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Agriculture Sector Modernization Project

OPERATIONAL MANUAL

RED ONION

AGRICULTURE SECTOR MODERNIZATION PROJECT

PARK
AGRICULTURE TECHNOLOGY DEMONSTRATION PARK

Prepared by -
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PROJECT DIRECTOR'S MESSAGE

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

Contents

1. INTRODUCTION

Red onions, scientifically known as *Allium cepa*, are a popular type of onions characterized by their deep red to purple outer skin and reddish-purple flesh. They are widely used in culinary applications for their mild to sweet flavour and vibrant colour. Red onions are an extensively cultivated and consumed vegetable, valued for their unique flavour and striking appearance.

Origin: The exact origin of red onions is not definitively known, but they are believed to have originated in Asia, possibly in the vicinity of present-day Iran and Pakistan. Red onions have been cultivated for thousands of years and have spread to various parts of the world, where they have become an integral part of local cuisines.

Botanical Description: Red onions belong to the Allium genus and are biennial plants that are typically grown as annuals for their edible bulbs. They are members of the Amaryllidaceae family, which also includes garlic, leeks, and chives. The plant consists of several parts, each with distinct characteristics:

- Bulb: The bulb is the edible part of the red onion and is composed of numerous layers of fleshy, modified leaves. The outer skin ranges in colour from deep red to purple, while the inner flesh is also red or reddish-purple.
- Leaves: Red onion plants produce long, hollow, and tubular leaves that emerge from the base of the plant. These leaves are green and contribute to the photosynthesis process essential for the growth of the bulb.
- Flower and Seeds: If allowed to grow for a second year, red onion plants produce a flower stalk that bears spherical umbels of small, white to pale pink flowers. The flowers give way to seeds, which can be used for propagation.

1.1 Optimum Growing Conditions

Red onions thrive in well-drained, fertile soils with a pH range of 6.0 to 7.5. They require full sunlight and consistent moisture for optimal growth.
Climate: Onions, as a plant, thrive in cool to moderate climates. They are considered a cool-season crop and grow best in regions with a temperature range of 13-24°C (55-75°F) during the growing season.

Although in Sri Lanka onions are used as a tropical crop, onions are, by physiological nature, a temperate crop. In tropical regions, onions may struggle to develop bulbs properly due to the high temperatures and humidity, which can inhibit bulb formation and lead to disease issues. However, with careful selection of onion varieties and proper management practices, it is possible to grow onions successfully in tropical regions as well as it is done in Sri Lanka.

Onions require a significant difference between day and night temperatures to promote bulb formation.

Soil: Well-drained, fertile soils with a pH level between 6.0 and 7.5 are optimal for onion cultivation. Sandy loam or loamy soils are preferred as they allow for good root development and water infiltration.

Sunlight: Onions require full sunlight for at least 6-8 hours per day to grow and develop bulbs effectively.

Water: Onions need consistent moisture, but they are sensitive to waterlogged conditions. Adequate irrigation should be provided, especially during bulb formation, while ensuring good drainage to prevent waterlogging.

2. LAND PREPARATION

2.1 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
3. Deep plough again perpendicular to the first pass

2.2 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.

2.3 Tractor

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

2.4 Drainage

Drainage is crucial for the Onion as the crop is susceptible to several bulb and 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 Onion.

a) Light Texture Soils: Light textured soils are preferred for the cultivation of the Onion.

- Sloping handmade ditches to evacuate water from rainfall quickly 30 cm wide x 15 cm deep.
- 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.
- 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.
- 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.

b) Heavy Texture Soils: Heavy texture soils such as clays are not very suitable for the Onion cultivation.

- Sloping drainage secondary canals 45 cm wide x 30 cm deep at 20 m intervals
- 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.

c) Waterlogged Soils: This type of soils must be avoided for Onion cultivation.

- Drainage lines 45 cm wide and 45 cm to 60 cm deep at 5 m to 10 m intervals
- 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.

d) Drainage Equipment: Backhoe Excavator or similar with 30cm or 45cm wide bucket

[1] 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 procuring moldboard plough to turn the soil over.

3. VARIETIES[2]

Onion	Location	Variety	Seed
Big Onion	Jaffna	Dambulla Selection	Produced by the ASMP in Jaffna
Red Onions	Jaffna	CO-ON-05	Imported from India

3.1 Seed Storage

Onion seed should be dried to 6.5% moisture before storage and kept under refrigeration at a temperature of 4 to 15.5 degrees Celsius in a well-ventilated cold storage room with shelves for onions in crates.

[2] The choice of varieties to plant were made consulting with the farmers, PPMU, DOA and other stakeholders. The choices of the farmers were given priority even if they were not recommended by the DOA

4. HIGH DENSITY PLANTING

Onions can be grown from seeds, sets (small bulbs), or transplants. The method of planting should be chosen based on the specific variety and local growing conditions. Planting depth should be around one inch. In Matale and Jaffna, transplants are grown from seed in ground level rectangular nurseries surrounded by bunds to facilitate the watering of the transplants during their growth and development.

4.1 Procedure[3]

Both big onions and red onions are planted in beds made by mechanical bed-makers pulled by tractors. They can also be made by hand. The beds should be 60 cm[4] wide and 50 cm high and are separated by a ditch 30 cm wide. This means the total distance from centre to centre of two adjacent beds is 90 cm. The height of the bed is very important for onion for the prevention of soil borne diseases and to improve internal drainage, but also to allow the bulbs ample space to develop and grow in size for big onion production.

Figure 1: Bed Preparation

[3] According to DoA, to utilize 75% of total land for planning (25% for bunds and drainage canals), the bed size should be 1 x 3 x 0.15m (W x Lx H) spacing 0.1x 0.1m and square pattern. According to ISP, In the normal production system made of bunds that form ponds, the net cultivated area is only 63% because of area used to make bunds and the buds themselves compared to 66.7% using the ISP recommended technology (Annex 4)

As mentioned above, the net cultivated area in the ISP recommended system is 66.7% of the total area, excluding the drainage system that is peripheral. The number of plants per hectare in this system is 784,778 compared to 727, 200 in the traditional pond system (Annex 1). However, the objective of the ISP was not to increase the population density of onion cultivation. The objective was to improve the pond system that promotes the water logging of the onion production areas.

The triangular planting recommended by the ISP increases the area explored by one plant by 25% over the traditional system. This increase results from a greater planting distance (11.8%) and the fact that plants are not placed in front of each other as in the square and rectangular systems. This placement increase competition for nutrients and water among neighboring plants (Annex 4)

[4] According to DoA, recommended bed width is 1m. Moreover, the bed height of 50cm is not practical in loose soils. As per ISP, the bed width of 0.6 m was chosen by the ISP because the best bed maker implement utilized achieved this width and the right bed height. The bed height is a very important component of the ISP technology, including elements of IPM (disease prevention), increased internal drainage, increase root exploration area with very low energy expenditure and ideal for the placement of the plastic mulch which is an integral part of the technology package.

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[5] is preferred for the rotation cropping in Jaffna where red onions follow the potato crop.

The drip tape is double layer, white in colour 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.

Figure 2: Planting

Six rows of plants are placed on every bed. The distance between the rows is 10 cm. The planting distance inside the planting rows of 10 cm as well and is marked with a planting guide or template that uses sharp nails to make the planting marks. The planting pattern for the crop should be triangular to minimize the high-density effect on plant-to-plant competition. This planting pattern is always preferred for high density planting.

Figure 3: Mulching

A new way to plant onions developed by Nalin Wijerathna, a farmer from Galnewa in Anuradhapura, is to use silver and black plastic mulch (30 to 40 microns gauge and 1.5 m wide). The mulch[6] is perforated at a distance of 10 cm which is the onion planting distance. A triangular pattern

[5] According to DoA, the drip trip has following issues:

- Lower durability (2 seasons max.) of drip tapes compared to the DoA recommended LLDPE laterals which be utilized for around 10 seasons under a proper maintenance.
- Lower irrigation uniformity under low pressure (lower pressure compensation property) compared to the laterals with PC emitters recommended by the DoA.
- There are higher chances of not distributing the water as well as the fertilizer uniformly throughout the bed, if the soil is excessively well drain and adequate amount of organic matter is not added.

ISP Response: Drip tapes were introduced to agriculture for short term use as a revolutionary low-cost drip irrigation system, very affordable to small farmers. Durability is usually 3 to 5 years depending on the management, care and maintenance given to the tapes. Under mulch, durability is improved. In developed countries such as the US, drip tape has become an integral component of the modern high intensity production systems for vegetables. In these systems, the drip tape becomes an annual recurring production cost and not an investment cost. Irrigation uniformity depends on the spacing and discharge rate of the tape emitters. The ISP recommends a spacing of 0.3 and a discharge rate of 2 L/Hour. This combination has given excellent uniformity results in different ecological zones in Sri Lanka. The height of the planting bed of 0.5 m recommended by the ISP assures the optimum distribution of the water for the crop and is part of the most critical elements of the ISP technology package which are high planting beds, drip tape irrigation and fertigation, plastic mulch and high-density planting

[6] According to DoA, This technique is practiced in onion cultivation in South Korea and introduced to KOPIA big onion producing model villages and practiced in large scale in villages and research fields of Onion breeding division at FCRDI in 2016 and completely failed due to the weed of Kaladuru (Callamus rotundus). But DoA introduced new rice straw mulch to onion cultivation gave higher yield and colourful bulbs and research paper was published in ASDA, 2017.

is used as well to perforate every planting row. A very hot iron or aluminium cylinders such as discarded processed food aluminium cans is used for this purpose. 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 to achieve the desired population density as precisely as possible.

4.2 Plant Spacings Within the Crop Rows

Onion	0.10 m

4.3 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

ISP Response: Is not clear whether the reviewer is referring to *Calamus rotundus* or *Cyperus rotundus* commonly known as Sedge, Nutgrass, or Coco Grass. Annex 3 provides an overview of the two plants, together with control measures, including agricultural plastics or plastic mulch. Rice straw mulch is a good approach. The problems are more related to the collection of the straw and the effort required to apply in an efficient manner in commercial fields. The ISP prefers the practicality of plastic, especially degradable plastic of proper thickness to prevent perforation by weeds

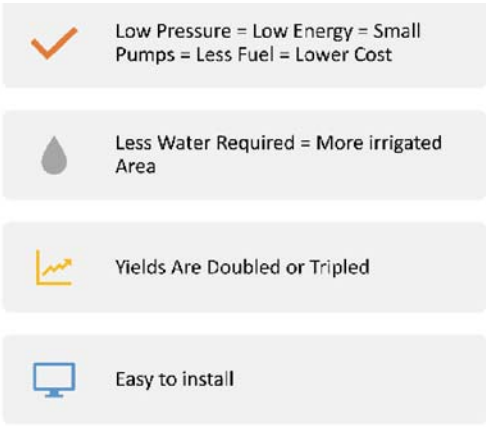
5. IRRIGATION AND FERTIGATION

5.1 Irrigation

Onion 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 case the system is a drip tape system that applies water drop by drop to maintain the soil moisture at field capacity.

Figure 4: Drip Irrigation System

Figure 5: Advantages of low-pressure irrigation



5.2 New Irrigation Concepts [7]

- 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)

5.3 Water Application

The Onion consumptive water use of 5 mm of water per day is equivalent to 35 mm per week. This weekly amount can be applied in three cycles. Under this application regime, the chart below is the recommended irrigation time per cycle to irrigate half an acre of Onion in Jaffna using the drip tape irrigation system with two drip tapes lines in the middle of the planting bed separated at approximately 30 cm to 40 cm.

Table 1: Irrigation Schedule

Irrigation Schedule	Emergence		Development		Maturity	
Irrigation Time (Hours/ Minutes)	0	31	0	51	0	38

5.4 Fertigation

Nutritional Requirements

Onions have specific nutrient requirements, particularly for nitrogen. A balanced fertilizer should be applied according to soil test recommendations to ensure proper growth and bulb development:

[7] DoA: It has been stated that the practices are new irrigation concepts. However, it has been provided general information on irrigation which have been some of the principals in irrigation for a considerable time period.
ISP: Irrigation concepts have been introduced by the ISP to small farmers that are new for them. These concepts are perhaps known to researchers and other agricultural specialists, but until the ASMP interventions, not known to farmers. Some of these include the concept of evapotranspiration to determine how much water to add to the crop on a daily basis, the use of the net cultivation area covered by irrigation to calculate fertigation quantities, the use of Phosphoric acid to maintain irrigation lines open and other practical concepts.

The primary macronutrients required by red onions are nitrogen (N), phosphorus (P), and potassium (K). Additionally, they require secondary macronutrients such as calcium (Ca), magnesium (Mg), and sulphur (S), as well as micronutrients like iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), and molybdenum (Mo).

Red onions require a sufficient supply of nitrogen, especially during the early stages of growth. Nitrogen promotes leaf and bulb development.

Phosphorus promotes root development and overall plant vigour, while potassium enhances disease resistance and bulb quality.

Red onions benefit from the availability of essential micronutrients[8]. If a soil test indicates a deficiency, micronutrient fertilizers can be applied according to the recommended rates.

Conducting a soil test is crucial for determining the nutrient status of the soil and identifying any deficiencies or imbalances. This information helps in formulating an appropriate fertilizer application plan.

Before planting red onions, it is beneficial to incorporate organic matter such as compost or well-rotted manure into the soil. This enhances soil fertility, improves water retention, and promotes nutrient availability.

Fertilizer Application Through Fertigation:

The fertilizer application is based on soil test results (Annex 2). The Onion Clusters soil analysis reports were interpreted using critical levels of nutrients for Onions in the soil and critical cation ratios to determine the cation balance of the soil. The results for the Kopay area of Jaffna 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 as a soil amendment is required to improve the Cations balance in the exchange complex of the soil[9]

[8] DoA: Application of Micronutrient is not necessary if DoA recommendations are followed. Organic matter (10 MT/ha) will be the source for them: According to ISP, 99% of the soils tested by the ASMP Project are deficient in micronutrients, especially Copper and Zinc. In fact, deficiency symptoms that are commonly shown on ASMP crops have been corrected by foliar applications of micronutrients. The levels of micronutrients in organic matter are very low and micronutrients take a longer time to be released for plant use upon the decomposition of organic matter because they become chemically fixed temporarily by chelation and complexation. Also, the rate of decomposition of organic matter affects the release of the small amounts of micronutrients held in organic matter. In Sri Lanka it is customary to apply organic matter on the surface of the soil. This procedure delays the decomposition of the organic matter and the release and subsequent movement of micronutrients into the root zone of the plants where nutrient uptake takes place. Decomposition of the organic matter is delayed because the bacteria that decomposes organic matter is found inside the soil. Not much on the surface. By incorporating the organic matter at land preparation as recommended by the ISP, the decomposition is accelerated, as well as the release of nutrients near the roots of the crop. These mechanisms maximize nutrient uptake by the roots of the plants of the crops

[9] Magnesium is not recommended as a nutrient by the ISP. It 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. However, Mg deficiency symptoms have been encountered in several ASMP Clusters and have been corrected by amending the soil with fertilizer grade MgSO4

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
$MgSO_4$ as a soil amendment will increase Mg/K and will provide required S making the soil more productive
Foliar fertilization with Ino-K Foliar Micronutrients or similar[10]

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

Recommendation	N	P	Mg
Kg/ Ha	160.0	3.0	100.0
Lb/ acre	160.0	3.0	100.0
Kg/ acre	72.7	1.4	45.5

Table 2: Nutrition Quantities

Recommendation	Urea	P_2O_5	MgO
Kg/ Ha	347.8	6.9	165.8
Lb/ acre	347.8	6.9	165.8
Kg/ acre	158.1	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)	158	5	455[11]

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	52	54	52	158
P Acid	1.7	1.8	1.7	5.2
MgSO4	150.0	154.5	150.0	455

Table 4: Quantities of fertilizer as per stage of development

[10] DoA: Why K has been recommended as a foliar application, where the fertigation system is there to apply MOP more effectively and efficiently. Moreover, the K quantity to be applied has not been mentioned.
ISP: K has not been recommended for foliar application. A fertilizer material named Ino-K has been recommended. This foliar fertilizer only contains micronutrients. K-Plus, another foliar fertilizer compound, was bought by the Project, but is not recommended for foliar fertilization by the ISP

[11] DoA: Very high dose of Mg SO4 (455 kg/ ac) has been recommended based on the soil test conducted in Kopay area in Jaffna. However, the quantity seems to be too much for a secondary nutrient (even too much for a major nutrient as well). High amount of Mg will tend to replace some important cations for plant growth, such as Ca and K, from the rhizosphere (antagonistic effects).
ISP: Is worth highlighting here that 455 Kg/Acre of MgSO4 fertilizer grade only supplies 45.5 Kg of Mg ion/Acre (112.43 Kg Mg /Ha = 56.215 pmm Mg = 0.468 meq of Mg). Hardly a very high application as a soil amendment. Not as a nutrient

Considering an Onion crop cycle in Sri Lanka of 9 weeks, the potential number of fertigation weeks is also 9 weeks. Thus, the fertilizer quantities per Acre per week are as follows:

Kg/Acre	Emergence	Development	Maturity
Urea	18.26	18.81	18.26
P Acid	0.60	0.62	0.60
$MgSO_4$	52.50	54.09	52.50

Table 5: Week-wise, fertilizer quantities[12]

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

Kg/Acre/Week	Emergence	Development	Maturity
Urea	9.130	9.407	9.130
P Acid	1.203	1.239	1.203
$MgSO_4$	26.3	27.0	26.3

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

These amounts are further reduced based on the net area cultivated in Onions. For a production plot with a size of half an Acre, the net area to be fertigated is only 0.14 Acres. Following are the fertigation recommendations for this net area:

Kg/Acre/Application	Emergence (Week 1-4)	Development (Week 5-11)	Maturity (Week 12-17)
Urea	3.10	3.19	3.10
$MgSO_4$	8.9	9.2	8.9
Applications/ week	2		
P Acid Every 2 weeks	242.2	249.6	242.2
Application of Foliar Micronutrients weekly or Bi-weekly, Especially Cu and Zn			

Table 7: Fertigation Recommendation per Application per Plot

In addition, foliar applications of micronutrients are required on a weekly basis, especially Copper (Cu) and Zinc (Zn).

[12] DoA: P has been recommended throughout the growing period (9 weeks duration), whereas the DoA recommendation is as a basal dressing only.
ISP: Basal applications of fertilizers are an old concept that has been replaced by fertigation using low-pressure irrigation systems that are based on the drop-by-drop (Bindu Bindu) concept of feeding nutrients to crops in liquid form which is the most efficient fertilizer application method. This concept has been scientifically shown to be more effective and efficient in supplying nutrients to plants near the root where nutrient uptake takes place. These concepts have cut the amounts of fertilizer applied to plants by half and even more

6. WEED CONTROL

Weeds are a problem in a bare soil system when the onion plants are young. At that time, the best weed control practice is to pull young and tender weeds off the ground by hand using labour. As the onion plants develop and grow to become tall and vigorous, weeds will be crowded out and will cease to be a problem. In a mulch system, weeds are controlled by the agricultural 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.
- 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 labour 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 tapeirrigation system.

The plastic mulch controls weed and lowers evapotranspiration rates, lowering the amounts of water required for irrigation.

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 using bush knives or any other cutting or chopping tool.

7. PEST AND DISEASE CONTROL

IPM concepts and practices must be applied to manage onion 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**		
Intensity	**Low**	**Medium**	**High**
Low	Observation	Observation	Localized
Medium	Spot Treatment	Localized	Full Treatment
High	Localized Treatment	Full Treatment	Full Treatment

Red onions (Allium cepa) are a popular and widely cultivated crop known for their distinctive flavour and culinary uses. However, like any agricultural crop, red onions are susceptible to a range of pests and diseases that can significantly impact yield and quality. Understanding the biology, life cycle, and control measures of these pests and diseases is crucial for effective management. Only pests and diseases that were encountered in the onion fields during the ASMP tenure will be discussed at length below.

7.1 Yellow Sticky Traps[13]

Figure 6: Yellow Sticky Traps

Yellow sticky traps play a crucial role in integrated pest management strategies for field crops, offering farmers a valuable tool for monitoring and controlling insect populations. By strategically placing these traps throughout crop fields, farmers can effectively monitor insect populations and identify potential threats to the crops. The bright yellow colour of the traps acts as a powerful attractant for a wide variety of flying insects, including aphids, thrips, leafhoppers, and other pests known to damage field crops. Once captured on the adhesive surface of the traps, these insects are effectively removed from the crop environment, helping to mitigate potential yield losses and reduce the need for chemical insecticides. By incorporating sticky yellow traps into their pest management plans, farmers can contribute to the sustainable and environmentally conscious cultivation of field crops, promoting healthier yields and minimizing the impact of harmful pests on agricultural production.

[13] DoA:

- This is non-selective destroying method and harmful for natural enemies
- To control adult Leaf eating caterpillars (Spodoptera exigua and S. letura) KOPIA project introduced PERAMONE trapstraps,it was successful in farmer fields and research fields in FCRDI for onion.

ISP: Yellow sticky traps are a selective method to lower insect populations especially for white fly, thrips and mites. The yellow color has been shown scientifically to attract the mentioned insects selectively. Pheromones are good insect attractants commonly used in insect traps but are not yet practical to be used by farmers within the scope of a broad pest control program. One of the problems is that they have shown themselves to be very specific in terms of insect species. This means, a given insect pest will require a specific pheromone. This fact makes manufacturing programs to provide control for several insect pests at the same time very complex in scope. Hopefully this effective technology can evolve to make it simpler and more practical.

Yellow sticky traps are typically coated with a bright yellow, non-drying adhesive that attracts a wide range of flying insects. Once insects come into contact with the sticky surface, they become firmly trapped, preventing them from causing further damage to plants. The yellow colour of the traps is particularly attractive to many types of insects, making them a popular choice for both professional growers and home gardeners.

Figure 7: Yellow Sticky Traps in Field

Environmentally friendly and easy to use, sticky yellow traps serve as a valuable tool in integrated pest management strategies, helping to maintain healthy plant growth without the need for harmful chemical pesticides. For Onions, sticky yellow traps are placed at 10 m intervals along the edge of the planting beds, alternating the side of the bed on which they are placed.
This arrangement creates a network of protection against harmful insects.

7.2 Pest Affecting Red Onions

1. Onion Trips (Thrips tabaci)

Biological Description: Onion thrips are tiny, slender insects measuring about 1-2 mm in length. They have piercing-sucking mouthparts and feed on onion foliage, causing silvering, distortion, and premature wilting of leaves.

Life Cycle: Onion thrips undergo incomplete metamorphosis, consisting of egg, nymph, and adult stages. They reproduce rapidly, with multiple generations occurring in a single growing season.

Prevention and Control:

- Cultural Control Measures: Implement crop rotation, remove weed hosts, and ensure proper field sanitation.
- Biological Control Measures: Encourage natural enemies such as predatory mites (e.g., Amblyseius cucumeris) and lacewings (e.g., Chrysoperla spp.).
- When chemical control is practiced, only pesticides that are registered in Sri Lanka should be used at DoA recommended amounts.

2. Onion Maggot (Delia antiqua):

Biological Description: Onion maggots are small, yellowish-white larvae measuring about 6-8 mm in length. They feed on onion roots and bulbs, causing stunted growth and rotting.

Life Cycle: Onion maggots complete their life cycle in the soil. Adult flies lay eggs near onion plants, and the hatched larvae tunnel into the bulbs or feed on the roots.

Prevention and Control:

- Cultural Control Measures: Practice crop rotation, remove crop debris, and use floating row covers to prevent egg-laying by adult flies.
- Biological Control Measures: Beneficial nematodes (e.g., Steinernema feltiae) can be applied to the soil to target onion maggot larvae.
- When chemical control is practiced, only pesticides that are registered in Sri Lanka should be used at DoA recommended amounts.

3. Onion Leaf Miner (Liriomyza spp.):

Biological Description: Onion leaf miners are small, yellowish maggots measuring about 3 mm in length. They tunnel inside onion leaves, causing serpentine mines and leaf damage.

Life Cycle: Adult flies lay eggs on onion leaves, and the hatched larvae feed and develop inside the leaves.

Prevention and Control:

- Cultural Control Measures: Remove and destroy infested leaves, implement crop rotation, and use reflective mulches to deter adult flies.
- Biological Control Measures: Parasitic wasps (e.g., Diglyphus isaea) can be released to control onion leaf miner populations.
- When chemical control is practiced, only pesticides that are registered in Sri Lanka should be used at DoA recommended amounts.

4. Cutworms (Agrotis spp.):

Biological Description: Cutworms are caterpillar larvae of various moth species. They are smooth, cylindrical, and vary in colour, often curling into a C-shape when disturbed. Cutworms feed on onion seedlings, cutting them at the base.

Life Cycle: Cutworm moths lay eggs in the soil, and the hatched larvae emerge and feed on young onion plants during the night.

Prevention and Control:

- **Cultural Control Measures:** Remove weed hosts, till the soil before planting to expose cutworm pupae, and use physical barriers (e.g., collars) around seedlings.
- **Biological Control Measures:** Beneficial nematodes (e.g., Steinernema carpocapsae) can be applied to the soil to target cutworm larvae.
- **Chemical Control Measures:** When chemical control is practiced, only pesticides that are registered in Sri Lanka should be used at DoA recommended amounts.

7.3 Diseases Affecting Red Onions

a) Alternaria Diseases of Red Onions

Alternaria diseases are a common group of fungal infections that affect various crops, including red onions (Allium cepa).

Biological Description: Alternaria diseases in red onions are primarily caused by fungal pathogens belonging to the Alternaria genus. The most common species associated with these diseases are Alternaria alternata and Alternaria porri. These pathogens are present in the soil and plant debris, and they can survive for extended periods under favourable conditions.

Life Cycle: The life cycle of Alternaria diseases involves several stages:

1. Overwintering: The fungal pathogens survive in the soil or plant debris, such as infected onion bulbs or onion crop residues.
2. Spore Production: As environmental conditions become favourable in spring or early summer, the fungi produce spores called conidia.
3. Dissemination: The conidia are easily dispersed by wind, water, or mechanical means to healthy onion plants.
4. Infection: When the conidia come into contact with vulnerable plant tissues, such as leaves, stems, or bulbs, they germinate and penetrate the host's surface.
5. Disease Development: Once inside the host, the fungus colonizes the plant tissues, leading to the characteristic symptoms of Alternaria diseases.

Prevention and Control Measures: To manage Alternaria diseases in red onions, it is crucial to implement preventative measures and integrated pest management strategies. Here are some effective prevention and control measures:

- Crop Rotation: Rotate onion crops with non-host crops for at least two years to reduce pathogen populations in the soil.
- Sanitation: Remove and destroy any infected plant debris or onion bulbs to prevent the spread of the disease.
- Seed Treatment: Treat onion seeds with appropriate fungicides or hot water treatment to eliminate potential fungal contamination.
- Proper Irrigation: Avoid overhead irrigation, as wet foliage promotes disease development. Instead, use drip irrigation or other methods that minimize leaf wetness.
- Weed Control: Remove weeds from the onion field, as they can harbour the Alternaria pathogens.
- Resistant Varieties: Planting resistant onion varieties can significantly reduce the risk of Alternaria diseases.
- Fungicide Application: When disease pressure is high, timely and targeted fungicide applications can help manage Alternaria diseases effectively.
- When chemical control is practiced, only pesticides that are registered in Sri Lanka should be used at DoA recommended amounts.

Alternaria diseases pose a significant threat to red onions, affecting their yield and quality. Implementing a combination of preventative measures and integrated pest management strategies is crucial for effective disease management. Chemical control measures, including the use of recommended fungicides, can be employed when necessary. However, it is essential to adhere to proper application rates and guidelines to ensure the safety and efficacy of the treatments. Regular monitoring, proper sanitation, and cultural practices are key to reducing the incidence and severity of Alternaria diseases in red onions.

b) Downy Mildew (Peronospora destructor)

Biological Description: Downy mildew is a fungal disease caused by Peronospora destructor. It primarily affects the foliage of red onions, resulting in the appearance of yellow-green patches on the leaves. These patches develop a fuzzy growth on the lower leaf surface, which consists of spores.

Life Cycle: The downy mildew pathogen survives in infected debris or as spores (oospores) in the soil. During favourable conditions, spores are released and spread through wind or water, infecting new plants. The disease thrives in cool and humid weather.

Prevention and Control Measures:

- Plant resistant onion varieties.
- Practice crop rotation to reduce pathogen buildup.
- Provide adequate spacing between plants for good air circulation.
- Avoid overhead irrigation; use drip irrigation instead.
- Apply fungicides containing active ingredients such as copper or mancozeb, following recommended application rates
- When chemical control is practiced, only pesticides that are registered in Sri Lanka should be used at DoA recommended amounts.

c) Onion White Rot (Sclerotium cepivorum)

Biological Description: Onion white rot is caused by the soil-borne fungus Sclerotium cepivorum. It affects the onion bulb, causing a soft rot that turns the affected tissues white and mushy. The disease can lead to significant yield loss.

Life Cycle: The fungus survives in the soil as hard, black resting structures called sclerotia. These sclerotia can persist for several years and infect new onion crops through contact with infected soil or contaminated tools.

Prevention and Control Measures:

- Use certified disease-free onion sets.
- Practice crop rotation with non-allium crops for at least 8-10 years.
- Improve soil drainage to reduce favourable conditions for the fungus.
- Avoid excessive irrigation and waterlogging.
- Fungicides are not effective for white rot control. Focus on prevention and cultural practices.
- When chemical control is practiced, only pesticides that are registered in Sri Lanka should be used at DoA recommended amounts.

d) Botrytis Leaf Blight (Botrytis squamosa)

Biological Description: Botrytis leaf blight, caused by the fungus Botrytis squamosa, affects the foliage of red onions. It results in the appearance of water-soaked lesions on leaves, which later turn brown and papery. In severe cases, the entire leaf may become blighted.

Life Cycle: The fungus survives in infected plant debris and can also be seed-borne. It thrives in cool and humid conditions, spreading through wind, water, or contact with infected plant material.

Prevention and Control Measures:

- Plant resistant onion varieties.
- Remove and destroy infected plant debris.
- Practice crop rotation with non-allium crops.
- Provide adequate spacing between plants for good air circulation.
- Apply fungicides containing active ingredients such as azoxystrobin or chlorothalonil, following recommended application rates.
- When chemical control is practiced, only pesticides that are registered in Sri Lanka should be used at DOA recommended amounts.

8. HARVESTING

Red onions are a popular and widely grown variety of onions known for their vibrant colour and distinct flavour. Harvesting red onions at the right time and using appropriate techniques is crucial to ensure optimal yield and quality.

Maturity: Maturity is an essential factor to consider when harvesting red onions. Harvesting them at the right stage ensures the best flavour, texture, and storage potential. Here are some indicators of onion maturity:

- Tops and foliage: The foliage turns yellow and starts to die back as the onions mature. When about 50% of the tops have fallen over naturally, it is an indication that the onions are nearing maturity.
- Bulb development: Mature red onions have well-developed bulbs with firm, tight skins. The bulbs should feel solid and heavy.

Size: Red onions come in various sizes, and the desired size may depend on personal preference or market demands. The size of the onion can influence its storage potential and culinary applications. Consider the following:

- Small onions: These are typically harvested early and have a milder flavour. They are ideal for pickling or using in salads.
- Medium onions: These are commonly preferred for general culinary purposes, such as cooking, grilling, or roasting.
- Large onions: These are best suited for dishes where a stronger onion flavour is desired, such as soups, stews, or caramelizing.

Harvesting Techniques: When harvesting red onions, follow these techniques to ensure minimum damage and maximum yield:

1. Loosening the soil: Gently loosen the soil around the onions using a garden fork or shovel to facilitate easy removal.
2. Lifting the bulbs: Carefully lift the bulbs from the soil by grasping the tops and pulling upward. Avoid excessive force to prevent damage.
3. Curing: Allow the harvested onions to cure in a well-ventilated, dry area for 1-2 weeks. This process helps the outer layers dry and enhances storage potential.

9. POST-HARVEST PROFILE

Post-harvest management is crucial for preserving the quality and extending the shelf life of red onions. Following is a profile outlining the key aspects of post-harvest handling for red onions:

1. Harvesting: Red onions should be harvested when the tops have dried down and about 50% of the foliage has fallen over. Care should be taken to avoid damaging the bulbs during theharvesting process, as this can lead to increased rotting and storage losses.
2. Curing: After harvest, red onions should be cured to toughen the outer skins and promote wound healing. Curing is typically done by placing the onions in a well-ventilated, dry area with moderate temperatures (around 25-30°C or 77-86°F) for 2-3 weeks. During curing, the onions should be spread out in single layers to allow for good airflow.
3. Cleaning and grading: Once the onions have been cured, they should be cleaned to remove any dirt or debris. Damaged or diseased onions should be discarded or used promptly. The onions can be graded based on their size, shape, and overall quality.
4. Storage conditions: Red onions should be stored under proper conditions to maintain their quality. They require cool, dry, and well-ventilated storage environments. The ideal temperature for storage is around 0-4°C (32-39°F) with a relative humidity of 65-70%. High humidity or temperatures can promote sprouting and rotting.

5. Packaging: Red onions can be packed in mesh bags, wooden crates, or well-ventilated containers that allow for air circulation. Packaging should protect the onions from physical damage while allowing them to breathe.
6. Monitoring: Regular monitoring of stored onions is essential to identify any signs of spoilage or decay. Damaged or rotting onions should be removed promptly to prevent the spread of diseases.
7. Ethylene sensitivity: Red onions are sensitive to ethylene gas, which can accelerate sprouting and decay. It is important to store red onions separately from ethylene-producing fruits or vegetables, such as apples and potatoes.
8. Shelf life: When properly handled and stored, red onions can have a shelf life of several months. However, their quality may gradually decline over time, with increased softening and loss of flavour.

9.1 Handling

Curing Red Onions

1. **Harvesting:** Wait until the onion tops have fallen over and turned brown. This indicates that the onions have reached maturity and are ready for harvest. Avoid harvesting onions with green tops, as they are not fully mature.
2. **Cleaning:** Gently remove excess soil from the onions by brushing it off with your hands or a soft brush. Avoid washing the onions, as moisture can promote rotting during the curing process.

3. **Trimming:** Trim the onion tops to about one inch above the bulb, using clean and sharp gardening scissors or shears. Remove any damaged or diseased tops to prevent the spread of infections during curing.
4. **Drying:** Find a well-ventilated area, such as a covered porch, garage, or shaded outdoor space, with good air circulation. Avoid areas with direct sunlight, as it can cause the onions to heat up and spoil.
5. **Curing Surface:** Prepare a curing surface by laying down clean and dry mesh racks, wire mesh, or wooden slats. Ensure that the surface allows air to circulate around the onions.
6. **Spacing:** Place the onions in a single layer on the curing surface, making sure they are not touching each other. Leave enough space between each onion for proper airflow.
7. **Temperature and Humidity:** Maintain a curing temperature of around 75°F (24°C) and a humidity level of 50-60%. Use a thermometer and hygrometer to monitor the conditions in the curing area.
8. **Air Circulation:** Ensure good air circulation by positioning fans or opening windows if necessary. Proper airflow helps in drying the onions evenly and preventing moisture buildup.
9. **Monitoring:** Regularly inspect the onions during the curing process. Check for any signs of rot, mold, or disease. Remove any onions showing these symptoms to prevent further spread.
10. **Turning:** After a few days, gently turn the onions to ensure even drying. This helps to prevent moisture accumulation and promotes uniform curing. Be careful not to bruise or damage the onions while turning them.

11. **Duration:** Allow the onions to cure for approximately two to three weeks. During this time, the outer skins will dry and become papery, and the necks will shrink and close tightly.
12. **Final Inspection:** Once the onions are fully cured, remove any remaining dirt or loose skins. Trim the roots if necessary. Inspect each onion carefully and discard any that show signs of spoilage.
13. **Storage:** Store the cured onions in a cool, dry, and well-ventilated area. Choose a storage method such as hanging them in mesh bags, placing them in wooden crates, or storing them in well-ventilated boxes or baskets.

9.2 Storage

Proper storage is essential to extend the shelf life of harvested red onions. Here are some tips:

1. **Remove excess soil:** Brush off any loose soil from the onions before storing to prevent the spread of moisture and decay.
2. **Optimal conditions:** Store red onions in a cool, dry, and well-ventilated area. Avoid storing them near potatoes, as they can release moisture and cause spoilage.
3. **Storage containers:** Use mesh bags, crates, or well-ventilated containers to allow air circulation and prevent the build-up of moisture.
4. **Shelf life:** Red onions can be stored for several months under optimal conditions. Regularly inspect stored onions and remove any damaged or decaying bulbs to prevent spoilage.

9.3 Collection Centre

Red Onion is an import substitution crop for the local market in Sri Lanka. This means the required post-harvest technology practices will mostly be implemented in a “Collection Centre” rather than in a “Packing Centre” for export. The Onion Collection Centre, therefore, will have minimum equipment and facilities. The main technical feature will be a 10-m long conveyor belt for sorting and grading to comply with local market specifications.

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 AND ONIONS

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	Emergence (Week 1-4)	Development (Week 5-11)	Maturity (Week 12-17)
Urea	1.31	1.35	1.31
$MgSO_{43.8}$	3.8	3.9	3.8
Application per week	2		
Phosphoric Acid (ml) *Application every two week*	102.3	105.4	102.3

Table 8: Fertigation Recommendation per Application per Plot

SOIL ANALYSIS RESULTS FOR MATALE MANGO AND ONIONS

		1:2.5, H_2O	%	µS/cm	Exchangeable (meq/100g)			Available (ppm)							cmol/kg						
Sample Code	**Lab No.**	**pH**	**OM**	**EC**	**Ca**	**Mg**	**K**	**N**	**P**	**S**	**Cu**	**Fe**	**Mn**	**Zn**	**CEC**	**Ca/Mg**	**Ca/K**	**Mg/K**	**Ca+Mg/K**	**Ca+Mg+K**	**Ca %**
Wawala Area	B1 435	7.76	1.34	196.3	6.99	5.68	0.95	49.2	25	12	8.9	143.5	17.4	1.9	13.62	1.23	7.36	5.98	13.34	13.62	51.32
Alakola Wewa	B2 435	7.17	1.61	201	5.12	2.53	1.11	54.4	124	12	11.6	113.7	38	3.4	8.76	2.02	4.61	2.28	6.89	8.76	58.45
Eraula	B3 435	6.93	0.81	181.5	4.39	1.7	0.96	65	7	19	10.6	105.1	32.4	1.9	7.05	2.58	4.57	1.77	6.34	7.05	62.27
Govigammanaya/Lenawa	B4 435	6.74	2.02	154.3	2.72	1.28	0.71	73.9	69	21	5.6	257.9	36.3	2	4.71	2.13	3.83	1.80	5.63	4.71	57.75
Welangolla	B5 435	6.7	0.94	142.1	3.39	1.32	0.64	64.2	118	17	6.7	137.6	38.5	5.4	5.35	2.57	5.30	2.06	7.36	5.35	63.36
Nikawatana	B6 435	6.74	2.15	171	5.32	1.6	1.3	58.2	21	19	8.5	102.5	22.4	6	8.22	3.33	4.09	1.23	5.32	8.22	64.72

Low or deficient nutrient

Interpretation: Organic matter low except in two locations; K the same; P very low in Eraula and marginal in two other locations; S, Cu and Zn generally low; Cation ratios out of optimal ranges. Mg dominates

Fertilization:

N	Required regardless of levels of Organic Matter and soluble N
Phosphoric Acid	Will add P to the soil and will prevent irrigation system from clogging
TSP	Will addd P required in most locations
MOP	K also required in most locations
CaSO4	Will lower the dominance of Mg in the soil exchange complex and will provide required S
Foliar Micro, specially Cu and Zn	Will address micro nutrient deficiencies

Important to add compost during land preparation to increase Organic Matter levels

Kg/ Plot/ Application	Emergence (Week 1-4)	Development (Week 5-11)	Maturity (Week 12-17)
Urea	0.27	0.44	0.43
TSP	0.06	0.10	0.05
MOP	0.20	0.34	0.50
CaSO4	0.44	0.44	0.44
Application per week	2		
Phosphoric Acid (ml) *Application every two week*	145	242.1	118.9

Table 9: Fertigation Recommendation per Application per Plot

ANNEX 3: CONTROL OF CALAMUS ROTONDUS AND CYPERUS ROTUNDUS (NUTGRASS OR COCO GRASS), INCLUDING AGRICULTURAL PLASTICS OR PLASTIC MULCH

Calamus rotundus and *Cyperus rotundus* are different plant species, and they belong to different genera and families:
Calamus rotundus:

- *Calamus rotundus* is commonly known as round-leafed sweet flag or simply sweet flag.
- It belongs to the Acoraceae family and the Calamus genus.
- *Calamus rotundus* is a wetland plant that grows in shallow water or moist soils and is native to Eurasia and North America.
- The rhizomes of *Calamus rotundus* are aromatic and have been traditionally used in herbal medicine and perfumery.

The control strategy for *Calamus rotundus* is simply to prevent the water logging of the cultivation field by micro drainage practices such as surface drainage and the use of drainage ditches. Even underground drainage is often used. Once the excess water problem is dealt with, other control measures can be applied, including plastic mulch.

Reference: "*Calamus rotundus L.*" - The Plant List

Cyperus rotundus:

- *Cyperus rotundus* is commonly known as purple nutsedge, nutgrass, or coco grass.
- It belongs to the Cyperaceae family and the Cyperus genus.
- *Cyperus rotundus* is a widespread weed found in many parts of the world, including Asia, Africa, and the Americas.
- It is known for its aggressive growth habit and ability to outcompete crops in agricultural fields.

Reference: "*Cyperus rotundus L.*" - The Plant List

Control Strategies for *Cyperus rotundus L.* or Nutgrass:

Nutgrass is a perennial weed that reproduces through underground tubers, making it difficult to eradicate once established. Traditional control methods such as hand weeding, herbicide application, and cultivation have limited effectiveness against nutgrass due to its underground tuber system. Therefore, alternative control strategies are needed to manage this weed effectively.

Agricultural Plastics and Plastic Mulch:

Agricultural plastics, including plastic mulch, have been used in agriculture for various purposes, such as weed control, moisture conservation, and temperature regulation. Plastic mulch is a layer of plastic film placed on the soil surface to suppress weed growth, conserve soil moisture, and enhance crop yields. When used correctly, plastic mulch can effectively control weeds like nutgrass by blocking sunlight and preventing weed germination and growth and the spread of seeds.

Research Studies:

Several research studies have investigated the efficacy of agricultural plastics and plastic mulch in controlling nutgrass in different crops. For example, a study by Smith et al. (2018) examined the use of black plastic mulch for nutgrass control in tomato fields and found a significant reduction in nutgrass infestation and increased tomato yields compared to traditional cultivation methods.

Benefits of Using Agricultural Plastics for Nutgrass Control:

1. Effective weed suppression: Agricultural plastics, especially plastic mulch, provide a physical barrier that inhibits nutgrass growth by blocking sunlight and preventing weed emergence.
2. Moisture conservation: Plastic mulch helps conserve soil moisture by reducing evaporation, which is beneficial for both crop growth and weed control.

3. Improved crop yield: Nutgrass competition can reduce crop yields significantly; therefore, controlling nutgrass with agricultural plastics can lead to increased crop productivity.

References:

1. Smith, J., et al. (2018). "Efficacy of black plastic mulch for nutgrass control in tomato fields." Weed Science Journal, 25(3), 112-120.

2. Brown, A., et al. (2019). "Utilizing agricultural plastics for weed management in vegetable crops." Agricultural Research Reviews, 36(4), 245-259.

Controlling *Calamus rotondus* and *Cyperus rotundus* in Florida

In Florida, *Calamus rotondus* and *Cyperus rotundus* are persistent problems. The first step in controlling them is to avoid providing an ideal habitat. These weeds thrive in areas that remain wet for extended periods of time. Also high foot traffic and resulting soil compaction are other risk factors.

Excessive irrigation is a common error in Florida landscape management. Before you begin the prevention and control of these obnoxious weeds by correcting the cause of continuously wet sites. Improved surface and subsurface drainage may also be necessary. The sooner these moisture problems are addressed, the sooner the weeds are not watered.

Once the environment has been corrected, you can start removing existing plants and applying other control and prevention measures such as plastic mulch. Inspecting the landscape to gauge the extent of the problem is a first step.

Reference: https://gardeningsolutions.ifas.ufl.edu/care/weeds-and-invasive-plants/sedges.html

ANNEX 4: ADDITIONAL MATERIAL TO REINFORCE RESPONSES TO ONION MANUAL COMMENTS FROM DOA

Planting System Recommended by ISP

Bed Width	0.6 m
Trench Width	0.3 m
Total Bed Width	0.9 m
Plant Rows per Bed Width at 0.1 m Spacing	7
Bed Length	100 m
Plts per Bed Length	1,000
Plts per Bed	7,000
No. of Beds per Ha	112
Pop. Density per Ha	**784,778**
Total Cultivation Area	10,090.0 m2
Net Cultivation Area	6,726.7 m2
Net Cultivation Area	**66.7** %

Pond System Utilized by Onion Farmers

Pond Size	1 m x 3 m x 0.15 m
Rectangular Plant Spacing	0.1 m
Periferal Bund Width	0.2 m
Periferal Pond Idle Space	0.1 m
Un-utilized Periferal Width of Pond	0.3 m
Plts per Bund Width at 0.1 m Spacing	8.0
Plts per Net Pond Length at 0.1 Spacing	27.0
Plts per Pond	216.0
Rows of Ponds per Ha	101.0
Lengths of Ponds per Ha	33.3
No. of Ponds per Ha	3,366.7
Pop. Density per Ha	**727,200**
Total Cultivation Area	10,100.0 m2
Net Cultivation Area	6,363.0 m2
Net Cultivation Area	**63.0** %

Triangular vs Rectangular Planting

Item	Triangular	Rectangular
Distance Between Plts (Spacing), m	0.112	0.1
Available Growth Area per Plant, m2	0.039	0.031
Increase in Growth Area, %	**25**	
Increase in Plant Spacing, %	**11.8**	