VEGETABLE NURSERY AND TOMATO SEEDLING MANAGEMENT GUIDE FOR SOUTH AND CENTRAL INDIA

P.V.L. Bharathi and M. Ravishankar

Technical partnership to support
the Green Innovation Centre
for the Agriculture and Food Sector
(tomato value chain)

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The **World Vegetable Center**, an international nonprofit institute, conducts research, builds networks, and carries out training and promotion activities to raise awareness of the role of vegetables for improved health and global poverty alleviation. The Center's improved vegetable lines and technologies help small-scale farmers boost yields, increase their incomes, and safely grow nutritious vegetables for their families and communities.

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Acronyms

DAS	Days after sowing	ml	Millilitres
GSM	Grams per square meter	Kg	Kilograms
EC	Electrical Conductivity	g	Grams
pH	Potential of Hydrogen	Sq m	Square metres
UV	Ultraviolet	WP	Wettable powder
ft	Feet	mS/cm	Millisiemens per centimetre
m	Metres	Km/h	Kilometres per hour
mm	Millimetres	%	Per cent
cc	Cubic centimetres	°C	Degrees Celsius
L	Litres		

1. Introduction

"A vegetable nursery is a place or an establishment for raising or handling of young vegetable seedlings until they are ready for more permanent planting."

The production of healthy seedlings plays a vital role in the establishment of a healthy crop in the main field. Management challenges faced by nursery growers require more research to overcome. However, a recent study conducted by WorldVeg in the nurseries of Narayangaon and Kadur found that most nursery owners are self-taught and do not believe they have any major technical problems. No training had been provided to nurseries, and many technical problems were observed that affected both the profitability of their businesses and the quality of seedlings provided to farmers. This included poor water, fertilizer and pesticide management, and the failure to effectively control viruses and insect-borne diseases that can later damage field crops[1].

The production of good quality seedlings is essential for getting higher yields and improving crop quality. In the past, the farmers themselves produced the seedlings required for transplanting at a lower cost, as most of the vegetable varieties were open pollinated types. Now, most commercial farmers are going for intensive vegetable cultivation using high yielding F1 hybrids to augment productivity. As these hybrid seeds are expensive, converting every individual seed into a healthy seedling becomes essential and this requires intensive nursery management. Vegetable seedling production is taken up by specialized farmers/companies or as a specialized activity in most advanced countries.

Figure 1: Open field nursery

In India too, the production of vegetable seedlings is gradually changing from open field nurseries (Figure 1) to protected raised bed or seedling tray production (Figure 2) in some of the intensive vegetable growing areas. Seedling production as a specialized practice is also rapidly catching up. However, establishment of a shade net nursery by every individual farmer owning a small piece of land under vegetable cultivation is not practically feasible and economically viable. Such farmers have to depend on commercial nurseries for hybrid vegetable seedlings to meet their requirements.

Some of the problems observed in traditional nurseries that can lead to lower yields:

- Higher pest and disease incidence (such as damping off)
- Poor germination due to improper management of moisture in beds
- Missing the right growing season due to delays in transplantation, particularly in rainfed farming
- Lack of awareness of improved nursery practices such as raised beds, seed treatment, protection against environment, etc.
- Availability of seedlings throughout the year

Many seedlings are still grown in the ground, pulled up when mature and sold as bare-root plants, or grown in plastic tubes in a mixture of soil, sand and compost. Many such seedlings suffered from soil-borne diseases or transplant shock when they are moved into the open field.

Figure 2: Protected nursery

1 Easdown W, Ravishankar M. 2016. STUDY OF TOMATO NURSERY PRODUCTION PRACTICES IN SELECTED DISTRICTS OF MAHARASHTRA AND KARNATAKA. World Vegetable Center, No. 16-807. 28 pp.

Many nursery growers do not use proven seedling raising technologies such as proper media preparation, using seedling trays, maintaining hygienic conditions, using quality insect mesh, shade net materials, or a double door system.

This guide describes a more efficient way of reliably growing healthier seedlings using sterilized artificial media, plastic seedling trays and fertigation. This requires different skills and equipment than traditional seedling production, but results in stronger, healthier plants that farmers prefer to get their commercial crops off to a good start.

2. SELECTING THE NURSERY SITE

Site selection plays a major role in the development and management of the nursery and helping to meet its marketing challenges.

Use slightly sloping land: Mildly sloping land (1- 2% gradient) is preferable to ensure a free flow of any excess water. In hilly areas, preferably locate the nursery in the foothills so it can avoid soil and water erosion.

Be close to high quality water: There should be a good water source near to the nursery as a reliable supply of good quality water is necessary. It may be useful to construct rainwater harvesting storage tanks next to the nursery. The volume of water to be harvested and the size of the catchment needed can be calculated based on average rainfalls in the location. A geologist or engineer may be consulted to help plan the appropriate size and location of the nursery's water storage tank.

Ensure good access but minimize road dust: Good accessibility is a requirement for a nursery area to ensure safe and easy transportation of nursery materials and seedlings to the planting sites.

Keep a free flow of wind without shade: Any obstruction adjacent to the nursery may act as a barrier for the free flow of wind. Avoid having a wind barrier as a border immediately around the nursery. Large trees around the nursery may have a shading effect, which will reduce photosynthetic activity and plant growth. The nursery area should be well lit in the open.

However, in windy areas, if space permits, 10 foot high windbreaks of thick vegetation can be planted at a distance of 150 feet away from the nursery to make sure that they do not shade the nursery plants (Figure 3). Selection of windbreak species depends on local preference. The location of the windbreaks should be according to the monsoonal wind direction.

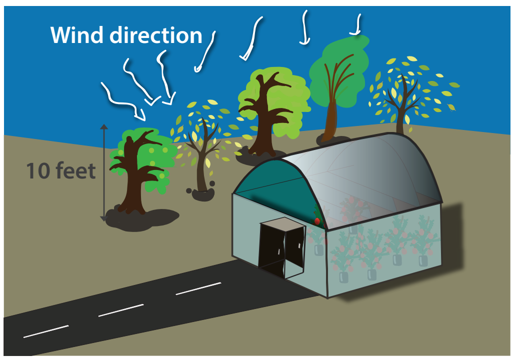


Figure 3: Windbreaks near nursery

Don't worry about soil type, but about the neighbouring crops: Non-cultivable land is a very good location for a nursery. Soil quality is not important, as seedlings are grown in soilless media in germination trays. Avoid areas with intensive fruit or vegetable cultivation around the nursery to prevent infestation of seedlings with insects, fungal and bacterial spores (e.g. mites, thrips, whitefly, or blight). Pests and diseases present on the crops in surrounding areas may be incidentally carried onto the seedlings in the nursery. Locating a nursery in a cereal cropping area is preferable as cereals do not harbour as many pests and diseases as vegetable seedlings.

3. A STURDY STRUCTURE TO PROTECT THE SEEDLINGS

Seedlings must be grown under cover, and there are three choices for the type of cover provided: polyhouse, nethouse and shade house. Because of their unique characteristics each can be used for a different growth stage of the seedlings, or they can be altered to suit seedlings of different ages.

3.1 Polyhouse

A polyhouse structure riveted with galvanized nuts and bolts is generally recommended as it will be stronger and easier to repair if it is damaged.

Suggested specifications for the structure:

- The width of a single span of the polyhouse should not exceed 26 ft (8 m).
- The roof structure should be extended at least 2.4 ft (0.75 m) on all four sides of a polyhouse to drain off rain water in heavy rainfall areas.
- The complete structure should be made of 2 mm thick galvanized steel tubular pipes.
- The gutter height should be at least 15 feet above the floor area.
- The gable needs to be covered with insect net instead of polythene to prevent insects entering the polyhouse from the roof.
- The height of the curtain wall or apron should not be beyond 1 foot from the ground level.

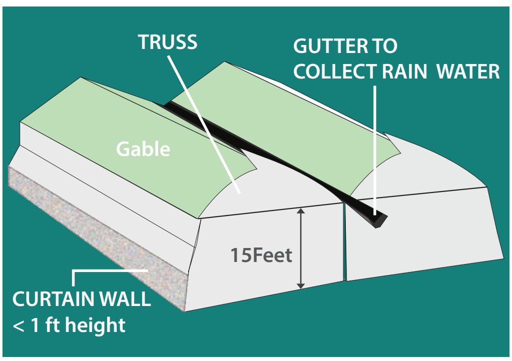


Figure 4: Polyhouse structure

- A truss height of 5-6 ft (1.5-1.8 m) is recommended for high rainfall and windy areas.
- Suggested direction of the windward side for good ventilation:

  Southwest monsoon region: southwest direction.

  Northeast monsoon region: northeast direction.
- Preferred orientation of the structure is north-south to capture the best sunlight.
- Movable iron tables, arranged contiguously with 3 feet (1 m) working space in between on which to place the seedling trays are ideal to prevent contact of seedlings with the soil.
- The length and breadth of each table could be 11 x 6 ft (3.5 m x 1.75 m) (Figure 5), so that two rows of tables could be arranged in a single span of the polyhouse leaving a working space of 3 feet in between (Figure 6).

Figure 5: Nursery table

Figure 6: Nursery tables in polyhouse

- Bamboo benches that can last for at least 1.5 – 2 years may be used wherever bamboo is readily available.
- A double door system that closes automatically is recommended with 6 feet (2 m) spacing between the doors. Doors should be sliding, not swinging to ensure there is no gap while closing. To ensure there are no holes or gaps in doors to allow insect entry, insert rubber flaps or brushes in the gaps.
- The side walls should be made of insect-proof net and the top to be covered with plastic to prevent rain water entering (Figure 7).

(*Note:* Please follow the NHB or equivalent guidelines for the specifications of the polyhouse structure).

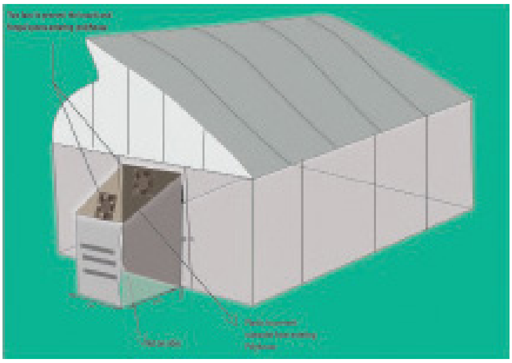


Figure 7: Polyhouse requirements

3.2 Nethouse

A nethouse can be recommended:

- In dry regions where high rainfall and humidity is not a problem.
- When the investor requires a lower cost structure that still provides protection against the environment and complete protection from pests and diseases.

This structure should not be less than 13 feet in height. Galvanized steel pillars 2.0 - 2.2 mm thick and 2.8 - 2.9 inches in diameter will usually withstand a wind velocity up to 140 km/h. UV stabilized insect-proof net with 40 mesh is generally recommended. For smaller structures and in cooler areas, 50 & 60 mesh can be used and this provides better insect exclusion. Red, silver or white shade nets can be used, but not green. Green coloured net cuts off more light.

When seedlings are grown in nethouses, it can be important to protect the seedlings from rainwater. Metal hoops have to be fixed over the raised beds and a polythene sheet is fitted over the hoops and fixed at one end of the raised bed. It is spread over the beds during rain (Figure 8).

Figure 8: Metal hoops covered with polythene sheets

3.3 Conditions maintained in a polyhouse

Light:

Light is the most critical factor to manage conditions in a polyhouse as it affects both plant growth and temperatures. Bright ambient sunlight has to be reduced by using shade netting to get the right light intensity for proper growth at different seedling stages. Retractable shade netting of different densities can reduce sunlight 30%, 50%, or 75% when installed below the roof.

A lux meter measures light intensity, and varying the light intensity is important to optimizing different growth stages. The easiest way to get a lux meter is to download an Android app (GPS Status) and to turn a smart phone into a lux meter (Figure 9). Light intensity requirements vary with the age of the seedlings. Soon after germination, the light intensity requirement is low and it increases as seedlings develop.

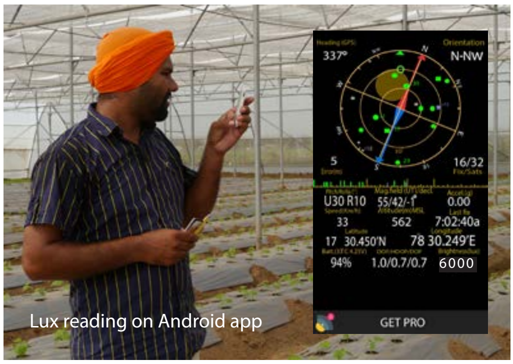


Figure 9: Checking light intensity with Android phone

Light intensity requirement with the age of seedlings

Days after sowing	Light Intensity (lux)
1-4	0
4-7	5000-7000
8-9	23000
10-15	40000
>16	75000 and above

In a polyhouse, light is controlled in such a way that plants receive the maximum necessary visible light and the remaining light gets reflected back outside the polyhouse.

The light intensity received depends on the type of shade net used. The lower the shade percentage, the higher the light intensity.

Light intensity is also affected by the age of the shade net used. When the shade net gets old, it accumulates dust and allows less light to penetrate. It needs to be cleaned regularly to improve light penetration. A layer of white shade net at the gutter height will help in regulating the amount of light to be received. White shade net is preferred over green because it will absorb a higher light intensity (Figure 10).

In South and Central India during summer months when the temperature goes above 30-35°C, nursery owners have found it useful to have a double layer of shade net below the roof. This may be removed or retracted on a cloudy day.

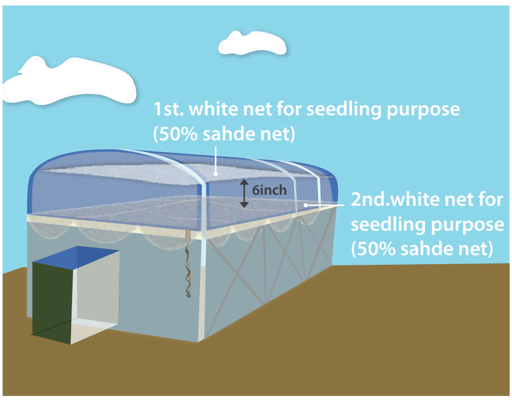


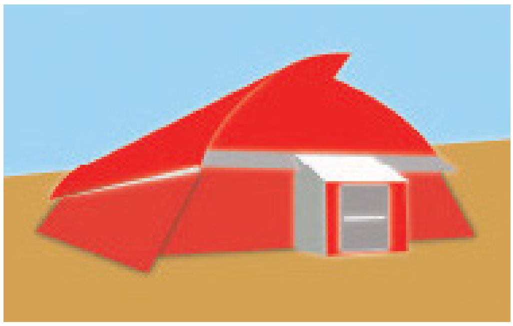
Figure 10: Layers of shade net in a polyhouse

The retractable shade nets to be used under the roof of polyhouse can be of different colors, varying in their functions.

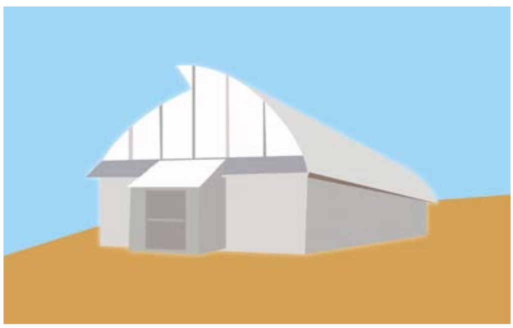
Types of shade net:

There are different types of shade nets preferred for different needs.

Green shade net: Produces lanky seedlings and is preferable for ornamental plants. It is not preferred for vegetable nursery seedling production as a 50% shade net cuts off more light and looks like 80% shade is provided to the seedlings, hindering the seedling growth. The common fact that green color in the plants is important for photosynthesis does not apply to the shade net.

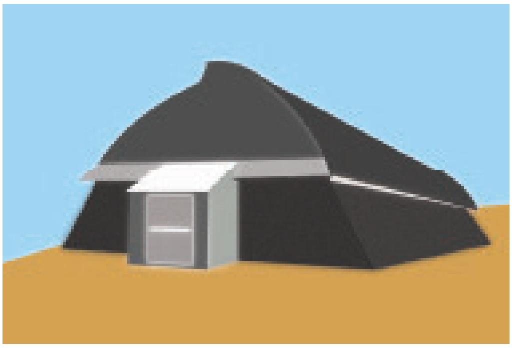


Red shade net: Not preferred in cloudy areas or during cloudy times of the year. If too bright double net can be used. It will cut infrared light and this can help produce higher yields in Capsicum.



White shade net: This will give compact seedlings, and works well for nurseries growing sun-loving plants such as tomato, eggplant, or chili.

Silver shade net: Ideal for sun loving plants such as tomato, eggplant and chili.



Black shade net: Produces lanky seedlings and is preferred for ornamental plants but not for vegetable seedlings.

Alumin shade net (thermal screens): Thermal screens can be used as a secondary layer in polyhouses and shade nethouses to reduce the temperature 4 degrees. In winter, thermal screens will retain the heat inside the nethouse/polyhouse.

Alumin net moderates the day/night temperature, enabling microclimate control in nurseries. It provides uniform shadows, controls air movement and optimum diffused light transmission to the seedlings.

Polythene sheeting that can be used to cover the roof of a polyhouse also plays an important role in regulating the amount of light that penetrates into the polyhouse.

Types of polythene sheets:

UV (Ultraviolet) stabilised polythene is recommended to ensure the longevity and durability of the sheets and prevent degradation from UV light. There are different types of polythene sheets available for different needs. For polyhouses, 200 GSM (grams per square meter), 5 layered, UV stabilised, anti-dust plastic sheets of different types can be used.

1. **Transparent:** More light penetration. This can be used in regions where the light intensity is low in general and often cloudy, such as in Bengaluru.
2. **Translucent:** Gives diffused light. Appropriate location is Kerala.
3. **Yellow:** Less light penetration. Can be used in dry places such as Pune, Kadur and Madanapalle. (In general, a yellow color increases the heat and humidity inside the polyhouse.)

The following diagram (Figure 11) shows the light penetration through various layers inside the polyhouse.

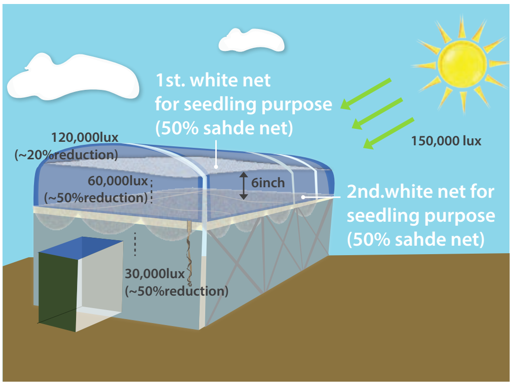


Figure 11: Light pentration in a polyhouse

After being used for a year, 50% shade net effectively changes to 80% shade net due to dust deposition blocking the light penetration. A thorough washing with clear water will increase light penetration back up to 10,000 lux. When a double layer of shade net is used, in places where the light intensity is very high or in peak summer, it is better to retract the second layer on a cloudy day. Otherwise, the light intensity received by seedlings will be too low. After a series of rains in a rainy season, it is always better to wash the polythene sheet roofing using a detergent to remove algal growth to enhance light penetration.

Temperature:

The steel framework of a polyhouse is covered by polythene and the inside temperature can rise up to 40°C. In such cases, foggers and misters can be used to reduce the temperature, but the cost of investment increases.

(Local vendors of irrigation systems may be contacted to obtain the price details and product ranges available.)

What is a fogging system?

A fogging system is the application of water in the form of a spray in order to reduce temperature through water evaporation and to increase humidity inside the polyhouse or nethouse. A fogger or mister is usually attached to an anti-leak or leak-proof device (LPD) that does not allow the flow of water droplets after the system is switched off. A LPD is a rubber valve that closes the outlet immediately when the system is below a specified pressure.

Why do we need a fogger?

- To provide optimal cooling or humidifying of polyhouses.
- To reduce polyhouse temperature.
- To increase humidity inside the polyhouse.

Figure 12: Fogger installation in a nursery

Type of foggers recommended for nurseries:

There are different types of foggers prescribed by different irrigation companies. Factors to be considered while choosing the right fogger will be the direction of water flow, the volume of discharge per hour, and a design that prevents dripping of water droplets on the floor of the polyhouse.

Most commonly used and recommended foggers in polyhouses (Figure 13) for reducing temperature and increasing humidity levels are four-way (spray water on four sides) anti-drip (water droplets do not spill on the floor) foggers that can discharge around 22 litres of water per hour. This rate of discharge is ideal for rapid evaporation.

- About 96 foggers will be required in a polyhouse of 600 sq m.
- Distance between the rows of sprinklers: 8 ft (2.5 m) (Figure 12)
- Distance between sprinklers along the row: 8 ft (2.5 m) (Figure 12)
- The sprinklers should be installed as high as possible above ground level hanging from the roof.

Foggers with sensors:

A mechanical sensor is usually a screen placed in the plant canopy that collects moisture and turns off a solenoid valve when it gets heavy.

There are two kinds of sensors available in the market:

1. **Temperature dependant:** Trigger the functioning of foggers when the temperature crosses the set limits.
2. **Relative Humidity dependant:** Trigger the fogger when humidity levels decrease.

In South and Central India, temperature-dependent sensors are preferred, as the temperatures inside polynet houses can rise dramatically in summer.

One sensor in the centre of the polyhouse hanging from the roof, one to two feet below the foggers will provide for the requirement of a 600 sq m polyhouse.

Humidity:

The preferred humidity level for vegetable production is 60% to 65% and this can be maintained by providing vents around the polyhouse to expel excessive humid air.

Ideally, there should be at least one large vent placed near or on the roof of the polyhouse to allow heat to escape. There should also be several vents placed around the perimeter of the polyhouse, near the base. This allows for the best, most natural type of ventilation: cross-ventilation.

Figure 13: Functioning of foggers triggered by sensors

4. PREPARING SUPPORTS FOR THE SEEDLING TRAYS

Seedling trays may be placed on raised beds or steel/iron/wooden tables, with each system having its own advantages and disadvantages.

4.1 Raised beds

These are cheaper than steel tables and are commonly adopted by small-scale nursery owners (Figure 14). There is a risk of seedlings coming into contact with the soil due to mechanical damage caused to the weed mat covering the beds. As a result, the seedlings may be affected by nematodes, fungal and bacterial infections.

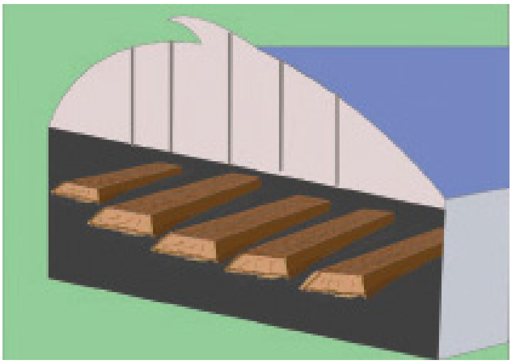


Figure 14: Raised beds in a polyhouse

Trapezoidal shaped raised beds that are 36 inches wide and 6 inches high with 2% slope on either side, prepared on a well-ploughed soil, covered with UV stabilised 70-90 GSM black weed mat available in local markets will serve the purpose of accommodating the plug trays. A good quality weed mat may serve for about 5 years, preventing the entry of algae, weed emergence and water dripping, but allowing the water to drain out. In general, the width of commercially available weed mat is 13 feet (4 m). Any length of mat can be used. One may need to purchase an extra 10 percent of weed mat to that of the nursery area to cover the plinth area without any gaps. Fish bone hooks can be used to fix the mat onto the land surface.

Care should be taken to ensure that the weed mat is spread in the entire nursery area, but not just on the beds alone. This will reduce the risk of soil borne diseases, water stagnation and weed growth.

4.2 Steel/aluminium/iron benches/tables

Benches or tables are highly recommended compared to using raised beds covered with weed mat. The entire area inside the nursery structure should be covered with weed mat without leaving any space whether benches, tables or raised beds are used.

Figure 15: Metal tables for placing the seedling trays

Steel/aluminium/iron tables (Figure 15) may be expensive, but they last for 20-25 years. The seedling tables also can be made with locally available bamboo, if it is plentiful. A quality bamboo table will not cost much and lasts for 4-5 years.

5. MAKING A SUITABLE ARTIFICIAL GROWING MEDIUM

Growing seedlings in an artificial medium without soil or compost is healthier as it prevents contact with soil-borne diseases. Drainage also can be easily varied in artificial media. Perlite, vermiculite and peat moss are expensive. Coco peat is a cheaper and effective alternative base for an artificial growing medium, but it is important to get the pH right and avoid any salt contamination.

Coco peat is the pith derived from coconut husks after the removal of fibre by the coir industry. The recommended pH of coco peat is 5.8-7. Highly acidic or alkaline coco peat will hinder seedling growth. It is suggested to test the pH of coco peat with a pH meter before using it.

It is always better to sieve the coco peat. Instead of raw coco peat alone as a medium, a mixture of coco peat, vermiculite and perlite in the ratio of 3:1:1 by volume is better for the growth of vegetable seedlings. Vermiculite or perlite not only reduces the weight of the medium but also provides better drainage and porosity to the medium, enhancing the growth of young roots.

Salinity is measured as Electrical Conductivity (EC). The EC of coco peat should be less than 1mS/cm. If the EC is higher, the seedlings grown in this media will be weak and lanky, and the EC needs to be reduced by either adding buffering chemicals (may be done by the supplier) or simply by repeated washing at the nursery level.

Soak the coco peat in good quality water, and then remove the water by squeezing it two to three times. Repeat the process two or three times to remove the salts and bring down the EC.

Figure 16: Undecomposed coco peat briquettes

Coco peat is available as briquettes (Figure 16) or in the loose form in bags (Figure 17). It is usually sterilized before sale, but if sterilizing is not done properly, every type of fungal infection may appear. To prevent this, nursery workers will have to treat the coco peat before using it.

Figure 17: Decomposed coco peat in bags

It is better to use decomposed coco peat as it can provide the required moisture for seedling growth immediately after sowing.

Undecomposed coco peat needs to be decomposed by wetting it regularly until it is ready (Figure 18).

Figure 18: Wetting the coco peat

5.1 Treating the coco peat

Hydrogen peroxide with nano silver is commercially available in the market in either 1 litre or 5 litre packs and is recommended as a disinfectant to treat coco peat. When used to sterilize the medium, the recommended dosage is 3 ml per litre of water. It is important not to use the sterilised media immediately, but to wait for at least 6 hours to avoid scorching of the seedlings. It is also worthwhile spraying the nursery once a week with this same chemical mixture to reduce problems from fungus and nematodes. The recommended spraying concentration is 0.5 ml per litre of water, and a 600 sq m polyhouse may require half a litre of the chemical per month.

5.2 Biological enrichment of coco peat to reduce pests and diseases

Coco peat or any similar substrate can be enriched to reduce pest and disease problems in seedlings by mixing the following biological additives to each tonne of substrate (Figure 19):

Neem cake @ 50 kg + carbofuran @ 5 kg + *Trichoderma harzianum* @ 2 kg + *Pseudomonas fluorescens* @2 kg. These additives either act as insecticides or bactericides and can be particularly useful for producing healthy seedlings of tomato, eggplant, capsicum, cauliflower, cabbage, chilies and onion.

The Indian Institute of Horticultural Research (IIHR) at Bengaluru has developed mass production techniques for a range of other biological agents that when mixed with substrates can reduce pest and disease problems more safely and economically than using chemicals. The following patented bio-pesticide formulations available as wettable powders (WP) can be used to treat coco peat in which seedlings are grown under shade net or protected cultivation. The recommended dosage is 5 to 10 g of formulation/kg of coco peat.

- *Pseudomonas fluorescens* 1% WP (an effective bio-bactericide with nematicidal properties)
- *Trichoderma harzianum* 1% WP & *Trichoderma viride* 1.5% WP (effective bio-fungicides with nematicidal properties)
- *Paecilomyces lilacinus* 1% WP & *Pochonia chlamydosporia* 1% WP (effective nematicides)

Figure 19: Enriching the coco peat

6. CHOOSING A SEEDLING TRAY, AND HOW TO SOW FOR RELIABLE GERMINATION

Plastic seedling trays (also known as plug trays or pro-trays) of different sizes are available in the market. The selection of the seedling tray size by the nursery owner depends on local farmers' preferences, but mostly, trays with 102 or 104 cavities (or plugs) are preferred.

> Nursery owners have observed a better root growth in 70 cavity trays when the temperature crosses 40°C during hot summer months.

There are two types of cavities in the trays available in the market: inverted cone shaped and inverted pyramid shaped.

The experiences of nursery entrepreneurs indicate that a tray with 104 cavities with an inverted pyramid shape is ideal for a strong stem and good root growth as it provides a wider space for the root system to grow. In contrast, the inverted cone shape narrows down the space for roots to spread, resulting in a cluster (Figure 20).

A seedling with a strongly developed tap root and secondary roots will establish in the main field faster than a seedling with a clustered root system.

Figure 20: Inverted cone shaped cavities vs. inverted pyramid cavities

The size of each cell is 25 mm x 25 mm wide x 32 mm deep, and the hole at the bottom of the cavity should not be less than 2 mm wide. Ideally, 25-40 cc of growing medium is required to fill each cavity.

Although it may seem like a good strategy to save money, it is better to buy non-reusable trays to avoid the risk of getting them back from farmers in damaged condition or carrying pests and diseases.

When reusable trays are used, they should be sturdier, with a minimum thickness of 0.8 mm.

A seedling that is 25-26 days old with 4-5 true leaves is at the right stage for transplanting.

6.1 Methods of sowing

Manual sowing:

To maintain uniform sowing depth and speed, sow the seeds with the help of a dibbler (Figure 21) that pokes uniform holes in the medium. The recommended dibbling depth is three times the seed diameter.

Figure 21: Dibbler

While filling the trays, care has to be taken not to pack the cavities too tightly. It will stop aeration and lead to poor root growth, water accumulation and a higher EC of the medium, if there are problems with the quality of the water being used.

After sowing, a layer of vermiculite or finely sieved coco peat is spread on the sown seeds to a depth of 1-1.5 times the diameter of the seed. It will be easier for the seed's epicotyl to push up through the light media while emerging.

Machine sowing:

In large scale nurseries a seeder assembly (Figure 22) can be used for automated tray filling, sowing, covering and watering. This enables about 90-100 trays to be filled in an hour.

Figure 22: Automatic seeder

6.2 Care to be taken after sowing for a good germination percentage

Whether in small-scale or larger well-established nurseries, it is important to transfer the sown trays to a darkened germination room / closed chamber that is kept at a mild temperature. If small-scale nurseries do not have space for a separate germination room, one of the corners may be closed off and used for the purpose.

This step is required to retain sufficient moisture for germination by reducing evaporation losses. Stacking many trays on top of each other is generally not recommended, as the top ones will compress the trays beneath. If the germinating

Figure 23: Arrangement of sown trays

trays need to be stacked due to space constraints, it is recommended to use a ziz-zag arrangement where the upper tray does not directly touch the media of the lower tray (Figure 23).

Tomato seeds germinate in 96 hours. Until then, the trays may be wrapped in a black polythene cover to maintain darkness and humidity. After 3 or 4 days, they will then have to be uncovered and the trays kept separate for uniform germination.

When nursery tables are used, the sown trays can be placed on the tables directly.

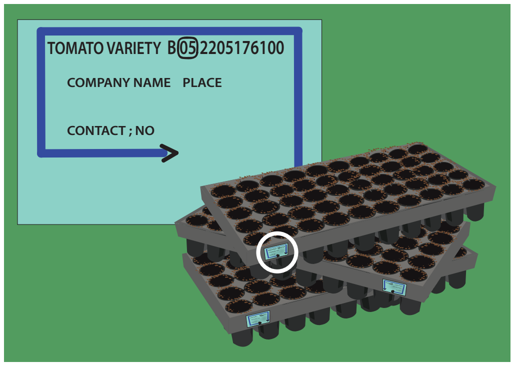


Figure 24: Label on the trays

6.3 Labelling the trays

It is important to label the trays to keep track of seedling production and reassure customers.

These sort of details have been successfully used in tray labels (Figure 24).

1. Tomato variety
2. Batch No.
3. Date of sowing
4. Date of dispatch
5. Company name
6. Contact no. & place

For example:

Date of sowing	Batch Number	Crop	Variety	Company	Contact No. & place
22/05/2017	**B052205176100**	**Tomato**	**1056**	**Syngenta**	

Details of Code on the label					
B 05	22	05	17	6	100
5th Batch	Date of sowing	Month of sowing	Date of transfer	Month of transfer	Batch size

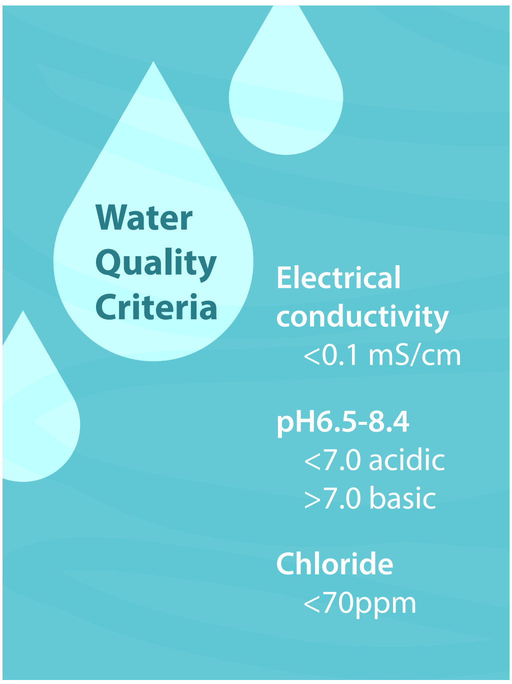
7. WATERING AND WEEDING FOR MAXIMUM GROWTH

Water quality is important and can have a big impact on the health and growth of seedlings. The most common water quality problems are from salts, particularly when bore water is used.

Water quality is measured by Electrical Conductivity (EC) and pH. The ideal ranges for these are:

- EC should be below 1 mS/cm. Seedling growth may be affected badly if the water EC is high.
- pH of water should be 6.5-8.4. Higher pH levels are associated with higher levels of salts that will damage seedlings.

An EC meter and pH meter need to be installed in all nurseries. Their uses were explained in the previous chapter.



A lower EC (less than 1 mS/cm) is always preferable. No correction will be required. If the EC is too high, there are several options to reduce the problem:

- A rainwater harvesting structure may be constructed to mix rainwater with ground water to reduce the EC.
- Water softeners (such as potassium choride) with bactericidal properties may be used to reduce water EC.

  Caution: Do not use sodium chloride to soften water, as it is toxic to seedlings.
- Good drainage in the seedling trays can prevent the build-up of salts, even when the EC is not initially ideal.

For clearing muddy water, it is suggested to use a sand filter. For silty water, use a hydrocyclone filter (Figure 25).

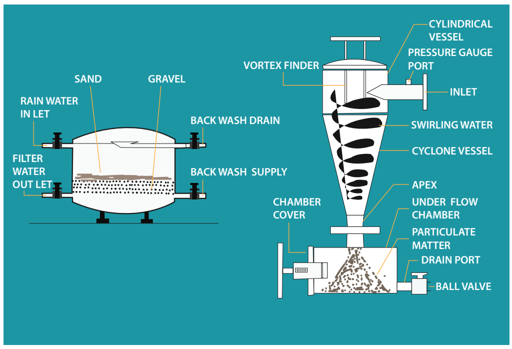


Figure 25: Types of filter

7.1 Suggested time and frequency of irrigation

It is best to irrigate in the morning. If seedlings are irrigated in the evening, water droplets will remain on the leaves and lead to fungal infections.

If the growing medium is porous, less water is required. Water two or three times a day depending on weather conditions. During damp weather, irrigation can be reduced to once a day. If drooping of seedlings is noticed, water immediately.

Reduce watering in the last week to assist in hardening of seedlings prior to transplanting (Figure 26).

Experienced labour should do the watering because they understand when to water and how much water is required. Excess watering leads to fungal problems.

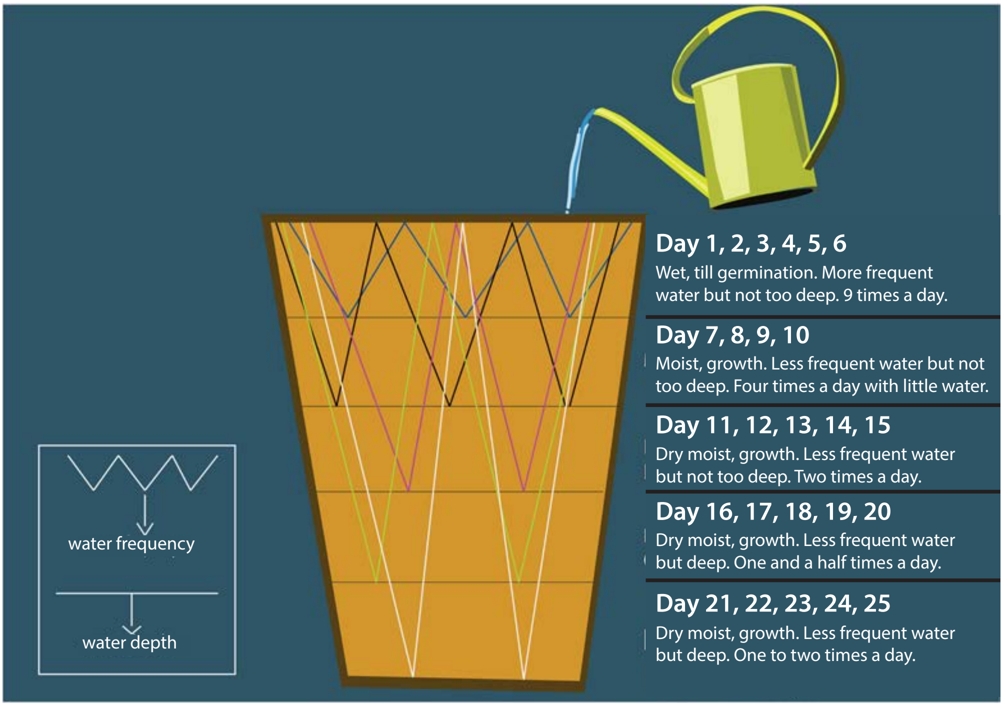


Figure 26: Irrigation frequency based on the age of seedlings

7.2 The importance of weeding

The nursery and its surroundings have to be weed-free. This is because weeds can host pests and diseases that can attack the seedlings.

Weed matting is a dark thick woven plastic mesh that prevents weeds germinating but allows water through. It should be used to cover the entire nursery area.

Outside the nursery, herbicide should be carefully used to kill weeds, being careful to keep it away from the seedling trays. Ideally herbicides should be used during the off-season when there are no seedlings in the nursery.

8. NUTRIENT SUPPLY

Fertlizers are not added to the growth medium, but nutrients are supplied to the growing seedling in the artificial medium through fertigation every day. There are several different ways this can be applied:

8.1 Basic fertilizer application

Daily application of 19:19:19 containing micronutrients @ 5 g per 10 litres of water, starting from the cotyledon stage till 16 days and gradually increasing the dosage every 3-4 days from 16 to 24 days, and then later stopping for hardening.

DAS	Fertilizer dosage (g in 10 litres of water 19:19:19+ micronutrients)
8-16	5
16-19	10
19-22	15
22-24	20

Figure 27: Advantage of fertigation over mixing fertilizer with the growing medium before sowing

8.2 Nutrient specific fertilizer recommendation (based on the EC of the medium)

The following table provides the scheduling of fertigation in 102/104 cavity trays under certain parameters.

Assuming the Buffered Media pH = 8.0, EC = 0.75

Assuming Water pH= 7.5, EC = 1.20

Days after sowing	Types of fertilizer combinations	EC level
9	Calcium Nitrate + EDDHA Fe	0.75
11	Calcium Nitrate + EDDHA Fe	0.9
14	19-19-19 + 13-0-46 (Potassium Nitrate) + Magnesium Nitrate + Micronutrients	1
16	19-19-19 + 13-0-46 (Potassium Nitrate) + Magnesium Sulphate + Micronutrients	1
18	Calcium Nitrate + Potassium Nitrate + Magnesium Nitrate + Iron	1.2
21	19-19-19 + 0-52-34 + Magnesium Nitrate + Iron	1.5
23	19-19-19 + 0-52-34 + Magnesium Nitrate + Iron	1.5
25	Potassium Nitrate + Magnesium Nitrate + Iron + Micronutrients	1.6

Note: All the above recommended fertilizer combinations are readily available in local markets. Input dealers may be contacted for the same. For recommended EC level, a dosing pump needs to be installed in the drip system that will take care of the right concentrations.

Additional nutrients may need to be applied because a combination of poor quality water and the medium may lead to specific deficiencies as shown in the images below:

8.3 How to apply

There are two ways of mixing fertilizer with water for fertigation.

1. Manual

The required dosage of fertilizer can be added to the water tank manually and mixed thoroughly. The EC and pH of the solution needs to be checked and adjusted by reducing or increasing the amounts of water soluble fertilizer and water to within the safe ranges before pumping the solution through the hosepipe to be used in daily watering.

2. Through a dosing pump

To reduce the risk of mixing an incorrect proportion of water and fertilizers resulting in a damaging EC or pH of the solution, non-electric water powered proportional dosing pumps can be used to ensure a proportionally blended chemical and water solution discharging into the water lines.

The dosing pump needs to be connected to the main line of drip system.

How to operate the dosing pump?

- Put the fertilizer concentrate in a container. Allow the dosing pump to dip into the fertlizer concentrate (Figure 28).
- Then, switch on the dosing pump before turning on the drip system valve.

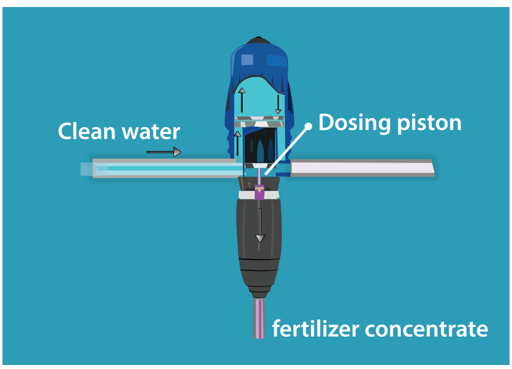
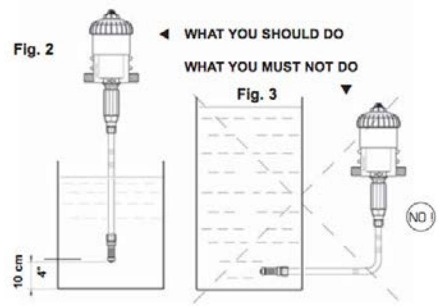


Figure 28: Water enters the dosing pump



- Dosing pump injects the liquid fertilizer concentrate and mixes it with the right quantity of water in its mixing cylinder (Figure 29).

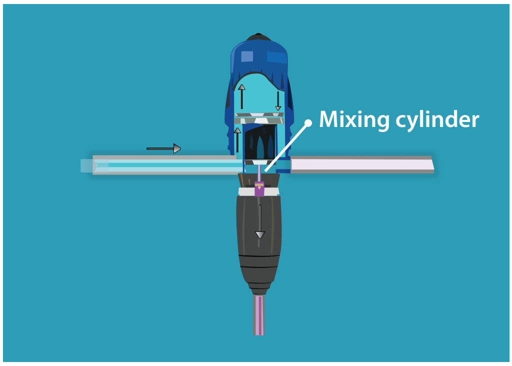


Figure 29: Concentrate mixes with the incoming water

- The right concentration of fertilizer solution ejects as output into the drip system for distribution (Figure 30).

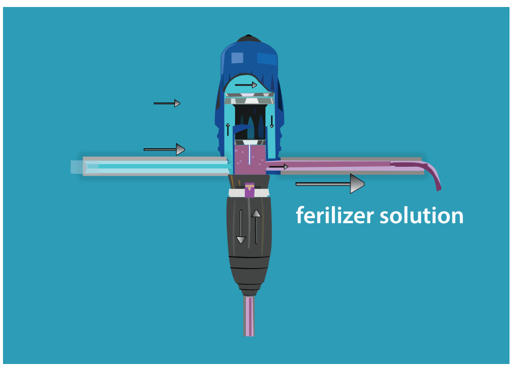


Figure 30: Blended solution is discharged into the water line

9. MANAGING COMMON PESTS AND DISEASES

Pest and disease problems can be minimized by careful construction and maintenance of the protective nursery structure. Some general precautions will help in reducing the number of sprays:

- Closing the doors properly without any gaps to exclude insects
- Repairing holes in the net whenever noticed
- Avoiding excess irrigation that promotes diseases
- Disinfecting the trays, nursery tools and nursery area
- Sterilizing the growing medium
- Installing sticky traps in between the two doors to catch any insects that do enter

Prophylactic sprays may be needed if seasonal conditions or local outbreaks suggest a potential problem. When pests and diseases are noticed, a quick application of mild chemicals is needed.

9.1 Cultural practices to manage common pests

The most commonly observed insect pests in nurseries are whiteflies, leaf miners, thrips and aphids.

Using sticky traps for monitoring and trapping insects:

Sticky traps are an important part of an Integrated Pest Management (IPM) program. They are easy to implement and inexpensive . Sticky cards will trap the adult stages of flying insects such as thrips, whiteflies, leaf miners and winged aphids. Remember, immature stages of thrips and white flies will not be caught on the cards.

Figure 31: Yellow sticky traps

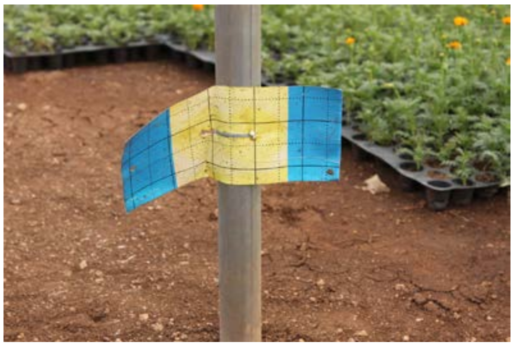


Figure 32: Yellow and blue sticky traps

Why use sticky traps?

Sticky traps/cards can be used to:

- Track insect population trends, and make more informed and timely pest management decisions.
- Mass trap adults during high incidence of insect pests.
- Mass trap Lepidopteran insects by sticking pheromones/lures on them.

Types of sticky traps

Most commonly, 3 by 5 inch sticky cards/traps are used in the polyhouse. Larger sticky cards are also available. Small cards are an excellent tool for monitoring while larger cards are good for mass trapping.

Some cards have a grid system that makes it easier to count the insects on the card.

In the absence of sticky cards, the best alternative could be empty tins painted in yellow or blue and coated with grease/vaseline/castor oil on the outer surface.

Sticky tapes or ribbons also can be used to trap insect pests.

Commercially available cards

YELLOW
Best for general pest monitoring
Attract whiteflies, leaf miners
and winged aphids

BLUE
More attractive to thrips
Used to detect thrips population

Assembly and placement of the trap:

After unwrapping the outer covering, carefully remove the plastic cover from the glued area of the trap to expose the sticky surface.

Then hang the trap above the crop using the plastic-coated wire provided. Attention should be taken to avoid placing the trap where the sticky surface can easily come in contact with either the plants or fittings.

Dispose of the wrapping and plastic cover correctly.

When to use:

It is important to install the traps after seedling emergence before insect pest populations start to build up. In a nursery where many cycles of seedlings are raised, traps may be required throughout the period.

How many traps to use:

Where the traps are to be used for pest suppression in nursery structures, as a guideline, use at least one trap per 10 square metres, increasing or decreasing the density depending on the severity of the problem.

For monitoring pest populations, traps can be used at a much lower density of 1 trap per 100 to 1000 square metres depending on the size of the structure.

Where to use:

Figure 33: In the chamber between the two sliding doors of the nursery

Figure 34: Inside the nursery structure

Servicing the trap:

The traps may be left in place until the trapping surfaces are covered with insects.

Generally, traps should be replaced when two thirds to three quarters of the surface is covered with insects or when the trap loses stickiness.

In the outdoors or in dusty conditions, the traps may accumulate significant quantities of dust which will reduce their efficacy. Regular replacement is essential to maintain top performance.

Suggestions on using traps:

- Additional cards placed near doors and vents will have a good effect on monitoring and trapping.
- Cards should be placed just above the crop canopy but not close to the roof or floor.
- Check the cards with a hand lens to distinguish the adult insects from waste moss or faecal matter deposited on the cards.
- More frequent inspections will allow quicker identification of localized infestations.
- Keep records of data from weekly inspections of sticky cards to help in proper pest diagnosis and management.

9.2 Recommended chemicals for the control of sucking insects and diseases

Seed Treatment:

Generally , commercially available seeds are treated. If not, treat the seed with Thiomethoxam 70 WS @ 10 g per kg of seed to control initial infestation by insect pests.

Precautions:

The fungicide Bavistin should be avoided as it has an antagonistic effect on the bio-pesticides incorporated into the growing medium.

Personal protective equipment such as long sleeved shirts and long pants, chemical-resistant gloves, mask, shoes and socks must be used while spraying.

Chemicals should not be sprayed when people are working in or around the nursery.

General recommended schedule of chemical controls:

If collar rot is noticed	Drenching with COC or Cymoxil 8% + Mancozeb 64%
	H_2O_2 + Nano silver spray @0.5 ml/L

Day	Recommendation
13	If damping off is noticed, drenching with COC @ 3 g/L of water / Copper Hydroxide @2g/L
17	Spray for leaf miner + Silicon@1 ml/L
24/25	Drenching with broad spectrum fungicide + systemic insecticide

Thrips	Fipronil 5% @ 2 ml/L or Diafenthiuron @2g/L or Thiomethaxam @0.3 g/L or Spinosad @ 175 ml /ha
Whitefly	Diafenthiuron @2g/L or Acetomaprid @0.2 g/L or Thiomethaxam @0.3 g/L or Flunicamid @150 ml /ha or Pyriproxifen @625 ml/ha
Leaf miner	Chloropyrifos -2 ml /L or Thiamethoxam -0.3 g/L
	Sprinkling of diatomaceous earth (powder form natural)
Damping off	Drenching with COC after germination @3 g/L of water or Copper Hydroxide 2 g / L of Water or Cymoxanil + Mancozeb @ 2-3 ml/L of water.
Blight	Mancozeb + Carbendazim@ 2.5- 3 g/L of water or Cymoxanil + Mancozeb@ 2-3 ml /L of water with sticker

Source: Private company recommendations - about 500 litres of chemical solution is required per hectare of land.

10. THE GRAFTING PROCESS

Soil-borne diseases and nematodes pose serious problems in vegetable cultivation. In acidic soils and under humid conditions, bacterial wilt is a serious threat to tomato production. Under such conditions, grafting commercial F1 hybrids or varieties onto resistant rootstocks is a viable option to improve yields.

Tomato seedlings can be grafted onto *Solanum torvum* or wilt-resistant brinjal varieties. For raising the rootstock, seeds of *Solanum torvum* are sown into seedling trays in a soilless medium containing three parts of washed coco peat and one part each of vermiculite and perlite. *Solanum torvum* takes at least 15 to 20 days to germinate.

Normally 8-10 seeds are sown in a single cell and when the seedlings reach the 3-4 leaf stage, excess seedlings are transplanted into a new tray at one seedling per cell. The rootstock seedlings require daily irrigation and fertigation once every 5-7 days.

Solanum torvum seedlings have an initial slow growth rate and may take around 30-40 days to grow to a height of 5-8 cm to get ready for grafting. Hence, they have to be sown 20-25 days before sowing the scion seeds.

There are three common types of grafting solonaceous crops: tube grafting, wedge grafting and slant/side grafting.

For tube grafting (Figure 35), 1 cm long hollow silicon tubes with a hole diameter of 2.0 – 3.0 mm are used. The rootstock seedlings are de-topped at a height of 5.0 – 6.0 cm above the base of the plant. The silicon tube is slowly slipped over the rootstock. Using a razor blade the seedling is then split longitudinally through the centre to a length of 1.0 – 1.5 cm. The scion seedling is then detached from the pro-tray by giving a horizontal cut 4.0-5.0 cm above the base. A small tapering cut is then made on each side of the detached scion to make a wedge 1.0 – 1.5 cm long. The prepared scion is then inserted into the split made in the rootstock and the silicon tube is pulled up over the joint to ensure that the scion and stock are aligned properly.

The scion can be any desired commercial hybrid or variety. Scion seeds are raised in seedling trays with 25 mm x 25 mm cells, at one seed per cell. The scion seedling will be ready for grafting in 15-20 days after sowing.

In wedge (clip) grafting (Figure 35), the same procedure is followed but the stock and scion are held together using a grafting clip made of plastic. This method is comparatively easier than using the silicon tube, which needs to be removed when the joint is established. Grafting clips can be easily detached from the graft joint and reused again.

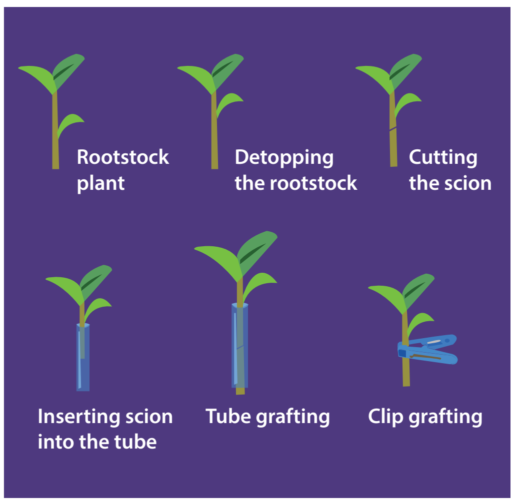


Figure 35: Grafting process

Slant/side grafting is also used for vegetable seedlings. The stock is de-topped using a slanting cut 5.0 – 6.0 cm above the base. A small polyethylene sleeve (1.0 cm long) is then fixed on the rootstock where the slanting cut has been made. A matching slanting cut is made on the scion seedling and it is then inserted into the polyethylene sleeve attached to the rootstock so that both the cuts are aligned with each other.

The vegetable seedlings after grafting are immediately shifted to a healing chamber that can provide a hot (25 – 30°C), humid (90 - 95% RH) environment for the grafts to heal. High humidity is maintained inside the healing chamber by spraying water or fogging at periodic intervals depending upon the weather. The spraying intensity increases in dry weather. After 4 to 5 days, when the grafts heal, they are transferred to a polyhouse and kept for a week for further hardening. The hardened seedlings are then transplanted.

It is important to harden seedlings before they are transplanted. Seedlings are grown in a controlled environment. The temperature is pretty much maintained, the light is not as strong as full sunlight outside, and they are protected from adverse environmental conditions such as wind and rain. As seedlings grown indoors have never been exposed to the harsher outdoor environment, they do not have any defences built up to help them deal with this growing environment. To prepare them, it is important to gradually expose them to the outside environment where they will have to establish and spend the rest of their lives.

The best way to help strengthen seedlings for the outside environment is to harden them off. It is an easy process and will enable the plants grow better and stronger when transplanted out into the main field.

Hardening should not be done outdoors because of the danger of pest and disease infections. The required high light intensity can be provided inside the nursery. When kept outdoors for hardening, seedlings are susceptible to sucking pests and early viral infections that may remain undetected until they later damage the field crop after transplanting. The hardening process should start from 16 days after sowing by slowly reducing the fertilizer and water supply.

When seedlings are hardened under a shade net in polyhouse, the shade net on the top should be removed and watering should be reduced.

11. MAINTENANCE , TRAYS AND TRANSPORT

Chalking of the polyethylene sheets of a poly-house using lime is not recommended. While it may reduce heat, it will more importantly block the free penetration of sunlight. Kaolin paste is a good alternative as it increases permeability.

The walls and roof of the protected cultivation structure should be periodically sprayed with hydrogen peroxide or any car wash solution for algae removal. It should be wiped off immediately to ensure no wetness remains.

The nursery floor has to be cleaned every day and insect netting needs to be cleaned once every three months.

To disinfect the seedling trays: Trays can be steam cleaned and then rinsed with water, or treated with water mixed with chlorine.

Mechanical damage (Figure 36) to the insect mesh/polyfilm or shade net due to wear and tear, high winds or rodents needs to be repaired immediately to avoid entry of insects and pathogens.

Figure 36: Damaged net

Figure 37: Seedling trays arranged in plastic crates ready for transportation

It is strongly recommended to go for disposable trays to reduce the risk of infections. However, some nursery owners use re-usable trays when they sell seedlings locally around their nursery.

While using re-usable trays, they have to make sure to replace them immediately if there is any wear and tear. If the trays are disinfected between the seedling cycles, they may be used 3-4 times before being discarded.

The best method for transporting seedling trays is to use plastic crates arranged one above the other (Figure 37) in the transport vehicle (Figure 38).

Figure 38: Transport vehicle

12. HOW TO CALCULATE THE ECONOMICS OF RUNNING A NURSERY

1. Fixed costs

i. Structure cost:

Assume that a structure will have a useful life of 10 years, so the cost of constructing it can be spread over this whole period and divided by 10 to obtain the cost per year.

For example: A 1000 sq m structure costs Rs 1,000,000, so the investment cost for one year would be Rs 100,000.

If the nursery owner can produce 350,000 seedlings in one batch and produces 10 cycles in a year, then the total seedlings produced per year would be 350,000 x 10 = 3,500,000.

Then the structural cost per each seedling would be 100,000/3,500,000 = Rs 0.03 or 3 paise

Similarly, calculate the other following fixed costs per seedling.

ii. Labour cost = Total wages paid for permanent labour in one year/No. of seedlings produced per year.

iii. Administration costs (electricity + stationery + fuel + telephone + water) = Expenditure for one year/No. of seedlings produced per year.

iv. Land cost = Leased-in amount paid for one year or expected leasing-in costs for own land/ No. of seedlings produced per year.

Total Fixed costs (a) = structure cost + labour cost + administration cost + land cost

2. Variable costs

i. Tray cost:

For single use trays = Amount spent on purchase of trays/No. of seedlings produced.

For multiple use trays = Total amount spent on purchase/No. of seedlings produced x 3 (assuming three uses for each tray)

ii. Labour cost = Total amount paid to the temporary labour engaged in one year/No. of seedlings produced

iii. Media cost = Total cost of media used/No. of seedlings produced.

iv. Fertilizers & pesticides cost = Total cost/ No. of seedlings produced.

v. Transport cost = Cost of transport/No. of seedlings produced

vii. Wastage costs = 0.15 x total cost (assuming 15% of seedlings produced are not sold or are discarded)

Note: Wastage costs include mortality of seedlings, irregular/abnormally grown seedlings, unsold aged seedlings, seedlings affected by pests and diseases, seedlings rejected by farmers, gap filling, etc.

Total Variable costs (b) = tray cost + labour cost + media cost + fertilizers & pesticides cost + transport cost + wastage cost

Total cost of producing one seedling = Total fixed costs + variable costs (a+b)

Knowing their costs of production, nursery owners can set their per-seedling selling cost with a margin that is acceptable in the market.

13. IMPORTANT GADGETS AND THEIR USES

EC meter:

An electrical conductivity meter (EC meter) measures the electrical conductivity in a solution, and this gives a measure of the amount of salts in the water. The higher the EC, the higher the salts in the water or media, the more likely they are to cause damage to the seedlings.

Figure 39: Measuring EC of the medium

How to measure the EC of media

Take a sample of the coco peat medium and mix it with bottled drinking water or demineralised water at 3 parts per 1 part of medium. Add some more water if required to ensure that the EC meter dips in the mixture properly (Figure 39). Stir the mixture well and leave it for 15 minutes. Then strain it and collect the solution in another container. Coco peat may be pressed using a spoon to release the solution. Measure its EC by dipping the EC meter in the solution and note down the reading (ECc). Measure the EC of the demineralised water directly (ECw).

Subtract ECw from ECc to get the true EC of the medium.

EC of coco peat = ECc - ECw

Similarly, check the EC of water to be used for irrigation.

pH meter:

This is used to measure the acidity or alkalinity of the medium and water. The more acid, the more hydrogen ions are present.

Figure 40: pH meter

How to test pH of the medium:

Take a sample of the medium and mix bottled drinking water or demineralised water at 2 parts per 1 part of medium. Mix well, shake vigorously and wait. Allow it to sit for 1-2 minutes.

Turn on the pH meter and be sure to calibrate the meter before running the test (please refer to instructions in the manual). Remove the cap to expose the sensor and dip the sensor completely in the solution. Record the reading displayed on the meter.

Similarly, test the pH of the water.

Lux meter:

This is used to measure the light intensity received by the seedlings in the nursery.

To measure the light intensity, turn the lux meter on, set the readings to 100 times lux, move the lux meter in different places and see if the reading changes. The higher the reading, the higher the light intensity.

An Android mobile / IOS phone can be used as a lux meter by downloading an app named ' GPS Status & Tool Box' from the Play Store or Google apps. When opened, the installed app it shows the values of temperature light intensity, altitude, latitude and longitude of the location. This app works offline and is simple to operate (Figure 41).

There are several other smart phone apps in the Play Store for installing 'lux meters' that measure only light intensity. Use one that has good ratings.

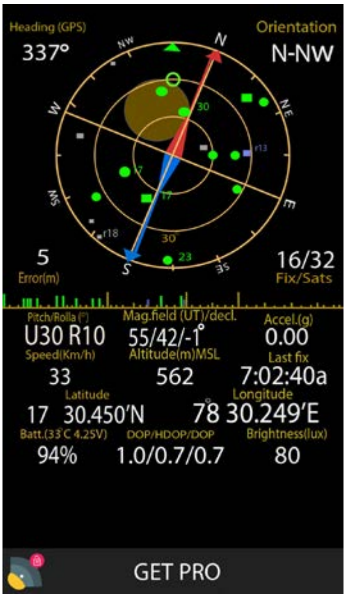


Figure 41: Lux meter reading

Figure 42: Lux meter

Dibbler:

A dibbler is used to make holes in the germination trays at a uniform depth.

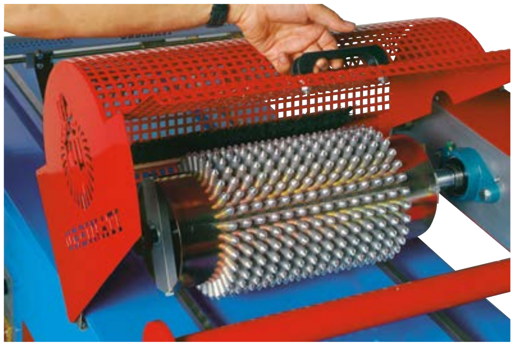


Figure 43: Dibbler

14. DO's and DON'Ts IN NURSERY MANAGEMENT

Go for double door system

Prefer nuts and bolts in place of welding

Prepare raised beds

Work on a tarpaulin sheet

Install EC meter and pH meter

Arrange the plastic crates properly in the transport vehicle

Do not spray when people are working without protective clothing

Do not leave gaps in the structure

Do not dump waste near the nursery

Do not allow weeds to grow at the nursery boundary

Ensure no gaps in the polythene cover

Do not leave gaps while spreading weed mat that may lead to weed emergence

Do not let water stagnate in and around the nursery

Do not keep the door open

Do not leave holes in the insect net

Do not allow the seedlings to come into contact with soil

Do not fold the seedling trays in the crate

Do not damage seedlings due to improper packing

Pack the seedling trays in plastic crates

Do not stack the sown seedling trays tightly

Do not allow other plants to grow inside the nursery structure

Do not overwater the growing medium

Do not dump unused material inside the nursery structure

Avoid black shade net under the roof during winter months

For further information, please contact

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