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Alteration in Flowering and Fruiting of Commercial Vegetable Crops under Protected Condition: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

India ranks as the second-largest global vegetable producer, yet its current productivity falls short of meeting the nutritional requirements of its expanding population. The country boasts an impressive array of vegetable varieties, spanning from tropical to subtropical and temperate regions. The adoption of protected cultivation for high-value crops has emerged as a pivotal technology to enhance productivity, elevate quality, and secure profitable returns. Optimal production quality can be ensured by implementing precise crop management techniques under controlled conditions, enabling the cultivation of two to three high-yield crops annually. Crop regulation planning entails the identification, selection, implementation, and monitoring of strategies to govern the yield and quality of vegetable crops. The timing of flowering can be strategically manipulated, either advanced or delayed, in response to market demand, leveraging a range of tools and techniques for flowering and fruit regulation. In pursuit of sustainability, it becomes imperative to maximize food

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production within limited areas. Employing flowering and fruiting regulation methods holds the promise of augmenting yields and, consequently, overall productivity, ultimately addressing the nutritional needs of a larger segment of the population.

Keywords: Crop regulation; High value crops; protected cultivation and sustainability.

1. INTRODUCTION

In the context of market globalization, land scarcity, and climate change, protected cultivation of high-value crops has become a pivotal technology for achieving increased productivity, improved quality, and profitability [74]. Flowering is a critical stage in the fruit development process since the presence of flowers directly impacts the presence of fruit. Events during flower formation and fruit set have significant implications for fruitlet development, final fruit size, quality, and overall return [34,39,41].

Protected cultivation involves manipulating the microclimate surrounding plants to shield them from adverse weather conditions. This approach optimizes energy use, particularly solar energy [47]. Growing vegetables in protected conditions not only enhances water and nutrient efficiency but also boosts productivity by 3-5 times compared to open-field cultivation in various agro-climatic conditions across the country [60].

Uncontrolled growth tends to favor vegetative growth over reproductive growth, necessitating the regulation of crops to avoid market oversupply and ensure a consistent vegetable supply. Increased flowering intensity resulting from stress indicates that flower differentiation occurs during moisture stress, and generative buds remain undeveloped until water is supplied. Moisture stress, followed by relief, effectively triggers vegetative growth [21,30,33,50]. Extended periods of stress, caused by factors like extreme temperature and humidity, can delay flowering [83]. Singh and Chadha argued that inducing stress led to uniform flushing, and the intensity of flushing correlated with the level of stress, as indicated by the plant's relative water content before relief.

In the case of commercial vegetable crops like tomatoes, bell peppers, and cucumbers grown under protected conditions, flowering time can be adjusted as needed, either through early intervention or by employing various tools and techniques for flowering and fruit regulation, including mechanical, environmental, and chemical methods [4,9,10].

2. PRINCIPLE AND OBECTIVES OF CROP REGULATION

Crop regulation entails the essential concept of altering a plant's natural flowering and fruiting patterns to optimize fruit yield, quality, and profitability [27]. This principle revolves around the understanding that the majority of crop flowers appear exclusively on young, tender, and rapidly growing vegetative shoots. The primary objective of crop regulation is to induce the plant to enter a rest phase, prompting it to yield an abundance of blossoms and fruits within a specific season [22]. The key reasons behind crop regulation are to ensure a consistent supply of high-quality crops and maximize both production and profits for the grower. Without this regulation, continuous and uninterrupted flowering would result in light crop yields throughout the year, significantly increasing monitoring and marketing costs [83].

3. IMPORTANCE OF PROTECTED CULTIVATION

Protected horticulture, being the most effective solution to counteract the challenges posed by climatic variations, holds the potential to cater to the requirements of small-scale growers. It not only multiplies crop yields but also significantly enhances food quality to meet market demands [82].

Protected cultivation represents a key approach in this endeavor. It constitutes an agrotechnology that involves the use of coverings to control both macro and microenvironments, ultimately fostering optimal plant growth, prolonging the growing period, encouraging early maturation, and bolstering both yield and quality [53,54,42,48]. Employing protected cultivation for crops ensures superior produce quality, increased productivity, year-round cultivation possibilities, controlled pollination, improved management of insect pests and diseases, reduced pesticide residues, simplified plant protection, efficient resource utilization, higher profitability, guaranteed production, and increased nutrient extraction [51,59,62]. Additionally, it creates opportunities for educated rural youth to engage in self-employment within the agricultural sector. It's important to note that the microclimate within greenhouses significantly influences crop growth, development, and overall productivity [73].

During the winter season, the primary systems for controlling the greenhouse climate include heating, ventilation, and CO_2 enrichment [6]. In contrast, during the summer months, the main systems utilized consist of ventilation (either natural or forced), shading through screens or whitening, CO_2 enrichment, and cooling through fan and pad systems [6].

4. FACTORS AFFECTING FLOWERING AND FRUITING UNDER PROTECTED CONDITIONS

4.1 Temperature

Because the steel structure of the poly home is wrapped with polythene, the interior temperature can reach 40°C [22]. The ventilation system, as well as cooling pads and fans, are utilised to regulate the temperature within the poly home Pickens and Sibley (2019). However, fruit set is determined by the 24-hour mean temperature and the temperature variation between day and night Hatfield and Prueger [58].

4.2 Relative Humidity

Relative humidity (RH) is a measure of the water vapor content in the atmosphere, and it's important to note that the air's capacity to hold water vapor is influenced by temperature [78]. To ensure the health and optimal growth of vegetables, maintaining an appropriate humidity level is crucial. Vegetables typically thrive in an environment with a humidity level ranging from 60 to 65 percent [12].

Transpiration, a vital plant process, serves multiple functions, including cooling the plant, facilitating nutrient uptake from the roots, and distributing resources throughout the plant. It plays a pivotal role in optimizing photosynthesis efficiency, the effective transport of nutrients within the plant, and the distribution of these nutrients for overall plant growth. Relative humidity plays a significant role in minimizing water loss through evaporation from plants, leading to efficient nutrient utilization. Moreover, it helps maintain cell turgidity, which is advantageous for enzymatic activity, ultimately resulting in improved crop yields.

4.3 Light

Photosynthesis exclusively takes place within the spectrum of visible light. In poly-house technology, the management of light is optimized to ensure that plants receive the maximum amount of visible light while any surplus light is reflected back [11]. In general, higher light intensity within the greenhouse leads to increased rates of photosynthesis and transpiration, which in turn elevates humidity levels and solar heat gain [8].

Studies have revealed that reducing light levels from 10,000 to 2,500 lux can delay the onset of flowering. Greenhouses are designed to capture a portion of the incident light, allowing up to 80 percent of the light to reach the crop around midday and an average of 68 percent throughout the day [28].

4.4 Carbon Dioxide

The ambient environment typically contains a CO_2 concentration of 0.03 percent, which is equivalent to 300 parts per million [86]. Plants use this CO_2 for photosynthesis. During the night within a poly-house, photosynthesis comes to a halt, but CO_2 is released as a result of respiration [26]. As a consequence, poly-houses consistently maintain a higher CO_2 concentration compared to the outdoor environment, particularly during the nighttime [16].

This surplus CO_2 becomes a valuable resource for plants in poly-houses, enabling them to undergo more rapid photosynthesis. Research has shown that when the CO_2 concentration in a poly-house reaches 1000 parts per million (ppm), vegetable yields can increase four to fivefold compared to regular conditions. The ideal CO_2 concentration typically falls within the range of 350 to 1000 ppm [20].

4.5 Wind Movement

If a poly-house has a higher humidity level, the risk of illness and pests increases. Under these conditions, the poly-side house's vents are opened to improve air flow within the structure. As a result of the increased air movement, the humidity level lowers and the risk of disease also decreases [11].

4.6 Nutrients Required by Plants

When conducting a chemical analysis of plants, it has been observed that they contain over 90 different components. However, only 17 of these components have been identified as essential for the successful growth and development of plants, based on the essentiality criterion [25]. Recent research has revealed the necessity of additional elements like vanadium, silicon, cobalt, sodium, and nickel for the growth of specific plants.

The carbon-to-nitrogen ratio, often denoted as the C/N ratio, in soil refers to the ratio of organic carbon to nitrogen content. This ratio plays a significant role in the rate of decomposition of organic matter in residues. Microorganisms responsible for breaking down residues require nitrogen, along with other crucial components, in addition to carbon. When the residue lacks sufficient nitrogen, the decomposition process is slowed down. Furthermore, in cases where the residue has a low nitrogen content, microbes may extract inorganic nitrogen from the soil to meet their nitrogen requirements. This can lead to competition with plants for nitrogen, ultimately reducing the available soil nitrogen for plant growth [1].

The optimal supply of nutrients has been found to promote early flowering in cucumber due to vigorous vine growth [24]. Additionally, the maturity of fruit is significantly influenced by fertilizer application, as demonstrated by prior research [63,64,65,68], which showed that 100% fertigation can induce early harvest in polyhouse conditions.

5. REGULATION OF FLOWERING AND FRUITING IN COMMERCIAL CROPS

5.1 Flowers

In the typical growth of tomato plants, clusters of flowers are usually left unclipped until three to four well-formed fruits have developed on the cluster. However, in the case of anomalous flowers, like the oversized captivated flower, immediate removal is necessary. These anomalous flowers can give rise to fruits with peculiar characteristics, such as a cat's face [22].

Young capsicum plants, when they have 7 to 13 leaves, typically commence flowering within a range of 2 to 6 weeks after being planted [18]. It's essential for the temperature conditions during flowering to fall within the ideal range, averaging between 20 and 21 degrees Celsius, both during the day and at night. Low night temperatures can negatively impact pollen viability in capsicum flowers, alter their floral structure, and diminish the effectiveness of self-pollination. Flowers that develop at night temperatures below 18 degrees Celsius tend to produce fruits with a 'tail,' characterized by elongation and a pointed blossom end. Insufficiently warm temperatures during flowering may lead to a reduction in the number of locules in the fruit, potentially resulting in fruit with only two locules, which is undesirable [70,72]. Conversely, excessively high temperatures, surpassing 28 degrees Celsius, can contribute to the development of blossom end rot [43].

Tomato Pollination: Tomato flowers have male and female organs [85]. To facilitate pollination in greenhouses, growers use methods like vibrators, air blowers, and bumble bees since natural wind is absent. Effective pollination is essential to maximize tomato fruit size and weight [75]. Bees, such as bumble bees or honey bees, are commonly employed as pollinators in greenhouses [3]. Using pollinators ensures better fruit formation, improved harvest, and earlier initial harvest [22]. Stingless bees have also proven to be efficient pollinators for greenhouse crops like tomatoes [89] and sweet peppers [35].

Cucumber Pollination: Cucumber pollen is large and sticky, requiring external assistance for transfer between flowers. Adequate pollination leads to well-formed, uniformly ripening fruits, while inadequate pollination results in undersized, malformed fruits and reduced yields [66]. In greenhouse settings, gynoecious slicing cucumber varieties do not require pollination. However, monoecious cucumber varieties need pollination, primarily performed by honeybees [142]. Bee pollination in greenhouses can be challenging, as bees need to adapt to the indoor environment. Nonetheless, native and Africanized bees also contribute to greenhouse crop pollination [92]. An insect's foraging behavior depends on several factors, including innate behavior and floral characteristics [44]. Successful greenhouse cucumber production relies on the use of pollinators [49].

5.2 Use of Growth Regulators

The tomato flower's female organs are encased within the male organs (five anthers form a cone around the female organ) [85]. When anthers

Table 1. Environmental control

Crop	Temperature	Relative Humidity	Carbon dioxide concentration
Tomato	22-29℃	55-75%	900-1200ppm
Capsicum	18-27℃	60-80%	900-1200ppm
Cucumber	19-31℃	60-75%	900-1200ppm

mature, they open to the interior, releasing pollen (Melissa, 2021). When mature, the anthers will be a bright yellow colour and the bloom will remain pollination-receptive for around 48 hours. Because natural wind is absent in the greenhouse, tomato growers must pollinate their crop using a variety of methods, including battery-operated vibrators, air blowers, and bumble bees. Additionally, growers should make every effort to transport the maximum amount of pollen to the flower's stigma [22]. The tomato fruit's size and weight are positively connected with the amount of pollen transported to the female portion of the flower [75,80,81,84]. Within the tomato, utilize pollinators such as bumble bees or honey bees inside the greenhouse to assure a set of high-quality crops (Ahmad 2009). Bees ensure that fewer fruits are malformed, that fruit set and first harvest are improved, and that the first harvest occurs slightly earlier [22]. Recent research demonstrates that stingless bees are also an effective alternative to honeybees for pollinating a variety of greenhouse crops of considerable economic and social importance, including strawberries [90,89,91,92] tomatoes [89], and sweet peppers [89,35].

5.3 Parthenocarpy

Auxin induced seedless fruits in cucumbers and watermelon, PCPA 50-100 ppm induced parthenocarpy in tomato and brinjal, and 2,4-D 0.25 percent in lanolin paste applied to the cut end of styles or foliar sprays applied to newly opened flower clusters has been reported to promote parthenocarpy. Plant growth regulators aid in the production of fruit in the absence of fertilisation (Parthenocarpy). Staminate flowers were generated in a parthenocarpic cucumber line using the plant growth regulator GA3 at a concentration of 1500 ppm and silver nitrate at a concentration of 200-300 ppm via four sprays at a 4-day interval Singh and Ram (2004).

5.4 Training and Pruning

The training approach places a premium on the plant's capacity to obtain sufficient sunlight for growth. Additionally, it is critical to maintain adequate air circulation around the plant to minimise the danger of pest infestation [82].

The interaction between the source and sink influences the growth habit, fruit bearing pattern, and seed yield of tomato. Tomatoes have a determinate, semi-determinate, or determinate growth behaviour [52]. Indeterminate varieties/hybrids are preferred for greenhouse hybrid seed production. These plants can be grown for an extended period of time and produce numerous fruit trusses [79]. Seed production of determinate or semi-determinate cultivars is less prevalent and is not favoured in greenhouse settings [32]. Training and pruning are an integral part of the greenhouse tomato production [36].

In tomato, manipulation of plant architecture by training and optimal spatial arrangement has been identified as a critical management strategy for maximising yield from greenhouse crops [29,56,88]. Tomatoes grown in greenhouses are clipped to a single stem. Plastic string is used to support the plants. With a short, non-slip loop, secure one end of twine loosely to the bottom of plants. The other end is connected to an overhead supporting wire located between 1.8 and 2.5 metres above the plant row. Twist the string around the plant as it grows in one or two gentle rotations for each fruit cluster. When plants develop larger and heavier, “twister” or plastic snap-on clips may be used to secure the plant to the string. The string is untied and lowered frequently when the plant reaches the wire, enabling the lower section of the plant to lie on the ground. Approximately 6-7 weeks before harvesting is to cease, the plant's growth tip is typically clipped off or topped. Numerous training methods are used like vertical, arch, V-shape, S-hook, lateral [7].

5.5 De-shooting

By pinching off any side shoots, prune tomato plants to a single stem. Avoid using a knife. This should be done at least once a week; side shoots should be removed while they are very little. Remove no side shoots above the most recent blossom cluster.

5.6 De-leafing

Remove the two to three leaves beneath ripe fruit clusters that begin to yellow and wilt. Before removing leaves, ensure that the fruit has reached the mature green stage [46].

Thinning of tomato flowers and fruits is discretionary [93-96,98]. Prune flower clusters and fruits to stimulate tomato growth. Trim excess blooms within clusters once three to four well-formed fruits have developed on each cluster. Remove abnormal flowers and misshapen fruits to reduce competition for fruit production [87].

Tipping, which involves the removal of the apical bud in tomato plants, leads to a six-day delay in maturity, similar to the delay resulting from leaf pruning [77]. Studies by Tanaka and Fujita (2004) show that photosynthates flow from sources to meet sink demands, and partial leaf removal compensates for the decreased net assimilation rate of remaining leaves, leaving fruit growth unaffected. These findings are in line with similar observations made by Starck (2013). Pruning plays a significant role in carbon partitioning, affecting the ratio and, consequently, the fruitfulness of tomato plants. According to Hernandez and Sanches (2012), pruning tomato plants to a single stem result in the longest fruit length and the greatest number of fruits.

Pepper plants usually initiate with a single stem and produce a terminal blossom after 9-13 leaves, at which point the main stem divides into two (Manisha P.). Occasionally, three to four shoots may spontaneously emerge instead of two, and two flowers may develop instead of one. The blossom at the base of the first branch is known as a crown bud. The terminal blossom is promptly removed before maturation. After cutting or pinching the remaining branches, each plant should have two main stems, leaving two leaves and one blossom at each internode. These two stems are trained along strings to the main wire that runs the length of the row at a height of 8–9 feet (Manisha P.). The stems can be trellised either loosely or tightly around the strings, secured with rings or plastic clips. During the period of rapid growth, training and pruning should be performed every two to three weeks. Given the poor photosynthetic efficiency of pepper leaves, a substantial active leaf area is required to produce an adequate amount of dry matter [5]. Pruning is used selectively when there is profuse growth. In sheltered cultivation, the stem structure of pepper plants is often inadequate to support the plant, necessitating training (Manisha P.B). According to Resh (2006), pruning peppers grown in greenhouses enhances light interception, fruit set, and fruit quality by reducing the number of branches. Jovicich et al. (2009) [69] observed that sweet pepper plants pruned to four stems produced higher marketable yields compared to those pruned to two or one stem. Generally, minimal or no pruning results in excessive vegetative growth on smaller fruiting plants. Bhatt and Rao (2007) [23] demonstrated that removing fruit from bell pepper plants' initial flowering node ten days after fruit set had no effect on the partitioning of dry mass to fruit on the upper nodes of the plant. The first flowering node's fruit serves as a significant sink for photosynthates, accounting for 10.2 percent during the initial 20 days after flowering, before becoming a weaker sink.

Various training methods are employed for greenhouse cucumber plants, primarily aimed at optimizing uniform sunlight interception. Pruning, canopy training, and proper spatial arrangement are essential practices for maximizing yields in greenhouse crop production [57].

The choice of system depends on the greenhouse facility, production method, and grower preference. The umbrella system is commonly used for vertical cordon or V-cordon trained plants. Gobeil and Gosselin (2009) found that pruning during the summer resulted in higher fruit production. Duong (2009) [40] observed that pruning had no impact on fruit length or mean fruit weight, but pruned cucumbers yielded more fruits per pound compared to unpruned cucumbers. Hong (2000) [67] noted that timing depends on the training system and spacing.

In the Single Head Training System, vines are trained using a single stem on the overhead wire. All flower buds and lateral branches are removed up to a height of 60cm, and fruits are allowed to grow, one per axil, on the main stem. When the main vine reaches the overhead wire, it is wound around the wire and left to grow downward.

In the Low Middle Training System, all blooms and lateral branches are removed up to a height of 70cm from the ground level, and 6–8 fruits are allowed. Subsequently, the vines remain fruitless until they reach the overhead wire. When the main vine reaches the overhead wire, it is wound up to 30cm on the cable and then clipped at the growing point. Three healthy laterals are selected: one grows in the direction of the main stem for 20cm along the wire, while the other two grow in the opposite direction of the main stem for 20cm and 30cm along the wire. These three branches develop downward, one per axil [37].

The Umbrella System is straightforward and labor-intensive. Cucumber plants are secured to a 7-foot-tall vertical wire, with the top growth point removed. Support is provided for each fruit on the lower part of the main stem, while all laterals are removed from the main stem's leaf axis. The top two laterals are trained to hang down on either side of the main stem over the wire [99-101]. These laterals grow to two-thirds of the main stem's length. After harvesting the first laterals, they are pruned back, allowing the second laterals to take over, ensuring continued productivity. Fruit size is typically commercially acceptable by the 11th day after the bloom opens during the spring season [37].

All lateral buds up to the sixth node should be removed. Pruning involves the removal of branches or twigs to promote fruiting or flowering. Palada and Chang reported that removing lateral sprouts increased cucumber yield. After 45 days of emergence, basal leaves should be removed to prevent them from becoming a harbor for pests and diseases. Along with lateral buds, all fruits up to this time should be eliminated. Large-fruited varieties should have only one fruit per node, while small-fruited varieties may leave all fruits intact.

To harvest a large number of cucumbers quickly, cultivars with numerous female flowers, such as multi-pistillate cucumbers or gynoecious parthenocarpic cucumbers, should be grown. However, it's essential to manage the number of fruits per plant and their size to ensure optimal quality and quantity of fruit production. Factors such as differences in plant hormones, sink size, and assimilate distribution influence fruit abortion in cucumbers [45].

6. SPECIAL PRACTICES

6.1 Tomato

6.1.1 Tomato plant growth control

To limit plant growth, remove the terminal growth point above the top flower cluster approximately 45 days before the desired crop termination date, as suggested by Guan (2018) [55]. It's essential to maintain 2-3 leaves above the top cluster to offer shade and nourishment to the upper fruits, as recommended by Bhakti [22].

6.1.2 Shading and cooling

During hot summer months, retaining as many leaves as possible provides effective shade for growing fruit and aids in cooling the greenhouse. Tomato plants transpire around 1-1.5 liters of water daily per plant, which collectively can lower the greenhouse temperature by at least 10°F [11].

6.1.3 Battery-powered vibrators for pollination

Utilize battery-powered vibrators to pollinate tomato flowers by gently vibrating the flower clusters' stems for a few seconds. This vibration effectively disperses pollen and fertilizes most ovules in the ovary (Marin 2019) [97]. Pollinate the flowers every other day in well-lit conditions with humidity levels between 60% and 80% [15]. Be cautious not to touch the flower directly to prevent damage to developing fruit. This method is efficient and suitable for small-scale operations (Rutledge 2015) and ensures the production of larger fruits [22].

6.1.4 Leaf blower pollination

Greenhouse tomato pollination can be achieved using a standard household leaf blower directed at the flower clusters. This method is quicker than using an electric vibrator but may lead to slightly reduced fruit size and weight [38].

6.1.5 Bumblebee pollination

Bumblebees are efficient pollinators for greenhouse tomatoes and can be used in one or two greenhouses to save time [17]. Bumblebees visit blossoms and efficiently collect pollen through brief vibrations, leading to effective pollination and fertilization. This method is known to result in larger and heavier fruits [71]. Bumblebees work diligently throughout the day, and each bee can potentially pollinate up to 350 flowers. Bumblebee pollination has been observed to produce the highest fruit yield among various pollination methods [31].

6.2 Capsicum

6.2.1 Fruit set

Optimal conditions for fruit set and initial growth include increased light and cooler day temperatures [2]. The entire duration from flowering to fully mature, colored fruit typically ranges from 7 to 12 weeks. For successful fruit development, it's recommended to maintain night temperatures around 18°C, day temperatures between 20-22°C, and a CO_2 concentration of 700-1000 ppm. However, for the second flush of capsicum fruit, lowering the temperature is not advisable as it may slow down the ripening of the first flush [61]. Generally, the subsequent fruits naturally set after harvesting the earlier ones [76].

6.2.2 Fruit load management

A young plant can typically support around 4-8 fruits at a time, while a mature crop can handle up to ten fruits per plant. To ensure desirable fruit weight (minimum 150 grams per fruit) and quality, farmers should carefully manage the fruit load. The most effective method to reduce the number of fruits is to remove any excess fruits [18].

6.3 Cucumber

6.3.1 Fruit formation and cucumber production

In cucumber plants, each node has the potential to yield one or more fruits [22]. Typically, it's advisable to thin multiple-fruit clusters to a single fruit, but in robust plants, multiple cucumbers per node may occasionally occur, while any misshapen fruit should be promptly removed. Cucumber growth is most rapid during the period between 6 to 14 days after the flower opens (anthesis). By day 14, the fruit reaches its maximum length, followed by an increase in diameter. Greenhouses play a crucial role in cucumber production, making it one of the most widely cultivated crops in greenhouse settings globally. Protected environments offer ideal conditions for cucumber growth, surpassing open field circumstances.

6.3.2 Cultivar selection in greenhouses

Special cucumber cultivars in the greenhouse are gynoecious and undergo parthenocarpic fruit development, meaning fruits form without the need for pollination (Boonkorkaew 2008). These cultivars are unsuitable for open field cultivation due to the potential for bitter fruits taking on a club shape at the flower end through natural pollination. Consequently, it is crucial to prevent bees and other pollinators from entering the greenhouse since they may introduce pollen from outdoor gardens or field cucumber plantings. Cucumber varieties are categorized into three groups based on their flowering patterns: gynoecious, which exclusively produces female flowers, predominantly gynoecious, which also bears some male flowers, and monoecious, which produces both male and female flowers. The first two types generate fruits parthenocarpically, while monoecious varieties necessitate pollination and can produce seeds.

7. CONCLUSION

India is the second largest producer of vegetables, which occupy 10.2million ha producing about 185.88 million tonnes with an average productivity of 18.40t/ha [13-15] of fresh vegetables, yet the productivity is not sufficient to provide diet to our growing population. Since, the population growth rate continued to be more than 2% per annum but rate of food grain production is less than population growth rate.It was noted food grain production was more than population growth rate till 1991. But, declined to 1.16% per annum in 1991-2001, these factors enhance the need of protected cultivation where more food can be produced in limited area and with the regulation of flowering and fruiting techniques there are chances of increasing the yield and thereby productivity which in turn can fulfil the needs of many people and to an extent resolve the problem of limited vegetable production and eventually increasing the GDP [19]. Therefore, employing flowering and fruiting regulation methods holds the promise of augmenting yields and, consequently, overall productivity, ultimately addressing the nutritional needs of a larger segment of the population.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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