Protected Vegetable Cultivation Manual

May 2019

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Introduction

Commercialization of vegetable has been one the main priorities of the Ministry of Agriculture and Forests since the 11th Five Year Plan. The Ministry through the Department of Agriculture has initiated various plans and programs to realize the target. One among them is the promotion of year-round vegetable production through staggering of production. However, year-round production can be achieved only by promoting protected vegetable production technology such as conventional production system which is directly dependent on many biotic and abiotic factors.

Although the use of green houses has been promoted for quite some time, its full use as a space for large scale production has not gained much popularity. ARDC Wengkhar with support from Commercial Agriculture and Resilient Livelihood Enhancement Programme (CARLEP) initiated on-station research on protected vegetable production or vegetable production in greenhouse from 2016 to 2018 and began a parallel program to promote protected vegetable production esp with youth commercial farms and lead farmers.

In order to derive maximum benefit to farmers from green houses, the extension supervisors across the geogs would have to be given adequate guides in promoting protected cultivation practices. Thus, a proper manual to help guide extension supervisors and increasing number of literate farmers is prepared. The following sections of this manual presents guides in knowing about protected cultivation practices developed based on the works initiated on station and on farm.

Essential materials for protected vegetable production

Amongst various materials, **a greenhouse structure** of right frame strength and covering material is required. Similarly, plants need right amount of water at the right time. **Drip irrigation (micro-irrigation) system** is required to ensure controlled application of water to drip near root zone through a network of emitters.

Likewise, mulching is also crucial to control weed, regulate soil moisture and temperature. Growers can use either **synthetic or plant-based mulch**. However, use of locally available plant-based mulch such as straw and crop debris is environment-friendly and cost-effective. These materials upon decomposition emit heat which regulate temperature in the greenhouse. Such practice is useful especially in areas with high variation in diurnal temperature.

In addition, depending upon the agro-climatic condition of the greenhouse site, **heating and cooling system** may also be required. For that matter, a greenhouse with top ventilation may be necessary in hot and humid areas. Other materials such **stakes and trellis** are also recommended. The detailed list of materials required for protected vegetable production is as outlined in (Table 1).

Table 1: Materials required for protected vegetable production

Production inputs/ materials	Description
Seeds	Seeds of right crop varieties are required.
Greenhouse structure	Frame of right strength, covering and ventilation materials are required.
Irrigation materials	Drip irrigation set, HDPE pipes and water storage tank are required.
Mulching materials	Plastic mulch or ground cover mat or locally available plant materials.
Knapsack sprayer	Lower capacity sprayer is required for application of pesticides or foliar application of fertilizers.
Pesticides	Broad spectrum insecticides/ fungicides for preventive application will be useful. If possible, organic pesticides should be preferred over synthetic pesticides.
Fertilizers	Well decomposed manure for basal application and soluble fertilizers for supplementary application are required.
Training and pruning materials	GI pole or bamboo pole and jute rope or GI wires are required to make training structure; Secateurs are required for pruning.

Pre-requisite for protected vegetable production

Site selection is the key factor for profitable and sustainable production under greenhouse. The main factors determining location and site selection of a greenhouse production area are: **cost of production, quality of produced yield and transportation cost to markets**.

Apparently, the cost including the investment in technology (simple or sophisticated), quality of production as well as management depend primarily on the local climate and greenhouse growing conditions. Thus, the following pre-requisite needs to be considered for vegetable production under greenhouse.

- It is important to choose the right greenhouse design and materials according to the topography and microclimate of the place.
- The selected site should have disease free and fertile soil with reliable water supply and preferably electricity as well.
- The selected site should have accessible market. In fact, it is always wise to plan greenhouse vegetable production in a peri-urban area for better market.

Green house

Greenhouse is the foremost requirement to begin protected vegetable production. Therefore, a prior planning is required to determine suitable structure and design based on the agro-climatic condition of a place. The design and orientation of greenhouse is described in the subsequent section.

Design and orientation

The main purpose of a greenhouse is to provide a conducive environment for plant growth on a year-round basis or to extend the growing season. The environment inside the greenhouse is dependent mainly on solar radiation apart from other factors. Solar radiation is the main climatic factor needed to evaluate the climatic suitability of a place for protected production.

The total solar radiation received by greenhouse at a particular time and location depends upon its orientation, which ultimately determines the temperature of the air inside. Air temperature is one of the most dominant parameters affecting the plant growth. Hence, it is important to consider orientation of the greenhouse. Studies conducted in other countries show that, in northern hemisphere, greenhouse should be oriented in East-West direction to ensure uniform sunlight in the greenhouse (Figure 1).

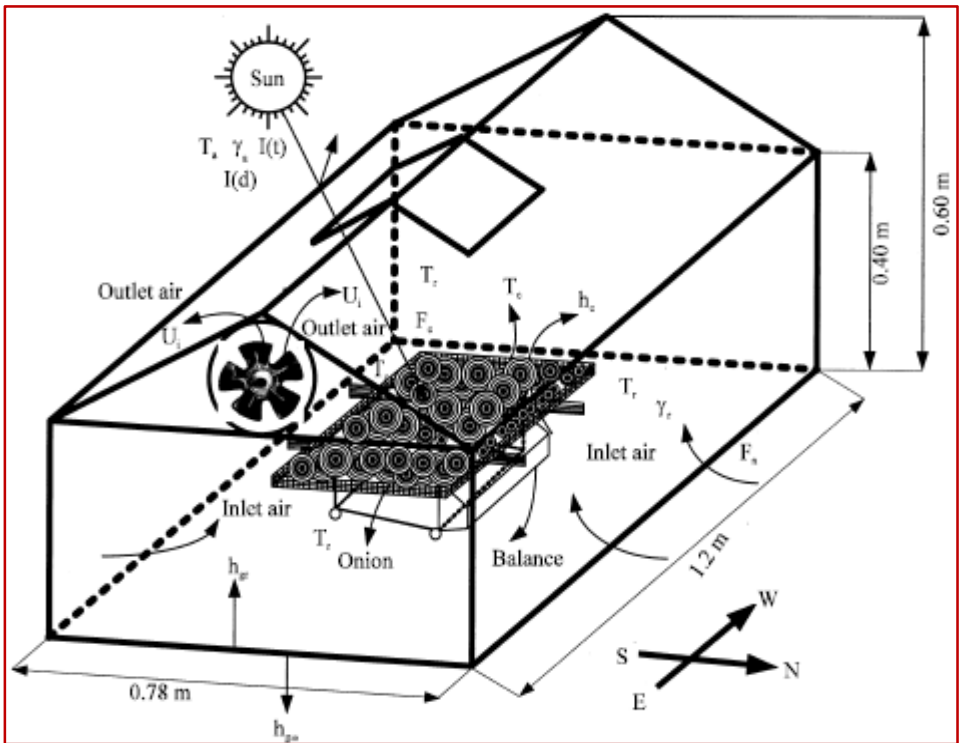

Figure 1: Orientation of a greenhouse

Further, the solar radiation received by a greenhouse also depends upon type of structure and design used. Therefore, it is advisable to use greenhouse covering with maximum light penetration. The structural parts that cast shadows in the greenhouse should be avoided. The most commonly used greenhouse design is a straight side wall and an arch roof.

However, the greenhouse design varies with the type of crops grown. Hence, the suitable greenhouse designs based on the type of crops are as follows:

- Straight side wall greenhouse design for tall growing crops.
- A hoop type greenhouse for short growing crops.

Adjusting greenhouse size

While it is possible to increase the size of greenhouse by adjusting the spacing between side angle posts (Table 2), it may not be a good decision to do so if a designated site is windy, experiences snow fall and hail storm, or has high pest and disease pressure. For instance, the size of greenhouse with a dimension of 10 m length x 5 m width, with an angle post spacing of 1 m can be increased to 15 m length x 5 m width dimension by adjusting the spacing between angle posts (Figure 2). Similarly, a greenhouse with a dimension of 20 m length x 5 m width with angle post spacing of 1 m can be increased to 30 m length (Figure 3). These alterations are done mainly to effectively utilize green houses.

Table 2: Adjustment of greenhouse size

Original dimension	Angle post spacing	Possible adjustment	Adjusted dimension
10 x 5 m greenhouse	1 m	0.5 m	15 x 5 m
20 x 5 greenhouse	1 m	0.5 m	25 x 5 m
10 x 5 m greenhouse	0.5 m	0.5 m	15 x 5 m
20 x 5 greenhouse	0.5 m	0.5 m	25 x 5 m

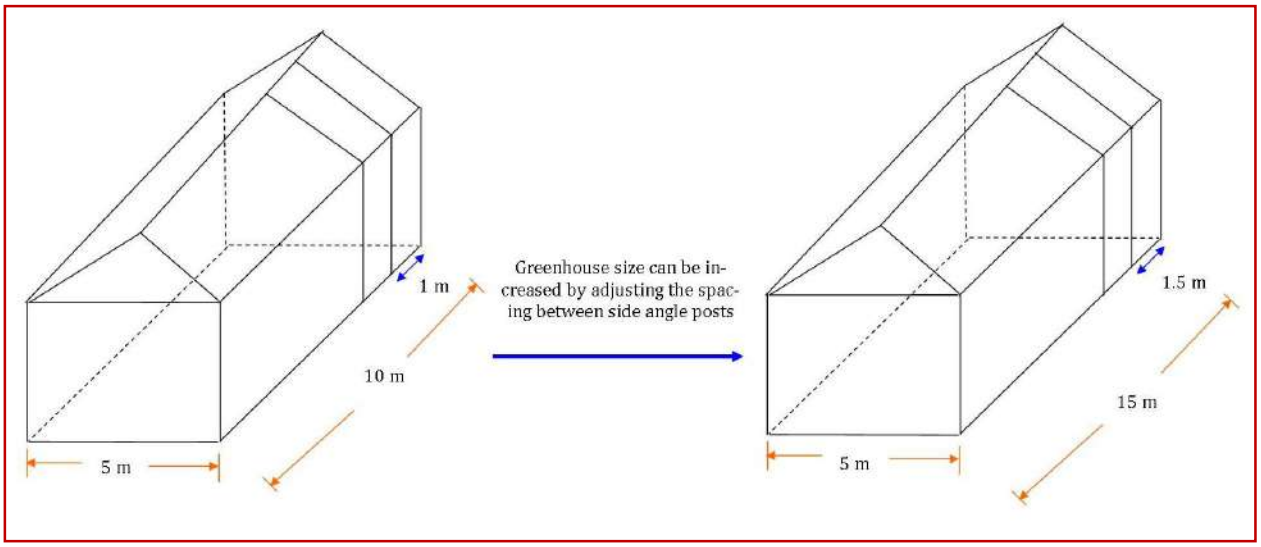

Figure 2: Increasing the size of 5x10 m greenhouse

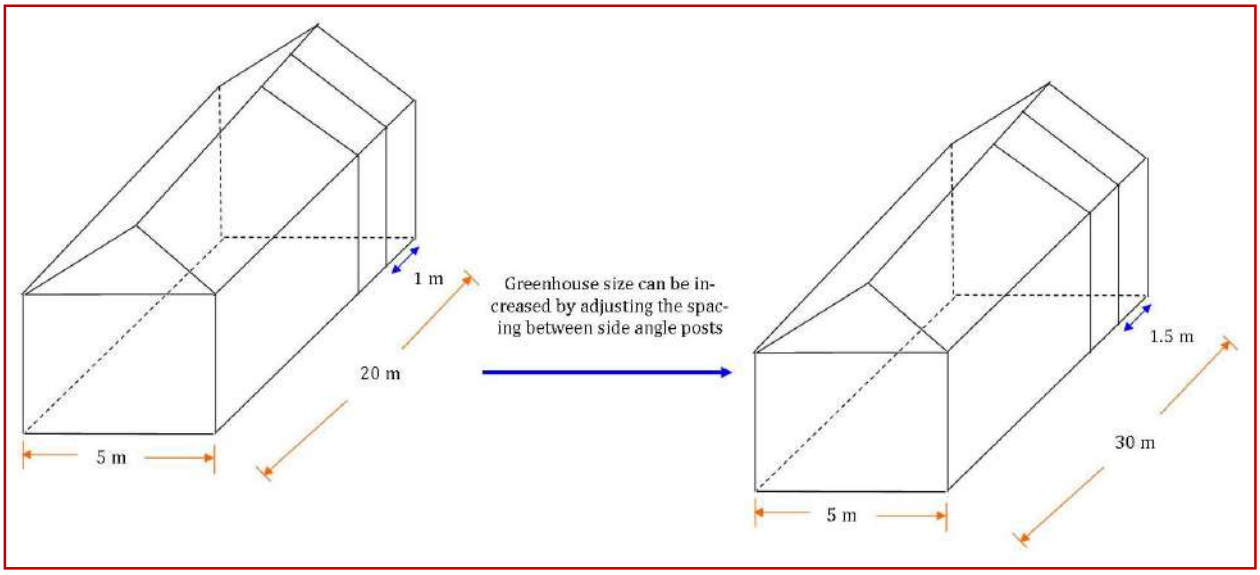

Figure 3: Increasing the size of 5x20 m greenhouse

Irrigation

Irrigation is crucial for both crop yield and product quality. Drip irrigation is the most common method for vegetables. Hence, to save time and resources, drip irrigation set with inbuilt non-pressure compensated emitters is suggested. Each set consists of 250 m length of drip line emitting pipe with a nominal flow rate of 1.6 L/h. Thus, for 20 m length and 5 m width dimension greenhouse (100 m^2 area) which can accommodate 8 rows of crops, 160 m length of drip line emitting pipe is required (Table 3).

Table 3: Greenhouse area utilization plan and determination of dripline emitting pipes required

Particulars	Length (m)	Width (m)	Nos.	Total
Greenhouse	20	5	1	**5**
Cropping bed	20	1.0	4	4.0
Between bed spacing	-	0.3	3	0.9
Between greenhouse edge and bed	-	0.05	2	0.1
No. of crop rows/ bed	-	-	2	8.0
Total width of greenhouse (m)				**5.0**
Dripline emitting pipe required (m)				**160**

Drip irrigation layout

As stated above, a greenhouse measuring 20 m length and 5 m width dimension, 4 beds of 1 m width with each bed of 2 crop rows can be accommodated. The dripline can be laid out along the crop rows. The commercially available drip set has emitter spaced at 0.3 m apart. Therefore, a plant to plant spacing has to be maintained at 0.3 m (Figure 4). Moreover, it is important to maintain adequate gravity between water tank and greenhouse. If possible, the drip irrigation system can be automated to save time and labour.

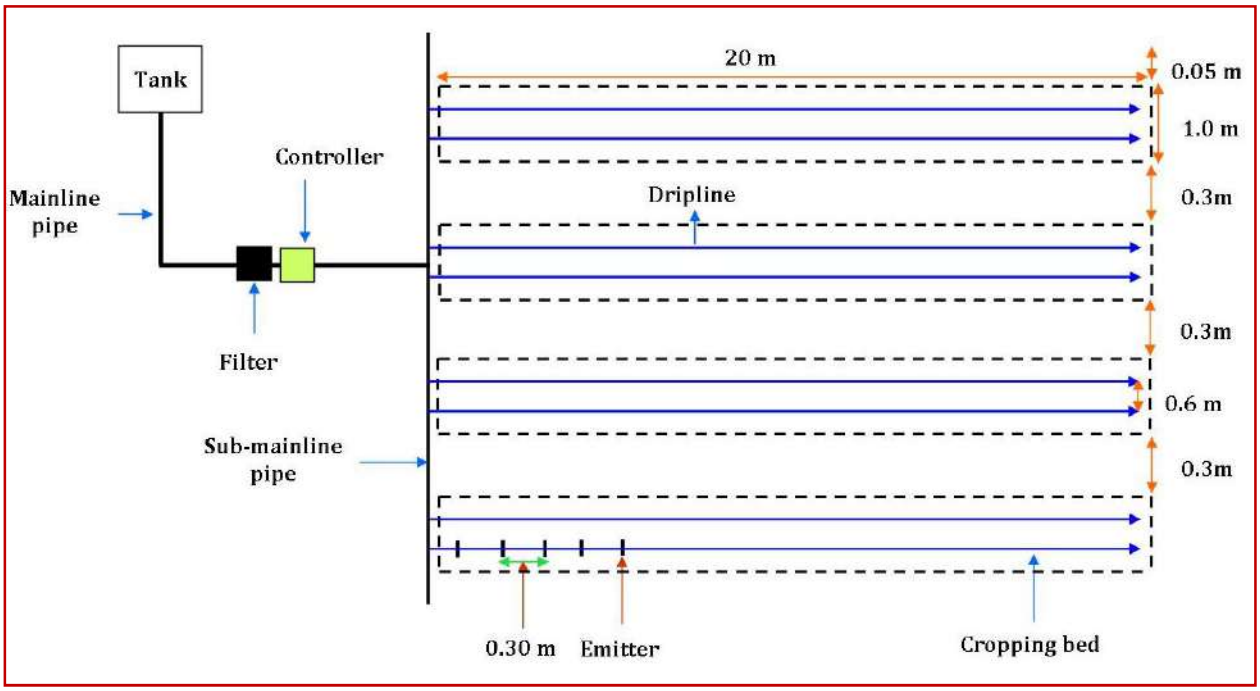

Figure 4: Drip irrigation system layout for 20x5 m greenhouse

Automation of irrigation system

Providing efficient irrigation system is very important is for successful production of any crops under protected cultivation system. However, at present most of the drip irrigation system are operated through manual control. This process sometimes consumes more water

and irregularity in watering causes the crops to dry. Water deficiency can slow growth rate and lead to lighter weight fruit. This problem can be solved by using automatic drip irrigation system in which the irrigation will take place only when the crops need to be watered. Valves are used to turn irrigation ON and OFF and is automated using controllers and solenoids in order to provide the right amount of water at the right time. Thus, automation reduces over watering and avoids irrigation at the wrong time of day thereby saving energy and labor cost compared to manual system.

The additional equipment required for automation of the irrigation system are as follows:

1. SMART irrigation controller: The SMART irrigation system consist of web or mobile app base controller with built in 8 watering zone expandable to 72 port. The controller can be connected to internet or local area network for controlling the irrigation system remotely. Each controller has the capacity to control the irrigation system for more than 100 greenhouses.
2. Solar panel, battery and charge controller: Solar panel with 40-50 Watt, 18AH rechargeable battery and a Charger controller are required for powering the irrigation controller. However, if the power is supplied directly from home 240 AC line, these equipment are not necessary. Instead, 5-10 Watt, 12V DC adaptor is required for this purpose.
3. Solenoid valve: Solenoid valve is an electrical valve which actually controls water flowing in the pipeline. At least one solenoid valve is required for each greenhouse
4. CPVC pipes and Joints: CPVC pipe and joints are required for making different watering zones and connection

Crop selection

Usually a warm season and high value crops are recommended for greenhouse production. However, in order to ensure right choice of crops and varieties, it is important to know the nature of pollination and other requirements. Some vegetable varieties pollinate on their own while some require pollens from other plants. Hence, vegetables have been classified into four groups based on their pollination requirement (Table 4).

Table 4: Classification of vegetables based on pollination requirement

Group	Pollination requirement
Group 1	Vegetables in this group have flowers that can receive only their own pollen (**Self-pollinated**) **Example: Beans, Peas and Tomatoes**
Group 2	Vegetables in this group have flowers that can receive pollen from an unrelated plant **Example: Cabbage and Radish**
Group 3	Vegetables in this group have flowers that can either receive their own pollen (**Self-pollinated**) or receive pollen from other plant (**Cross-pollinated**). They can be further sub-divided into two groups: (1) Pollinated by air-borne pollen; **Example: Beets, Carrots, Swiss chards, Onions, Celery and Spinach**; (2) Pollinated by Insect borne pollen; **Example: Broccoli, Brussels sprouts, Gourds, Parsley, Kale, Parsnip, Cauliflower, Kohlrabi, Peppers, Lettuce, Pumpkins, Collards, Muskmelon, Cucumbers, Mustards, Squashes, Eggplant, Okra, Watermelons**
Group 4	Vegetables in this group have male and female flowers on separate plant (**Dioecious**). Seeds are formed only when male plants furnish pollen. **Example: Asparagus, Spinach and Hybrid cucumbers**

Similarly, it is also important to know the classification of vegetables based on their humidity requirement as greenhouse would be more humid than open field. Therefore, the vegetables are usually classified into four classes ranging from low humidity to very high humidity requiring crops (Table 5).

Table 5: Classification of vegetables as per their humidity requirement

Class	Humidity requirement
Very high	Vegetables in this group require very high humidity (85~95%) **Example: Cucumber, Celery, Spinach, Mushrooms, Lettuce**
Relatively high	Vegetables in this group require relatively high humidity (70~80%) **Example: Cabbage, Beets, Carrots, Parsnips, Parsleys, Potatoes, Peas**
Relatively moderate	Vegetables in this group require relatively moderate humidity (55~65%) **Example: Tomatoes, Peppers, Beans**
Relatively low	Vegetables in this group require relatively low humidity (45~55%). **Example: Yellow watermelons, Pumpkins**

Considering the specific crop requirements outlined above, it is good to choose warm season crops such as tomato, chilli, brinjal, beans and cucumber for protected condition. Further, it may be important to note that hybrid seedless varieties perform better under protected condition than the open pollinated varieties.

Crop management

Crop management is vital to optimize productivity under protected condition. Hence, emphasis should be given to maximize utilization of limited space in the greenhouse. Accordingly, priority may be given to tall growing crops such as indeterminate type of tomatoes to effectively utilize vertical space of the greenhouse. Important amongst many agronomic requirements is training and pruning. For instance, tomato crop needs to be trained on vertical cordon system (Table 6).

Table 6: Specific management required

Crops	Specific management required
Tomato	Tomato plants should be on Vertical cordon system. Prune to a single stem; remove all suckers up the plant to the wire; allow two suckers to develop at the wire; break out top, and let suckers grow back toward ground.
Cucumbers	Cucumbers are trained on vertical cordon or trellis or umbrella system using wire and string. Remove all lateral branches, flowers and tendrils to 8-10 leaf nodes for proper development of root and vegetative stem prior to fruit set.
Pole beans	Pole beans are wrapped from a single stem. The side shoots are not removed.
Chilli	Chilli is usually trained to grow vertical. Use nylon threads or string to trellis each fruiting branches. Remove the basal leaves, shoots and some flowers for proper growth. Shorten lateral shoots maintaining 2-3 fruits on secondary shoots and maintaining 2-4 branches.

Staggering of production under protected condition

Greenhouse allows year round production. However, as noted earlier, vegetable crops have specific climatic requirements. Hence, in order to optimize staggered production through adjustment of cropping calendar under protected condition, some of the key management as illustrated in Table 7.

Table 7: Key guide to optimize production under protected condition

Months	Task	Crops
November to December	• Remove shading and clean up greenhouse. • Repair any damage which could cause heat loss. • Keep ventilators open on hot sunny days and close at night.	✓ Plant beans/ raise nursery for Chilli, Tomato and Cucumber in low altitude areas.
January	• Ensure that the greenhouse receives enough sun light. • Avoid over or under irrigation to prevent disease. • Monitor for whitefly, Aphid and Powdery mildew. • Procure seeds and compost for crops.	✓ Transplant Chilli, Tomato and Cucumber in low altitude areas.
February	• Irrigate frequently but avoid under or overwatering. • Install automatic drip irrigation system. • Clean up greenhouse and spray if necessary. • Raise nursery for spring planting.	✓ Raise Tomato, Chilli, Cucumber and Trap crop nursery in mid/high altitude areas
March	• Maintain greenhouse temperature between 10° to 20°C by keeping the ventilators closed. • Keep ventilators open during the day and close at night. • Use liquid fertilizer to ensure early uptake by plants. • If possible, apply fertilizer through drip system (fertigation). • Monitor for whitefly, red spider mite and spray if required. • Install traps/ integrate trap crops to control pest.	✓ Check training system, irrigation structure and prepare for transplanting
April	• Maintain greenhouse temperature between 10° to 25°C • Monitor for whitefly, red spider mite and spray if required • Install training system and check for irrigation structure	✓ Transplant Tomato, Chilli and Cucumber
May	• Maintain greenhouse temperature below 30°C during hot sunny days. In hot areas, keep the greenhouse floor wet and use table fan to regulate temperature. • In high altitude areas, mulching may also help regulate soil temperature.	✓ Train Tomato and Cucumber plants. ✓ Provide supplementary nutrition.
June	• Provide shading to plants which are prone to scorching. • Keep the ventilators open and greenhouse floor wet to regulate temperature during hot summer days. • Maintain sanitation and restrict entry to people coming from disease infected areas	✓ Harvest early Tomatoes and Cucumbers
July	• Maintain shade if you are growing crops prone to scorching. • Monitor for whitefly, red spider mite and spray if required. • Provide supplementary nutrition to plants. • Keep the ventilators open and greenhouse floor wet to regulate temperature during sunny days	✓ Harvest early Tomatoes and Cucumbers ✓ Raise nursery and prepare for second crop
August	• Uproot and clean up greenhouse and prepare for second crop • Monitor and repair greenhouse if there are any	✓ Transplant second crop

	damages	
September	• Temperature can fluctuate. So close ventilation at night. • Check plants for pest and disease if any, before bringing in	✓ Manage second crop
October	• Open ventilators during the day and close at night. • Water plants sparingly and carefully. • Remove diseased plants or plant parts or fallen leaves to prevent spread of disease.	✓ Harvest second crops

The cropping calendar for production of Tomato, Chilli and Cucumber under protected condition at different altitude range is shown in Figure 5. Please note that the cropping calendar is developed only as a general guide to enable growers to effectively schedule production under protected condition.

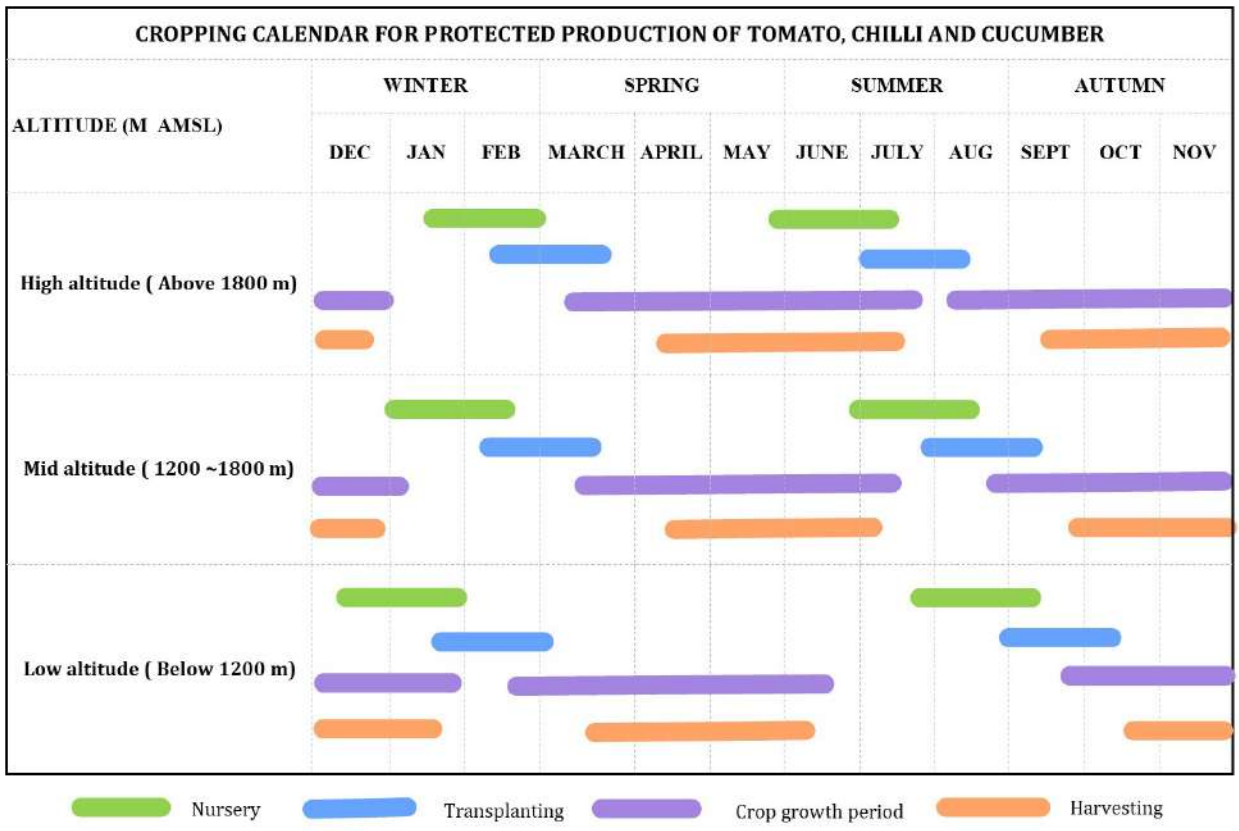

Figure 5: Production calendar for staggering of production at different altitude range

Pest and disease control

The incidence of pest and disease in greenhouse condition depends on sanitation. Failure to maintain strict sanitation will lead to introduction of pest and disease in the greenhouse. Once the protected environment gets contaminated, it is quite difficult to control as hot and humid condition leads to rapid pest population build up.

Hence, following preventive measures may be useful to maintain proper sanitation and avoid introduction of pest and disease in the greenhouse:

- Avoid sites with a record of high pests and disease incidence.
- Use pest and disease-free growing media and seeds/ seedlings. Keep the area free from weeds as they are known host to most pests and diseases.
- Regulate entry of people into the greenhouse. Adopt a practice of sanitizing the tools before and after use.
- Follow recommended crop management practices.

Soil Fertility

While chemical fertilizers and micro nutrients are useful in ensuring proper soil fertility, properly decomposed compost and vermi compost are equally important. A proper compost yard is recommended to ensure continued fertility of soil. Application of improper decomposed Farm yard Manures are not recommended as it emits foul smell and attracts pests such as while flies. Top soils collected from surrounding forests mixed with compost can be a perfect soil media to ensure fertility. Periodic soils test is recommended to ensure only required fertilizers are applied.

Determining profitability of protected production

In order to ensure that protected production is profitable and competitive in the long run, it is important to continually monitor production system and adjustment required. The cost includes fixed (or initial investment) cost, variable cost (cost of producing a particular

vegetable) and gross return obtained by selling the product at prevailing market prices. The fixed cost should also consider depreciation on fixed cost.

In this way, the growers will be able to determine profitability of protected vegetable production and point out if any specific adjustment in the production system is required.

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