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Pruning and Training Under Protected Structures

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Protected cultivation refers to the practice of cultivating crops in controlled environments, such as greenhouses or tunnels, to enhance their quality and yield, particularly during unfavourable weather conditions. This method allows farmers to increase their profitability by enabling year-round production of desired vegetables, regardless of the season. By optimizing plant density through closer spacing and encouraging more fruiting branches per unit area, protected cultivation significantly boosts crop yields.

The management techniques involved in protected cultivation differ from those used in open-field farming. In regions like Northern India, high-value vegetables such as tomatoes, cherry tomatoes, coloured bell peppers, parthenocarpy cucumbers, pole-type French beans, winter watermelons, and muskmelons can be successfully cultivated out of season using polyhouses or walk-in tunnels (ICAR-CISH, 2015).

Training gives the plants a desirable shape and structure to grow well, utilizing the available space and other resources so that the maximum yield potential can be reached. It is of great importance in the purview of protected cultivation. The major objectives of training include the removal of excess growth, providing the desired architecture for the plants, minimizing direct contact with soil, maximizing the efficiency with which the resources are utilized and facilitating easy intercultural operations. Some of the common training methods followed in vegetable crops under protected cultivation are single stem training (tomato, cucumber), two stem training (tomato), three stem training (tomato), four stem training (capsicum), V-system and umbrella system (cucumber), *etc.* (Parmar, 2020).

Tomato

Training: Every branch is guided individually along a distinct plastic twine suspended from an overhead GI wire trellis support system positioned 3 meters above ground level. This method ensures that branches remain intact and do not succumb to the weight of foliage and fruits. Tying and supporting of the branches start from one month after transplanting before the appearance of tendrils at regular intervals. The plants are tied carefully and tenderly to avoid damage or breakage to the growing parts.

Lowering of plants

The indeterminate plants tend to grow upward and they need to be lowered periodically to maintain them at required workable height. This is done by providing an extra length of supporting plastic twine from the beginning stage. Lowering the plants is done at 20 to 30 days interval starting from 80 to 90 days after transplanting.

Deleafing

The older leaves that are shaded by the new growth or touching the ground surface are removed periodically to reduce fungal infections and pest accumulation. Starting from 70 days after transplanting, leaves are retained to a length of about 1.5 m on the stem from the growing tip at any stage of growth.

Kumar and Patel (2016) reported that significantly maximum fruit volume (146.45 cm^3), pericarp thickness (8.30 mm), equatorial diameter (6.18 cm), polar diameter (6.68 cm), dry matter content (5.23 g), fruit texture (4.22 kg cm^{-2}), total soluble solids (4.07 Brix), vitamin A (1109.44 IU), lycopene content (2.60 mg) and shelf life (20.65 days) were observed in single stem training system.

When different systems of lowering the plants by using hangers and different crop densities were compared for long-cycle cultivation of tomatoes in the greenhouse during various cropping seasons, it revealed that increasing density and using hangers enhanced the production between 10 and 34%, and the profitability of the cluster tomato crop between 16 and 48% compared to the traditional system. Also, in low-

height greenhouses, the use of hangers at low or medium heights is recommended (Gazquez et al., 2017).

However, Liang et al., in 2017 reported that pruning and lowering of the tomato plants resulted in a slight increase in the air temperature in a greenhouse with a height of 4m and a floor area of 750 m^2. But, both before and after pruning the greenhouse air temperature was most of the time cooler than external air temperature.

Pruning

Initially, tomato plants spaced at 60 x 45 cm are pruned to retain two stems per plant. Pruning operation starts 20 to 30 days after transplanting at weekly intervals. The main stem of tomato plants branches into two after the first flower cluster. Tomato plants are pruned to remove axillary buds and leaves. Plant pruning creates a drier microclimate in the lower plant, but also provides numerous points of entry for many pathogens such as *D. lycopersici* and *B. cinerea*. Pruning wounds on tomato plants are less likely to become infected by these pathogens if the leaves are cut close to the stem.

Suckers forming in the axils between the leaves and the main stem are removed. A strong main stem is encouraged by removing all suckers below the first flower cluster. Only two branches are retained and all other branches and buds/ suckers developing at the base of the stem are also removed. For pruning the entire sucker is removed at the base or the tip of the sucker is pinched out.

Pruning is best done early in the day when plants are turgid but dry and this also allows the wound to dry sufficiently during the day making it less susceptible to decay organisms. It is best not to prune during cloudy periods because drying of the wounds is not optimal (Hanafi, 2003).

Capsicum

Spacing

Capsicum is planted at a distance of 45cm x 30 cm in a triangular manner.

Pruning and training

Capsicum plants are pruned to retain four stems. The tip of the plant is allowed to split into two at 5th or 6th node and is left to grow. The pruning is done after 30 days of transplanting. These two branches again split into two giving rise to four branches. The axillary buds are removed periodically resulting in bigger fruits with better quality and high productivity. The main stem of the plant is tied with plastic twine to train along and tied to GI wire grid provided on the top of the plants. This is practiced after four weeks of transplanting. The new branches and plants are trained along the plastic twines.

Deleafing

The older leaves that are shaded by the new growth or touching the ground surface are removed periodically to reduce fungal infections and pest accumulation. Leaves are retained to a length of about 1.0 m on the stem from the growing tip at any stage of growth.

Parthenocarpic Cucumber

Spacing

Cucumber is planted at a distance of 60cm x 60 cm in a triangular manner.

Pruning and training

The cucumber plants are trained upwards retaining 2 branches for better interception of light. The main stem is pruned to 25 cm and two strong laterals are allowed to grow. If too many fruits are set at once, fruit thinning is necessary to avoid malformed and non-marketable small fruit. Such fruit should be removed as soon as possible when they are produced in bunches. Weak and unproductive lateral branches should be removed.

Deleafing

The older leaves that are shaded by the new growth or touching the ground surface are removed periodically to reduce fungal infections and pest accumulation. Leaves are retained to a length of about 1.5 m on the stem from the growing tip at any stage of growth.

Brinjal

Training and pruning

Brinjal crop should be trained by keeping two main shoots which helps in utilizing vertical space, avoid the overshadowing of plants. Leaves at the base that are dried or touching the ground should be

removed. It helps in the proper translocation of food material to the upper productive portion of the plant.

Impact of cropping systems and cultural practices on vegetable quality

An increase in plant density generally correlates positively with yield. However, it correlates negatively with the proportion of the marketable yield. Cultivating season also influences the yield under different plant densities. Thus, Heuvelink and González-Real (2008) recommend plant densities related to cultivating seasons: typically, a tomato crop in the Netherlands has a planting stem density of 2.5 plants per m^2 in the summer and when radiation availability is higher, stem density is increased by 50% to 3.75 stems per m^2**.**

In cherry tomatoes grown hydroponically, two different pruning methods were compared, namely, T0 (control) pruning was performed in two sprouts, leaving the primary and secondary sprout that sprouts below the second inflorescence and treatment T1 (candelabra) pruning was performed in two sprouts, also leaving an auxiliary sprout below the second inflorescence of primary and secondary stems that form the structure of the plant. The results revealed that there were no statistically significant differences between treatments T1 (candelabra) and T0 (control) in terms of increase in the number and weight of the total and marketable fruit per area. However, the treatment T1 got greater values in terms of the fruit quality parameters like soluble solids content and lower acidity (Franco et al., 2009).

Pruning is an operation used to support training, to improve light relationships, equilibrate plant growth and development, provide better control of diseases to minimize yield losses, and improve product quality (Gruda and Tanny, 2014). Wrong pruning, such as a higher quantity of cucumber fruits will lead to the pushing-off of young fruits, even if the plants are well supplied with nutrients. Pruning clusters to three fruit increased the total marketable yield and fruit weight of different greenhouse tomato cultivars, cultivated in different growing media in two successive seasons (Hanna, 2009).

Removal of all branches up to 45 cm height helped in achieving higher yield in cucumber grown under polyhouse. The maximum number of fruits per vine (38.17), fruit weight (118.04 g) and yield per m^2 (17.71 kg) were found when all the branches were removed up to 45cm height (Kapuriya, 2016).

INNOVATIONS

Robotics and automation

Crop maintenance and harvesting are much more difficult to automate because the position, shape, size and colour of products vary widely and thus high-tech mechanization, robotics, or mechatronic systems are required. These systems rely extensively on sensors and computing power to process data and to mimic the intelligence and very efficient eye-hand coordination of humans. (Giacomelli et al., 2008).

Currently, in the Netherlands, two commercial projects are underway to develop robots for crop maintenance and harvesting. One project, called Tomation, has a goal to develop a leaf removal robot for tomato plants grown in a high-wire cultivation system. Another project proposes building a harvesting robot for roses. In Japan, work is underway to construct a strawberry harvesting robot. Given the growing pressure on horticultural companies to improve the efficiency of their production, high-tech robotics and automation will have an important future in protected cultivation (Giacomelli et al., 2007).

System Logistics

A paradigm shift has become apparent in horticultural industry. Instead of the maintenance staff moving to or through the crop, the crop is transported (on movable benches or movable gutters) and brought to the staff for maintenance and harvest. This approach is common practice in the production of potted plants. Production of roses, gerbera, chrysanthemum and even tomato has been evaluated in the Netherlands. However, the success of these systems is not guaranteed and research into this direction is required (Giacomelli et al.,2007).

Sensing Techniques - Monitoring with Sensors

A novel sensing technique for greenhouse horticulture is based on measuring organic volatile components emitted by the plant when changes in the health and metabolic state of the crop occur (Jansen et al., 2008).

The topic of 'speaking plant' has been discussed for a very long time, and now there are more opportunities than ever to listen to the plant. The plant condition within the greenhouse environment is more important than the greenhouse climate condition. Much study is in progress to monitor the near real-time plant conditions (Giacomelli et al.,2007).

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