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Agriculture Sector Modernization Project

OPERATIONAL MANUAL

POTATO

AGRICULTURE SECTOR MODERNIZATION PROJECT

A PARK
AGRICULTURE TECHNOLOGY DEMONSTRATION PARK

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Message from Project Director

Sri Lanka takes great pride in its rich heritage, with a written history that spans thousands of years. Its fertile soil, diverse landscapes, and strategic location have long made it an ideal hub for farming.

While agriculture evolved globally, Sri Lanka faced challenges. The industry became less profitable and labour-intensive, compounded by the introduction of an open economy. The fragmentation of cultivable land into small, inefficient plots further compounded the challenges as farming was no longer seen as a reliable career.

Sri Lanka allocates a significant portion of its foreign exchange on importing agricultural commodities. Recognizing the potential of its nutrient-rich soil, the government saw an opportunity to cultivate crops that meet international demand while reducing imports and boosting foreign exchange through exports. To capitalize on this, the government prioritized advanced agricultural technologies. In 2017, the "Agriculture Sector Modernization Project" (ASMP) was launched with the World Bank funding.

The project focused on areas where Sri Lanka had the most potential, such as export-oriented tropical fruits and vegetables . It started pilot project in year 2018 with World bank funding with seven districts in five provinces (Jaffna, Mulaithevu, Batticaloa, Anuradhapura, Polonnaruwa, Mathale and Monaragala) and expanded with the grant of the European Union, in another five districts (Kilinochchi, Vavunia, Ampara, Kandy, Badulla) (Kilinochchi, Vavunia, Ampara, Kandy, Badulla) The project secured a loan of USD 64 million from the World Bank, along with a grant of USD 25 million from the European Union. To date, the project has generated USD 65 million in foreign exchange earnings, with potential savings of up to USD 3 million domestically.

The project focused to high-demand tropical fruits and vegetables. Small farms were consolidated into larger groups of 300 to 400 entrepreneurs into Agriculture Technology Demonstration Parks (ATDPs) and modern technologies were introduced.

Tropical Fruit varieties are the main crops selected for Agriculture Technology Demonstration Parks of the Agriculture Sector Modernization Project (ASMP) by the International Service Provider (ISP) identified as Tropical Queens (Banana, Mango , Guava, Papaya and Pomegranate) which are among the most popular fruits in the world. ISP engaged in producing those competitive and marketable commodities for both local and export markets

The socio-economic problems and the COVID pandemic of the Country during year 2020- 2022 affected the implementation of the ISP technology packages. Because of this, the ISP and the ASMP developed optional technology packages, designed to overcome the shortfalls of the crisis. Procurement of equipment and supplies already available in the Country was given priority to avoid import delays and constraints. Different irrigation systems were used when the preferred system was not available. Options are also being developed for inputs such as fertilizers and pesticides. Intercropping was implemented as the ideal weed control practice and staple food crops to provide much-needed food to the Country. More emphasis is given to IPM systems to control pests and diseases. Even existing crops were given pre- and post-harvest technology to start exports without waiting until newly planted crops are harvested. Therefore, most of ASMP crop clusters have both existing crops and new crops with complete ISP technology package. Therefore, the Operational Manuals of Dr Julian; the Agronomist of ISP are based on technology for both existing crops of farmers as well as new crops with entire technology package .

ASMP started with Pilots by introducing Department of Agriculture (DOA) technology. With the intervention of Dr. Julian, ASMP involved in Vertical upliftment of the existing DOA technology from land preparation to pre / post-harvest technology to end up with modern processing technology with reefer container protocol for export which have never been practised in Sri Lanka . High density double Row planting, Low pressure irrigation (mini sprinklers, Drip tapes), irrigation based on mini whether station data , soil test based fertigation, modern training and pruning of fruit trees (box and espalier), use of poly mulch , pre and post- harvest Technology (use of colour bagging , colour ribbons, fruit desk etc) are some of the promising technologies introduced by the ISP. ASMP has produced Operational Manuals for Banana (Ambul, Kolikuttu, Cavendish), Mango, Guava , Papaya, Soursop, Passion fruit, chilli, Vegetables , Jumbo peanut, potato , Red onion and Maize .

The project introduced innovative methods for increasing land productivity. Techniques like high-density double-row planting and the "espalier" method allowed agroprenuers to double or even triple their yields. Automated water-controlling systems based on weather station data ensured a effective use of water supply, enhancing productivity reducing use of fertilizer. Solar energy was harnessed to power these systems, reducing reliance on the main electricity supply..

Over the past seven years, the project had transformed the concept of "farming" in Sri Lanka. Once viewed as an unattractive profession, farming had become a thriving opportunity, attracting the new generation. This shift had marked a major change in societal attitudes and had empowered farmers as agropreneurs, driving innovation and growth in the agricultural sector.

A key initiative of the project was the transition from individual farming to the establishment of farmer companies. Farmers were organized into "Public Unlisted Companies (PUC)," raising the status of farming from a mere livelihood to an esteemed profession. This shift established a structured system, elevating agriculture to a professional level and instilling a sense of pride in the farming community.

Farmers of the Agriculture Technology Demonstration Parks of the Agriculture Sector Modernization Project (ASMP) were organized into Farmer Producer groups and these groups were later registered as Farmer Companies under the Companies Act No 7 of 2007, in the Public Unlisted Company category. There are 59 Farmer Companies already functioning in the ASMP crop clusters.

The Farmer Company model facilitated direct business transactions between local farming organizations and international buyers, creating new global business opportunities

Specialized processing centres for each Farmer Company ensure that crops are processed, graded and packaged according to international standards. This system provides the buyers with access to high-quality products through a structured, well-organized, and accountable framework, ensuring benefits for both agropreneurs and buyers alike.

Dr. Rohan Wijekoon
Project Director
Agriculture Sector Modernization Project

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1. FOREWORD

The technology package described in this manual was used in two very different potato production areas with very good results in productivity and quality, Jaffna and Badulla[1]. This was strong indication to the ASMP that this technology package is applicable to all potato growing areas of Sri Lanka, except perhaps the prevention and control of pests and diseases, although the IPM practices recommended by here would be applicable as well.

2. INTRODUCTION

The potato plant, scientifically known as *Solanum tuberosum*, is a member of the Solanaceae family, which also includes tomatoes, peppers, and eggplants. The potato is an herbaceous perennial plant, but it is typically cultivated as an annual crop for its edible tubers.

Originating in the Andean region of South America, specifically modern-day Peru and Bolivia, the potato has a long history of cultivation dating back thousands of years. It was domesticated by indigenous peoples in the Andes and played a vital role in their diet and culture.

Botanically, the potato plant consists of several parts:

- Stem: The stem of the potato plant is erect, herbaceous, and typically reaches a height of about 60-100 centimeters (24-40 inches). It is green and produces leaves and flowers.
- Leaves: The leaves of the potato plant are compound and alternate. They are composed of several leaflets attached to a central stem, known as a petiole. The leaflets are oval or lance-shaped and have a slightly serrated margin.
- Flowers: The potato plant produces small, white, or purplish flowers with five petals. The flowers are arranged in clusters called inflorescences, which develop at the tips of the stems.
- Tubers: The most significant part of the potato plant is the tuber, which is an underground modified stem used for storage. The tubers vary in size, shape, and color depending on the variety. They are typically elongated or round and can have smooth or rough skin. The flesh of the tubers is starchy and can be white, yellow, red, or even purple.

2.1 Optimal Ecological Requirements

Potatoes thrive in a cool and temperate climate, and the optimal ecological conditions for potato growth include the following factors:

1. Temperature: Potatoes prefer moderate temperatures ranging from 15°C to 21°C (60°F to 70°F) during the growing season. They can tolerate temperatures as low as 7°C (45°F) but are sensitive to frost and freezing temperatures. Extreme heat or frost can adversely affect their growth.
2. Sunlight: Potatoes require ample sunlight for photosynthesis and growth. They perform best when exposed to at least 6 to 8 hours of direct sunlight each day. Ensure that the planting location provides sufficient sunlight.
3. Soil: The soil should be well-drained and loose, with a pH level between 5.0 and 6.5. Loose soils (loamy sands to sandy loams) allow the tubers to expand and develop properly, while good drainage prevents waterlogging and rot.
4. Moisture: Potatoes require consistent moisture throughout the growing season. However, they are susceptible to waterlogged conditions, which can lead to rotting. Adequate irrigation and drainage are essential to maintaining the right moisture level.

[1] ASMP has tried the same technology package in Badulla with very good results. Therefore, ISP's opinion is that this technology package is applicable to all potato growing areas of Sri Lanka, except perhaps the prevention and control of pests and diseases, although the IPM practices recommended by the ISP would be applicable as well.

5. Rainfall: Ideally, potatoes require an average annual rainfall of around 500 mm to 800 mm. However, if rainfall is deficient, supplemental irrigation may be necessary to prevent the soil from drying out completely.
6. Growing Season: Potatoes generally have a growing season of approximately 80 to 120 days, depending on the variety. In Jaffna, Sri Lanka, the potato growing season is between 70 to 75 days.

It is important to choose varieties that are suitable for your specific climate and growing season length.

3. LAND PREPARATION

3.1 Primary Land Preparation

1. Deep ploughing using a 60 cm diameter disk plough.
2. Incorporation of organic matter/ Compost by broadcasting 12 MT per hectare or 5 MT per acre of compost.[2] Organic matter is used as a soil amendment to improve the soil chemical and physical properties and to increase the population of beneficial soil micro-organisms. For these purposes, the level of organic matter in the soil should be kept at 2% or above.
3. Deep plough again perpendicular to the first pass

3.2 Secondary Land Preparation

1. Heavy Soil Textures
    a. Disk harrow using a disk harrow implement with disks having a diameter of 40 cm.
    b. Two passes perpendicular to each other are required.
2. Light Soil Textures
    a. Cultivate using a tine tiller implement.
    b. Two passes may be required in sandy clay loam soils.

3.3 Tractor

1. Tractor size 75 to 99 HP (75 to 85 POT), four-wheel drive[3]

3.4 Drainage

Drainage is of particular importance for the Potato as the crop is susceptible to several root diseases. Good internal drainage provided by raised beds (50 cm high) and a network of drainage ditches to quickly evacuate high amounts of rainfall are very important practices to prevent root rots and other soil borne diseases affecting Potato and to provide an optimum environment for the size development of the potato tubers.

1. Light Texture Soils
    a. Light textured soils are preferred for the cultivation of the Potato.
    b. Sloping handmade ditches to evacuate water from rainfall quickly 30 cm wide x 15 cm deep.
    c. These ditches will discharge into a larger sloping drainage trench 75 cm wide with a depth between 45 cm to 60 cm according to the conditions of the land.

[2] Lower rates of soil amendments can be used when incorporating organic materials since the product will be totally exposed to decomposing organisms inside the soil and the nutrient by-products of decomposition can be placed in the proximity of the root system of the crop to enhance uptake by the plants.

[3] It is unfortunate that Sri Lankan farmers do not have access to bigger tractors. It is recommended to procure modern machineries for Sri Lankan farmers, which can enable more efficient land preparation. ISP also recommends to procure moldboard plough to turn the soil over.

d. This is a "U" type drainage design for small plots made up of two lateral drainage ditches at the extreme ends of the plot that drain into a primary drainage canal that evacuates the water away from the plot.
e. Before making the ditches, it is necessary to observe the slope of the plot and the East-West direction of the double row planting. Ideally, the double rows should drain into the lateral ditches without much effort.

2. Heavy Texture Soils
   a. Heavy texture soils such as clays are not very suitable for the Potato cultivation.
   b. Sloping drainage secondary canals 45 cm wide x 30 cm deep at 20 m intervals
   c. These canals will discharge into a larger primary type sloping drainage canal 1 m wide with a depth of 60 cm according to the conditions of the land.
3. Waterlogged Soils
   a. This type of soils much be avoided for Potato cultivation.
   b. Drainage lines 45 cm wide and 45 cm to 60 cm deep at 5 m to 10 m intervals
   c. These lines will discharge into a larger primary type sloping drainage canal 1 m wide with a depth of 60 cm according to the conditions of the land.
4. Drainage Equipment
   a. Backhoe Excavator or similar with 30cm or 45cm wide bucket

4. VARIETIES

Potato seed is imported every year because of the shortage in Sri Lanka. In fact, availability of seed is the most important limiting factor for potato cultivation in Jaffna, in most part due to the planting season being different from other potato planting seasons in Sri Lanka. This production timing difference creates a serious seed supply problem for Jaffna farmers. Fortunately, the ASMP has a seed production program for Jaffna in Badulla.

The most common imported varieties are Red La Soda and Sassy. Red La Soda is a red variety from the US and Sassy is a brown variety from France. When supplies of Red La Soda and Sassy are short, Prada, another European variety released in Germany in 2017, has been used by Jaffna farmers as well.

Detail	Red La Soda	Sassy	Prada
Maturity	Normal maturity (75 to 85 days)	Medium to early variety (70 to 75 days)	Very early variety (60 to 65 days
Color	Red skin, white flesh	Deep yellow skin, yellow flesh	Yellow skin, yellow flesh
Sprouting	Normal. Several sprouts can emerge. Apical dominance common	Only a main sprout is developed. Very few lateral sprouting even when main sprout removed (low apical dominance)	Normal. Several sprouts can emerge. Apical dominance common
Tuber size	Medium to large	Large	Large
Tuber shape	Round	Round to oval	Oval

5. SEED STORAGE

Seed potatoes should be kept in a dark and cool place that is well ventilated. The temperature should stay between 4 and 10 degrees Celsius (40-50 degrees Fahrenheit), and the humidity should stay between 85-95%. It is important to keep the potatoes in an environment that is not too moist or too dry.

Figure 1: Potato Storage

6. HIGH DENSITY PLANTING

The timing of potato planting in Jaffna must be very precise because of the threat of intense rainfall in November and December. Ideally, preparing the land by the middle of November and planting immediately after is the best timing that allows for the full development of the tubers before ambient and soi temperatures become too high in February and March. Planting in late December and early January is very risky due to seed rot and tuber development and harvesting under high soil temperatures conditions in late March and early April.

6.1 Procedure

The Potato is planted in beds made by mechanical bed-makers pulled by tractors. They can also be made by hand. The beds should be 60 cm wide and 50 cm high and are separated by a ditch 30 cm wide. This means the total distance from center to center of two adjacent beds is 90 cm. The height of the bed is very important for potato not only for the prevention of soil borne diseases and to improve internal drainage, but also to allow the tubers ample space to develop and grow in size.

Figure 2: Bed Preparation

After making the beds, two drip tape lines are installed towards the middle of the bed and on the inside of the planting bed for irrigation purposes. This double drip tape system is preferred due to the rotation cropping system in Jaffna where red onions follow the potato crop.

Figure 3: Drip Tapes lines installed.

POPULATION DENSITY

74,667/Ha
29,915/Acre
14,957/Half Acre

The drip tape is double layer, white in color and UV resistant (the outer layer is UV treated). Its wall is 0.30 mm thick, and the tape has a 16 mm diameter. Emitters are spaced at 30 cm on the tape and the flow rate for the emitters is 2 Lt/Hr at 1 Bar of pressure. The drip tape is followed by a silver and black plastic mulch that blocks light penetration to prevent potato greening. Mulch with a thickness (gauge) between 30 microns to 40 microns and a width of 5 ft (1.52 meters) is ideal for potato cultivation as long as it has light blocking properties. A thicker mulch up to 70 microns may be necessary when light blocking mulch is not available. The mulch is placed on top of the planting beds fixed with soil or with pegs (steel wire or bamboo).[4]

Two rows of plants are placed on every bed. The distance between the two rows is approximately 40 cm to 45 cm. The planting distance (spacing) inside the planting rows of 30 cm is then marked on the mulch with a planting guide or template that uses sharp nails to make planting marks. The planting pattern for the two rows of the crop on every bed should be triangular to minimize the high-density effect on plant-to-plant competition. This planting pattern is always preferred for high density planting.

Plastic mulch, combined with drip tape irrigation, high planting beds and high-density planting is considered the current "state of the art" technology for high value crop production. This combination is one of the most efficient and productive systems for maximizing both yield and irrigation efficiency.

The mulch is then perforated by using very hot iron or aluminum cylinders such as discarded processed food aluminum cans. The metal cylinders are kept red hot with burning charcoal.

For planting purposes, all distances are carefully measured and staked out in the field with construction twine in order to achieve the desired population density as precisely as possible.

[4] DoA feels that under high density planting and polythene mulching, there are increased incidence of the bacterial diseases especially in the Ervina. According to ISP, Erwinia is a disease that shows up when there is excess humidity or moisture in the soil. The height of the bed recommended by the ISP in combination with the poly mulch and the ditches in-between planting beds are a good combination of practices against Erwinia rot.

6.2 Plant Spacings Within the Crop Rows

Potato	0.30 m

The difference between a high-density potato planting with high technology and a traditional Badulla planting can be clearly seen in the photo near the left margin of the page.

6.3 Planting Aids

1. Construction twine (preferably white coloured)
2. A good number of wooden stakes to layout base lines and crop rows
3. Previously made planting templates
4. Measuring tape
5. Markers

7. IRRIGATION AND FERTIGATION

7.1 Irrigation

Potato requires 6 mm per day of water for optimum production. Low pressure irrigation is the best method of applying uniform and precise amounts of water directly to the root zone of the plants, as per their above requirement, through emitters at frequent intervals over a period, via a pipe network comprising of mains, submains, and laterals. In this system, water is applied drop by drop or by micro jet (micro sprinkler), on the soil surface or below it (sub-surface), at a rate lower than the infiltration of the soil.

Figure 4: Micro-Sprinkler System

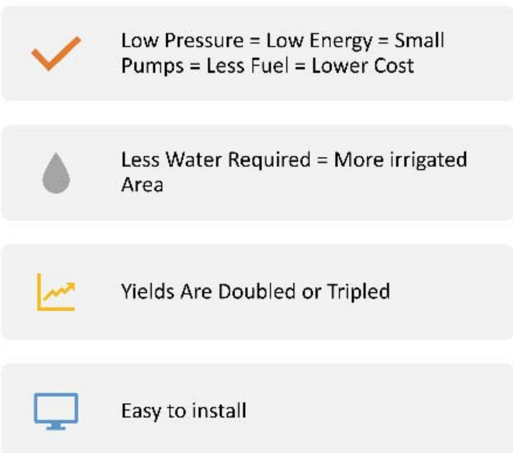

Figure 5: Advantages of low-pressure irrigation

7.2 New Irrigation Concepts

- Net Area Irrigation – Water for Cultivated Area Only
- Evapotranspiration for irrigation scheduling rather than soil moisture content.
- Consumptive Water Use by Crops: Different Crops Different Amounts of Water
- Water Amounts Are Adjusted to The Physiological Development of the Crops (Kc Constants per Crop)

7.3 Water Application

The Potato consumptive water use of 6 mm of water per day is equivalent to 42 mm per week. This weekly amount can be applied in 3 cycles. Under this application regime, the chart below is the recommended irrigation time per cycle to irrigate half an acre of Potato in Jaffna using the drip tape irrigation system with one drip tape line in the middle of the planting bed separated at approximately 30 cm to 40 cm.

Table 1: Irrigation Schedule

Irrigation Schedule	Week 1-4		Week 5-11		Week 12-17	
Irrigation Time (Hours/ Minutes)	0	34	0	58	0	43

7.4 Fertigation

Potatoes are sensitive to high amounts of Nitrogen. They require a sufficient, but regulated, supply for healthy foliage growth and tuber development. Excessive nitrogen can lead to imbalanced growth, with an overemphasis on vegetative growth at the expense of tuber development. This can result in an abundance of lush foliage but smaller, lower-quality tubers. By controlling nitrogen applications, growers can strike a balance between vegetative growth and tuber production, promoting overall plant health and maximizing yield potential.

Furthermore, excessive nitrogen levels can negatively impact tuber quality. High nitrogen availability can lead to an increased incidence of certain potato disorders, such as hollow heart and internal brown spot. These disorders affect tuber appearance and marketability. By carefully managing nitrogen applications, growers can reduce the risk of these disorders and produce potatoes of higher quality and market value.

Other nutritional requirements for potatoes include major and minor nutrients as follows:

- Phosphorus is essential for root development and early growth.
- Potassium is crucial for overall plant health, disease resistance, and tuber quality.
- Although required in smaller quantities, micronutrients such as iron, manganese, zinc, and boron are important for potatoes.
- Consider applying fertilizers at the right timing to meet the crop's nutrient demands.
- Maintaining a balanced nutrient ratio is important for optimal growth. The ideal nutrient ratio for potatoes is often expressed as N-P-K, with varying ratios depending on the soil test results and specific potato variety.

For the potato Cluster in Jaffna, fertilizer application is based on soil test results (Annex 2). Soil test results are interpreted using critical levels of nutrients and several other chemical and physiological considerations to develop a complete fertilizer recommendation.

The results for the Kopay area of Jaffna for the Potato Cluster soil tests indicated the following:

Organic matter moderate to adequate
Copper deficient
Zinc marginal levels
Cation Ratios very narrow, especially Mg/K (Magnesium/Potassium. Mg is required to increase the Mg/K ratio

Therefore, the recommendations for the application of fertilizers for this soil test are as follows:

Nitrogen (N) required regardless of levels of Organic Matter and soluble Nitrogen (N). However, too much Nitrogen (N) could lower potato yield and size of tubers since potato is very susceptible to vegetative overgrowth from more than adequate N applications
$MgSO_4$ will increase Mg/K and will provide required S
Foliar fertilization with Ino-K Foliar Micronutrients or similar

Based on the above considerations, the amount of nutrients to be applied is in elemental and oxide form below:

Recommendation	N	P	Mg[5]
Kg/ Ha	100.0	3.0	100.0
Lb/ acre	100.0	3.0	100.0
Kg/ acre	45.5	1.4	45.5

Table 2: Nutrition Quantities

Recommendation	Urea	P_2O_5	MgO
Kg/ Ha	217.4	6.9	165.8
Lb/ acre	217.4	6.9	165.8
Kg/ acre	98.8	3.1	75.4

For these amounts, the quantities of fertilizer materials per year (season) are:

Kg/ Acre	Urea	P Acid	$MgSO_4$
Fertilizer per year (Season)	99	5	455

Table 3: Quantities of fertilizer materials per year (season)

Considering the stage of development of the crop, the quantities of fertilizer materials required per season.

Ratio Based on Tree Age	Emergence	Development	Maturity	Total
Urea	6	66	27	99
P Acid	1.7	1.8	1.7	5.2
$MgSO_4$	150.0	154.5	150.0	455

Table 4: Quantities of fertilizer as per stage of development

Considering a Potato crop cycle in Sri Lanka of 10 weeks, the potential number of fertigation weeks is also 10 weeks. Thus, the fertilizer quantities per Acre per week are as follows:

Kg/Acre	Emergence	Development	Maturity
Urea	2.92	10.95	13.66
P Acid	0.86	0.30	0.86
$MgSO_4$	75.00	25.76	75.00

Table 5: Week-wise, fertilizer quantities

These amounts are to be applied in 3 cycles per week. On a per application basis (irrigation cycle), the amounts of fertilizer materials required are:

Kg/Acre/Week	Emergence	Development	Maturity
Urea	1.458	5.476	6.831
P Acid	1.718	0.590	1.718
$MgSO_4$	37.5	12.9	37.5

Table 6: Fertilizer quantities, as per application basis (irrigation cycle)

These amounts are further reduced based on the net area cultivated in Potatoes. For a production plot with a size of half an Acre, the net area to be fertigated is only 0.34 Acres. Following are the fertigation recommendations for this net area:

<table>
<tr><th>Kg/Acre/Application</th><th>Emergence (Week 1-2)</th><th>Development (Week 3-8)</th><th>Maturity (Week 9-10)</th></tr>
<tr><td>Urea</td><td>0.50</td><td>1.87</td><td>2.26</td></tr>
<tr><td>$MgSO_4$</td><td>12.7</td><td>4.4</td><td>12.7</td></tr>
<tr><td>Applications per week</td><td colspan="3">2</td></tr>
<tr><td>P Acid
Application every two weeks (ml)</td><td>346.0</td><td>118.8</td><td>346.0</td></tr>
<tr><td colspan="4">Foliar Applications of Micronutrients every two weeks, especially Cu and Zn</td></tr>
</table>

Table 7: Fertigation Recommendations per Application and per Plot

8. WEED CONTROL

Weeds are controlled using agricultural type plastic mulch which offers several distinct advantages in agricultural applications:

- One of its primary benefits is weed suppression, as the opaque nature of the mulch effectively blocks sunlight, preventing weed growth and reducing the need for chemical herbicides.
- Additionally, plastic mulch helps to conserve soil moisture by minimizing evaporation, thus supporting more efficient water use and reducing the frequency of irrigation.

[5] Magnesium is recommended as a soil amendment to improve the chemistry of the soil cation exchange complex and make the soil more fertile and productive. Small supplemental quantities of Mg from 50 Kg/Ha to 100 Kg/Ha (0.21 meq to 0.42 meq of the Mg^{2+} ion) are recommended. Because the concentration of Mg in fertilizer grade MgSO4 is only 10%, a large application of the fertilizer is required to supply to the soil with a low amount of the Mg^{2+} ion.

- The mulch also serves to warm the soil, promoting earlier planting and enhancing overall crop development, particularly in cooler climates.
- Furthermore, the use of plastic mulch can lead to improved fruit and vegetable quality by preventing direct contact with the soil, reducing the risk of rot and spoilage.

Overall, plastic mulch contributes to increased crop yields, improved crop quality, and more efficient use of resources, making it a valuable tool in modern agricultural practices. Nevertheless, while plastic mulch offers several benefits in agriculture, including weed suppression, soil moisture retention, and increased soil temperature, it also presents several notable management challenges:

- The prolonged use of plastic mulch using non-biodegradable materials can lead to pollution and soil contamination when left in the field for a long time after the cropping season.
- Unproper disposal of plastic mulch can result in visual pollution in agricultural areas and contribute to long-term soil degradation.
- The use of plastic mulch as a continuous field practice, crop after crop, can impede natural soil aeration and microbial activity, potentially disrupting the soil ecosystem, and causing the accumulation of plastic residues in the soil.
- The cost of purchasing and removing plastic mulch, as well as the labor involved in installation and disposal, can be significant but are alleviated by the financial returns from the higher yields and better quality obtained with plastic mulch, particularly for small farmers.
- The use of plastic mulch must be accompanied by drip tape irrigation and high planting beds to avoid excess water runoff that causes the loss of nutrients that can lead to environmental contamination, impacting surrounding water sources.
- The accumulation of water on the surface of the plastic mulch from rainfall and/or irrigation must be prevented to avoid the possibility of waterlogging in some instances.
- The physical barrier between the soil and the atmosphere caused by plastic mulch can interfere with the natural nutrient cycling processes, potentially leading to imbalances in soil nutrient levels and impacting long-term soil fertility when fertigation is not practiced using the drip tape irrigation system.

If there is a need to control weeds by other means, only mechanical weed control practices are to be used. Herbicides are not allowed for social and environmental reasons. The most common mechanical weed control practices are:

1. Cultivation with a tractor using a rotavator implement.
2. Motorized weed cutters that use plastic cords to cut weeds (weed eaters)
3. Workers use bush knives or any other cutting or chopping tool.

9. PEST AND DISEASE CONTROL

IPM concepts and practices must be applied to manage Potato pests and diseases. The Quantity/Intensity factor is a practical and easy to apply IMP concept in deciding whether to apply pesticides:

Quantity	**Coverage**
Intensity	**Severity**

	Quantity		
Intensity	**Low**	**Medium**	**High**
Low	Observation	Observation	Localized
Medium	Spot Treatment	Localized	Full Treatment
High	Localized Treatment	Full Treatment	Full Treatment

Potatoes are susceptible to various pests and diseases that can affect their growth and yield. Here are some of the most common pests and diseases of potatoes:

9.1 Thrips

Thrips are small, slender insects belonging to the order Thysanoptera, and they are known to be a significant pest of potatoes (Solanum tuberosum). Thrips infestations can cause considerable damage to potato crops, leading to reduced yield and quality.

Identification and Biology:

Thrips are tiny insects, usually less than 1 millimeter in length, and can vary in color from yellow to dark brown. They have rasping-sucking mouthparts, which they use to feed on plant sap. Thrips reproduce rapidly, with females laying their eggs within plant tissue. Nymphs develop through two active stages before reaching the adult stage. These pests are known for their ability to transmit plant diseases, further exacerbating their impact on potato crops.

Damage:

Thrips damage potatoes by feeding on the leaves, causing characteristic silvering, or bronzing of the foliage. This damage can reduce the photosynthetic capacity of the plant, leading to stunted growth and decreased tuber development. Additionally, thrips can transmit diseases such as tomato spotted wilt virus (TSWV), which can have devastating effects on potato yields.

Management:

Integrated pest management (IPM) strategies are crucial for controlling thrips in potato crops. Cultural practices, such as crop rotation and the use of certified, disease-free seed potatoes, can help reduce thrips populations. Additionally, the application of insecticides, both conventional and organic, can be effective in managing thrips infestations. However, it is essential to carefully consider the potential impact of insecticide use on non-target organisms and the environment.

Controlling triphs on potatoes typically involves the use of insecticides. Some of the chemicals that have been used or recommended for controlling thrips on potatoes include:

1. Imidacloprid: A systemic insecticide that can be applied as a soil treatment or as a foliar spray to control thrips and other pests.
2. Spinosad: An insecticide derived from naturally occurring bacteria that is effective against thrips and other pests. It is considered a more environmentally friendly option.
3. Chlorpyrifos: An organophosphate insecticide that has been used for controlling thrips, although its use has become more restricted due to environmental and health concerns.
4. Bifenthrin: A pyrethroid insecticide that has been used for thrips control in potatoes and other crops.
5. Acephate: A systemic organophosphate insecticide that has also been used for controlling thrips on potatoes.

It's important to note that the use of chemical pesticides should be approached with caution, and it is essential to follow all safety guidelines and regulations set forth by local agricultural authorities. Additionally, integrated pest management (IPM) strategies that incorporate cultural, biological, and other non-chemical control methods are increasingly being encouraged to reduce reliance on chemical pesticides and minimize their potential impact on the environment and non-target organisms.

Thrips pose a significant threat to potato production due to their feeding damage and ability to transmit plant diseases. Effective management of thrips in potatoes requires a multi-faceted approach that integrates cultural, biological, and chemical control methods. By implementing comprehensive pest management strategies, potato growers can minimize the impact of thrips and protect the health and productivity of their crops.

9.2 Other Pests Affecting Potatoes

a) Aphids (Various species):

Aphids are small, sap-sucking insects that can transmit viral diseases to potato plants. They cause damage by stunting plant growth and distorting leaves. Aphid populations can multiply rapidly, leading to widespread infestations. Systemic insecticides like imidacloprid and thiamethoxam are commonly used to control aphids in potato crops. Additionally, biological control agents such as ladybugs and lacewings are employed to manage aphid populations in an environmentally friendly manner.

b) Wireworms (Various species):

Wireworms are the larval stage of click beetles and can cause significant damage to potato tubers by tunneling into them. These pests have a long-life cycle and can persist in the soil for several years, making their control challenging. Soil insecticides like chlorpyrifos, clothianidin, and thiamethoxam are effective in managing wireworm populations. Crop rotation and the use of trap crops can also help reduce wireworm infestations.

c) Potato Tuber Moth (Phthorimaea operculella):

The potato tuber moth is a destructive pest that primarily affects potato tubers during storage. The larvae feed on the tubers, causing extensive damage and rendering them unsuitable for consumption or sale. Pesticides such as chlorpyrifos, methomyl, and Spinosad are commonly used to control potato tuber moth infestations. Good storage practices, including proper ventilation and temperature control, can also help minimize the risk of infestation.

d) Potato Cyst Nematodes (PCN) (Globodera rostochiensis and Globodera pallida):

Potato cyst nematodes are microscopic roundworms that infect potato roots and cause significant yield losses. These pests are particularly challenging to control as they can survive in the soil for long periods. Nematicides like oxamyl and fosthiazate are commonly used to manage PCN populations in potato fields. Crop rotation with non-host crops, such as cereals, and the use of resistant potato varieties are essential components of an integrated approach to PCN control.

Additional Pests of Potatoes

a. Aphids: Aphids are small, sap-sucking insects that can transmit viral diseases to potato plants. They can cause stunted growth, distorted leaves, and reduce overall plant vigor.
b. Potato Leafhopper (Empoasca fabae): Leafhoppers are tiny insects that feed on potato leaves by sucking sap. They can cause yellowing, curling, and browning of the leaves, leading to reduced photosynthesis and yield.
c. Wireworms: Wireworms are the larvae of click beetles. They are slender, brownish worms that feed on potato tubers, causing tunnels and holes. Infested potatoes may rot or become unmarketable.

9.3 Diseases Affecting Potatoes

a) Late Blight (Phytophthora infestans):

Late blight is a devastating potato disease caused by the oomycete pathogen *Phytophthora infestans*. It can rapidly destroy entire potato fields, affecting foliage, stems, and tubers. Fungicides containing active ingredients like chlorothalonil, mancozeb, and mefenoxam are commonly used to manage late blight. However, the regular application of fungicides combined with cultural practices, such as planting resistant potato varieties and practicing proper crop rotation, is crucial for effective control.

b) Early Blight (Alternaria solani):

Early blight is a common fungal disease that affects potato leaves, stems, and tubers. It causes circular lesions with concentric rings, leading to defoliation and reduced tuber yield. Fungicides such as chlorothalonil, azoxystrobin, and mancozeb are commonly used for early blight control. Implementing cultural practices like removing infected plant debris, providing adequate spacing between plants, and promoting good air circulation can also help manage early blight.

Other Diseases of Potatoes

- Potato Scab (Streptomyces scabies): Potato scab is a bacterial disease that affects the tubers. It causes rough, corky lesions on the surface of the potatoes, making them unattractive and reducing their market value.
- Verticillium Wilt (Verticillium spp.): Verticillium wilt is a fungal disease that affects many plants, including potatoes. It causes wilting, yellowing, and browning of the leaves, and can lead to reduced yield.
- Potato Virus Y (PVY): PVY is a viral disease that affects potatoes. It can cause leaf curling, mosaic patterns on the leaves, stunted growth, and reduced tuber size and quality.

It is crucial to emphasize the importance of integrated pest management (IPM) practices, which involve a combination of cultural, biological, and chemical control methods. Farmers should aim to minimize pesticide use and adopt sustainable approaches to protect both crop health and the environment.

10. HARVESTING

Potatoes are typically harvested when the plants have reached maturity, and the tops have died back. Care should be taken during the harvesting process to avoid bruising or damaging the tubers, as this can lead to increased spoilage during storage. In Jaffna, potatoes are harvested “off season” around March when the local market in Sri Lanka is undersupplied. This fact gives Jaffna farmers a comparative advantage against other farmers in other production areas.

Late plantings that reach harvest maturity after March usually yield small tubers because of the inhibition of tuber development due to high soil temperatures conditions in late March and early April. These climatic conditions make the potato production cycle in Jaffna have a duration of only 70 to 75 days.

Sometimes farmers harvest potatoes by size to bring the harvest forward. This practice calls for the farmers to carefully dig into the tubers and pick those that already meet the size specification according to the market. Harvesting potatoes by size is a common practice to maximize the yield and quality of the potato crop. The process involves carefully digging and selecting potatoes based on their maturity and desired use. Harvesting potatoes by size allows for efficient storage, marketing, and distribution, as well as providing consumers with sizes to suit their individual needs and preferences.

11. POST-HARVEST HANDLING

Post-harvest management of potatoes is a critical aspect of ensuring the quality and marketability of the crop. Proper handling, storage, and processing practices are essential to minimize losses and maintain the nutritional value of the potatoes.

11.1 Handling and Storage

After harvesting, potatoes should be handled carefully to prevent physical damage. They should be cured for a period of 7-10 days at temperatures of 50-60°F (10-15°C) and high humidity to allow the skins to set and minor injuries to heal. Following curing, potatoes should be stored in a cool, dark, and well-ventilated environment to minimize sprouting and prevent greening. Ideal storage temperatures range from 35-45°F (2-7°C). Monitoring for signs of disease and rot is essential during storage, and damaged or diseased potatoes should be removed promptly to prevent the spread of spoilage.

11.2 Processing and Packaging

Potatoes intended for processing into value-added products such as chips, fries, or dehydrated products require specific handling and processing methods to maintain quality. Proper cleaning, sorting, and grading are crucial steps in processing potatoes for the market. Packaging should be designed to protect the potatoes from physical damage and exposure to light, as well as to provide adequate ventilation to prevent the buildup of moisture.

11.3 Quality Control

Regular monitoring of stored potatoes for sprouting, rot, and quality deterioration is vital to identify and address any issues promptly. Quality control measures should be implemented at every stage of post-harvest management to ensure that only high-quality potatoes reach the market.

Effective post-harvest management of potatoes is essential for preserving the quality and market value of the crop. By employing proper handling, storage, processing, and quality control measures, producers can minimize losses and ensure that consumers receive potatoes that meet high standards of quality and freshness.

12. COST BENEFIT ANALYSIS

Table 8: Farmer Level Cost Benefit Analysis

Item	Unit	Without project	With Project
Fresh Production /ha	mt	12	63.75
Investment/ha	LKR	848,057	2,593,700
Cost/Kg	LKR	83	60
Gross Income/ha	LKR	1,491,485	9,211,875
Net Income/ha	LKR	653,603	5,978,190
Gross Margin per kg	LKR	64	110
Benefit/Cost Ratio		**1.8**	**2.9**

ANNEX 1: FERTIGATION PROTOCOL

Management of the Irrigation System

1. Turn irrigation pump on and allow the operating pressure of the system to become stable at the correct operating pressure (1 Bar to 2 Bar).
2. When pressure is stable, make sure venturi system is working correctly using only water in the fertigation tank or container.
3. Once venturi system is checked, proceed to fertigate with the fertilizer solution.
4. After fertigation, allow the system to continue to apply irrigation water to the plot for at least 10 minutes in order to flush out any fertilizer solution residue remaining in the system.
5. Make sure to apply Phosphoric acid every two weeks as recommended to make sure system remains unclogged by deposits of calcium salts.

Using Fertigation Solutions

1. Carefully follow "*Irrigation and Fertigation Recommendations"* issued by the ISP to make sure the right amounts and types of fertilizer materials are used for fertigation.
2. To prepare the fertigation solution, accurately weigh the correct amounts of fertilizer materials using a portable weighing scale.
3. Mix the weighed fertilizer material with water in an appropriate container such as a 20-litre plastic bucket using a clean wooden stick to stir the fertilizer material into the water to make sure all the fertilizer material is dissolved.
4. In case there is a fertilizer material that is not 100% soluble in water such as TSP, mix for at least 5 minutes to dissolve as much material as possible.
5. Filter the fertigation solution into the fertigation container to be used with the venturi system (fertigation tank or container) using a cloth filter such as an old t-shirt or similar.
6. After filtering, the fertilizer material left on the cloth filter when using a partially soluble fertilizer material such as TSP must be saved into a container to be used in the next fertigation with the same material.
7. Close the main valve of the irrigation system and open the valves of the venturi system to force the irrigation water to flow through the venturi system. This will create the necessary vacuum to suck the fertigation solution into the irrigation system to be distributed throughout the plot and applied to the crop.
8. After the fertigation solution is applied, add clean water to the fertigation container and allow this water to flow though the venturi system to clean it.
9. Open the main valve and close the venturi system valves to allow for normal irrigation to resume.

ANNEX 2: SOIL ANALYSIS RESULTS AND FERTILIZER RECOMMENDATIONS

INTERPRETATION OF SOIL ANALYSIS FOR JAFFNA POTATOES

Basic Parameters							Cations, meq/100 g				Micronutrients, ppm						Cation Ratios				
Site	Sample	LAB NO	pH	OM	NH_4-N	EC	Ca	Mg	K	P	S	Cu	Fe	Mn	Zn	CEC	Ca/Mg	Mg/K	Ca+Mg/K	Ca Sat.	Ca+Mg+K
Potato	JF-III	R9 432	7.07	1.88	13.0	305.0	11.97	1.55	1.3	133	77	9.6	50.4	44	11.4	14.8	7.7	1.2	10.4	80.8	14.8

Interpretation:

Basic parameters very good

Cu and Zn a bit low

Ca/Mg and Mg/K ratios narrow. High Ca saturation

Fertilizer Recommemndations

Nitrogen - Fertigation for maintenance of basic N nutrition (100 Kg/ha/Season)

Mg - Fertigation to widen Mg/K ratio (100 Kg/ha/season). It will lower Ca saturation as well

Cu and Zn - bi-weekly foliar applications recommended to avoid hidden hunger. Begin applying two weeks after crop emergence

Kg/ Plot/ Application	Initial	Mid	Late
Urea	0.50	1.87	2.26
$MgSO_4$	12.7	4.4	12.7
Application per week		2	
Phosphoric Acid (ml) *Application every two week*	346.0	118.8	346.0
Foliar application of micro-nutrients, especially Cu and Zn			

Table 9: Fertigation Recommendations per Application per Plot