compact and an impermeable layer will develop in subsoil. This will hamper the drainage and percolation of water. Hence, fields need to be ripped once in five years by using a special tine plough behind a 45 hp plus tractor

- ### Levelling Once in Five Years:
  Many fields are partly inundated after heavy rain due to depressions in the surface of the field. Thus 10-20 % of plots often had no yield. By laser levelling the field, perfectly sloping 0.5% into one direction, all plants get equal water and the field is properly drained.

- ### Farm Pond Construction at the End of the Field to Collect Run-Off Water:
  Due to changes in rainfall patterns and extreme wet and dry periods in the same season, water out of farm ponds can be used for emergency irrigation of fields in dry spells.

Semi-Automatic Potato Planter

With growing labour problem, mechanisation is gaining importance in recent years. The GIC project has introduced an adapted semi-automatic potato planter and fully automatic potato planter in Pune district and has done trials with potato farmers.

This gender friendly machine has helped farmers to overcome the challenges of the labour availability and in saving of time and cost. Further, this has helped in following the good agricultural practices particularly planting seed tubers on the ridges which resulted in better yield.

Advantages Of Using Potato Planter Are:

- Bigger ridges, optimum moisture holding, lesser greening and more yield
- Reduced dependency on labour
- Faster planting: 3 hours/acre
- Planting is also possible in night hours
- Avoids rotting of seed tubers during excess rains
- Reduced cost of planting
- Spacing and depth of planting are adjustable

WATER MANAGEMENT

03

Water is One of the Most Important Factors in Potato Production.

Adequate water supply is essential in all growth stages for optimal potato yields and tuber quality. Water stress caused by too little or too much water can severely affect the plant growth and tuber formation. Too little water slows growth resulting in a smaller leaf canopy, enhances early senescence and usually leads to lower yields. On the other hand, too much water in waterlogged conditions leads to the leaching of soil nutrients, poor tuber formation and rotting. Uneven and alternating water supply can lead to tuber disorders.

At planting, the soil should have appropriate moisture level to facilitate proper sprouting and root growth. If the soil is too wet during this period, it may induce the rotting of the potato seed. If the moisture level is not enough, the sprouting will be a problem. Hence, light irrigations of 7-10 mm during this period will help for good germination of the seed tubers.

During vegetative growth, the transpiration rate of potatoes is low, and the plants require relatively little water. Irrigations must be limited to 15-20 mm per irrigation run, as the roots are still shallow. Too much water during this period promotes a shallow root system and can wash nutrients out of the root zone.

During tuber initiation, adequate soil water is very important to ensure good tuber formation and subsequent development. Adequate soil water around the tubers can also protect them against common scab infections and the development of lesions. During tuber growth, potatoes require adequate water. Water stress at this stage strongly limits tuber size.

During tuber maturation stage, i. e. 75-80 days onwards, the water requirements decline. High water at maturation can lead to the development of enlarged lenticels and quality defects. On the other side, if the soil is too dry at harvest, tubers can become easily damaged.
Generally, due to the high-water requirements of the crop, most farmers in India grow potatoes from June to October (*Kharif* season), when the rains are regular and moderate. However, farmers with access to irrigation water are recommended to grow potatoes in dry periods instead of rainy seasons, as the risk of late blight infection is strongly reduced. Higher prices of potatoes obtained during the dry seasons can offset investments in irrigation equipment in a long term.

Farmers who grow potatoes with irrigation use furrow irrigation, a few use sprinklers and very few drip irrigation. Furrow irrigation is the least efficient method, as less than half of the applied water is available to the crop but has the advantage that the foliage remains relatively dry which helps to reduce disease development. While sprinkler irrigation is also less efficient than the drip method, it is much better than furrow flooding. It is estimated that about 7 litres of every 10 litres applied by sprinkler irrigation become available to the crop. Frequent irrigation with sprinklers every other day provides a more regular soil moisture and fewer percolation losses, although this can be challenging for farmers who do not have a fixed irrigation system for the whole field but must move the system from one field to another.

Irrigation is preferably done between 9 am and midday. Irrigating earlier or in the later afternoon increases the risk of late blight infection while irrigating between noon and 3 pm could scorch the crop if temperatures are high.

NUTRIENT MANAGEMENT

04

Balanced Application of Nutrients is Key for Getting a Good Yield.

Key points to be considered for good nutrient management are:

Use NPK in a ratio of 1:1:2 (this is taking into consideration availability in the soil after application). Farmers applying too high a dose of Nitrogen and too low a dose of Potassium predispose the crop to blight problems and thus get low yields, while paying a lot for unused fertilizer.

Apply all P and K as basal dose.

Apply 50 % of N as basal and 50 % around 30 days after sowing. Often farmers applied all nitrogen in one go, especially in the Hassan area. This was predisposing the crop to late blight and to early blight.

Use micronutrients (Zn, Mg, B)

Use Ammonia-based fertilizers for Chips potatoes. Farmers use preferably Urea as it is cheap, early application of that can cause rot of seed potatoes, but later applications can reduce the dry matter content and increase the sugar content of the final product. Hence, use of Calcium Ammonium Nitrate (CAN) is good for chips potatoes.

Use Sulphate of Potash as K source for chips potatoes. Farmers use preferably MOP as it is cheap, but it reduces dry matter and increases the sugar content of chips potatoes which is undesirable. Apply SOP instead of MOP.

Use Sencor at the rate of 200 gr/ac. Farmers were postponing weeding till a certain size and faced the problem that the soil is too wet for weeding to be done. Apply Sencor with spray equipment at 200 gr/ac before the emergence of the potato.

If it is raining

- Urea: 2 bags at the rate of 20 - 25 days
- Urea: 1 ½ bags at the rate of 40 - 45 days
- Urea: ½ bag 55 - 60 days

REMEMBER!

Higher vegetative growth ≠ Higher yield

(High Nitrogen use, over-irrigation and imbalanced nutrition, induces higher vegetative growth)

Balanced vegetative growth = Higher yield

SOIL FERTILITY MANAGEMENT

05

Intensive farming practices primarily rely on mineral fertilisers to supply nutrients to the crops. Soil fertility management, however, is neither limited to the addition of fertilisers nor to achieving high crop yields alone.

It is about building up a rich, stable and living soil. Therefore, much attention needs to be given to building up the medium to long-term fertility of the soil.

Soil organic matter is a key element of natural soil fertility, as it drives the biological activity of the soil. So, it is important to feed the soil, so that the soil can feed the plants in a balanced way. To feed the soil, farmers need to apply organic materials to the soil. These include compost, animal manure, green plant material or other organic materials. Ideally, farmers should follow certain practices to improve organic matter or humus or even build up the organic matter content of the soil. Maintaining soil fertility can be a challenging task under subtropical and tropical climate conditions, where high temperatures and humid or dry conditions encourage rapid degradation of organic matter in the soil and where the risk of soil erosion is high. Soil fertility management can be seen as a three-step approach, whereby each step builds the foundation for the next one. The aim is to encourage the natural rejuvenation of the soil and to minimise the application of chemical fertilisers, soil amendments and irrigation water.

Step 1
Conserving the soil, its organic matter and water from loss.

Step 2
Improving the organic matter content of the soil.

Step 3
Supplementing the nutrient requirements as well as improving the growing conditions by applying some soil amendments.

In the long run, these steps will result in saving on the costs of fertilisers and prevent possible negative impacts on the farm ecosystem.

Step 1
In the first step, farmers should aim at establishing a stable and less vulnerable soil as the foundation for managing fertile soil. They do this by:

Preventing the soil from being eroded by rainwater or winds by keeping it covered as much as possible. They can cover the soil with living plants (so-called cover crops) especially within perennial crops or with dead plant material (so-called mulching).

Farmers can also dig and construct barriers across the slope to reduce the speed of movement of rainwater down the slope.

These practices conserve the soil structure, reduce the risk of soil compaction, increase water infiltration, reduce runoff, and reduce evaporation, thus improving water storage.

Step 2
In the second step, the aim is to build an active soil with a good structure, which can store water and supply plant nutrients.

Farmers can achieve this by applying practices which improve the organic matter content of the soil and enhance the activity of soil organisms. Such practices include growing green manures, intercropping, mulching, or retaining crop residues in the field after harvest, growing trees and shrubs for agroforestry, composting, and applying manures.

Step 3

In situations of heavy nutrient depletion, unfavourable growing conditions, or specific nutrient deficiencies, farmers can apply supplementary measures that are necessary to speed up the improvement of growing conditions for plants.

These entail organic residues (e.g. seed oil cakes, pelleted chicken manure, brewery by-products, fruit peels, coffee husks and plant ashes) that can be mixed with other materials for compost production.

Amendments such as lime are used to correct low soil pH. Microbial fertilisers such as Rhizobia, and potentially also Mycorrhizal fungi, can enhance nitrogen fixation in the soil and nutrient mineralisation and thus improve the nutrient availability of crops. Application of micro- or trace elements such as magnesium, boron and manganese can be important, particularly on lighter soils that may not supply enough of these elements.

Water is also essential to plants. Insufficient water supply limits the mineralisation and transportation of nutrients in the soil and from the soil to the plant and thus affects plant growth and yield development negatively. Too much water, however, encourages nutrient losses through leaching, and may also cause root rots. In dry conditions, appropriate use of irrigation to supplement soil water requirements can be essential to achieve good yields.

Other Good Practices for Soil Fertility Management

a) Green manures

Green manuring means growing plants with the primary purpose of incorporating their biomass into the soil in order to supply nutrients to the soil and thus improve its nutrient content and its fertility.

Cover crops and green manures are near-synonyms. While the main purpose of growing cover crops is to cover the soil with a low vegetation cover to protect it from sun and rain as well as to suppress weeds, green manures are grown with the main purpose to build maximum biomass. Mostly, leguminous plants are used for green manuring, as they can collect considerable amounts of nitrogen from the air and fix it in their roots in addition to providing food for soil organisms.

Green manures are farm-grown fertilisers and are therefore a cheap alternative to purchased fertilisers. They complement animal manure well and are of high value on farms where animal manure is scarce. Green manures can provide an incentive to abandon harmful traditional practices, such as burning crop residues. Although the use of green manures is not common among potato farmers, there is a shortage in the application of organic matter and farmers commonly purchase organic manure from others if they want to apply.

To avert the shortage of organic materials, it is recommended to plant:

- **Sunhemp** as a border crop to produce organic matter. Sunhemp also attracts spiny bollworm adults who will deposit eggs in the sunhemp crop instead of in the potato field. Sunhemp can be used as mulch or compost.
- *Cassia siamea* as a border crop and for the source of organic matter.

Neem can be used by maning enriched neem cake which can be applied to the soil, or using neem oil or neem seed kernel extract spray.

b) Compost

Compost is a highly valuable organic fertiliser, especially in tropical conditions, as it will contribute stable organic matter and help to build the soil in the long term.

Compost is a common name used for decomposed organic materials. Compared with uncontrolled decomposition, as it naturally occurs, decomposition in the controlled composting process is faster, reaches higher temperatures and results in a higher-quality product. Nutrients provided by compost are more balanced from a plant perspective than nutrients derived directly from animal manure. Compost improves soil structure and increases the water retention capacity of soils. It also can suppress soil-borne diseases in some cases.

Compost making relies on materials that are available on the farm and does not require any special equipment (maybe with exception of a shredder and watering cans or some kind of sprinkler, or if the operation is done on a large scale), making it a cheap method. On the other hand, compost-making requires a lot of work for collecting and preparing the materials, and subsequently turning the compost heap regularly during the composting period. Therefore, compost production may be economical mainly in cropping systems with high-value crops such as vegetables and potatoes.

Ideally, compost is made from equal amounts of animal manure and fresh plant materials and dry woody materials. Farm-based plant material includes collected crop residues, weeds, or plants that are cultivated specifically for their biomass. Wood ashes and some old compost can be added as well. Compost production requires humid conditions. Therefore, regular watering is required in dry weather to ensure a proper decomposition process.

c) Farmyard manure

Animal manure can be recommended for the basic fertilisation of potatoes, for farmers who keep or collaborate with livestock farmers.

Ideally, animal manure should be stored for 60-90 days before application or composted together with plant materials.

Manures should be applied before planting potatoes to prevent food-borne illness to humans from *Escherichia coli* or other bacteria found in manure. The applied manure should be worked into the soil immediately after application to prevent losses of N through volatilisation.

As a rule, not more than 25-30 tonnes of manure should be used, because too high doses lead to a prolonged nitrogen supply to the potato crop and impede its maturation by lengthening the vegetative growth phase. In case of dryness or heavy soil, the succeeding crop might benefit more from the nutrients than the potato crop itself.

A balanced dose of manure can have a positive effect on the K content of the tubers, whereas excessive fertilising with manure leads to a decrease in starch and dry matter content in the tubers which renders the potatoes not good for processing. Cattle manure is rich in potassium, whereas pig manure contains less K, but has higher amounts of phosphorus. Poultry manure contains about three times as much nitrogen, four times as much phosphorus and similar potassium contents as cattle manure.

Manure, composted manure and other composts provide plenty of potassium and magnesium to crops. However, composted manure has a significantly lower effect on nitrogen supply than stacked manure. Slurry from cattle is relatively high in K and N. On the other hand, pig slurry has higher N and P contents. While manures and slurries mainly have a short-term fertilising effect, but a low effect on long-term soil building, composted manures have a higher positive effect on soil fertility and soil biological activity.

d) Crop rotation

Crops are arranged in such a manner as to contribute in the best possible way to the fertilisation of the following crop, to the maintenance of soil fertility and moisture, and to the control of soil-borne pests, diseases, and weeds. To design an appropriate crop rotation plan involving potato, crops can be grouped into two major categories:

Grouping of crops based on their nitrogen (or nutrient) demand, distinguishing heavy feeders, moderate feeders and fertility builders. Heavy feeders include crops such as maize, cabbage or leek. These crops depend on high amounts of nitrogen to produce good yields. Moderate feeders include root and tuber crops, fruits as well as leaf vegetables. Fertility builders include legume crops such as beans, peas, and (leguminous) green manures that are cultivated mainly for the improvement of soil fertility.

Grouping of crops based on their susceptibility to diseases and pests is also important for the control of soil-borne pests such as nematodes and the build-up of inoculums of late blight and other pathogens from one season to another.

For this reason, crops of different botanical plant families should be rotated. To prevent the build-up of soil-borne pests and diseases most crops, including potatoes, should not be grown on the same field more than every third or fourth season. As long as no soil-borne pests or diseases are noticed, potatoes may be grown every third season in the same field.

During the cultivation break, also other crops related to potatoes such as tomatoes, capsicums (peppers), eggplants, and others should not be cultivated in this field.

In addition, volunteer potato plants (or volunteer crops in the same family as potato) need to be rogued out. Instead crops like carrot, onion, sorghum can be grown after the potato crop. Specifically, the potato crop has a relatively high nitrogen demand in the first half of its growth period. Therefore, it does especially well after crops that leave a loose soil and a high amount of easily degradable organic material behind. Thus, suitable preceding crops include grain legumes such as beans and other vegetables.

WEED MANAGEMENT AND EARTHING UP

06

Weed control is important, as weeds compete with potato plants for water, light and nutrients thereby affecting the tuber development and yield.

To give the crop a competitive advantage over the weeds, 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. If weeds are not removed, crop yields can be severely reduced, and diseases and pests are encouraged. Thus, weeding and hilling are important operations after planting.

Strong leaf growth based on good nitrogen supply leads to early crop covering and thus better weed suppression. While weeding, hilling (or earthing up) is recommended to prevent the stolons from becoming aerials, and to protect tubers against insect pests, disease infection and greening.

Hilling helps to conserve soil moisture and aids early tuberization. Hilling serves to cover the tubers and stolons with soil to prevent toxic green tubers, protecting the tubers from pests such as the potato tuber moth, and creating large and stable ridges to encourage the production of new tubers. Moving soil for hilling furthermore breaks up the soil surface and improves aeration and water infiltration into the ridges. This leads to better mineralisation of organic matter and improves nutrient availability for the plants. At the same time, hilling controls weeds until the crop canopy covers the soil.

Most smallholder farmers use the traditional hoe for hilling. Hilling, whether it is done with a hand hoe or a machine, should be executed with care, as it can damage the delicate root hairs of the potato plants at the sides of the ridge, and can lead to damage on the leaves, stolons and small tubers, reducing yield. Roots and leaves may then offer ways for diseases to enter the plant.

Any mechanical weeding work should always be carried out when the soil is sufficiently dry to avoid damage to the soil structure. Preferably, hoeing is carried out in the evening, when the potato leaves are upright, as it reduces the risk of covering them with earth. Besides hand and mechanical weed control, farmers commonly use pre-emergence herbicides. However, the use of herbicides for weed control is not a good practice.

Other preventive weed management measures include proper soil cultivation (tillage), the selection of competitive varieties with rapid youth development and strong leaf formation and weed-suppressing crop rotation design and proper spacing.

PEST AND DISEASE MANAGEMENT

07

Pests and diseases are major constraints for potato production in India. The most common pests in states are white grubs and Potato Tuber Moth (PTM), *Spodoptera, Helicoverpa*, Red mite, Aphids and Leaf miner.

Bacterial *Ralstonia solanacearum* causes bacterial wilt, tuber and soil-borne diseases like *Rhizoctonia solani* cause black scurf and *Streptomyces scabies* result in common scab. Managing pests and diseases is a challenge for most farmers. The wide diversity of pests and diseases, and limited knowledge of the characteristics and the cycles of the pathogens make it difficult to choose the right preventive and direct control measures.

Farmers need to know which pathogens create damage in the fields. Proper determination of the pathogen is the first step to effective pest and disease management. To avoid major crop losses, the farmers should be able to implement affordable and effective measures without substantially increasing the production costs or harming beneficial organisms in and around the field. Effective prevention minimises costly direct control measures. Ideally, pest and disease management requires minimal extra cost and uses techniques, which are easy to prepare and apply, are effective under local conditions, safe to handle and have minimal or no negative effect on other organisms, on water, soil, air and agricultural products.

For pest and disease management in general, an integrated systems approach should be taken for the control of pests and diseases in potato production.

7.1 Pests

Potato plants attract many pests at different stages of the crops. Prominent pests are Mites, Aphids, White Grub, Spodoptera and Potato Tuber moth. To control these, farmers spray broad spectrum insecticides like *Profenophos Cypermethrin*. It is not a good practice.

Alternatively, they can use the following formulations to control them:

- Neem oil: 1 l/acre
- Spodoptera litura Nuclear Polyhydrosis (SNPV) 250 LE/ac (Larval Equivalent)
- Poison bait: 1 g/l

For Aphids, whiteflies, leaf miners and other minor pests use:

- Neem oil: 1 l/acre
- Install yellow and blue sticky traps at the rate of 10 numbers/acre each

To control Mite:

- Proper irrigation
- Sulphur: 80% WG (Water Dispersible Granules)– 3 g/l – 60 days
- Preventive sprays

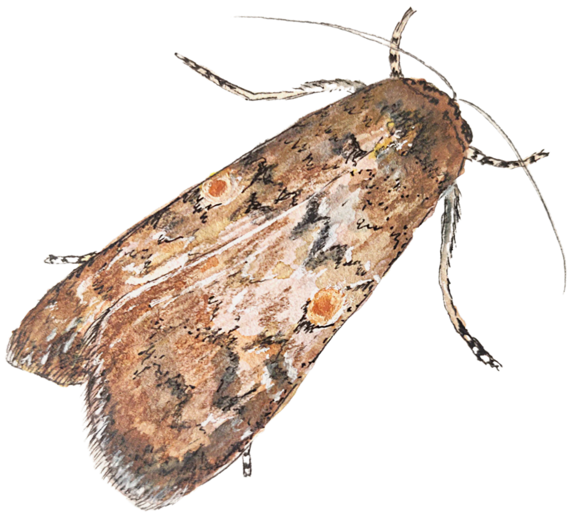
7.1.1 White Grub

White grubs lay their eggs in June after a good rain, the larvae tunnel into the developing tubers in the soil, damaging them and creating an entrance for fungal and bacterial diseases.

White Grub Management: Put a light trap (one per hectare) in the evening for about 2 hours. Make sure a basin with water and a little kerosene is under the trap.

7.1.2 Spodoptera

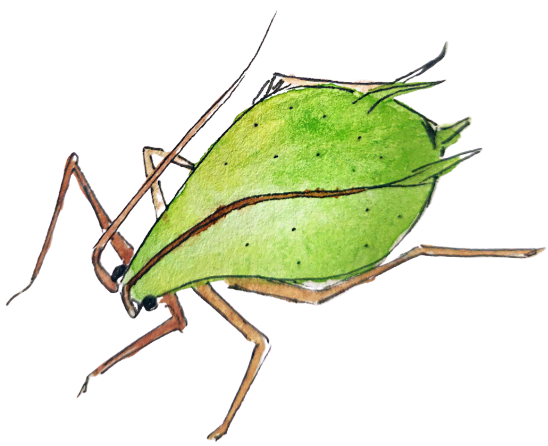
The project found that farmers were trying to use broad-spectrum pesticides to control the larvae when they noticed damage on the crop. As this is too late to control the pest and as it is ineffective as the larvae hide in the soil by daytime and emerge by night, the project investigated the prevention of the build-up of the population. Eggs are laid on the underside of the leaf in a cluster of 300 eggs. So, monitoring the adult population is important.



Spodoptera Management: Place Spl-lures Pheromone traps at planting time. Replace lures every 20 days, scout for egg masses if more than 5 adults are trapped in a night (this requires daily emptying of pheromone traps, which is often not done). Plant maize around the field. Collect egg masses, spray Neem Seed Kernal Extract (NSKE) or Spl_NPV (Nuclear Polyhedrosis Virus). Use Dipel as a spray at first instar, if still getting out of hand place poison baits (rice bran, sugar, Methomyl 150 gr/acre). Be careful with children and dogs as they might get attracted and poisoned.

7.1.3 Aphids

Aphids are transmitting viral diseases that reduce the production potential. Farmers used to spray broad-spectrum pesticides at the emergence of the crop to control them which led to the development of red mite populations as predators were killed.



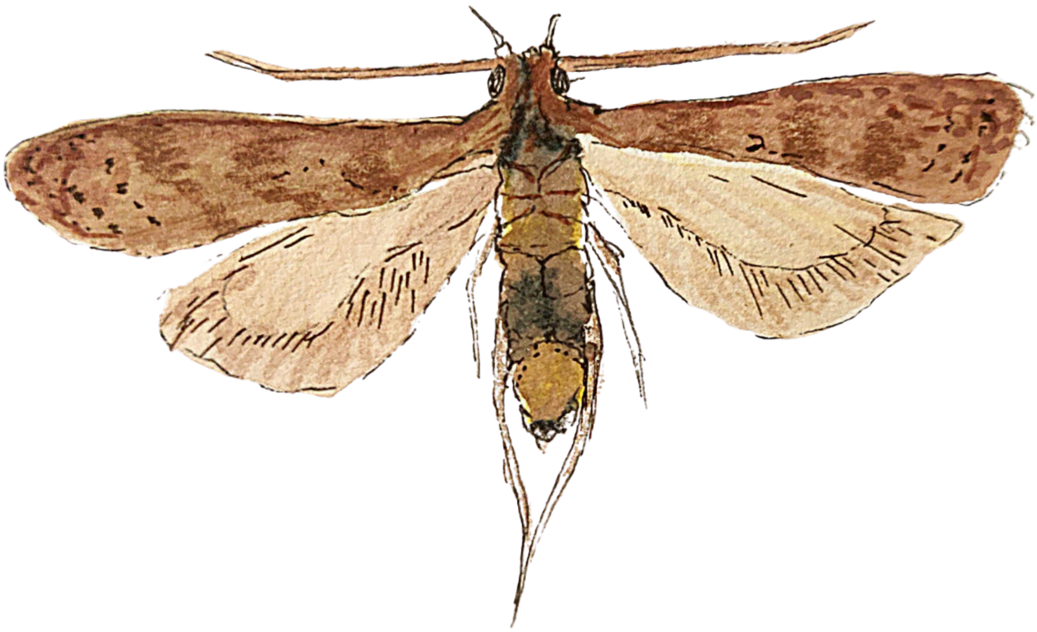
Aphids Management: Abstain from using broad-spectrum pesticides till day 60. Use 5 % neem oil instead for spray. Place yellow sticky traps at the rate of 10 per acre at least.

7.1.4 Potato Tuber Moth (PTM)

The Potato Tuber Moth (*Phthorimea opercullella*) is the most serious pest of potatoes. The small butterfly occurs wherever potatoes are grown. Besides potatoes, the insect also attacks tomatoes and other nightshades. The damage is caused by the larvae of the moth (caterpillar) that makes tunnels in the potato tubers. The female moths are active after sunset and at dusk and lay eggs into sheltered places of leaves and stems of the potato plants and near the eye buds of exposed tubers through cracks in the soil or in the store.

The moths also lay eggs on potato buds during pre-sprouting and on bags with potato tubers in the store. One female lays up to 200 eggs. When the whitish to later pale greenish caterpillars hatch from the eggs after 8 days, they feed below the upper skin layer of the leaves and stems and bore their way to the tubers, where they make long, irregular black tunnels filled with excreta. Caterpillars hatching from eggs that were laid onto tubers begin feeding on the tubers immediately upon hatching. In the feeding tunnels disease-causing fungi, bacteria and mites develop. The tubers start to rot and develop an unpleasant smell. Infested tubers cannot be used for human consumption anymore. When the 15 mm large caterpillars have fed enough after about 2 weeks, they pupate in a cocoon covered with soil particles and debris among dead potato leaves, soil litter, and eyes of tubers. In storage, the pupae are found between tubers, in the entrance to the larval tunnels, and on the walls and floors of the storage room.

At harvest, the pest is transferred with the tubers from the field to the store, where it can reproduce and infest other tubers. Stored-infested tubers can result in the destruction of the entire crop at storage. Between potato crops, the pest survives as pupae in the soil, or in discarded potatoes left in the field at harvest. The tubers are attacked when they grow larger and come nearer the soil surface. At this time, the soil cracks and the larvae move from the foliage to attack the tubers and lay eggs on or near them. Infestations are worse in heavy soils that crack when dry. The adult moth is 8 - 10 mm long. The males have fringed brown wings with dark spots, the females have an X pattern when wings are together. The moths live for up to 10 days.



Prevention of tuber moth damages includes:

- Use of healthy, clean seed, since infested seed tubers are the main cause of re-infestation in the field.
- Avoid planting into rough soil and too light and loose soil, as it facilitates exposure of tubers.
- Planting at least 10 cm deep.
- Ridging at least three times during the growing season creating compact ridges. Compact ridges prevent moths from reaching the tubers to lay eggs, and moths emerging from infested tubers to fly off.
- Keeping the ridges moist to prevent soil cracks until the end of the cultivation cycle.
- Targeting an early harvest to avoid late infestation, and harvesting the tubers immediately when ready, as tubers left in the field for a longer period are highly infested.
- At harvest, ensure that the tubers are not exposed to moths before they are properly protected in the store. All harvested tubers have to be stored properly before late afternoon.
- Carefully sorting the tubers before storage removing all tubers with openings or galleries and destroying all infested potatoes immediately.
- Decontaminating the storage rooms carefully before storing new potato tubers.
- Removing all remaining tubers and plant residues from the field and destroying all volunteer potato plants before planting new potato crops.
- In case of heavy infestation, the crop rotation should be extended to 5 years.

Protection

Intercropping potatoes with hot pepper, onions or peas keeps the moths away to some extent. Mulching the ridges with neem leaves during the last 4 weeks before harvest can significantly reduce insect damage. Treatment of the potato plants with neem during cultivation limits the proliferation of the pest. At storage, storing potatoes in layers with branches of lantana (*Lantana aculeate*) or *Eucalyptus globulus* provide some protection for the tubers. Tuber infestation can be reduced by bedding the potatoes in the leaves of the Peruvian pepper tree (*Schinus molle*).

The tubers can also be sprayed with neem seed extract with 1 kg of neem extract in 40 litres of water before they are packed in bags. Alternatively, Bt (*Bacillus thuringiensis*) powder mixed with fine sand (1:25) dusted controls the pest in the store too. Application of plenty of wood ash or diatomite earth onto the plants prevents the rapid build-up of tuber moth. Pheromone traps can be placed in the storage room to confuse the moths

Management of PTM

Ensure that seed potatoes are not infected with tuber moth when drying . Put 40 mesh insect net on top and ensure that no holes are present, and then make sure the ridges stay intact and tubers are not exposed. When cutting haulms, make sure all cracks are filled. Place light traps to catch the PTM adult and finally, store sorted and graded potatoes in field cover with 40 mesh insect net and ensure no openings.

7.1.5 Black Leg and Soft Rots in Tubers

The Black leg disease of potatoes is caused by several species of bacteria that are transmitted through the tubers (Dickeya ssp., Pectobacter ssp. and others). The disease can cause severe economic losses to the potato crop. However, the occurrence of blackleg depends very much on the growth conditions, particularly temperature and rainfall after planting. As the Blackleg disease is also a bacterial disease, just as bacterial wilt, symptoms, life cycle and management are similar.

Symptoms

Early blackleg develops soon after the plants emerge. Foliage is stunted and yellowish and has a stiff, upright habit. The lower stem is dark brown to black and extensively decayed. Infested young plants do not develop further and die. Blackleg may also develop later in the growing season. The first symptom is a black discoloration of below-ground stems, followed by rapid wilting and yellowing of the leaves. Entirely diseased stems decay become desiccated and are often lost from view.

Source and spreading

The bacteria are mostly spread via seed tubers. Soft rot forms when the conditions for bacteria to thrive are optimal with sufficient water and the resistance of the tuber can be overcome. Healthy tubers are rarely infested. At storage, the dormant infection can spread after the tubers have been washed or are stored in plastic bags (due to warm and humid conditions). Bacteria thrive in cooler wet conditions. Infection is promoted by tuber blight (dry rot), tuber damage by millipedes, Tuber moth, tools, impact or waterlogging.

The disease can be controlled through good hygiene. Control measures, which reduce bacterial contamination on seed tubers, also reduce the risk of soft rot and black leg.

Management and Prevention includes:

- Use of healthy seed only
- Promotion of quick emergence
- Prevention of tuber blight
- Avoiding waterlogging and over-irrigation
- Proper crop rotation with recommended intervals between nightshades

In case of infection, the spreading of the disease into healthy fields should be avoided by using clean machinery only. Cleaning of the grader prior to grading of harvested potato limits the spreading of infection during sorting. Infested tubers should be marketed unwashed.

7.2 Diseases

7.2.1 Late Blight

This important disease is caused by the fungus *Phytophthora infestans*. It regularly infects plants from the tuber initiation stages up until harvest and often causes high yield losses. Infections are encouraged by rainfall, high humidity and low temperatures. This disease acts very quickly. If it is not controlled, infected plants will die within two or three days.

Symptoms:

- Brown spots, partly looking oily with a blurred, light green transition to healthy tissue on the upper side of leaves and stems.
- On the underside of the leaves grey/black spots are found, and white fungal growth (looking like flour) after rain or morning dew (especially on the edge).
- Severe infections cause all leaves to rot, dry out and fall to the ground, stems to dry out and plants to die.
- In case of heavy rainfalls, the spores from leaves can be washed into the ridges and infect tubers. These turn brown and exhibit wet and dry rots.
- The flesh of cut-open tubers is brown, too.
- The disease is not to be confused with ‘sunburn’, early blight (both have no transition zone around the leaf spots) or grey mould (grey fungal growth on the surface/underside of leaves).

Source and spreading

The initial infection of the leaves can be brought on by (latently) infected planting material, volunteer potatoes or tubers on compost heaps, or it can be brought in by wind from a greater distance. Tubers are infected through seepage of spores from infected leaves, or smear infection during harvest. Transmission of spores by air occurs when the relative air humidity is over 90% and the temperature is around 18°C. For the spores to infest the plant, drops of water are needed on the surface. The leaf wetness is therefore an important factor in the development of the disease. If the infection is very likely, the fungus can infect an entire crop within a few days. Depending on the weather conditions, it takes between 2-3 weeks and 2 months for the plants to die off after the initial infection. In dry weather, the infection stops spreading; in wet weather, it increases.

Management and prevention includes the following measures:

- The use of resistant or highly tolerant varieties with fast tuber growth. To reduce the risk of breaking the resistance of individual varieties, different varieties should be cultivated in separate rows. More susceptible varieties should be cultivated on the side of the field downwind of the prevailing wind direction. Alternating cultivation in rows of susceptible and less susceptible varieties can delay the spread of the disease.
- Planting healthy tubers reduces the risk of an early outbreak of the disease. Pre-germination of seed uncovers infected tubers, as they will start to rot during pre-germination and can be removed and disposed. Pre-germination also shortens the period to harvest. Discarded tubers should be composted at 60°C or buried in a deep hole and covered with soil.
- Choose well-ventilated locations that allow the crop to dry off quickly after rain or dew.
- Avoid narrow spacing, as it will increase humidity in the plant stand and support late blight infections.
- Planting a strip of at least 12 m of a different crop such as maize perpendicular to the prevailing wind direction delays the propagation of the disease, too.
- Avoid over-supply of nitrogen, which makes the plants more susceptible.
- Avoid heavy weed infestation to allow faster drying of the crop.
- Remove potato plants from waste heaps or cover them with soil. Containment of the disease is most likely to be possible in the early stages of infection.

Hence, the crops should be checked for the typical symptoms every two days in the morning. Any infected individual plants or stoves identified must be pulled out and burnt or buried. Timely de-haulming (cutting back foliage when tubers reach their optimum size) can help prevent disease from moving from foliage to tubers or to surrounding potato plants.

The most effective plant protection product against late blight is inorganic copper. Copper provides long-lasting protection to plants against different fungal and bacterial diseases such as late blight. However, copper is a heavy metal and is accumulated in the topsoil. In high doses, it acts toxic to microorganisms and earthworms in the soil. Thus, it can also inhibit microbial nitrogen mineralisation, which is important in organic farming. Copper is also toxic to fish and livestock and causes acute gastrointestinal disturbances in humans. The long-term future of copper for use in certified organic farming is uncertain.

Alternative active substances have been researched for years. First, effective products may be available in the coming years. Most farmers in India apply pesticides with a backpack sprayer. This can lead to an uneven application of the products and requires a lot of time. Since copper needs to be applied at least 1-2 hours before rainfall to dry on the leaves and protect the potato plants, efficient application of the product is crucial.

Other points to be considered are:

- Using disease-free, certified seed
- Seed treatment with Mancozeb 4 g/l
- Disinfecting the cutting tool with formalin
- Growing late blight tolerant varieties. For example, Kufri Himalini is tolerant when compared to Kufri Jyothi and other varieties which are mainly grown for processing purposes
- Avoid growing alternative hosts like tomato, chilli and brinjal

It is highly difficult to control the disease after infection. Hence prevention is most important.

Following are the suggested contact fungicides for prevention:

- Mancozeb 75% WP (Wettable Powder) – 3 g/lit (600-750 g/acre)
- Chlorothanlonil 75% WP – 1 g/lit (200 g/acre)
- Propineb 70% WP – 3 g/lit (600 g/acre)
- Potassium phosphite – 3 g/lit (600 g/acre)
- Mandipropamid 23.3% – 1 ml/lit (200 ml/acre)
- Mancozeb is an effective and economical fungicide. Mixing Potassium phosphite further improves efficiency.

Spray any one of the above-mentioned fungicides at 7 days interval. If the weather is dry without any rain, the spray interval could be extended up to 10 days. If it rains and washes off the protective fungicide from the leaf surface, spray on the next day. The first spray can start at 50–60 % emergence of plants in the field.

7.2.2 Potato Early Blight *(Alternaria solani)*

If drought conditions prevail, especially when intermittently high humidity conditions are present, early blight attacks are probable. It usually occurs at the end of the season when the crop is facing nitrogen shortages.

Management: Rotate fields with non-early blight sensitive crops as early blight is soil born disease. Increase organic matter in the soils to prevent water and nutrient stress. Reduce the use of Phosphorous to a level required by the crop (the issue here is that both high and low pH negatively influence the availability of Phosphorous to the plant through fixation) Blueprint doses thus cannot be relied upon. Doses should be linked to soil characteristics. Ensure that by the first sign of yellowing of leaves after 40 days after sowing, additional Nitrogen is given. Don't overdose as then late blight will develop. Protect the crop weekly with a spray of Mancozeb/potassium phosphite. If symptoms are noticed apply chemicals. Ensure no dry-wet cycles through improper irrigation.

The management proposed for late blight should suffice to control early blight too, but it is obligatory to spray every 10 days. Topdressing of fertilizer at 60 days after sowing recommended dose should reduce infection rates. Properly drip-irrigated crop probably has less chances of being infected.

Spray Schedule For Early Blight:

Mancozeb + Potassium Phosphite spray should be started at 6-8 leaf stage – as a preventive spray for both late blight and early blight.

1st spray: Mancozeb – 30 g/15 l + Potassium Phosphite – 45 g/15 l

2nd spray: Mancozeb – 45 g/15 l + Potassium Phosphite – 45 g/15 l

3rd spray: Mancozeb – 60 g/15 l + Potassium Phosphite – 45 g/15 l

Note: Just increase the dose of Mancozeb for every spray.

If one misses the window go for curative chemicals.

If lesions occur, then start spraying anti-sporulant. Take the spray of Cabrio Top (2 g/l) or Amistar (1ml/l)

7.2.3 Bacterial Wilt

Bacterial wilt is caused by the bacterium *Ralstonia solanacearum* (formerly known as *Pseudomonas solanacearum*). This disease is extremely dangerous, especially in regions where potato is cultivated intensively. Besides potatoes, the pathogen also infects other crops of the nightshade family such as chili, tomato, tobacco, black nightshade and eggplant. It also spreads on several weed species. In some areas, it is the biggest cause of reduced production. It is a soil-borne disease that can be introduced by infected seed potatoes. Once it is established it will attack also healthy seed potatoes especially in lighter soils and under very moist conditions. The tuber will rot, and no plant will be established, leading to substantial yield depression

Symptoms

This disease causes rapid wilting and death of the entire plant without any yellowing or spotting of leaves. All branches wilt at about the same time. The first visible symptom is a wilting of the leaves at the ends of the branches during the heat of the day and often in the afternoon. At night, wilted leaves recover.

The reason for the wilt is the interruption of the water supply of the plant, as the bacteria inside the plant clog the vascular bundles. As the disease develops, a brown-coloured ring is visible due to the rotting of the vascular ring, when stems are cut. The leaves develop a bronze tint.

Mildly infected tubers do not show any outward signs of disease, but when a tuber is cut in half, black or brown rings will be visible. If left for a while or squeezed, these rings will exude a thick white fluid. Soil sticking to tuber eyes when crops are harvested is a typical sign, too. Serious infection causes tubers to rot. Characteristic rot caused by bacterial wilt produces a very bad smell.

Source and Spreading

Bacterial wilt can be spread quickly over water, soil, plants, plant parts such as seed tubers and rogue potato plants, cutting tools, livestock and people, and be transferred to healthy plants. But it can also be transmitted from other crops or weed plants that can host bacterial wilt. Bacterial wilt can survive in soil and water without a host for several years. Therefore, rotation is not effective against bacterial wilt. Infected tubers must not be stored or used for seed, as the disease will spread rapidly in the warmer temperatures in storage areas, and will cause tubers to rot

Management:

The disease needs to be managed through cultural practices. An essential element is the prevention of disease development on a farm. This includes:

- Using healthy (certified) seed only,
- Using resistant varieties where available,
- Maintaining a proper crop rotation with non-nightshades,
- Regularly applying compost to the soil.

If bacterial wilt is observed on a field, further development and spread of the disease in the field must be prevented by:

- Careful removal and burning of infested plants and tubers to reduce the spreading of the disease from plant to plant,
- Spreading dolomitic lime around infected plants to increase soil pH,
- No cultivation of potatoes or other nightshades on these fields for several years (in serious cases for more than 10 years).

As bacterial wilt spreads rapidly in flooded fields, avoid watering the field or try to make sure water does not flow over the infested surface of the field by digging channels that allow water to flow around it, not using water contaminated with bacterial wilt to irrigate the crop, disinfecting farming tools after use.

Although crop rotation is not sufficient to control bacterial wilt, the disease incidence can be reduced, if the cultivation of non-susceptible crops such as cereals is combined with other control measures. The earlier bacterial wilt infections are detected, the better.

Therefore, farmers are recommended to observe their potatoes (and other nightshade crops) for symptoms of bacterial wilts from 35 days onwards.

7.2.4 Fungal Wilt

Fungal wilt caused by a soil-borne pathogen Fusarium osysporum attacks potato, if the soil is infested by this fungus. This fungus will enter through the roots and interfere with the water conducting vessels of the plant. As the infection spreads up into the stems and leaves it restricts water flow causing the foliage to wilt and turn yellow.

Management:

- Crop rotation
- Deep ploughing
- Enriched Trichoderma Application
  - Neem cake 1000 kg or farmyard manure 800 kg
  - Neem cake 200 kg
  - *Trichoderma viridae* 4 kg
  - *Pseudomonas fluorescens* 4 kg
  - *Paceilomyces lilacinus* 4 kg

Mix them thoroughly and maintain optimum moisture. Cover them with a plastic sheet and incubate it for 20 days, also make sure to mix it regularly (4-5 days) to maintain moisture. Apply in the field when sufficient moisture is available.

7.2.5 Viral Diseases

Potato is affected by different viruses, one being the Potato Leaf Roll Virus (PLRV). The symptoms on the plants after infection vary depending on the virus, ranging from leaf mottling to mosaic appearance of the leaves and crinkling to dwarf growth.

Heavily infected plants will give a poor crop of small tubers. In mild infections, plants often show no signs of disease at all. Therefore, virus infections are underestimated by most farmers because the viruses are not visible by the eye, and the plants rarely die.

The viruses are transmitted by aphids and other sucking insects such as thrips, mites and whiteflies, and with infested tubers. Aphids spread the disease within the field and from one field to another.

Mechanical transmission through tools is also possible, but secondary compared to transmission by aphids. Some viruses like PLRV also infect other nightshade crops and weeds such as tomato, tobacco and jimson weed.

Often virus infection is due to continuous re-use of farm-own planting material, transferring infection from one crop to the next with infested seed tubers. When farmers select the smaller tubers for seed, and the chosen tubers are those already infected with viral diseases (leading to smaller tubers), the risk of transmission of the pathogens is increased.

As symptoms appear during the early stages of potato growth, observations should begin when the plants rise, walking along the raised seedbeds and looking for plants showing symptoms of the disease.

Management principles are nearly the same for all viral diseases. Viruses can be controlled by:

- Using virus-free seed tubers,
- Using resistant varieties where available,
- Uprooting infected plants to reduce the spreading of the disease within the field and destroying them. Maximum effectiveness is obtained when removing all the plants in a radius of 1 m around the diseased plant,
- Controlling nightshades and volunteer potatoes on own and neighbour fields because these plants can be reservoirs for the pathogen,
- Avoiding overlapping of potato crops, and
- Controlling sucking insects as the main vectors of the viruses spraying.

7.2.6 Other Important Notes for Disease Management

- **Preventive sprays are more effective** than curative sprays
- **Cost of preventive fungicides is much lower** than curative fungicides
- **Water management:**
  - Drip irrigation is the best method of irrigation for potato
  - As the leaf moisture on the leaf surface for more than 4 hours increases the chance of disease incidence, care must be taken while using sprinkler irrigation. The sprinkler can be started after the drying up of dew in the morning (may be around 9-10 am) and the sprinkler´s position must be changed once in 2-3 hours. Based on the weather conditions, sprinkler irrigation can be stopped around 4 pm.
- **If furrow irrigation is followed, use less quantity of water.** Irrigating with more water increases the chances of spore movement from affected plants to healthy plants through the water.
- **Balanced fertilisers application:** Application of balanced nutrients including secondary, and micronutrients provides resistance to plants. Potash plays an important role in disease tolerance. Reduce nitrogenous fertiliser when there is a disease severity.
- Fungal spores can survive up to 4 years in the soil. Hence **crop rotation with non-host crops is essential.**
- During harvesting, **diseased haulms and tubers must be burnt or bury them** in a pit below 2 ft from the soil surface
- For effective disease management, the **suggested practices must be practiced by the entire community.**

Regular Field Observations (Climate, Soil, and Biotic Factors)

- Monitor the field situations at least once a week (soil, water, plants, pests, natural enemies, weather factors, etc.)
- Make decisions based on the field situation and pest: Defender ratio (P:D ratio 2:1)
- Take direct action when needed (e.g., collect egg masses, remove infested plants, etc.)
- Inundate release of parasitoids/predators or usage of microbial biopesticides, insect growth regulators, botanicals, etc. depending upon the type and stage of insect pest.
- Synthetic chemical pesticides should be the last option
- If disease symptoms are found in any patch, that patch must be destroyed (uproot and burn) followed by an antisporulant spray. Nearby farmers can take up systemic fungicide spray based on the weather condition.


KisanKraft
KK-708

SPRAYING TECHNIQUES

08

Spraying techniques matter the most for judicious use of Chemicals and their effectiveness.

However, farmers largely neglect this aspect and use the sprayers whatever is available in the market.

Hence, the problems are:
- Indiscriminate use of pesticides
- Usage of defective nozzles which have high discharge, leading to dripping of chemicals from leaves
- Non-uniform spray pattern due to too swinging of lance
- Less use of personal protection equipment
- Less knowledge about pre-harvest interval of pesticides

Right spraying methods need to be followed for an efficient result.

8.1 Nozzles

Nozzles have an effect on:
- Amount of chemicals applied,
- Uniformity of spray,
- Coverage of chemicals on the surface, and
- Drift

Nozzle Selection and Spray Quality

Flat Fan Nozzles: Standard and even spray types. These standard types can be used on small multi nozzle booms whilst even spray designs produce uniform deposits from a single nozzle.

The flat fan nozzle has a lens-shaped or elliptical orifice. This produces a narrow lens-shaped pattern, with the highest spray deposit occurring immediately under the nozzle and the amounts of spray lessening towards the edges of the fan. This means the swaths must be overlapped to achieve an even deposit on the target, and hence are usually used in an overlapping fashion on a spray boom.

These nozzles are produced in a range of sizes and possible spray angles although the most used spray angles are either 80° or 110°. The larger spray angle (110°) gives a wider swath but generally produces smaller droplets.

Fan nozzles are most suitable for spraying flat surfaces such as soil when applying pre-emergence herbicides, to walls of buildings, for example, when spraying against insect disease vectors or stored product pests.

A special type of flat fan nozzle is known as the 'even spray' nozzle. This is designed to give an even deposit across the swath to eliminate the need for overlapping swaths and is best suited for a single nozzle on a knapsack lance when band or strip spraying. They are most commonly available only with an 80° spray angle.

Most flat fans are designed to produce a specified throughput and spray angle at a spray pressure of 40 psi or 3 bar. However, also available are low-pressure (LP) flat fan nozzles, which give the same flow rates and spray angles but at 15 psi (1 bar). These tend to produce larger droplets and so are better for herbicide spraying to minimise drift.

Checking Application Quality using Water-Sensitive Papers to ensure Optimal Coverage

If available, use water-sensitive papers to check likely target surface coverage. If no paper is available, spray with water only. If the leaves are soaked and water drips from the leaves then the application volume is too high.

Using Water-Sensitive Paper

Use paper clips or staplers, to fix water sensitive papers in the crop, particularly in target areas where you need to get good spray coverage. Spray the area following your normal spray practice with clean water. Collect the papers and look at the droplet coverage.

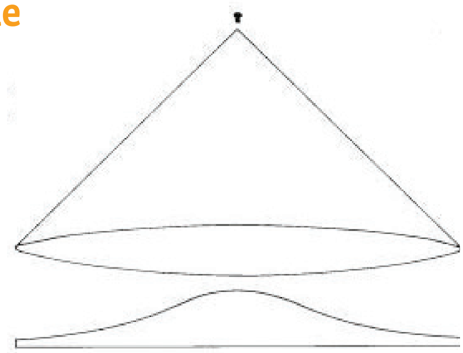
8.2 Low-Cost Boom Sprayer For Effective Spraying

The Boom Sprayer developed by the project enables an approximately 8 times faster and more uniform application of crop protection products, thus contributing to the reduction of inputs that are harmful to nature and humans. For optimal protection of the plants, the top and bottom of the leaves must be treated.

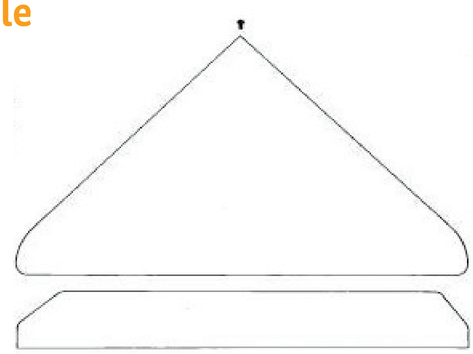
8.3 Do's And Dont's While Spraying And After Spraying

Do's	Don'ts
• Wear gloves when handling nozzles • Clean a nozzle with water and a light brush • Protect nozzles from blockages with the use of recommended filters • Frequently clean nozzles • Calibrate nozzles and sprayer every season • Replace the nozzle if damaged • Follow any product label recommendations • Change nozzles as necessary depending on the crop, growth stage and product mode of action	• Clean a nozzle with an abrasive implement • Clean a nozzle by blowing through it with your mouth • Use damaged or worn nozzles • Use fine spray drop sizes on a windy day

Conventional Nozzle



Improved Nozzle



Five Golden Rules For Safe Use Of Crop Protection Products

Exercise Caution Always

1

Read and Understand the Product Label

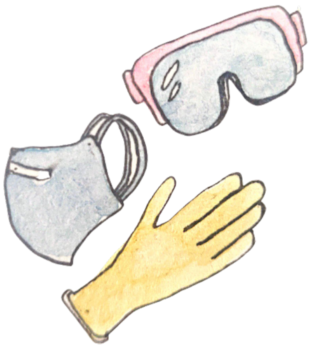
2

Practice Good Personal Hygiene

3

Take Care of and Maintain Application Equipment

4



Wear Appropriate Personal Protective Clothing and Equipment (PPE)

5

Wrong and unsafe application leads to health risks!

It also leads to higher costs! Farmers are unable to work and may incur medical costs for hospitalization.

- Deposition of pesticide should be 100%, not more and not less
- pesticide losses due to drift or deposition on soil results in reduced effect
- Higher use results in more costs

Precautions

- Check sprayer for leaks with clean water (always before use)
- Calibrate sprayer output (at least once per season)
- Ensure an even and uniform application
- Clean the sprayer after each use

Spraying quality

- Steady height
- Steady speed
- Constant pressure
- Calibrate sprayer
- Avoid drift because it causes:
  - Contamination of environment and farmer
  - Loss of product
  - Damage possible to neighbouring crop
- Ensure good coverage
- Check distribution
- Droplet size
- Avoid Runoff

After application

- Clean the sprayer properly
- Spray, when possible, the cleaning water over the crop instead of letting it run off
- Store leftover pesticides at a safe place
- Bath/shower after application
- Change clothes
- Wash clothes separate from other clothes
- Don’t enter the field for 1-2 days.

HARVESTING, GRADING AND TRANSPORTATION

09

The appropriate time of harvesting potatoes may vary with cultivar, climate, disease and pest pressure, and sometimes price.

Uneven soil conditions and late blight or other infections often lead to uneven maturation of the tubers. A well-timed haulm removal promotes more even maturation as well as the early setting of skin and early maturity. Seed potatoes are harvested at 80-100 days after planting, depending on the variety, to avoid infections that may occur in the second half of the growing season. Viral diseases, late blight, stem rot and bacterial wilt in particular spread to tubers if stems begin to wilt and dry out. Too early harvest can lead to unripe tubers that have low starch contents and store poorly.

Further, too early harvest can result in leaf regrowth and increased tuber necrosis. Immature potato tubers have a thin, poorly developed skin, are easily bruised, have low dry matter content, and can only be stored for a short period. This can result in easy infection by fungi and bacteria. Late blight attack is the most common reason for harvesting potatoes early. If the growing potato plants are healthy, delayed harvesting can be beneficial as it can lead to higher starch contents, better baking properties and a better flavour.

9.1 Dehaulming

For most varieties, yellowing of the potato leaves indicates that the potato crop has reached maturity. However, a stable skin of the tubers is the basic indicator for harvest readiness of potatoes. The removal of the above-ground plant parts of the growing potato is termed as dehaulming. To induce skin formation of tubers, farmers should stop watering about a month before intended harvesting or dehaulm 2-3 weeks before intended harvest.

Dehaulming induces the skin of the tubers to harden, which reduces the spread of diseases and skin damage while harvesting. Damaged skin will reduce the market value and storability of harvested potatoes.

Dehaulming is done when the tubers have reached their preferred size for marketing or if no further growth of marketable yield is expected. If a heavy infestation of late blight took place and more than half of the leaf area is destroyed, the crop should be dehaulmed to preserve the tubers from tuber blight.

At dehaulming, the tops of the plants are cut manually or mechanically at the base of their stems. If the foliage is healthy, it can be collected and composted. Leaves with disease symptoms must be burnt or composted adequately with frequent turning and thorough heat periods in the pile to kill the disease.

After dehaulming, the tubers are given 14-21 days to develop matured and hardened skins. Well-matured tubers are less sensitive to damage and storage rot. The tubers are mature when the skins are firm and cannot be removed by lightly rubbing the tubers with the fingers. When the tubers are mature, the harvest should not be unnecessarily delayed if weather and soil conditions allow the safe lifting of the tubers. Delayed harvest poses more risks to tuber quality caused by wireworms, millipedes and Rhizoctonia disease.

9.2 Harvesting Methods

Potatoes are best harvested when the soil is moist. Very dry soil conditions complicate manual and mechanical harvest. If soils are very dry and cloddy, irrigation with 5-15 mm of water per sqm can facilitate the harvest operation. Harvesting in wet soil conditions requires extra cleaning to remove clods without causing damage to tubers. Harvesting during rain or wet soil can cause wet rot infestation to a high number of tubers. In the case of mechanical harvesting, the potato harvester's settings should be checked at each batch by additional digging and tuber evaluation to ensure a gentle harvest.

Small-scale farmers traditionally harvest potatoes with a spading fork or a plough. The GIC project has developed a small semi-automatic potato digger that is mounted to a tractor. The mechanical harvester greatly speeds up and facilitates harvesting, thus reducing the time and cost of labour compared to the traditional harvesting methods. The single-bed potato harvester excavates the tubers and separates them from the soil with the help of a vibration sieve. The dugout tubers then lay on the soil surface and can be picked up easily by hand.

9.3 Minimising Damage

Careful handling during and after harvest is essential to ensure good tuber quality. Pressure and bruising during harvest, storing, sorting, loading, washing, packing and transporting can result in tuber damage.

At harvesting, it is important to avoid bruising or other injuries which provide entry points for storage diseases and reduce the commercial quality and storability of the tubers. Damaged tubers must be sorted out before storage. The damaged spots will only become visible after a few days when the discolouration takes place. Tubers with attached soil are best left on the ground for two hours to let the soil dry out and fall off, as the attached soil can cause them to rot. Generally, after harvesting, the tubers should be dried off as fast as possible within the first 24 hours to allow wound healing and prevent rotting.

Drying off is done by providing good ventilation. Freshly harvested tubers should not be washed, unless they are meant for immediate cooking. Harvested tubers should be sorted by size and quality, separating healthy from damaged ones, and then placed carefully in a box or a basket. Potatoes should not be thrown from a distance.

Field Hygiene

After harvesting, the field should be cleaned off remaining plant parts and tubers. Post-harvest field sanitation is an important part of controlling pests and diseases, as it removes potential sources of contamination for the next crop. Average yields Average potato yields in India for local potato varieties are 20-30 t/ha.

9.4 Storage

Storage losses are commonly incurred due to pests(e.g. potato tuber moth) and diseases while physiological disorders are also a major constraint. It is therefore important for farmers to think of post-harvest on-farm storage of potatoes well ahead of harvesting time. The ideal conditions for storing dried-off potatoes is a dry and ventilated environment at about 12 °C. In such conditions corking and wound healing is promoted, and rot is minimised. However, most farmers do not have access to such storage facilities. Sometimes farmers store potatoes in the field using some of the diseased foliage of the potato plants to cover the potato storage structures.

This practice is discouraged. If temporary storage is needed in the field under a shed or a tree, all diseased potatoes should be removed prior to storage, and all potential insect entry points need to be covered with a fine, insect-proof mesh netting to prevent potato tuber moth from entering. The potatoes should be placed on a bed of straw, 1-3 m wide, with a ventilating duct along the bottom, and covered with grass instead of leaves of the potato plants, in a way to allow ventilation of the pile. In case of rain, farmers should cover the heaps with tarpaulin.

- Remove haulms about 14 days before optimum harvest time.
- Harvest crop as close as possible to crop duration but more than 75 days old. Harvest at proper maturity (depending on the variety used).
- Use mechanical harvester: soils are often too wet for mechanical harvesting leading to poor separation of potato and soil clods. Labour is short in supply thus manual harvesting is becoming expensive and it is difficult to organize labour to come and harvest.
- Dry potatoes in the field. wet potatoes lead to rotting in the heap. Dry potatoes mainly after 3 pm when temperatures are lowering.
- Remove damaged and diseased potatoes. Damaged potatoes mixed with diseased potatoes lead to rotting (the project observed 70 % loss under farmer practice). Remove damaged and diseased tubers, sort out diseased and destroy them, and sell off damaged potatoes as early as possible.
- Store in heap in an area that remains dry even with heavy rains. Heaps are often found in poorly drained areas, thus rotting. Make a heap at the higher end of the field preferably construct a plateau that is elevated in the shade of a tree.
- Cover the heap with 40 mesh insect nets to prevent PTM damage. Cover a heap of potatoes with 40 mesh insect net, ensuring no opening. Many openings are observed in traditional structures through which PTM can enter.
- Insert pipes in the heap to lower the temperatures and control CO_2 build-up. Moist conditions combined with improper ventilation lead to high temperatures and high CO_2 leading to rapid degradation of the quality of stored potatoes and thus low prices. Insert pipes in the heap so that hot air and CO_2 can escape, bottom part of the heap an air vent should be available, cover vents with 40 mesh insect nets.

9.5 Crop Rotation

Crop rotation is a traditional method of conserving soil fertility and reducing pest and disease pressure. By planting crops with different nutrient demands in a sequence, soil fertility is maintained. Furthermore, rotating crops breaks the reproductive cycles of micro-organisms and insects, which are detrimental to the crop.

- The potato crop is susceptible to a wide range of soil-borne diseases, so it is important to not plant potatoes in the same field year after year.
- Potatoes also get many of the same diseases as tomato, chili and brinjal, so avoid planting potatoes in a field that grew these crops in the previous season.
- Rotation of pulse crop followed by potato crop and planning of any cereal crop is the ideal crop rotation plan.

Farmers who due to economic or social conditions do not practice crop rotation must rely on other measures to avoid carry-over effects, which often involve a more intensive use of agrochemicals

COST OF CULTIVATION

10

This is an indicative cost sheet of cultivation depicting the comparative analysis of conventional practices and improved practices.

Cost Item		Farmer Practice			Improved Practice			Improved technologies	Remarks
	Unit	Unit Cost	# of Units	Amt	Unit Cost	# of Units	Amt		
Land Preparation									
Duck foot plough- 5 times	hr	700	5	3500				Deep Ploughing with reversible plough/MB plough	
Reversible Plough	hr				900	3	2700		
Seed									
Local Seeds	kg	16	600	9600				Certified/Quality seeds	
Quality seeds	kg				20	800	16000		
Seed Preparation									
Local (Cutting)	lab	200	3	600				Seeds grading, spreading, and treating with Gibberellic acid and M-45	
Seed grading and Chemical for treatment	lab				150	2	500		Labour for Seed grading and chemical cost Rs. 200
Planting									
Seed bed preparation: tillage by bullocks	pairs	500	2	1000				Planting: While planting tillage is done by Rotavator and whole tuber is planted	
Seed bed preparation: Rotavator	hr				800	3	2500		Rs. 100 for driver bata
Planting by labours	lab	200	10	2000					
Planting by machine + 2 labours	hr				1000	3	3500		
Nutrient Management and Pesticides									
Nutrient Management				4000			7000	Basal Dose: DAP-75 kg (Rs.1800), MOP-150 kg (Rs.2100), Setright-100 kg (Rs.880). Top dressing: Urea at 20th day-50 kg (Rs.300), micronutrient spray1(Rs.235) and 40th day-50 kg (Rs.300), micronutrient spray1(Rs.235), 55-60 days Urea-25 kg (Rs.150)	Fertilizer cost Rs. 6000 (including micronutrients N top dressing) and labour Rs. 1000

Cost Item		Farmer Practice			Improved Practice			Improved technologies	Remarks
	Unit	Unit Cost	# of Units	Amt	Unit Cost	# of Units	Amt		
Fungicide				4000			5900	Preventive sprays with Mancozeb, PP and curative sprays Moximet/Curzate	Cost of the chemical
Insecticide				1000			500	Sulphur spray (Mites)	Cost of the chemical
Spraying -Farmer practice	lab	200	4	800					8 sprays
Spraying - Improved practice	lab				200	8	1600		
Weeding and intercultivation									
Weeding by using labour	lab	200	7	1400				Weedicide is used for controlling weeds and one time earthing up	
Earthing up 2 times with Bullocks	Pairs	550	2	1100					
Weedicide							760		
Earthing up							500		Rs. 560 for weedicide and 200 for appln and one earthing up- 500
Irrigation	Lab	200	4	800			800		
Harvesting				8000			5000	Harvesting by digger	15 labours/ac, Rs. 2000 for tractor
Miscellaneous				3000			3000		Miscellaneous
Cost of cultivation (per acre)				**40,800**			**50,260**		
Yield Quantity (kg)				**5000**			**8000**		
Average Price (Rs/ kg)				**10.0**			**10.0**		
Gross Returns (Rs)				**50,000**			**80,000**		
Net Profit				**9,200**			**29,740**		
B:C ratio				**1.23**			**1.59**		

It can be observed from the table above that though the overall cost of cultivation is more while practicing the improved practices , the net profit is high from improved practices compared to the conventional practices. In terms of yield, there is an **increase from 5 to 8 tons per acre and the profit is three times higher.**

CASE STUDY

11

Effective Reduction of White Grub and Wilt disease

Farmer Introduction

Rohini Ghule is member of **Veerbaba Shetkari Vikas Gat Farmer Study Group (FSG)** and board member of **Satgaon Farmer Producer Company (FPC)**. She owns a total land of around 0.7 ha.
She cultivates potato as a major crop in the Kharif season and onion, and jowar in the Rabi season. Apart from this, every year, they lease around 5-acre land on lease in the neighbouring villages mainly Karegaon and Dasturwadi.

Mrs. Rohini Ravindra Ghule
Village: Thoratmala
Taluk: Ambegaon
District: Pune, Maharashtra

Problems Faced In Potato Cultivation

The biggest problems on her farm were white tuber leaf blight, bacterial wilt and late blight. Due to heavy infestations of white tuber leaf blight and bacterial wilt, about 30% to 35% of the potential potato crop was lost. Infestation with late blight also had a major impact on yields. The heavy infestation of the above diseases resulted in huge losses in potato cultivation, reducing yield and profit.

Innovative solutions from GIC project

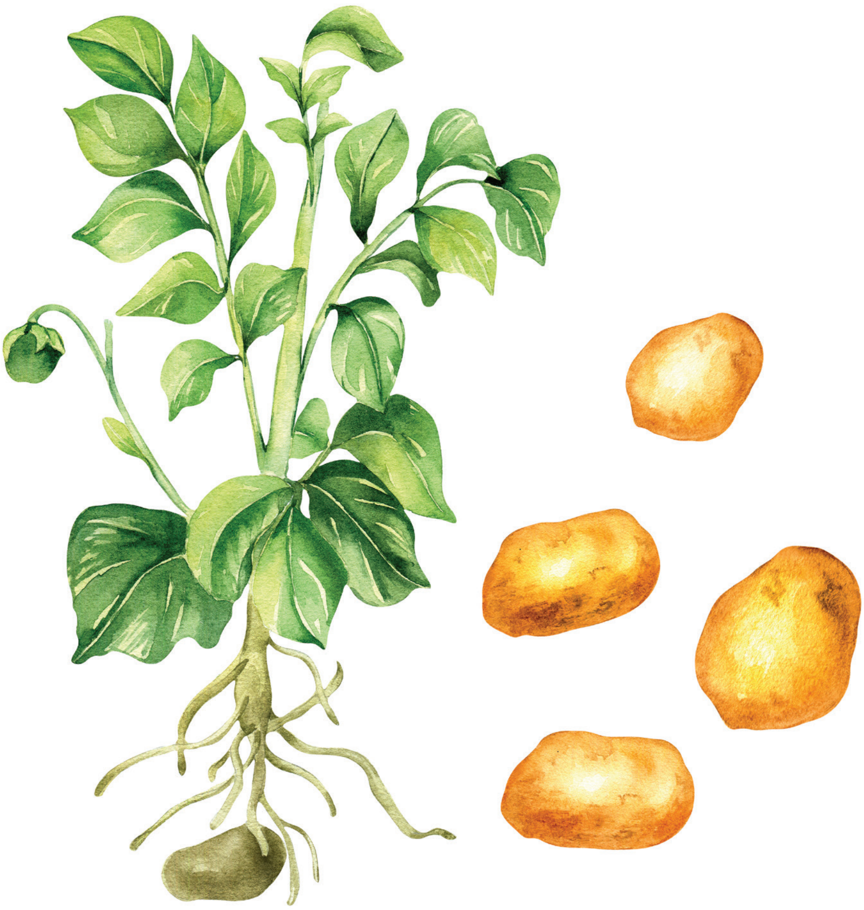
Among the few important innovations that have been practiced is the preventive method of controlling white grub infestation. Since white grub control is a community level initiative, we prepared a local light trap to start with the mechanical method to catch the adults of the white grub. In this method, we first pruned the neem trees around the field because they are the host plants of the adults. As a preparatory measure, a small pit of standing water is dug under the host plants (neem tree, babul tree, ber tree) before the first rain and kerosene is added to the water. Then a light source is placed to attract the adults, which come and are drowned in the liquid. An adult pest lays about 50 eggs, so if they get controlled before production, the spread of larvae can be contained. This method is used not only at the individual level, but also at the group level.

In the next step, we used the technique of preparing enriched neem cake, in which 500 kg of neem cake is fortified with 5 types of biological control agents (1 kg each) - Bacillus subtilis for bacterial wilt, Pseudomonas fluorescence Trichoderma viridae for fungal diseases and pests, Paecilomyces lilacinus for nematodes and Metarhizium anisopliae for white infestation. The above-mentioned biological control agents get mixed into the neem cake and the enriched neem cake is then sprinkled with water to make it slightly moist. It gets covered with a jute bag and is kept for 20 days in the shade (e.g., under a tree). After 20 days, the enriched neem cake is ready and is spread in the field when sowing. This technique was used for 3 years and resulted in a reduction in white grub infestation and wilt disease.

Result and Conclusion

The techniques in potato cultivation which Rohini learned and applied in her field gave her tremendous results in all aspects. After implementing the innovations on the main field, she was able to reduce costs by 50% and increase yield by 30%. Following are the changes displayed she got on her 0.7 ha field.

SN	Particulars	Before joining GIC	After joining GIC	Remark
1	**Seed rate**	23 bags	14 bags	Getting uniform and quality seeds reduces the no. of seed potatoes bags needed
2	**Seed price**	73,600	39,200	Saved Rs. 34,400 in seed purchase due to direct purchase through FPC and required fewer bags due to uniform size of potatoes
3	**Fertilizer price**	1,300	1,000	Rs. 300 saved per bag due to direct purchase through FPC
4	**Pest and disease Management (IPM)**	15,000	7,500	Saved Rs. 7,500 in IPM
5	**Yield**	100 to 110 bags	150 to 170 bags	Increased yield of 50 to 60 bags



Improved Pest and Disease Management

Introduction

Mr. Ramkrishna Madhukar Shind
Village: Sriramnagar
Taluk: Ambegaon
District: Pune, Maharashtra

Ramkrishna Shinde, resident of Sriramnagar village, Ambegaon Taluka, Pune district is a group member of **Nisargraja Shetkari Vikas Gat Farmer Study Group (FSG)** and shareholder of **Satgaon Farmers Producer Company (FPC)** Pvt ltd. He is also an "innovation farmer" selected by his group members. Academically, he has a degree in agriculture, but he has chosen the practical profession of farming. He owns a total of about 3.5 hectares of land. He grows mainly potatoes on 2.4 ha and corn on 0.8 ha in the Kharif season, followed by sorghum and onions in the Rabi season. He also runs a dairy farm and owns 10 cows and 2 buffaloes.

Problems Faced In Potato Cultivation

A major problem he faced was late blight, which caused up 30 to 40% loss of yields. The cost of pesticides and fungicides had increased, and yet crop damage could not be contained, resulting in lower yields.

Innovative solutions from GIC project

Through the trainings in the GIC project, an important insight was gained: When farmers can see the pests and diseases with their eyes, it is already very, if not too late. Therefore, the preventive control method is much better than the curative one. Not only does it save about 50% of the cost per hectare (ha) and spray to control the infestation, but these bio-fungicides such as potassium phosphite are also environmentally friendly and have no harmful effects on beneficial pests.

In addition, proper application of nitrogen in divided doses at 30- and 50-day intervals has reduced infestations of other pests such as sucking pests and red spider mite. A late blight control spray schedule is currently being developed with project support that includes a combination of mancozeb 45 (500 to 1,000 g), potassium phosphite (1,000 g), neem oil (500 ml) and sulphur (500 g) as a preventive spray to control late blight. After technical training, about 4 to 5 sprays per acre are carried out at weekly/fortnightly intervals, depending on climatic conditions.

Result and Conclusion

Overall, the best practices learned and applied in potato cultivation have shown grreat results. Ramkrishna now focuses more on preventive measures, which has allowed him to save about 50-60% of pest control costs, as the cost of preventive pesticides is much lower than that of curative and antisporulant agents. **The total cost of pest and disease control on 6 ha of potato area is now 24,090 INR (for 1 ha the total cost is about 4,015 INR), while before participating in the project it was 51,000 INR (for 1 ha the total cost was 8,500 INR).** This means a total saving of Rs. 26,910 in pest and disease control. He also observed that the number of friendly insects on his farm have increased.

Benefits of Laser Levelling

Introduction

Mangal Santosh Kand, resides in Kohinde village, Khed Taluka, Pune district. She is an active group member of the Farmer Study Group (FSG) **Sant Tukaram Krishi Vikas Gat Kohinde** and a shareholder of **Bhama Bhima Farmers Producer Company (FPC).**

She owns a total of about 7 hectares (ha) of land, of which only 3 ha are cultivated, and the remaining 4 ha are fallow land. She mainly grows potato, soybean and groundnut in Kharif season followed by Jowar in Rabi season.

Mrs. Mangal Santosh Kand
Village: Kohinde (Brudak)
Taluk: Khed
District: Pune, Maharashtra

Problems Faced In Potato Cultivation

Since her land was very uneven, heavy, and irregular rainfalls caused waterlogging in her fields. As a result, she had huge crop losses due to rotting of her potatoes. In addition, late blight was a big problem that reduced yield and profit.

Innovative solutions from GIC project

Laser levelling technology is a glimmer of hope for water stagnation and rot problem. In this method, the laser transmitter emits a laser beam. This is intercepted by the laser receiver, which is mounted on the levelling bucket. The control panel for this system is located on the tractor and evaluates the signal from the receiver and opens or closes the hydraulic control valve.

Loose soil particles are picked up by the bucket and delivered down the field. First, the land is measured with the help of a laser and the gap in the land, the slope to be given, is determined. After ploughing, the soil is levelled with the laser, and later the planting of potatoes can take place. The levelled areas contribute to an even distribution of soil moisture. In the field levelled with the laser, there was no water stagnation, which resulted in uniform and good germination and increased the efficiency of the use of inputs.

Result and Conclusion

The introduction of laser levelling technology has produced tremendous results. In the field where laser levelling was done, the yield is about 10-15 bags higher (in a field of 0.2 ha) than in the field without laser levelling.

This translates to an additional yield of 4.5 tonne/ha and is equivalent to a profit of about Rs. 90,000/ha (at Rs. 20/kg for the additional 4.5 tonnes). The cost of laser levelling is about Rs. 20,000/ha (4 hours per acre at about Rs. 2,000/hr). The B/C ratio is therefore 4.5. The positive effect of laser levelling pays for itself after only one year, and the procedure only needs to be repeated every 5 years.

List of Abbreviations

AFC	Agriculture and Finance Consultants
B	Boron
BMZ	German Federal Ministry for Economic Cooperation and Development
Ca	Calcium
CEC	Cation-Exchange Capacity
Cu	Copper
DAP	Days After Planting
EC	Electrical Conductivity
Fe	Iron
FYM	Farm Yard Manure
GAP	Good Agricultural Practices
GIC	Green Innovation Centres for the Agriculture and Food Sector
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit Gmbh
HEEU CoH	Horticulture Education and Extension Unit College of Horticulture
IIHR	Indian Institute of Horticulture Research
IIVR	Indian Institute of Vegetable Research
IPM	Integrated Pest Management
K	Potassium
LE	Larval Equivalent
Mb	Molybdenum
Mg	Magnesium
Mg	Manganese
N	Nitrogen
NABARD	National Bank for Agriculture and Rural Development
NHRDF	National Horticulture Research and Development Foundation
NIPHM	National Institute of Plant Health Management
NPK	Nitrogen, Phosphorus, Potash
NPV	Nuclear Polyhedrosis Virus
NSKE	Neem Seed Kernel Extract
P	Phosphorus
pH	Power of Hydrogen
PPE	Personal Protective Clothing and Equipment
PSB	Phosphate Solubilizing Bacteria
PTD	Participatory Technology Development
S	Sulphur
UHSB	University of Horticultural Sciences, Bagalkot
WG	Water Dispersible Granules
WP	Wettable Powder
Zn	Zinc

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