ADVANCES IN PRODUCTION TECHNOLOGY
OF COMMERCIAL VEGETABLE CROPS

(8th to 28th November 2016)

Organized by:

CENTRE OF ADVANCED FACULTY TRAINING IN
HORTICULTURE (VEGETABLES)
Department of Vegetable Science
Dr Y S Parmar University of Horticulture and
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Vegetables play an important role in food and nutritional security. Vegetable cultivation also plays a significant role in farm economy, and is a boon to the small and marginal farmers. Vegetable production in the hilly regions fetches remunerative prices during the off-season. As result, protected cultivation of vegetables has been taken up on a large-scale by the farmers in Himachal Pradesh, and several other regions of the country.

India is the 2nd largest producer of vegetables after China, and produces 168.3 million tonnes of vegetables on an area of 9.54 million hectares. At present, the productivity of vegetable crops in India is 17 t/ha, but we need to attain the productivity levels of 25 t/ha to meet the projected demand of 350 million tonnes by 2050. The major challenge is to develop technologies that ensure high productivity and quality under decreasing availability of land, declining natural resources, and increasing biotic and abiotic stresses. There is a need for standardization of technologies for sustainable vegetable production to increase the income of vegetable growers. To increase the production and productivity of vegetables, we need to undertake cultivation of high yielding disease and insect pest resistant varieties along with integrated nutrient and crop management practices. This calls for expanding the horizons of the vegetable research, and reorient the strategies for vegetable production to improve productivity, quality and post-harvest processing to remain competitive in future. Under the present circumstances, the topic entitled, “Advances in Production Technology of Commercial Vegetable Crops”, chosen for the present training course under the Centre of Advanced Faculty Training in Horticulture (Vegetables), is highly relevant and appropriate. I am sure that the lectures delivered by the faculty of this university, the invited guest speakers from other organizations, and practical demonstrations in the experimental farms and laboratories during this training will enriched the technical knowhow of the participants, who will make a significant contribution in vegetable production in future. The compilation of the lectures in the form of compendium will also be of great value in strengthening the teaching programs in different institutions. This information will also be useful for the extension agencies, NGOs and the farmers. The faculty of the Department of Vegetable Science has done a commendable job in conducting this training programme professionally and systematically, and I am sure that this information will be highly useful to the stakeholders in future.

(Hari C Sharma)
Vice Chancellor
ACKNOWLEDGEMENTS

Vegetable being an effective alternative to protective food has become an essential component of human diet. Although there has been spectacular increase in the vegetable production from 15 million tonnes during 1950 to 168 million tonnes during the current year, but we still need to produce more vegetables to meet the minimum requirement of at least providing 300 g of vegetables/day/capita. Therefore, we need to frame strategies to enhance the productivity of vegetable crops to meet this requirement.

Growing vegetables has become major occupation of farmers of hilly region because of off-season produce and high prices in the market. This has not only improved the economy of the growers but also adding to the state exchequer annually. The possibilities of growing vegetables at different times to fetch the off-season and early prices in the market will be a useful step towards increasing production and productivity of vegetables per unit area especially in the hilly regions, where cultivable land is scarce. This will also complement round the year production of vegetables throughout the country. Looking into this, there is a need to generate and share the knowledge advances in vegetable production technology. The present compendium on “Advances in Production Technology of Commercial Vegetable Crops” is a significant contribution in creating instructional material by the Centre of Advanced Faculty Training in Horticulture (Vegetables). The advances in vegetable production technology complied in this compendium will help in updating the knowledge of teachers and scientists. The Centre of Advanced Faculty Training in Horticulture (Vegetables) gratefully acknowledges the patronage provided by Dr H C Sharma, Hon’ble Vice Chancellor of this University. The financial assistance received from Indian Council of Agricultural Research in conducting the training and compilation of compendium is highly acknowledged. The Centre also appreciates the sincere efforts of all the resource personnel within and outside the university for sharing their experiences and latest knowledge. All the faculty members and staff of the Department of Vegetable Science, Deans and Directors of the University and other Statutory Officers deserve special thanks for their help and cooperation for making this programme a success.

(H S Kanwar)
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Recent Trends and Future Thrust of Vegetable Production in India

H S Kanwar
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Dr Y S Parmar University of Horticulture and Forestry
Nauni 173230 Solan, Himachal Pradesh

Food security has been defined as access by all people at all times to the food needed for a healthy life. The Food and Agriculture Organization of the United Nations (FAO) estimates that food production will have to increase by 70 per cent globally to feed an additional 2.3 billion people by 2050. Vegetables tick almost all the check boxes for providing food and nutritional security to humans. Almost all vegetables have many times more crop productivity than the current staple crops i.e. food grains. Vegetables have much needed diversity in diet to ensure prevention of malnutrition and 'hidden hunger’. Several vegetables such as European carrots have very high vitamin and mineral content also classified as nutraceautical crops.

Importance of Vegetables

Vegetables are an important source of food and nutrition. High productivity potential of vegetables is advantageous for small holder farmers. Vegetables offer better on-farm and off-farm employment opportunity. Short duration of vegetables makes them highly suitable for all types of farming systems. There is high income potential in production of specialty crops like exotic vegetables and protected cultivation. In addition, vegetables also have good export potential as an earner of foreign exchange provided quality benchmarks and commitments are met.

Vegetables are a source of vital importance for micronutrients, fibre, vitamins and minerals and are essential components of a balanced and healthy diet. Forty per cent of the world’s malnourished children are in India and 60 per cent of Indian women are anaemic. Per capita consumption of vegetables in India is only about 200 g/day/person, which is much below the minimum dietary requirement of 300g/day/person.
Table 1: Vegetable groups according to principal source of nutrients

<table>
<thead>
<tr>
<th>Group of nutrients</th>
<th>Vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>Potato, sweet potato, dry beans, yam, cassava</td>
</tr>
<tr>
<td>Protein</td>
<td>Beans, sweet corn, peas, leafy crucifers</td>
</tr>
<tr>
<td>Fat</td>
<td>Mature seeds of some legumes and cucurbits</td>
</tr>
<tr>
<td>Pro-vitamin A</td>
<td>Carrot, pepper, green peas, squash, green beans, green leafy vegetables</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>Crucifers, peppers, melons, tomato, leafy vegetables, bean sprouts</td>
</tr>
<tr>
<td>Minerals</td>
<td>Crucifers, leafy vegetables</td>
</tr>
</tbody>
</table>

Vegetable Production: Challenges

Vegetable production, both domestically and globally, is beset with many challenges, particularly in south Asia where undernourished people are highest in the world. In India productivity is stagnant for several important vegetable crops. Even the present productivity levels are fairly low compared to global levels and India is languishing at the bottom among top ten producers of the vegetables in terms of productivity. According to NHB estimates for 2015-16 area under vegetable cultivation is 9.54 million hectares and production is around 168.30 million tonnes. However, despite increase in production, productivity is stagnant around 17 tonnes for several years (Table 3). This poses a worrisome picture as projected demand of vegetables for India by 2050 is 350 million tonnes. In addition, the projected changes in climate pose additional challenges for reorientation of research and production strategy.

Table 2: Vegetable Production – Global Scenario

<table>
<thead>
<tr>
<th>Country</th>
<th>Area (in Million HA)</th>
<th>Production (in Million MT)</th>
<th>Productivity (in MT/HA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>24.5</td>
<td>573.9</td>
<td>23.4</td>
</tr>
<tr>
<td>India</td>
<td>9.5</td>
<td>168.3</td>
<td>17.6</td>
</tr>
<tr>
<td>USA</td>
<td>1.1</td>
<td>35.9</td>
<td>32.5</td>
</tr>
<tr>
<td>Turkey</td>
<td>1.1</td>
<td>27.8</td>
<td>25.0</td>
</tr>
<tr>
<td>Iran</td>
<td>0.8</td>
<td>23.4</td>
<td>26.8</td>
</tr>
<tr>
<td>Egypt</td>
<td>0.8</td>
<td>19.8</td>
<td>25.7</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>0.8</td>
<td>16.0</td>
<td>20.3</td>
</tr>
<tr>
<td>Country</td>
<td>Year</td>
<td>Area (in Million HA)</td>
<td>Production (in Million MT)</td>
</tr>
<tr>
<td>-----------</td>
<td>------</td>
<td>----------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.7</td>
<td>13.5</td>
<td>19.9</td>
</tr>
<tr>
<td>Spain</td>
<td>0.3</td>
<td>12.5</td>
<td>39.3</td>
</tr>
<tr>
<td>Italy</td>
<td>0.4</td>
<td>12.2</td>
<td>27.3</td>
</tr>
<tr>
<td>Others</td>
<td>19.1</td>
<td>261.4</td>
<td>13.7</td>
</tr>
</tbody>
</table>

**Source: NHB 2015**

**Table 3: Vegetable production: Indian Scenario**

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (in Million HA)</th>
<th>Production (in Million MT)</th>
<th>Productivity (in MT/HA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991-92</td>
<td>5.59</td>
<td>58.53</td>
<td>10.5</td>
</tr>
<tr>
<td>2001-02</td>
<td>6.15</td>
<td>88.62</td>
<td>14.4</td>
</tr>
<tr>
<td>2002-03</td>
<td>6.09</td>
<td>84.81</td>
<td>13.9</td>
</tr>
<tr>
<td>2003-04</td>
<td>6.08</td>
<td>88.33</td>
<td>14.5</td>
</tr>
<tr>
<td>2004-05</td>
<td>6.74</td>
<td>101.24</td>
<td>15.0</td>
</tr>
<tr>
<td>2005-06</td>
<td>7.21</td>
<td>111.39</td>
<td>15.4</td>
</tr>
<tr>
<td>2006-07</td>
<td>7.58</td>
<td>114.99</td>
<td>15.2</td>
</tr>
<tr>
<td>2007-08</td>
<td>7.84</td>
<td>128.44</td>
<td>16.4</td>
</tr>
<tr>
<td>2008-09</td>
<td>7.98</td>
<td>129.07</td>
<td>16.2</td>
</tr>
<tr>
<td>2009-10</td>
<td>7.98</td>
<td>133.73</td>
<td>16.7</td>
</tr>
<tr>
<td>2010-11</td>
<td>8.49</td>
<td>146.55</td>
<td>17.3</td>
</tr>
<tr>
<td>2011-12</td>
<td>8.98</td>
<td>156.32</td>
<td>17.4</td>
</tr>
<tr>
<td>2012-13</td>
<td>9.20</td>
<td>162.18</td>
<td>17.6</td>
</tr>
<tr>
<td>2013-14</td>
<td>9.39</td>
<td>162.89</td>
<td>17.3</td>
</tr>
<tr>
<td>2014-15</td>
<td>9.54</td>
<td>168.30</td>
<td>17.6</td>
</tr>
</tbody>
</table>

**Source: NHB 2015**

**Vegetable Research in India**

In India, yields per unit area in vegetables are still about 25 to 50 per cent of the yields in the developed world. There is little scope for horizontal expansion due to population pressure on land. Therefore, there is need for cutting-edge research for increasing yields per unit area through:

- Appropriate and rapid breeding programmes,
- Location-specific modern production technologies,
- Protected cultivation, Postharvest and value-addition
- Disease and pest management and,
- Dissemination of developed technologies
Globally, four themes have been identified for sustainability of vegetable production viz, germplasm conservation, breeding of productive and nutritious cultivars, safe and sustainable production technology, and postharvest management and market opportunities, nutritional security and diet diversification and human health.

**Genetic Resources in Vegetable Crops**

Germplasm is a vital component of crop improvement programmes. No breeding programme can succeed in the absence of sufficient variability in any crop. NBPGR, being the nodal agency, is responsible for collection, maintenance and characterisation of germplasm of vegetables. However, scouting for desirable traits in a large gene pool is a difficult task and requires sophisticated phenotypic tools for rapid identification of desirable traits. Hence, in addition to availability of germplasm, adequate tools and techniques for assessment of germplasm is also an essential pre-requisite for the success of any modern day breeding programme.

**Table 4: Number of vegetable accessions available at NBPGR, New Delhi as of 2014-15**

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>No. of Accessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solanaceous vegetables</td>
<td>9118</td>
</tr>
<tr>
<td>Cucurbitaceous vegetables</td>
<td>4682</td>
</tr>
<tr>
<td>Leguminous vegetables</td>
<td>4850</td>
</tr>
<tr>
<td>Malvaceous vegetables</td>
<td>3099</td>
</tr>
<tr>
<td>Cole crops</td>
<td>461</td>
</tr>
<tr>
<td>Bulbous vegetables</td>
<td>932</td>
</tr>
<tr>
<td>Root vegetables</td>
<td>391</td>
</tr>
<tr>
<td>Leafy vegetables</td>
<td>1012</td>
</tr>
<tr>
<td>TOTAL</td>
<td>24545</td>
</tr>
</tbody>
</table>

**Cultivar Improvement**

More than 70 kinds of vegetables belonging to different groups namely Solanaceous, Cucurbitaceous, Leguminous, Cruciferous, Bulbous, Root Crops, Leafy vegetables and Okra are grown in India from tropical to temperate regions. A total of 316 improved varieties (270 OP & 46 Resistant) in twenty-one
vegetable crops have been identified/recommended through All India Coordinated Research Project on Vegetable Crops at the national level since 1970-71. Hybrid cultivars’ share has grown exponentially in major vegetables. 134 hybrids of vegetables have been recommended through AICRP Vegetables. Private sector is playing a dominant role in supplying quality hybrid seeds to growers and in some vegetables like tomato, cabbage and capsicum has near complete dominance.

Development of superior quality cultivars having high degree of resistance to diseases and insects is still a big challenge. To develop superior, high quality, disease and pest resistant cultivars, effectively and rapidly, use of biotechnological tools such as genetic transformation, molecular mapping and marker assisted breeding is essential.

**Production Technology**

Most of the vegetable crops and their cultivars are sensitive to environment and have specific nutrition, moisture, space, soil pH, temperature and photoperiod requirement for their growth. It is necessary to study responses of vegetable crops to manures and fertilizers, moisture and irrigation, cultural practices and weed control, population density, seasonal influences etc, and develop specific recommendations for their optimum growth and yields. In India, first successful effort on standardization of agro techniques in vegetable crops was in late fifties in snowball group of cauliflower in Himachal Pradesh to produce quality seed economically at IARI Regional Vegetable Research Station Katrain.

Systematic research work on agro techniques was undertaken in the All India Coordinated Vegetable Improvement Project from 1971 onwards. 328 vegetable production technologies have been developed in different vegetable crops from 1970-71 to till date. Major emphasis is being laid on the management of water, fertilizers, organic matter, crop geometry and weed control.

**Protected Cultivation**

Protected cultivation is a specialized agricultural system in which a certain control of the soil–climate ecosystem is exercised modifying its conditions (soil, temperature, solar radiation, wind, humidity and air composition). Plants are cultivated by means of these techniques modifying their natural environment to
prolong the harvesting period, alter the conventional cropping cycles, increase yields, improve product quality, stabilize production and provide products when open field cultivation is limited (Wittwer and Castilla, 1995).

Several structures are being used in protected cultivation of vegetables in HP. Of these, naturally ventilated polyhouses with or without cooling are the most common. In some areas low-cost poly-tunnels/trench type polyhouses are also being used. In higher reaches low-height with deep arches are desirable because of snow during winters and high velocity gravity winds. Low incidence of diseases and insect-pests can be achieved if proper sanitation is maintained inside the protected structures.

Major vegetables that are being cultivated in greenhouses are: bell peppers (coloured varieties), tomato (large fruited and cherry type), cucumber (slicing type such as beit alpha), snap beans, snow peas, zucchini, high value leafy vegetables and aromatic herbs.

**Exotic Vegetables**

Exotic vegetables offer several advantages for growers in terms of novelty, high productivity and comparatively stable prices. Technology of several major exotic vegetables has been standardised at Dr YS Parmar University of Horticulture and Forestry. Some of these are: lettuce, celery, parsley, broccoli, Brussels’ sprouts, European carrots, European radish, European turnip, sugar/table beet, snow peas, baby corn and Chinese cabbage. In addition, a cultivar Kinner Red in red cabbage has been developed, in Chinese cabbage one cultivar Solan Band Sarson has been developed and released, in lettuce two cultivars have been identified and released. A new lettuce cultivar Solan Kriti has been developed and European carrot cultivar Solan Rachna has been developed and released.

**Vegetable Seed**

To improve the productivity of any crop, use of quality seeds is essential. The seed replacement rate in varieties of important vegetables varies from 42 per cent in leafy vegetables to 99 per cent in tomato, the overall replacement of the seed being nearly 80 per cent. Under the All India Co-ordinated Research Project on Vegetable Crops, a total of 135 seed production technologies have been developed with major emphasis on seed germination, seed pathology, seed longevity, seed storage and seed production techniques.
Due to peculiar environmental conditions, Himachal Pradesh is known for production of temperate vegetable seeds. Typically, temperate vegetables are those which require vernalisation of their vegetative stage below $7.2^\circ C$ for several weeks. Hence, Cabbage, Brussels sprouts, European carrots, turnips and radishes are some vegetables whose seed can only be produced in zones where such conditions are prevalent. Technology for the seed production of all these vegetables have been standardised at IARI, Katrain and Vegetable Research Station, Kalpa of Dr YS Parmar UHF, Solan.

**Vegetable Exports**

India can become one of the largest fruit and vegetable exporters in the world and can equally be a large importer given its projected population. There should be technology up-gradation, quality management, firm adherence to export commitments and acquisition of appropriate negotiation skills. Many non-traditional vegetables like processed gherkins and others like asparagus, celery, bell pepper, sweet corn, green and lima beans and organically grown vegetables are being increasingly exported.

Presently, onion is the major commodity exported among vegetables. However, by improving production technology and postharvest management the export of other vegetables can also be increased significantly.

**Table 5: Export of Onions from India (APEDA, 2015)**

<table>
<thead>
<tr>
<th>Sr No.</th>
<th>Country</th>
<th>Quantity (metric tonnes)</th>
<th>Value (Rs. Lakhs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bangladesh</td>
<td>4,56,734.50</td>
<td>77,964.61</td>
</tr>
<tr>
<td>2</td>
<td>Malaysia</td>
<td>2,15,194.39</td>
<td>41,621.67</td>
</tr>
<tr>
<td>3</td>
<td>Sri Lanka</td>
<td>1,31,646.45</td>
<td>25,839.13</td>
</tr>
<tr>
<td>4</td>
<td>United Arab Emirates</td>
<td>1,31,630.19</td>
<td>24,772.72</td>
</tr>
<tr>
<td>5</td>
<td>Nepal</td>
<td>70,543.31</td>
<td>13,940.27</td>
</tr>
<tr>
<td>6</td>
<td>Singapore</td>
<td>28,597.82</td>
<td>6,001.85</td>
</tr>
<tr>
<td>7</td>
<td>Indonesia</td>
<td>45,629.04</td>
<td>5,788.98</td>
</tr>
<tr>
<td>8</td>
<td>Qatar</td>
<td>25,414.31</td>
<td>5,303.42</td>
</tr>
<tr>
<td>9</td>
<td>Kuwait</td>
<td>24,874.08</td>
<td>5,026.99</td>
</tr>
<tr>
<td>10</td>
<td>Mauritius</td>
<td>10,528.00</td>
<td>3,263.87</td>
</tr>
</tbody>
</table>
Table 6: Export of other vegetables to different countries from India (APEDA, 2015)

<table>
<thead>
<tr>
<th>Sr No.</th>
<th>Country</th>
<th>Qty (MT)</th>
<th>Value (Rs. Lakhs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pakistan</td>
<td>3,34,641.17</td>
<td>71,095.53</td>
</tr>
<tr>
<td>2</td>
<td>Nepal</td>
<td>2,06,799.91</td>
<td>39,454.99</td>
</tr>
<tr>
<td>3</td>
<td>U Arab Emts</td>
<td>79,503.65</td>
<td>30,784.68</td>
</tr>
<tr>
<td>4</td>
<td>U K</td>
<td>16,870.17</td>
<td>17,674.56</td>
</tr>
<tr>
<td>5</td>
<td>Saudi Arabia</td>
<td>22,015.19</td>
<td>11,606.35</td>
</tr>
<tr>
<td>6</td>
<td>Qatar</td>
<td>17,232.60</td>
<td>9,847.19</td>
</tr>
<tr>
<td>7</td>
<td>Sri Lanka</td>
<td>34,283.24</td>
<td>9,149.87</td>
</tr>
<tr>
<td>8</td>
<td>Kuwait</td>
<td>18,073.89</td>
<td>8,082.29</td>
</tr>
<tr>
<td>9</td>
<td>U S A</td>
<td>5,484.35</td>
<td>5,031.16</td>
</tr>
<tr>
<td>10</td>
<td>Bangladesh</td>
<td>24,785.73</td>
<td>4,631.42</td>
</tr>
<tr>
<td>11</td>
<td>Oman</td>
<td>12,282.41</td>
<td>4,304.56</td>
</tr>
<tr>
<td>12</td>
<td>Maldives</td>
<td>9,300.75</td>
<td>3,797.43</td>
</tr>
<tr>
<td>13</td>
<td>Baharain</td>
<td>7,282.31</td>
<td>3,216.07</td>
</tr>
<tr>
<td>14</td>
<td>Singapore</td>
<td>5,911.80</td>
<td>3,209.32</td>
</tr>
<tr>
<td>15</td>
<td>Russia</td>
<td>9,146.47</td>
<td>2,679.96</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>8,03,613.60</strong></td>
<td><strong>2,24,565.40</strong></td>
</tr>
</tbody>
</table>

Postharvest Technology

Vegetables are living, breathing parts of plants and contain 65 to 95% water. After harvest, internal food and water reserves decline over time and vegetables deteriorate and rot. Anything that increases the rate at which food and water reserves are used up increases the rate of deterioration. Acceleration of deterioration can be due to high temperature, low humidity, incorrect
atmosphere and/or physical damage. About 25-30 per cent of the production is wasted due to lack of adequate processing and infrastructure facilities.

Emphasis should be laid on minimising postharvest losses which at present are around 35% in vegetables. Supply chain management and quality control from harvest to consumption to prevent losses. The more closely optimum storage conditions for vegetables are adhered to throughout the supply chain, the longer is the postharvest life span and minimum will be postharvest losses. Work on standardising protocols and technologies for fresh-cut and minimally processed vegetables are required. Development of new processed and ready-to-eat products is in consonance with present urban lifestyle.

**Future**

There is a need to prioritise the research, development and extension to make vegetable cultivation a key component of economic development. Entry of corporate sector in retail means that retailing will depend upon strategic alliances and reliable supply chain management. Strengthen research on impact assessment of climate change on vegetable crops using controlled environmental facilities and simulation models, analysis of past weather data and integration with productivity changes (including extreme events). Intensification of research on production, economics and trade, sensitive stages and process during crop development, diversity and dynamics of major insects, microbes and pathogens and weather relationships, etc.

In view of changing climate and increasing stress on natural resources, there is need to develop a system to get enhanced water productivity by increasing the water and nutrient use efficiency. There is need to work on development of production and post-harvest technologies to improve product quality and minimize environmental impacts. Develop the production systems that minimize wastes and maximize usage. Development of Value chain management to improve global competitiveness is required. Use of Biotechnological tools with conventional breeding for rapid transfer of genes of interest through marker assisted selection is needed. Intensive work on integrated and rapid management of emerging diseases and pests should be initiated. Emphasis should be on identification of new and effective bio-molecules for management of biotic stresses for eco-friendly and sustainable management of diseases and pests.
Suggested Readings


Improving the Availability and Quality of Vegetable Seeds for Higher Profitability

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2. PhD Scholar, Division of Seed Science & Technology, ICAR-IARI, New Delhi

India ranks second in vegetable production, but productivity it lags behind in most of the vegetable crops (FAO, 8). Apart from other factors, limited availability of quality vegetable seed and at reasonable price is one of the major cause. However, quality seed alone can lead to 15-20% increase in productivity Singh et al. (28). India grows vegetables in an area of 9.3 million ha and requires around 51,000 tonnes of seeds for sowing annually but the actual availability is around 40,000 tonnes and large quantity of seeds is still being multiplied by farmers themselves (Dutta, 7).

Indian seed industry is the 5\textsuperscript{th} largest in world and is worth of 2.7 billion US $ (Dubey, 6). Vegetable seed industry consist of agencies viz. like National Seeds Corporation, state seed corporations, SAU’s, ICAR institutes and private seed companies. Unlike cereals, vegetable seed is categorised as low volume high value seed, and dominated by the private seed companies. The private sector concentrate on the production of hybrids seeds of tomato, cabbage, brinjal, chilli, okra and cucurbits, where the seed production is comparatively easy and more profitable. The government R&D institutes and production agencies are largely concentrated on development and seed production of OP varieties. Although 461 varieties have been released by AICRP- (vegetables) but more than 60% varieties are open pollinated. ICAR institutes and SAU’s produce breeder seed, which is made available to the seed producing agencies/corporations and small private seed companies which don’t have their own R&D setup.

Private seed companies are making available quality vegetable seeds to the farmers, but high seed cost is limiting factor to small and medium farmers who are unable to afford the high cost of seed e.g. capsicum and tomato seed price can be as high as 60-90 thousand rupees/kg. The availability of quality seeds can enhanced by two approaches one by increases the production and productivity of seeds and second by increasing the quality of the seeds by enhancing the germination, seed vigour and storability etc. There by reduction of seed rate could be possible. The use of improved seed production and seed enhancement technologies shall not only be helpful in increasing the profitability
of the seed producers but will also helpful to vegetable growers by making available the best quality seed. The technological interventions could improve the seed productivity and increase the availability.

1. **Strengthening the breeder seed production and public private partnership in seed production**
   India has the large network of 63 SAU’s, ICAR research institutes and many autonomous research institute working on the vegetable improvement which have large land banks, which can be utilized to produce breeder seed and the same must be provided to of 15 state seed corporations, National Seeds Corporation, KVK’s and 100’s of smaller and medium seed companies and producers which don’t have R & D setup.

2. **Practicing the generation system of seed production:** The varieties and hybrids gain acceptance when the farmer gets genetically pure seeds of high quality. Employing the generation system comprises of breeder, foundation and certified seed could provide adequate safeguard to quality reduction by rouging frequently at farmer’s field. Thus it will cut down the labour cost and increase the net profit from seed production. The choice of a proper seed multiplication model is the key to further success of a seed programme. For Self-pollinated & asexually reproduced crops (garden pea, methi, cowpea, cluster bean, potato and garlic) 5 generation model, often cross pollinated crops (okra, brinjal, broad bean, dolicus bean) 4 generation model and in cross pollinated crops (cole crops, leafy vegetables and cucurbits) 3 generation model is suggested for multiplication to minimize the expenditure involved in rouging.

3. **Seed production of hybrids & high yielding varieties:** Since, the vegetables are being cultivated by resource poor farmers and largely selfsaved seed is being used by them and contribution of hybrid seed is less of total seed demand and limited to selected crops. The seed production of hybrids varieties is one of the means to meet the demand of quality seed. Since hybrids/varieties have been released in number of vegetable crop by public sector. Thus, production of genetically pure and quality seeds by adopting suitable seed production techniques specifically in remote areas where market for fresh vegetables are not adequate.

   Hybrid seed production on commercial scale is being done by hand emasculation and pollination. Hence, involvement of skilled labours resulting
employment to rural youth and also producer fetches higher price of hybrid seed as compare to open pollinated variety seed production and vis-à-vis commercial vegetable production.

4. **Identification of new productive seed production pockets:** The state of Karnataka produces nearly 90% of the total vegetable hybrids in India and majority of the area is concentrated around Ranebennur area, apart from it Jalna in Maharashtra and few other pockets in Telangana and Gujarat. There is a need to identify new seed production pockets which are having higher production potential eg: onion seed is traditionally produced in Maharashtra, where the seed yield is around 700-800 kg/ha, whereas the seed yield in Saurashtra region of Gujarat is 1000-1200 kg/ha (Gupta and Sharma, 9). Identification of new areas of seed production is also essential to reduce the build-up of soil borne disease eg. Sproun valley in Solan, Himachal Pradesh has become endemic to black rot disease of cauliflower and made the seed production uneconomical and forced to shifting to other crops.

5. **Seed demand forecasting:** It is essential since the seed multiplication under generation system requires at least 4-5 years of advance planning. Forecasting based on production trends, consumer preference and other economic analysis is an essential to ensure the adequate production and supply of seed.

6. **Healthy nursery raising for transplanted crops:** Quality seeds of hybrid seeds is costly and even the single seeds is valuable, but in traditional system of nursery raising the demand for seed is higher due to lower seedling establishment. In order to reduce seed demand, uniform seedling growth, seedling production under adverse condition and enhance production one should opt protected nursery raising. A plug-tray nursery raising technology by using vermiculite, cocopeat and perlite (3:1:1) as soilless media has been standardized for raising seedlings of many vegetables. This high-tech nursery raising technology is capable of vigorous root development, virus free healthy seedling production and suitable for raising of large number of seedling at minimum space without any damage to the seedlings. Besides, the production of quality seedlings, the plug tray production under protected structures could be adopted by the agricultural graduate and farmers as a side business for enhancement of income.
7. **Methods of growing:** There are four methods of growing viz. flat, ridge and furrow, raised bed and hill channel method in different crops. Flat bed method reduces the crop growth, fruit set and increase susceptibility to disease and pest. Legume vegetable like garden pea should be grown in raised bed to protect the crop from frost during flowering and pod development by providing the irrigation between the raised beds, otherwise flood irrigation suppresses the growth and podding and reduces the yield. A successful demonstration of raised bed seed production of garden pea cv. Pusa Pragati has been successfully adopted by Shri. Man Mohan Singh in Amritsar, Punjab. Onion bulb crop could be grown over raised bed for better bulb development & reduction in disease incidence which ultimately reduces the cost of cultivation. Hill channel method in cucurbits is economical for seed production as compared to flat bed, saved inputs.

8. **Relay sowing of cucurbits for higher seed yield:** In north India early sowing especially in wheat belt crops like musk melon and water melon can be planted as a relay crop in hill channel method to protect the crop from low temperature and better growth. The relay planting in wheat resulting more fruiting and more time for fruit development and maturity leading to higher seed yield & better quality in musk melon & water melon.

9. **Stacking & Pruning:** In traditional system of growing plants are allowed to grow at the soil, hence fruits prone to the disease infestation and leads to more number of fruit decay on the ground because fruits have to stay till maturity in seed crop. In order to enhance the seed yield and quality the intervention of stacking can play a vital role. During rainy season or under irrigated situations, the vegetable crops like tomato, chilli, capsicum and brinjal should be stacked. So that the fruits can be prevented from direct contact with the soil and water and are supported with the stick or rope for vertical growth to protect from disease & proper aeration.

10. **Trailing in cucurbits:** Seed production of cucurbits by use of low cost trailing system has been done and various studies have indicated the superiority of trailing method over traditional methods. The trailing method resulting more number of fruits, seed yield and quality in case of bottle gourd seed production of Pusa Hybrid-3 & Pusa Naveen Kalyanrao *et al.* (16); Sharma *et al.* (26). Trailing method avoids shading and allows better utilization of the sunlight. The superiority of quality attributes is due to the sound development of fruit and seed due to an early induction of male and
female flower in trailing and protection of fruit from rotting which also leads to production of seeds with less fungal load as indicated from the table 1.

**Table 1: Effect of trailing on seed yield and quality traits in bottle gourd cv. PH-3 & Pusa Naveen**

<table>
<thead>
<tr>
<th>Characters</th>
<th>PH-3 Trailing</th>
<th>PH-3 Traditional</th>
<th>Pusa Naveen Trailing</th>
<th>Pusa Naveen Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of fruit set/vine</td>
<td>6.65</td>
<td>4.70</td>
<td>4.08</td>
<td>3.48</td>
</tr>
<tr>
<td>Seed weight/fruit (g)</td>
<td>98.14</td>
<td>59.78</td>
<td>98.33</td>
<td>77.64</td>
</tr>
<tr>
<td>Seed yield/acre (kg)</td>
<td>689.6</td>
<td>248.2</td>
<td>410.13</td>
<td>371.00</td>
</tr>
<tr>
<td>Germination %</td>
<td>97.85</td>
<td>93.11</td>
<td>97.54</td>
<td>95.21</td>
</tr>
<tr>
<td>Disease infestation (%)</td>
<td>44.62</td>
<td>87.29</td>
<td>45.02</td>
<td>83.08</td>
</tr>
</tbody>
</table>

11. **Direction of sowing**: Seed production by adjusting the orientation of the row can influence the light interception as well as crop canopy micro climate significantly which in turn may change the crop growth parameters and pest & disease scenario and leads to increased production of fruits and higher seed yield. In bottle gourd (Sharma and Tomar, 26) reported that sowing of seed in E-W direction (over the trailing) is beneficial as compared to other crop orientations for attaining better plant growth, fruit yield, seed setting, higher seed yield and quality traits. The comparison of direction of sowing is given in table 2.

**Table 2: Effect of direction of sowing on seed yield and quality traits in bottle gourd cv. Pusa Naveen during Kharif 2014**

<table>
<thead>
<tr>
<th>Characters</th>
<th>Direction of sowing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E-W direction</td>
</tr>
<tr>
<td>Number of fruit set/vine</td>
<td>4.40</td>
</tr>
<tr>
<td>Seed weight/fruit (g)</td>
<td>107.06</td>
</tr>
<tr>
<td>Seed yield/acre (kg)</td>
<td>423.75</td>
</tr>
<tr>
<td>Germination %</td>
<td>97.65</td>
</tr>
<tr>
<td>EC (μmhos/cm/g)</td>
<td>92.20</td>
</tr>
</tbody>
</table>

12. **Frequency of leaf cutting in leafy vegetable seed production**: Seed production of leafy vegetable without cutting leads to lodging of crop, less
reproductive phase and causes problem during monitoring and makes seed production uneconomical. Thus, leaf cutting is beneficial practically in leafy vegetables *viz*; palak, methi, coriander and vegetable mustard which favoured the high penetration of light, reduces disease incidence, less crop growth and more reproductive phase and sale of cut leaves fetch additional benefit. Two leaves cutting in palak variety All Green has given 6 quintal seed yield per acre valued of 60,000 under Delhi condition & makes leafy vegetable seed production economical in peri-urban area of Delhi.

13. **Enhanced pollinator activity and pollination method:** Pollination management is essential particularly for producing the hybrid seeds. Urbanization, pesticide application and habitat loss of pollinators have reduced the pollinator load which results in insufficient pollination of flower, less fruit and seed set and lower yield and quality in seed production plot. However, in order to increase seed set and seed yield 2-3 medium bee hives needs to be introduced in the periphery of seed production plot of cauliflower, cabbage and onion.

14. **Method of pollination:** Hand pollination is employed for hybrid seed production in many vegetable crops being hand pollination favour to higher number of fruit set, higher number of seed per fruit and seed yield per plant in bottle gourd and pumpkin (table 3) Vishwanath *et al.* (35) and Tomar *et al.* (32) than natural pollination. Generally single pollination is recommended for higher seed set in cucurbits, but in case of tomato repeated pollination has been reported to increase fruit set and seed yield under poly-house condition.

**Table 3: Effect of methods of pollination on seed yield and quality traits in bottle gourd & pumpkin hybrid seed production**

<table>
<thead>
<tr>
<th>Characters</th>
<th>Methods of hybrid seed production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bottle gourd</td>
</tr>
<tr>
<td></td>
<td>Natural pollination</td>
</tr>
<tr>
<td>Number of fruit set</td>
<td>6.70</td>
</tr>
<tr>
<td>Seed yield/plant (g)</td>
<td>146.01</td>
</tr>
<tr>
<td>Germination %</td>
<td>85.00</td>
</tr>
<tr>
<td>EC (µmhos/cm/g)</td>
<td>90.60</td>
</tr>
</tbody>
</table>
15. **Mulching:** Black-gray, bio-degradable plastic mulch enhances crop performance during winter season in north Indian condition coupled with drip irrigation lead to higher root growth and development of plant. Natural mulches like wheat or paddy straw mulching can be used in crops like onion for higher yield and quality seeds Anisuzzaman et al. (1) reported that synthetic plastic opaque mulches do not allow the light but control of weed is effective, it also raises soil temperature and protected from frost injury.

16. **Foliar spray of micro nutrients:** Application of mineral nutrients is essential to fetch the higher yield and quality because Indian soils are deficient in micro nutrients. For better plant growth and development micro nutrients are needed but in small quantities however their deficiency cause a greater disturbance in the physiological and metabolic processes and ultimately reduced seed yield and quality. Micro nutrients elements, especially B, Zn, Ca and Mg avoid antagonistic effects of nutrients during uptake from soil. In onion Sanjay et al. (25), reported that foliar spray in combination of B+Zn+Ca+Mg (Recommended dose at 30 & 60 DAP) is beneficial for getting higher number of productive umbels, seed yield and quality.

Table 4: Effect of foliar spray of mineral nutrients on seed yield, quality and disease infection in onion cv. Pusa Riddhi

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Seed setting (%)</th>
<th>Seed yield/umbel (g)</th>
<th>Seed yield/ha (q/ha)</th>
<th>Germination %</th>
<th>EC (µmhos/cm/g)</th>
<th>Disease infected plants (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RD of B at 60DAP</td>
<td>83.82</td>
<td>3.33</td>
<td>7.03</td>
<td>90.08</td>
<td>1.85</td>
<td>15.5</td>
</tr>
<tr>
<td>RD of Zn at 60DAP</td>
<td>79.69</td>
<td>3.69</td>
<td>7.14</td>
<td>89.42</td>
<td>2.09</td>
<td>9.5</td>
</tr>
<tr>
<td>RD of Ca at 60DAP</td>
<td>81.41</td>
<td>3.74</td>
<td>7.25</td>
<td>89.00</td>
<td>1.82</td>
<td>12.5</td>
</tr>
<tr>
<td>RD of Mg at 60DAP</td>
<td>79.29</td>
<td>3.67</td>
<td>7.25</td>
<td>88.50</td>
<td>1.75</td>
<td>19.0</td>
</tr>
<tr>
<td>RD of B+Zn at 30 &amp; 60DAP</td>
<td>89.05</td>
<td>3.64</td>
<td>7.48</td>
<td>90.40</td>
<td>1.68</td>
<td>10.0</td>
</tr>
<tr>
<td>RD of B+Zn+Ca at 30 &amp; 60DAP</td>
<td>91.37</td>
<td>3.93</td>
<td>7.89</td>
<td>90.83</td>
<td>1.50</td>
<td>10.0</td>
</tr>
</tbody>
</table>
### Table 5: Comparative performance of seed production under drip and flood irrigation

<table>
<thead>
<tr>
<th>Crop Variety</th>
<th>Drip irrigation</th>
<th>Surface irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Seed yield /plant (g)</td>
<td>Seed yield /plant (g)</td>
</tr>
<tr>
<td></td>
<td>Germination %</td>
<td>Germination %</td>
</tr>
<tr>
<td>Onion cv. Pusa Madavi</td>
<td>94.61</td>
<td>44.08</td>
</tr>
<tr>
<td></td>
<td>92.13</td>
<td>79.75</td>
</tr>
<tr>
<td>Carrot cv. Pusa</td>
<td>41.27</td>
<td>28.37</td>
</tr>
<tr>
<td></td>
<td>98</td>
<td>97</td>
</tr>
<tr>
<td>Cauliflower cv. Pusa</td>
<td>34.00</td>
<td>14.93</td>
</tr>
<tr>
<td></td>
<td>99</td>
<td>97</td>
</tr>
<tr>
<td>Onion cv.</td>
<td>15.33</td>
<td>13.20</td>
</tr>
<tr>
<td></td>
<td>98</td>
<td>97</td>
</tr>
<tr>
<td>Turnip cv.</td>
<td>43.77</td>
<td>39.47</td>
</tr>
<tr>
<td></td>
<td>99</td>
<td>98</td>
</tr>
</tbody>
</table>

17. **Post harvest ripening enhances seed yield:** Fleshy fruits usually need to be stored before seed extraction for after ripening. Vinod et al. (34) reported that pumpkin fruits harvested at 70 DAA and cured for 10 days had highest seed yield and seed quality parameters. After-ripening facilitates the further development of the seed and removal of dormancy.

18. **Use drip-irrigation and fertigation:** The water management and fertigation studies have revealed that seed productions over low pressure drip/pressurized drip not only saves farm inputs but also increases the seed yield and quality. Tomar et al. (33) realised that seed yield and quality in onion crop was the highest over drip irrigation method as compared to surface irrigation and similar results were obtained in carrot, cauliflower, onion and turnip. The comparative performance of drip and flood irrigation is given in the table.

19. **Manipulation of sex expression in cucurbits:** Auxin, ethylene and gibberlic acid are the important PGR’s which regulate various physiological responses in plant. Alteration of sex ratio to produce more female flowers particularly in monoecious cucurbitaceous crop like cucumber, bitter gourd and production of male lines in gynoecious lines of cucumber is essential to increase the productivity. NAA 50 ppm and cycocel 750 ppm spray in cucurbits doubled the number of female flowers. In summer squash cv. Pusa Alankar spray of 350 ppm ethephon at 2-4 leaf stage can enhance the number.
of female flowers for hybrid seed production. 100 ppm GA$_3$ spray in chilli can enhanced the seed yield by 30%.

20. **Bio-fertilizers and integrated nutrient management:** The role and importance of bio-fertilizers in sustainable crop production has been studied by several authors and found that chemical fertilizers integrated with vermicompost and bio-fertilizers were found to be superior in improving the seed yield and seed quality. The combined application of bio-fertilizers - Rhizobium + PSB + PGPR resulted in 13% increase in garden pea seed yield Mishra et al. (20).

21. **Use of protected structures for seed production:** Grow seed crops under protected structures for higher seed yield and quality. Insect proof net house has been utilized for hybrid seed production of tomato, sweet pepper, chilli, okra, brinjal and cucurbits under north Karnataka condition. However, Kaddi et al. (14) reported higher seed yield of cucumber Pant Shankar-1 in insect proof net house as compared to open field condition under Delhi condition (table 6).

**Table 6: Effect of growing condition on seed yield & duality in cucumber cv. Pant Shankar-1**

<table>
<thead>
<tr>
<th>Growing conditions</th>
<th>Seed yield/1000 m$^2$ (kg)</th>
<th>Germination %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>4.2</td>
<td>63.85</td>
</tr>
<tr>
<td>Net house</td>
<td>14.17</td>
<td>71.69</td>
</tr>
<tr>
<td>Poly house</td>
<td>14.06</td>
<td>72.30</td>
</tr>
</tbody>
</table>

Semi-climate controlled greenhouse is suitable for hybrid seed production of indeterminate hybrids, cherry tomato, sweet pepper and parthenocarpic cucumber varieties. Seed yield is 3-4 times higher than open filed.

22. **Seed quality enhancement and fruit regulation:** Seed quality and yield in vegetables can be enhanced by regulating the fruit number. One fruit per vine in pumpkin cv. Pusa Hybrid-1 Kumar et al. (18) during summer and three fruits/vine in bottle gourd cv. Pusa Hybrid-3 during Kharif, Kalyanrao et al. (16) have been reported for superior seed yield and quality under open field condition in Delhi. Two fruit/vine in cucumber Cv. Pant Shankar-1 and summer squash variety and Pusa Alankar given higher seed yield and quality under insect proof net house under Delhi.
Improving the availability of the seed by upgrading the seed quality

Quality seed refers to seed which is genetically pure, free from inert matter, disease free, higher germination % and seed vigour. Good quality seeds not only yield better but also helps in reducing the seed rate and following approaches shall be helpful.

a) Revising the seed quality standards: A seed can be termed as quality seed if it genetically pure. Breeder seed should be 100 % genetically pure, foundation seed 99.5 % and certified seed should be 99 % genetically pure. Hybrids and seeds produced by hand emasculation or by use of CHA’s should be 95 % and 90 % genetically pure respectively. Apart from this the seed lot should have high germination percentage and a minimum of inert, weed and other crop seeds and are free from diseases. The genetic purity of OPV and hybrids produced by use of male sterility system can be maintained by adhering the isolation requirement, following seed village concept if the isolation distance is not adequate. IMSCS, 2013 prescribes for seed health standards at field level and health test of the seed lot is not a mandatory. Seed health testing should be included as a routine test since the seed in most case act as a primary inoculum for disease. Seed vigour determines the true planting value of the seed lot. At present there is a need to standardize the appropriate vigour test in vegetable seed and the same needs to be incorporated as a lab test for quality test of seed lot. Germination standards of many vegetables are very low and needs to be increased eg. in case of cucurbits the minimum germination requirement is 60 % which is very low and needs to relook.

b) Moisture impervious packing and dessicants for enhancing the seed viability: Most of the vegetable seeds are poor storers and cannot be stored beyond 8- 9 months without loss of seed vigour and viability. The seed viability can be enhanced by reducing the moisture. Fluctuating Relative Humidity (RH) in the tropical country like India bringing down the seed moisture to safe storage level is difficult. Khanal and Paudel (17) reported that the moisture of onion, pea and tomato seeds can be reduce to 4-6 % by using zeolite beads within 3-4 days and the seeds maintained higher germination and vigour after storage.

c) Seed coating and pelleting for enhancing the planting value and precession sowing: Coating of seeds with thin layer of polymers is helpful in adhesion of plant protectants, water absorption, protection against
temperature stress etc. Polymers also increase the flowability and the ballistic properties of the seed which help in precision planting. Hydrophobic coatings reported to reduce soaking injury (Hwang and Sung, 11) and imbibitional chilling injury (Chachalis and Smith, 4; Taylor and Kwiatkowski, 31). The reduction of water uptake by hydrophobic polymer coatings, especially the absorption of water from the vapour state Henning, (10) may also have a role in improving seed storage by maintaining lower moisture content in uncontrolled storage conditions. Polymers can also be colour coded which helps in visibility, appearance and overall marketability of seeds. Brooker et al. (3) reported that the polymer coating of seeds along with plant protectants like captan, metalaxyl and or thiabendazole reduced the soil borne diseases and the polymer provided extended release of active ingredients due to less leaching loss in the soil. Seed pelleting alters the shape and size of the seeds so that the direct seeding can be done in small seeded crops like onion, lettuce etc. Plant protectants, micronutrients, growth hormones can also be included in the peletting material. Due to improved efficacy of the applied pesticides, the polymers coating and peletting also reduces the dosage of the pesticides to be delivered with seed

d) Seed sorting using image analysis and chlorophyll fluorescence marker: The advances in imaging technology have been utilized in the seed processing industry. It serves two purposes 1) discarding contaminating seeds of other crops or weeds and inert material, and 2) eliminating poor physiological quality seeds. In both cases, seed is conditioned using cleaning equipment which uses vibrating or rotating sieves, and air-stream separation techniques allowing a non-destructive separation of weed seeds, inert matter, undersized or immature seeds (Copeland and McDonald, 5). The technique of chlorophyll fluorescence to enhance the germination was reported by Jalink et al. (12) in white cabbage (Brassica oleracea L.) and in carrot (Daucus carot subsp. sativus) seeds by Sreckel et al. (30).

e) Seed stimulation by use of electromagnetic waves: The exposure of the seeds for short period of time to electromagnetic field has been reported to increase the seed germination as well as vigour of seeds. Podlesni et al, (23) reported reduced germination time, increased seed vigour and seed yield in broad bean. Moon and Chung, (21) reported that percent germination rates of the treated tomato seed were accelerated about 1.1–2.8 times compared with that of the untreated seed. Even though the benefits of magnetic
stimulation on seed have been reported by several workers its commercial exploitation is limited due to operational difficulties of the technology for treating large quantities/ volume of seeds.

f) Seed quality enhancement through seed invigoration: Seed priming is defined as controlling the hydration level within seeds so that the metabolic activity necessary for germination can occur but radicle emergence is prevented. Seed priming can be effective on-farm technique to which can not only reduce the seed rate but also increases the field stand. Priming has been reported to increase germination and field emergence in onion and tomato (Singh et al. 29; Pandita and Nagarajan, 22)

g) Seed quality improvement through monitoring and seed legislation: Seeds act 1966 provides various provisions for regulation of seed quality during production and sale. Regular inspection and quality checks can check the sale of spurious/ substandard vegetable seeds.

Vegetable seed industry has enormous employment generation potential. Hybrid seed production of vegetable requires lot of manual labour for emasculation and pollination. There is a need to diversify the vegetable seed production hubs to non-tradition high productive regions. Funds under various government programmes like Tribal sub plan, MNREGA should be made available to the rural areas for training them in seed production. Village level entrepreneurship development must be encouraged. Promotion of ancillary activities and diversification of farm enterprise is one of the important strategies outlined by the government to double the farmers’ income by 2022, for which seed production of vegetables can be a major role player in doubling the farmers’ income. India with its diverse climatic and soil and vast pool of man power can become the world leader in export of vegetable seeds and can ushering the rural prosperity.
References:


Recent advances in Seed Production of Root Crops

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Root crops include carrot, radish, turnip, beetroot and parsnip etc. and are greatly contributing to the vegetable production basket in India. Due to the development of varieties for round the year production off-season production and storage facilities, radish and carrot remain in the market most of the year. At national level National Seed Corporation (NSC) and at state level State Seed Corporations (SSCs) are responsible for quality seed production. There is a big gap between estimated demand of quality seed and supply. This gap is bridge up to some extent either by the private sector companies or from the own farm save seed by the farmers. To improve use of quality seed, there is a need of production of quality seeds and also need for the development of seed production practices of root crops in order to enhance the availability of quality seed for commercial production in these crops.

Status of variety development: The crop-wise developments of varieties from public sector in root crops are given below

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Crop</th>
<th>Asiatic/Tropical</th>
<th>Temperate/European type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Radish</td>
<td>Pusa Chetki, Pusa Desi, Pusa Reshmi, Pusa Mridula, Pusa Jamuni, Pusa Gulabi, Kalianpur No. 1, Co-1, Nadauni, Arka Nishant, Kalyani White, HR-1, Kashi Sweta</td>
<td>Pusa Himani, Rapid Red White Tipped, Scarlet Globe, Scarlet Long, Japanese White, Chinese Pink, White Icicle</td>
</tr>
<tr>
<td>2</td>
<td>Carrot</td>
<td>Pusa Kesar, Pusa Meghali, Pusa Vristi, Pusa Asita, Pusa Rudhira, Selection-233, Hisar Garlic</td>
<td>Nantes, Pusa Yamdagini, Chanteny, Imperatar and Zeno, Pusa Nayanjyoti (F1)</td>
</tr>
<tr>
<td>3</td>
<td>Turnip</td>
<td>Pusa Sweti, Pusa Desi (Red type), Pusa Kanchan, Punjab Safed-4</td>
<td>Pusa Chandrima, Pusa Swarima Purple Top White Globe, Golden Ball, Early Milan Red Top</td>
</tr>
<tr>
<td>4</td>
<td>Beet root</td>
<td>-</td>
<td>Detroit Dark Red, Crimson Globe, Crosby Egyptian, Early Wonder</td>
</tr>
</tbody>
</table>
Areas of seed production: The seed productions of Asiatic varieties of root crops are done in Punjab, Haryana, U.P. and parts of Rajasthan & Gujarat. Whereas the seed production of temperate varieties is done in Sproon valley, Kullu valley, Kalpa valley of H.P., Kashmir valley of J&K and selected location of Northeast region specially Sikkim, Arunachal Pradesh. The seed production of beet root is being done by DRDO in Leh region of J&K.

Climatic requirement for seed production: Although, root crops are well adapted to cool season but their seed production are being done in plain & hills during winter or after over wintering. The Asiatic/tropical varieties produce their seeds freely in the plain without chilling requirement (for bolting). The temperate/European types need chilling/vernalization stimulus of 4-5°C temperature for 40-60 days duration for bolting depending upon the range of temperature. Therefore, their seed production is organized in hilly areas. Due to limited activity of honeybee at the high temperature i.e. 32°C or above the seed setting hampered in radish as well as turnip. Similarly, high temperature at flowering in carrot also caused desiccation of tertiary umbels due to reduced availability of pollen supply for secondary umbels and reduced the seed setting resulting in lower seed yield.

Methods of seed production: There are two methods of seed production:
(a) In-Situ method (Seed to seed method).
(b) Ex-Situ method or transplanting (Root to seed method).
In seed to seed method, the crop is allowed to over-winter in the same field and produce seed in the following spring at their original position. However, in root to seed method, during autumn when roots fully developed are lifted and selection of true to type is made. Under developed, deformed, split, forked, smoothness and off-type roots are rejected. The roots are also examined for pithiness and spongy tissue development in radish and turnip, core size and colour in carrot and zoning in beet root. The tap root is pruned (half or two-third part) and tops are clipped without damaging the crown shoots retaining 4-5” top with growing shoots. The selected roots are transplanted immediately in well prepared field. The roots are stored in lower temperature and planted in March where the temperature goes very low/below freezing (temperate region). The ideal storage temperature for roots is 10°C with 90 to 95% relative humidity. The roots are stored in trenches in Leh region.
**Isolation Distance:** The seed production field must be isolated from other varieties of the crop, wild relatives and other cultivated species of crop to ensure the production of genetically pure seed. Root crops being highly cross pollinated, therefore isolation distance for mother root production for both foundation and certified seed is 5 m whereas for seed production the minimum isolation distance is 1600 m and 1000 m for foundation and certified, respectively.

**Inspection stages during root production:** For root crops generally first inspection is done at 20-30 days after sowing for off type. Second inspection at the time of root development or root lifting to check the root shape, colour, pithiness, number of leaves at maturity, relative height and leaf shape.

**Seed production practices of root crops:**

**Land requirement:** Sandy loam to loam soil with pH between 6.0 to 7.5 and rich in organic content is suitable to attained good root and colour development. However, in heavy soil the production of root is hampered and high production of deformed root realized.

**Sowing time:** In plains, sowing of Asiatic varieties of carrot should be done in last week of August or first week of September. Among, the Asiatic varieties of radish i.e. Pusa Chetki & Pusa Rashmi should be sown in September and middle of October, respectively. However, the sowing of the biennial or temperate types is done in middle of August under hills of H.P. and J&K. The Japanese White, should be sown in the first week of August where as Pusa Himani is sown in the middle of August. The sowing of beet root is in Mid July in hills where as the late varieties are sown from the end of June to Mid July. The sowing of annual or Asiatic type of turnip varieties is done from July to September where as the biennial or temperate types are sown in last week of August to first week of September in hills.

**Seed rate:** For radish 8-10 kg seed/ha is sufficient for the production of root for 3-4 ha of land. For carrot 6-8 kg seed /ha is sufficient for root production for further planting. However, in seed to seed method 5-6 kg seed/ha is enough. For turnip 3-4 kg seed is sufficient to produce the root for transplanting in 6-10 ha of land. For beet root 8-10 kg seed is sufficient for one ha of land which is sufficient to plant 2-3 ha area under seed crop.
**Thinning:** In root crops, thinning is one of the most important operations where seedling is singled as soon as possible following emergence to allow better root and colour development. Thinning should be done in order to maintain 4-5 cm spacing between plants in root production.

**Method of Seed Production:** In beet root, root to seed method is usual for seed production in hilly areas of Kullu valley. In this method, during November-December the well-developed roots are lifted. After selection, the tap root and top of the roots are trimmed without damage to crown and planted in a well-prepared field. In case of turnip seed to seed method gives better yield than root to seed method. However, root to seed method is generally used for the production of breeder/nucleus seed.

**Spacing:** In radish, sticklings are transplanted on ridge at 60×30 cm apart. In carrot, sticklings re-planted at 45×30 cm spacing. In beet root the planting distance should be 60 cm between rows and 45-60 cm within the root. In turnip it should 45×25-30 cm.

**Selection of roots for seed production:** The roots are lifted along with tops when fully developed and arranged in rows to select the true to types. The roots are selected based upon the size, shape, foliage and further cut into the half to examine for pithiness. The core size and colour is also examined after cutting of root i.e. self-core colour in case of carrot cv. Pusa Kesar, Pusa Rudhira and Pusa Ashita. The cracked forked and roots having root hairs should be rejected. The normal roots after twisting the top are put in the bucket of water. Those roots with a degree of pithiness, floats are discarded and the solid roots sink are retained (Watts 1960). While in case of round rooted variety only tap root is removed before planting. In turnip during November fully development root is lifted and selected for true to type character and transplanted immediately.

**Preparation of stickling:** In radish the selected root should be cut to half of its size and at least 4.0 to 5.0 cm shoots with crown must retained for better crop establishment and higher seed yield. The stickling of these crops should be treated with thiram or captan 0.3% solution to protect the root from soil fungi.

**Time of transplanting:** In hills, radish roots are transplanted in last week of October i.e. before onset of chilling winter, while in plain transplanting should be in first fortnight of November.
**Inspection stages during flowering stage:** Third inspection is done at flowering stage to check the isolation, off types and diseases. In carrot forth & fifth inspection also made during flowing to check the isolation, off-type etc and Sixth inspection is made at maturity to verify the true nature of umbel.

**Pollinating flowering and seed setting:** Radish is cross-pollinated and pollination is done by honeybees. In radish flowering in Asiatic varieties begins in second fortnight of December and full blooming at the end of January. However, the flowering in biennial type under Kullu-valley occurs during 1st week of April and by the end of April whole crop attain complete blooming. In carrot Asiatic types tend to be annual and flowers during March (early spring) in plain. However, bolting in temperate cultivars occurs in first week of April and flowering starts by end of May in hills. The individual carrot flowers are normally protandrous and much pollination occurs between plants in seed crop. However, because of the extended flowering period resulting from several successive umble per plant and the succession of flower in individual umble, the possibility of selfing is always remains there. Seed setting is influenced by the position of umble, order of umble, bee’s activities and that temperature at flowering. Beet root is predominately wind pollinated. Bolting in beet root start in first fortnight of April in Kullu valley and crop is in full bloom from mid-May to mid June. The inflorescence is a large panicle and seed maturity begins from the base of panicle.

**Harvesting and threshing:** In radish the pods become brown and parchment like when the seeds are near maturity. The seed stalks are cut and kept in small piles for drying at threshing floor. Although, no shattering of pod, but, dropping of pods is severe at the time of harvesting, if crop allowed to over desiccation in field. The seed stalks should be dried thoroughly to facilitate the easy seed extraction from the pod. Threshing is done by tractor treading or by stick beating. There is a chance of damage of seed coat in mechanical threshing. In carrot seed matures in the middle of May and end of June in plain and hills respectively. The harvesting of umbles should be done where the secondary umbel is fully ripe and third under umbles have started to turn brown. For high quality seed, primary & secondary umbles should harvest and rest should be avoided. The ployvinyl acetate is sprayed to avoid the loss of seed from primary umbel. The umbel is cut by manually without taking the stem part. The harvesting is done in early morning to take an advantage of dew to reduce the loss from dropping. The carrot seed has spines and these must be removed by deharders before further cleaning operation. Beet root crop matures in July in Kullu valley. However, harvesting may start as early as the last week of June, but usually it
is done in July. Rains at maturity may affect the seed quality of seed crop. Generally, when 70-80% of seed balls on plant get hardened and those at the base of the inflorescence turn brown, the crop in harvested. Delaying in harvesting may lead to shattering of seed during harvesting. The seed crop is then stacked for curing and then dried under sun. Threshing is done manually by beating with stick or by tractor treading. Turnip has a tendency of shattering therefore care is required in cutting. It is therefore, suggested to cut the whole crop when 60-70 of pods turns yellow brown in colour. The crop is cut with sickle and left in windrows until the seeds are mature. Through drying of crop is essential for easy threshing. The threshing is done by beating with a stick or by thresher. The seed should be dried under sun thoroughly prior to cleaning of seed.

**Seed yield and 1000 seed weight:** In carrot seed yield varies among the Asiatic and temperate types. Generally, seed yield is higher in Asiatic cultivars than temperate types. Singh et al (1960) obtained 330-350 kg/ha seed yield from cv. Nantes in Kully-valley. However, seed yield of 500-600 kg/ha is common in cv. Pusa Kesar, Pusa Rudhira and relatively low 350-400 kg/ha in Pusa Vrishti. The 1000 seed weight is 0.8 g. In radish the average seed yield varies from 600-800 kg/ha but variation within the variety were also recorded. The average seed yield/ha of radish cultivars reported by Singh et al (1960) are 400-500 kg/ha for White Icicle, 700-900 for Japanese White and 600-700 kg/ha for Pusa Himani/Rapid Red White Tipped. In beet root, Singh et al (1960) reported the seed yield of 8-10 q/h in variety DDR. The 1000 grain weight is 17 g while rubbed and graded seed has the lower 1000 grain weight of 10 g but it also varies between seed lot. In turnip from 300 kg to 700 kg/ha seed yield can be achieved in hilly area, depending upon the variety. However, seed yield of Asiatic variety Pusa Sweti is 1028 kg /ha as observed by Tomar (2001). The 1000 seed weight in turnip ranges 3 g and 2.5-3g in temperate and tropical, respectively.

**Seed Standards:** The lot should confirm the following seed standards but at the time of labelling only pure seed, inert matter and germination % are essentially to be mentioned.

<table>
<thead>
<tr>
<th>No.</th>
<th>Factors</th>
<th>Radish</th>
<th>Carrot</th>
<th>Beet root</th>
<th>Turnip</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>F C</td>
<td>F C</td>
<td>F C</td>
<td>F C</td>
</tr>
<tr>
<td>1</td>
<td>Pure seed (minimum) (%)</td>
<td>98</td>
<td>98</td>
<td>95</td>
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<td>2</td>
<td>Inert matter (Minimum)</td>
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<td>2</td>
<td>5</td>
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</table>

31
<table>
<thead>
<tr>
<th></th>
<th>Other crop seeds (Minimum) (per kg)</th>
<th>5</th>
<th>10</th>
<th>5</th>
<th>10</th>
<th>5</th>
<th>10</th>
<th>5</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Weed seeds (Minimum) (per kg)</td>
<td>10</td>
<td>20</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>10</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Germination (Minimum) (%)</td>
<td>70</td>
<td>70</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>5</td>
<td>Moisture (Minimum) (%)</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>6</td>
<td>6</td>
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<tr>
<td>6</td>
<td>For vapour-proof container (Minimum) (%)</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

F= Foundation Seed; C= Certified seed

References:


Protected Cultivation of Vegetables Under North-Western Plains of India

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Agriculture is demographically the broadest economic sector and plays a significant role in the overall socio-economic fabric of India (Anon., 2016). Besides population increase, improved purchasing power of the people has enhanced the demand for quality food. The present cropping intensity of 137 per cent has registered an increase of only 26 per cent since 1950-51. Therefore, amplification in production and productivity is deliberately important for sustaining the economy. After the crack of dawn of green revolution, more focus is now laid on the quality of the agricultural product along with the quantity of production to cater the ever-increasing food and nutritional requirements. Moreover, in majority of cropping systems, the gap between potential and actual yield is very high. The present average yield in most of the crops is just one third of the achievable yield. In order to meet these demands, the environment for the plant growth needs to be duly controlled. Therefore, need arised to grow the crops particularly, vegetables under protected conditions.

Protected cultivation has potential to produce more per unit area with increased input use efficiency. It has been estimated that, if one lakh hectare of vegetable crops brought under poly-house cultivation, the annual availability can be increased by100 lakh tons (Anon., 2012). Besides, it will also increase the significant jobs opportunity for the skilled rural men, youths and rural women. Total production of vegetables in India is next to China, but per capita availability of vegetables is much lower than the required. There is a lot of pressure on cultivable land because of industrialization, urbanization and expansion of the rural villages. Therefore, it is necessary to improve the productivity of crops including vegetables by adopting intensive cultivation, hydroponics and poly-house cultivation. The improvement in economy of farmers with the decreasing land further demand focus under protected conditions. Moreover, the problem of glut during a short period of harvesting can also be minimized by prolonging the harvesting span.
Types of Protected Structures

Despite of varied agro-climatic conditions, vegetable cultivation in India has been restricted to regional and seasonal needs. In North India especially plains, though soils are very fertile, but temperature fluctuate from 0 to 48 °C, which restrict round the year cultivation of vegetables (Singh and Sirohi, 2006). Moreover abiotic, viruses and other biotic stresses appearing in one season or another aggravate the situation further. Thus protected conditions for vegetable cultivation can be created by using different types of structures. These structures are generally season and location specific. Temperature, humidity, wind velocity, soil conditions, etc. are the main factors that decides the design of greenhouse or any protected structure.

(i) Mulching
Covering of the surface around plants makes the condition more conducive for growth through moisture conservation, better carbon dioxide control exchange for root system and soil structure maintenance. Black mulch is more popular, which checks the weeds under surface. In addition to this, silver and white coloured films are successfully used for repelling the aphids and white fly, respectively.

(ii) Low and Walk-in Tunnel
Row covers or low tunnels are flexible transparent covering that are installed over the rows or individual beds of transplanted vegetables to enhance plant growth by warming the air around the plants in the open field during winter season. They can also warm the soil and protect the plants from hails, cold wind, injury, and advance the crop by 30 to 40 days than the normal season. This low cost technology for off season cultivation of capsicum and cucurbits like cucumber, muskmelon, bottle gourd and summer squash, etc. is suitable and may be quite cost effective for the growers in northern parts of the country, where the night temperature during winter season goes below 8°C for a period of 30-40 days. Walk-in tunnels or man sized tunnels are high enough for working and can accommodate tall crops such as tomato. These tunnels are also suitable to raise off-season nursery and off-season vegetable cultivation. The simplest form of walk-in tunnel is made up of iron hoops over which plastic is stretched.

(iii) Naturally Ventilated Green-houses
Naturally ventilated greenhouses are the protected structures, where no heating or cooling devices are provided for climate control. Simple techniques
are however, adopted for increasing or decreasing the temperature and humidity. Even light intensity can be reduced by incorporating shading materials like nets. The temperature can be reduced during summer by opening the side walls. These are simple and medium cost greenhouses, which can be erected with a cost of Rs.500-600/m². These greenhouses can be used successfully and efficiently for growing year round parthenocarpic slicing cucumber, tomato and sweet pepper. Three crops of cucumber, tomato and sweet pepper can be successfully grown in these houses over a period of 8 to 9 months with higher yields and better economics.

**Net-house Cultivation**

The net-house cultivation is a good alternative, wherein, vegetables are produced with minimum use of pesticides. Cultivation of vegetables under net-house can play a good role in improving the quality, advancing maturity as well as increasing fruiting span and productivity. Net-house is a framed structure consisting of GI pipes covered with ultra violet (UV) stabilized net of 40 mesh size, which is large enough to control the entry of flying insects and save crop from attack of insect-pests and diseases. To get the maximum utilization of sunlight, net-house should preferably be constructed in the East-West direction. Punjab Agricultural University has recommended the early cultivation of capsicum, tomato and brinjal in the net-house.

**Nursery Raising under Protected Conditions**

In the past, vegetable growers either grow transplants in greenhouses, net houses and low tunnels using flats or ground beds or in outdoor ground beds. Recently growers have made the transition to greenhouse grown transplants using various types of containers, primarily plug trays. With this system, each transplant grows in an individual cell, thus there is less competition among plants and more uniformity. Plug plants establish better in the field because roots are not damaged when pulled. For raising nursery of vegetables in plug trays, commonly used soil-less media are coco peat, vermiculite and perlite, which are mixed in 3:1:1 ratio on volume basis. The size and volume of the cells of pro-trays also have been standardized for different vegetable crops.

**Production Major Vegetable Crops Under Protected Conditions**

Cultivation of vegetable crops is constrained by various biotic and abiotic stresses. To mitigate the adverse effects of abiotic stresses, Punjab Agricultural University, Ludhiana recommends cultivation of tomato, bell pepper and brinjal.
under protected conditions. The main advantages of protected cultivation are (i) improving early and total yields (ii) improving fruit quality in terms of colour, taste and external appearance (iii) minimizing the use of pesticides for safe vegetable production (iv) judicious use of farm inputs (v) increasing availability span of the vegetables (vi) protecting the crop from inclement weather to produce blemish free fruits and (vi) vertical utilization of space by training crops upright. The cultural practices for various vegetable crops grown under Poly/Net-houses are given in Table 1.

**Table 1: Cultural practices of vegetables grown in polyhouse**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Cultural practices</th>
<th>Tomato</th>
<th>Bell pepper</th>
<th>Brinjal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mid-September</td>
<td>End-September</td>
<td>Rainy season: Mid June, Autumn season: Mid September and Spring season: End November</td>
</tr>
<tr>
<td>1</td>
<td>Sowing time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Transplanting time</td>
<td>Mid-October</td>
<td>End-October</td>
<td>One month after sowing</td>
</tr>
<tr>
<td>3</td>
<td>Seed rate per acre</td>
<td>40g</td>
<td>120g</td>
<td>160g</td>
</tr>
<tr>
<td>4</td>
<td>Spacing</td>
<td>0.90m x 0.30m</td>
<td>0.90m x 0.30m</td>
<td>0.90m x 0.30m</td>
</tr>
<tr>
<td>5</td>
<td>Fertilizer requirement per acre</td>
<td>FYM: 10 tonnes DAP: 100 kg Urea: 120 kg MOP: 44 kg</td>
<td>FYM: 20 tonnes DAP: 100 kg Urea: 140 kg MOP: 20 kg</td>
<td>FYM: 20 tonnes DAP: 55 kg Urea: 80 kg MOP: 20 kg</td>
</tr>
</tbody>
</table>

**Soil sterilization**

When nursery or the crop is grown on the same piece of land repeatedly, soils get sickened by soil borne pathogens. Soil sterilization is recommended to check soil borne pathogens. For chemical sterilization of the soil, apply 2.0% formalin solution (20 ml formalin in one liter of water) and drench the soil with the solution @ 4.0 - 5.0 liters per m². After the application, cover the soil with polythene sheet for 48-72 h. After removing the polythene sheet, stir the soil for 3-4 days, so that chemical fumes are eliminated from the soil. Alternatively, the
soil can be sterilized by covering the soil with transparent polythene sheet of 50 micron thickness for 50-60 days in May-June. Solarization of wet soil is more effective than the dry soil.

(i) Cultivation of tomato

The Department of Vegetable Science evolved five indeterminate varieties ‘Punjab Gaurav’ and ‘Punjab Sartaj’ for table purpose and ‘Punjab Red Cherry’, Punjab Sona Cherry and Punjab Kesar Cherry as novelty. Cherry tomatoes are miniature versions of table tomatoes and usually have more sugars content. Cherry tomatoes are very popular in countries like USA, Canada, Australia and many European countries. In India, demand for this novel fruit segment is picking up due to increased awareness and affordability of the consumer. Treat the seed with 3g Captan per Kg of seed before sowing and sowing should be done in beds. Seedlings are protected from viruliferous whitefly (*Bemisia tabaci* Gennadius) by providing 40 mesh net cover. Before uprooting, spray the seedlings with Malathion 50 EC @ 4ml per liter of water. This will protect the crop from insect vector, the whitefly. To check weeds, apply Stomp 30 EC (Pendimethalin) @ 1.0 liters per acre on prepared beds, 3-4 days before transplanting. For surface irrigation, first irrigation is applied immediately after transplanting and after that, apply irrigation at regular intervals for proper establishment of the seedlings. Drip irrigation is recommended for protected cultivation of tomato to reduce water losses, to improve fruit quality, and to improve input utilization, especially fertilizers by supplying plant nutrients right to the root zone of the plant. Through drip, apply irrigation at 2-3 days interval during October; 4 to 5 days interval during November-February; 2 to 3 days interval in March; and 1 to 2 days interval during April-May. Through the drip, 120 kg Urea per acre is applied in 15 split dozes at 10 day intervals. Black polythene mulch of 25 micron thickness is recommended to increase the soil temperature in winters and decrease the soil temperature in summers; decrease water loss through evaporation; suppresses weed growth; reduces disease occurrence; and improve fruit quality, shelf life, early and total fruit yield.

After 20-25 days of transplanting, earthing up is to be done. To get higher yield, the crop should be staked properly. This keeps the plants in an upright position preventing the fruit from touching the ground. Side shoots are pruned regularly at least twice a week, at least once or twice in a week, and 3 or 4 shoots are trained upright. All lateral branches must be removed when they are one to three inches long. Lower leaves are regularly removed to manage vegetative growth. This training and pruning of branches and leaves allows maximum air
circulation and reduces pest control problems. Once the lowest fruits have been harvested, continue the pruning by removing those leaves that were above the harvested cluster and that are now below the next lowest fruit bearing cluster. Harvesting of fruits start in end February and continues till end May. Harvesting can be done at turning stage, half-red stage or full red stage, depending upon the market demand and consumer preference. Grading of fruits is important to fetch higher price in the market. Fruits are graded for uniformity in size, shape and maturity; and the under sized, over sized, diseased and insect damaged fruits are culled.

(ii) *Bell pepper cultivation*

For optimum yields, bell pepper requires 20-25°C day and 15-17°C night temperature accompanied by 75% relative humidity. Hybrids ‘Bharat’ of Indo-American Hybrid Seeds and ‘Indra’ of Syngenta Seeds are recommended for cultivation under net-house. Installation of micro-irrigation system with drippers spaced at 30cm is also recommended to save irrigation water and facilitate nutrient application right into the root zone of the plant. Black polythene mulch of 25 micron thickness is recommended to increase early and total fruit yield, extend shelf life of fruits and to improve fruit quality, especially colour of capsicum fruits, when seed is sown around 1st of October and seedlings are transplanted about a month later. Mulching also helps to conserve soil moisture and suppress weed growth. To protect the crop from excessive heat, use white or red coloured shade net from mid-April onwards. Fruits are harvested when fully developed (about 60g) but still shining green. First picking is possible in end February and harvesting continues till first week of June. Harvesting is done regularly at 3-4 day intervals.

Yellow coloured Orobellle and red coloured Bomby hybrids are recommended for cultivation under naturally ventilated polyhouses. Five-six week old seedlings are transplanted in late evening on 1m wide raised beds having plant x plant spacing maintained at 30cm. However, seedlings can also be planted in paired row pattern with R-R and P-P @ 45 x 45 cm from the centre of bed, with zigzag transplanting i.e. in a triangle shape (means plants of second row should be placed in the centre and parallel of the plants of the first row) and the spacing between the paired rows should be 105 cm.

In order to maximize production the plants have to be pruned and trained regularly to ensure a balanced growth. Remove all lateral branches from the base to the seventh node. Remove the old leaves at least one foot from the ground level. To facilitate pollination and fruit setting plants or trellis wires are tapped
with the help of stick. It must be emphasized that sweet peppers are pruned to 1-2-4 stems, and if possible maintain six fruits per stem to maintain vegetative and fruit balance. Picking of marketable size starts 45 days after transplanting. All coloured sweet pepper fruits are initially of green colour and then they start changing their colour to red or yellow after three to four weeks. At harvestable maturity mature Bomby fruits develop bright red colour and Orobelle fruits bright yellow colour. Average fruit weight of both hybrids at harvestable maturity is around 100g.

(iii) Brinjal cultivation

Brinjal can be grown in net-house during rainy, autumn and spring seasons. Rainy season crop gives maximum yield in outer conditions, but severely attacked by brinjal shoot and fruit borer (50-70% damage). The use of heavy doses of pesticides for controlling it is a matter of concern for human health, environmental safety and economics of the crop. To bring down the pesticide usage, Punjab Agricultural University has recommended the Net-house cultivation of this crop. Net-house acts as a barrier against all stages of the insect and increases the marketable yield of brinjal. Hybrids PBHR-41 and PBHR-42 are suitable for cultivation under Net-house. Both are medium tall, thornless hybrids with solitary flowers. The nursery should be raised under 40-mesh size net to prevent insect-pest infestation. To get early and high yields from November transplanted crop, the beds should be covered with black polythene mulch (25 micron thickness) from the last week of November to first week of March. First irrigation should be given immediately after transplanting. During dry and hot weather irrigate the crop at 4-5 days interval, but it depends upon the rains in rainy season. Sandy soils should be irrigated more frequently than heavy soils. Preferably, use underground pipes attached with drip irrigation system in the net-house. Otherwise, with open channel irrigation water must pass through fixed net in the ground. Sieving of water prevents the entry of eggs, larvae, pupae and adults of the insects carried along with water of open channel.

Brinjal grows luxuriantly under Net-house and become lanky with dense foliage, sparse flowering and less fruit setting. Therefore, plants should be trained by retaining two main shoots. The trained plants use vertical space of the Net-house, prevent overcrowding of side branches, facilitate the distribution of the sun light to lower parts, ease the supplementary pollination, harvesting and other cultural operations. Supplementary pollination is must for cultivation of brinjal under Net-house. The occurrence of heterostyled flowers (long, medium, short and pseudo styled) leads to insufficient pollination and affects its
yield potential. Mostly fruit setting occurred on long and medium styled flowers in field. Under open field conditions, the pollinators (insects, bees etc.) and wind facilitate the pollination in brinjal. However, the entry of the pollinators is prohibited and wind does not blow with normal pressure in net-house. Thus, pollination is affected and fruit setting is poor with deformed fruits, particularly in long styled flowers. Therefore, to facilitate pollination plants should be tapped on main stem with wooden stick at the time of pollen shedding (1to 3pm) in the flower and it helps to double the yield of brinjal under Net-house. Harvest immature, tender, fully developed and shining fruits of brinjal at 4-5 days interval. Clean and grade the fruits in uniform sizes before packaging and sending to the market.

(iv) Cucumber Cultivation

Cucumber crop can be grown twice in a year under polyhouses. The first crop of cucumber should be sown in last week of August to first week of September depending on the temperature and relative humidity. The second crop should be sown in first fortnight of January. For an area of one acre, 12000-14000 seedlings are required depending upon the bed size, row to row and plant to plant spacing. Parthenocarpic cucumber is suitable for grown in the poly-houses. Hybrid seeds of Multistar and Sunstar (Rijk Zwaan), KUK-9 (Namdhari), Kafka (syngenta), Kian and Isatis (Nunhems), and Hilton (Simillus Fito) etc. are suitable to grow.

The beds are made 90 cm wide from base and 15 cm height and gave slant while preparing the bed. Between two such beds a spacing of 30-45 cm is sufficient. Two rows of cucumber are planted on one bed. Seedlings should be transplanted in a paired row pattern with row to row and plant to plant spacing of 45-60 cm and 30 cm respectively with zig-zag transplanting i.e. in a triangle shape (means plants of second row should be placed in the centre and parallel of the plants of the first row). The plants are trained upwards so that the main stem is allowed to climb to the overhead wire along a polythene twine. All the laterals and fruits should be removed on the main stem upto 30 cm above the ground level. The plant need frequent pruning to a single stem and training along vertical wires to maintain an optimal canopy that intercept maximum light, to promote flower and fruit production and to allow sufficient air movement.

Fruit are ready for picking after 40-45 days after sowing in August/September sown crop whereas January sown crop takes 60 days after
sowing to first picking. An average yield of cucumber is 300 quintals per acre for August/September sown and 400 quintals/acre for January sown crop.

**Precautions for protected cultivation**

- Plug all holes in doors and walls of the polynet house. Fix the polythene/net properly in soil to prevent insect entry.
- Use double door system in poly/net house. Always close the door properly, while entering the house.
- Inspect the polynet house regularly for wear and tear.
- Monitor the crop regularly to check incidental entry of insect-pests. In case of infestation, destroy the infested leaves, shoots, or fruits immediately.
- Remove the dry and fallen off leaves at frequent intervals.
- Sterilize the soil in poly/net house with 2% formalin solution.

**Major constraints in protected cultivation**

Protected horticulture has undergone slow progress during the last two decades in India and the level of protected horticultural crop production in this country is still much lower than that in developed countries. Many problems still need to be solved. Some of the problems are as follows;

- Cost effective design of green house suitable for different climate needs to be standardized.
- The package of practices including fertigation needs to be worked out.
- Pest and disease management is crucial under protected environment as it provides favourable conditions for their proliferation. Intensive cultivation in green house gives rise to the growth and development of numerous pathogens including nematodes. Effective and eco-friendly control measures are to be evolved.
- Development of suitable varieties for protected cultivation requires an immediate attention and effort to reduce dependence on imported seeds.
Production Technologies for Cultivation of Onion

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Onion (Allium cepa L.) belongs to family Alliaceae and thought to have ancestors in Central-Asia. Physiologically onion is a long day plant, but due to suitability for cultivation to specific photoperiod and temperature, it is classified into temperate long, intermediate and short day and, tropical short day bulb, shallot and multiplier groups. Short day varieties, includes not only populations developed within the tropics, but also developed well out side the tropics as over winter crop to provide early fresh bulb. Such varieties can also be grown as over winter crop under sub-tropical conditions due to adaptation for bulbing at approximately equinoctial day lengths.

Onion is mainly grown for bulb, which is used almost daily in every home. Its main use is due to its aromatic, volatile oil ally-propyl disulfide that impart cherish flavor to the food. Worldwide onion is grown on 43.64 lakh ha with 863.44 lakh MT production and 19.79 MT ha⁻¹ productivity. In last decade 53.49% increase in area, 72.87% in production and 12.63% in productivity are the indicators of onion growth on the globe. India ranked first in area (12.03 lakh ha) and second in production (194.02 lakh MT) of onion in the world. Though, onion production in India has increased by 300% in last two decades, but country requires 211 lakh MT onion by 2050 with present rate of consumption (6.7 kg per capita⁻¹), export (9%), processing (6.75%) and losses (20%). If export and processing is increased by 25 and 9%, respectively than 286 lakh MT onion would be required. Which can be achieved by increasing productivity to 28 MTha⁻¹ or by expansion of area under onion. Hence, for increasing productivity and making availability of we have to focus on development of high yielding varieties/hybrids, improved production technologies, efficient crop management practices and better post-harvest handling and proficient marketing systems.

1. Production Technologies

Production technologies have key role in enhancing the production and productivity of onion. All cultural requirements depend upon soil type, season and geographic conditions for cultivation of the onion. Yield determinant of onion
are the bulb size and bulb numbers produced from per unit area. Its potentials can be realized from well-drained soils, where water is not limited and nutrients are readily available. Affect of high temperature, drought, floods and insect-pests at critical stages significantly harm the growth and lower the productivity. Plant density and spacing are essential for determining bulb size and numbers. Yields are higher, where early leaf cover is produced and then maintained for a long period prior to bulb formation.

**(i) Sowing and Transplanting:** Under Indian conditions onion cultivation begin with sowing of seed in the nursery followed by transplanting of the seedlings in field. Onion seed is highly perishable in nature for emergence and storage life. Therefore, seed must be genetically true to type, high in germination and vigour. Onion seed may be infected with seed-borne pathogens like *Aspergillus niger*, *Botrytis aclada* and *Fusarium oxysporum* f. sp. cepae, which are known as causal agents of black mould, neck rot and basal rot diseases, respectively. These pathogens can be transmitted from infected seeds to seedlings, sets or bulbs. Soil and seed treatment with copper fungicides or Carbendazim can be effective in preventing such diseases. Use of *Trichoderma viride* for seed and soil application found beneficial in controlling the damping off in nursery. Solarization of nursery beds with clear plastic sheet also found effective for checking the pathogens and weeds. Seedling growth can also be promoted with applications of soluble fertilizers, vermin-wash, vermin-compost and neem-cake. Depending upon season, variety and germination, 6 - 8 kg seed is required to raise nursery for transplanting one hectare. Seed for *rabi* should be sown in Oct-Nov., *kharif* in May-June and late *kharif* in Aug.-Sept on the raised seed beds in lines at 5-7 cm spacing. It takes 8-10 weeks to attain 0.8-1.0 cm thickness and 20-25cm height, which are considered ideal for transplanting. Over aged seedlings are prone to bolting and establish late, whereas, under aged do not establish well. Crop geometry of 65-70 plants/m² is considered ideal for getting optimum yield in onion.

**(ii) Fertilizers and Manures:** Onion is a shallow rooted (25-30 cm) crop and a balance inflow and outflow of the nutrients in the soil must be maintained for getting good yield, otherwise major share of the nutrients lost through leaching. The diagnosis of soil and plant nutrient status is helpful in determining the nutrient status required for healthy growth. To produce one tonne of onion 2.10-2.16 kg N, 0.7-0.8 kg P, 2.00-2.69kg K are removed under tropical conditions of India. The nutrient uptake starts after establishment of plants and increases up to 60 days of transplanting. The application of nutrients through external
sources must match with the crop nutrient demand for higher nutrient use efficiency. N, P, K and S in mature healthy leaves should be 3-4, 0.3-0.4, 3.5-5.5 and 0.3-0.5% at pre-bulbing and 2, 0.1-0.3, 2-4 and 0.2-0.3% at bulbing stage of onion, respectively. It is considered deficient below 1% of N and K each, and 0.1% of P concentration. The use N from 150-200 kg ha⁻¹ increased the yield and excessive use causes thick stem, thick neck, delay maturity, soften bulbs, poor storage and high incidence of foliar diseases. To have higher efficiency, N should be applied in split dozes, incorporated in soil to avoid volatization in granular forms or with organic manures. Phosphorus is essential for root development and boost establishment in early phase of the plant growth. The recommended doze of P is 50-80 kg ha⁻¹ and given as basal doze at the time of transplanting. P get fix in the soil complexes and remains in available equilibrium also. Onion root development is severely affected below 10ppm level of P in the soil. Phosphorus Solubilizing Bacteria (PSP) can further enhance P availability along with application of organic manure. Potassium accumulates high dry matter and sugars and provides diseases resistance. It is important under conditions of high nitrogen application. K requirement in onion is more or less equal to N. Generally, 120-200 kg ha⁻¹ K is recommended and Potassium Chloride (Muriate of Potash) is a main source. It is highly mobile and 0.5% spray of sulphate of potash gives good results. Sulphur is critical for taste and pungency of the bulb. It should be applied @ 15 kg in sulphur sufficient and 25 kg ha⁻¹ in deficient soils. Low level of S also affects the availability of P. The application of potassium sulphate is considered better than potassium chloride.

Micronutrients like Zn, Fe, Cu, Mn, B and Mo are found 48, 12, 4, 5, 33 and 13% deficient in Indian soils, respectively. Among them availability of Zn and B is critical. Soil pH, organic matter, calcium carbonate, sodium, calcium and magnesium govern the availability of micronutrients. Soil application of micronutrients should be given only after the diagnosis. The indiscriminate use of micronutrients causes toxicity to the plants, therefore, critical appraisal through soil and plant tissue test is must before application. Soil application generally, affects its availability; hence foliar sprays are preferred. Regular application of FYM @10-15 MTha⁻¹ keeps the check on deficiency of micronutrients in onion.

Continuous use of organic manures enhances organic matter and physical properties like hydraulic conductivity, porosity, aggregate stability and soil biological activity along with lower bulk density. Soil microorganisms like Azospirillum sp., Enterobacter sp., Azotobacter sp. and Pseudomonas sp.
encourages plant growth by promoting secondary roots, protectors against microorganism by releasing plant hormones and siderophores. Therefore, for increasing onion production at sustainable manner we have to opt combination of chemical fertilizers, organic manures and microbial inoculants at optimum time of application. Further, nutrient use efficiency can be enhanced with a focus on uptake pattern of the plant, losses management, microbial inoculation and developing efficient ideotype.

(iii) Irrigation: Onion is a shallow rooted crop and demand frequent and light irrigation for growth and bulb development. Onion needs to be irrigated at transplanting, three days after transplanting, and subsequent irrigation at 7-10 days interval depending upon soil type and moisture content. In general kharif crop needs 5-8 irrigation, late kharif 10-12 and rabi 12-15 irrigations. In general frequent irrigations are required at early growth, more frequent at bulb development and none at maturity of the crop. Bulb development stage is considered crucial for availability of moisture. In onion, water use efficiency was considered higher at IW/CPE of 1.2. Heavy irrigation at harvest time cause immature thick-skinned bulbs, delay maturity, become cause of Fusarium infection. Onion gives high response to drip irrigation and fertigation due to its shallow root system. Yield with this approach is improves by 30%, water saved 25%, fertilizer 20% along with better storage than the flood irrigation system. Results of micro-sprinkler also give encouraging results for saving the water and improving the onion yield.

(iv) Weed control: Onion is a poor competitor of weeds due to short stature, non-branching habit, sparse foliage, shallow root system and frequent irrigation requirement. Manual, mechanical and chemical methods are followed for weed control in onion. Close spacing make the manual and mechanical method of weed control tedious, expensive and time consuming. Some times non-availability of labour at optimum time delay the operation and resulted in poor yield. Therefore, use of pre and post emergence weedicides commonly used for controlling the weeds. Pre-emergence herbicides are Mertibuzin (Sencor Lexone) @0.35, Propachlor (Ramrod)@4.5, Oxyfluorfen (Goal)@0.15-0.25, Fluchloralin (Basalin) @ 1.5-2.0, Pendiimetalin(Stomp)@2.5-3.5, Oxadiazon(Ronstar)@ 1.25, Methabenzthiazuron (Tribunal)@1.4, Nirtofen (Tok)@2.0, Linuron (Lorox)@0.94, Trifluralin (Treflan)@1.0 and Oxydiargyl (Raft) @0.25 kg or liter ha\(^{-1}\). Whereas, pre-emergence and post planting herbicides are Loxynil (Toxynil)@0.5, Pendiimetalin(Stomp)@2.5-3.5, Butrlin(Tamex, Sector)@3.5, Oxyfluorfen (Goal)@0.15-0.25, Fluchloralin (Basalin) @ 1.5-2.0, Alachlor(Lasso)@2.0,
Trifluralin (Treflan) @1.0 and Oxydiargyl (Raft) @0.25 kg or liter ha$^{-1}$. These herbicides are applied at recommended doze under optimum moisture conditions. Manual weeding for 2-3 times during the crop season also keeps the weed under control.

2. Mechanization: In onion, all operations starting from nursery sowing, transplanting, weeding, harvesting, grading and storage are carried out manually, consequently cost of cultivation is increased and net-returns are lowered. Involvement of manual labour in high number and lack of mechanization is also one of the reasons for limited area under onion in northwestern plains of India. Various institutes made sporadic efforts for development of machinery required in onion cultivation. As nursery seed drill have been developed by PAU, seed drill for direct sowing in field by PAU and IIHR; Pneumatic seeder imported from Italy by CIAE and PAU; seedling transplanter by IIHR; seedling transplant marker by PAU, bulb digger by IARI and PAU; seed extraction machine by IIHR and bulb grader by DOGR and IIHR. All these machines should be tested thoroughly and for comprehensive use as a package for onion cultivation in the country.

3. Seed Production: Seed is the basic input and contributes one-third in total productivity of the crop. The genetic purity is of more concern in this highly cross-pollinated and entomophilous crop for maintaining the uniformity of colour, size, shape and maturity; tolerance to bolting, splitting, non-bulbing and insect-pests; longer storability. Genetic purity begin with choice of true to type variety from reliable source, healthy bulb production practices, proper storage of mother bulbs, maintenance of more than 1000m isolation distance, ideal soil and climatic conditions for seed production, proper harvesting, threshing, cleaning and storage practices for onion seed. Onion seed production requires dry and moderate sunny days (18-25 °C) with cool nights (4-14 °C) at flowering and seed setting stage. Warm weather and high humidity leads towards perpetuation of fungal diseases. Some of the traditional areas considered suitable for onion seed production are Saurashtra in Gujarat; Nashik, Ahmednagar, Satara and Marathwada in Maharashtra; Khargaon, Indore and Dhar in Madhya Pradesh; Jaipur, Chittorgarh, Udaipur and Sriganganagar in Rajasthan; Kurnool in Andhra Pradesh and northern Karnataka. The bulbs used in seed production should be produced in recommended regions of the variety for maintaining the genetic stability. Onion seed is produced through annual and biennial methods. In annual method, seed-to-seed approach can be followed by advance sowing of seed and transplanting of nursery by two months, but seed
produced through this approach should be used for commercial bulb crop only, not again in seed cycle. The *kharif* season varieties are of short duration with low vernalization requirement and can complete the seed-bulb-seed cycle in one year also. However for *rabi* season varieties, biennial approach has to be opted due to more low temperature requirement for induction of flowering. About 25 quintals of medium sized (4-6 cm) bulbs are enough for planting one-hectare seed crop in month of Oct-Nov. All healthy production practices should be followed to get good seed yield. Seed setting percentage can further be enhanced by putting 4-6 honeybees boxes in one hectare. After harvesting seed should be cleaned, graded and dried to 6% moisture for storage at 16-20 ⁰C and 30-40% RH. Onion seed yield depends upon variety and weather conditions, but on an average 6-8 q ha⁻¹ seed can be harvested.

The annual onion seed requirement of the country is about 9600 tonnes @ 8.0 kg ha⁻¹, besides 20% additional stock required to cover poor germination, storage losses and as buffer stock. In this, 8% is supplied by the public sector organizations, 9% by the private seed companies, 13% by private traders and rest 70% by the farmers from their own saved seed. Thus, a big gap is there between the availability of improved varieties seed and the requirement. To cope this gap holistic planning is needed for production of breeder, foundation, certified and truthfully labeled seed by identifying areas for bulb and seed production of recommended varieties for different regions and for export. The objective should be to replace at least 50% area under improved varieties in the next ten years.

**4. Inset-pest and diseases management:** World wide, 40 fungal, 14 bacterial, six nematodes, three viral, one phytoplasmal and one parasitic plant have been reported, however, in India 29 fungal, three viral and four bacterial pathogens have observed. These diseases can cause up to 50% losses during crop production and storage. Among them, purple-blotch, Stemphyllium-blight and Anthracnose causes severe losses, whereas, downy mildew prevalent in temperate regions and, pink-rot and *Fusarium* basal-rot also cause damage in onion growing areas. The severity of the diseases is influenced by the seasonal effect, variety and growing conditions.

Purple-blotch (*Alternaria porri* (Ellis) Cif.) requires 22-25 ⁰C temperature and 90-100% RH for sporulation and infection. It forms small, water-soaked areas on leaf or seed stalk and turns brown. The enlarged spot becomes zonate and more or less purplish. The margin is a shade of purple or red and
surrounded by yellow halo that extends upwards and downwards for some distance. It can cause up to 80% yield losses under Indian conditions. *Stemphylium* leaf-blight (*Stemphylium vesicarium* Wallr.) occurs at the same time and even on the same plant as of purple blotch and forms the diseases complex. Its symptoms start with small, yellow to brown purple, water soaked lesions. These lesions elongate, become spindle shaped to ovate-elongate and turn into diffusive spot, often extending to leaf tips. The spots frequently coalesce into patches blighting leaves. As conidiophores and conidia develop on the lesions, turn light brown to tan purple at the center, and later dark olive-brown to black. Similar symptoms also occur on the scape of onion. Perithecia may appear in blighted areas of leaves and scape as small, black, pin-head like raised bodies.

*Anthracnose* (*Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc.) mainly shows white sunken-oval lesions, which turns into pale yellow water soaked spots and cover whole leaf in later stage. In severe cases pseudo-stem twists and show abnormal elongation. The favorable conditions for conidia germination and infection are high humidity and 23-30 °C temperature. It is more prevalent in *Kharif* crop. *Downy mildew* (*Pernospora destructor* (Berk.) Casp.) is highly destructive under cooler and humid regions and develops white to purplish downy growth first on entire surface of the older leaves. The affected parts become pale-green, yellow and collapse. The fungus requires cool moist nights and moderately warm days for best development. The conidia produced in humid atmosphere between 4-25 °C with optimum at 13 °C. Cloudy days favour most, as 8 hour of light kills the conidia.

Above fungal diseases can be managed by following clean cultivation, crop rotation, raised bed planting and proper drainage. Seed treatment with Bavistin (0.1%) and hot water (50 °C for 20 min), high rates of calcium, phosphorus and potassium also reduce diseases infection. Application of *Trichoderma viride*, *Bacillus subtilis*, *Saccharomyces cerevisiae* or Salicylic acid helps in managing these diseases. Foliar sprays of Mancozeb @ 0.25%, Tricyclazole @ 0.1% and Hexaconazole @ 0.1% effectively controls the diseases also.

Viral diseases are becoming major constraint in onion production. However, number of viruses like Iris yellow spot, Groundnut bud necrosis, Tobacco streak, Onion yellow dwarf, Allexi and Rymo viruses infect onion, but Iris yellow spot virus (IYSV) and onion yellow dwarf virus (OYDV) are more common. IYSV is Tospovirus, which develops spindle/diamond shaped chlorotic lesions on leaves and scapes and ultimately wither and twists the infected parts. This is sap transmitted and thrips are the main vector. OYDV is Potyvirus, which
develops yellow streaks, flattened leaves, dwarf plants, twisted flower stalk and under developed bulbs. It is transmitted by aphid vector. To control these viruses use virus free bulbs, control insect-vector and follow seed-seed approach.

Large number of insects including thrips, leaf miner, leafhopper, psyllid, beet army worm, curt worm, gram borer, red spider mite, onion maggot and nematodes attack onion. Among these all, thrip (*Thrips tabaci*) is wide spread and cause damage not only by feeding and oviposition, but as a vector of tospoviruses. Thrip infestation is directly associated with spread of fungal diseases also. Thrips can be managed with regular monitoring of inner-most whorl of the leaves. Thrip nymphs and adults are visible on plant, eggs laid inside the plant, while pre-pupal and pupal stages occur in the soil and debris. Use yellow and blue sticky traps, lure with ethyl isonicotinate and methyl isonicotinate. Time of planting, crop rotation, barrier crops, irrigation, fertilization, intercropping, deep ploughing, weed control, reflective mulches and clean management followed for cultural control of thrip. So far, non of the genotype with complete and stable resistance have been reported, but some tolerate thrips. Biological control of thrip with mired bug, *Orius sp.* and predatory mite *Amblyseius*; and entomopathogens, fungi, *Verticillium*, *Metarrhizium* and *Beauveria*; nematodes, *Steinernema feltiae*, *Thripinema* and *Heterorhabditis* have been reported under the green houses. Chemical insecticides belonging to organophosphate, carbamate and pyrethroid groups are widely used for controlling the trip in tropical onion. Seedling root-dip with Carbosulfan (0.025%) or Imidacloprid (0.04%) solution for 2 hours protect the plants up to 30 days. Foliar sprays of Lambda Cyhalothrin, Imidacloprid, Abamectin, Spinosad, Thiamethoxam, Fipronil, Acetamiprid, Acibenzolar-S-Methyl and Clothianidin lower the thrip population in onion.

5. **Post-harvest management:** A huge loss (40-50%) occurs during post-harvest handling and storage of onion, which includes weight loss (25-30%), rotting (10-15%) and sprouting (8-10%). Post-harvest losses depends upon variety, cropping season, cultural practices, crop maturity and post-harvest handling. Pre-harvest application of Maleic Hydrazide (MH), ethephon, calcium nitrate (0.5%), zinc sulphate (0.5%), abscisic acid (10 umol l⁻¹) and CIPC (2%) suppress the sprouting, particularly in *Kharif* onion. Exogenous application of calcium nitrate and calcium chelate improves the cell wall structure integrity and reduce microbial decay caused by black rot, neck rot and basal rot. A balance use of nitrogenous fertilizer and controlled irrigation before harvesting keep check on physiological weight loss of onion. Among post harvest management practices,
curing is the most important, which allows formation of strong intact outer protective skin and closure of onion neck. Curing significantly decrease the surface area and volume and, increase the bulk density and hardness of the freshly harvested bulbs. Curing under field conditions for 3-4 days with wind-row method and at 30 °C in controlled chamber found effective for storage of bulbs. Exogenous application of ethylene and ethylene binding inhibitor, 1-methylcyclopropene (1-MCP) suppress sprouts during storage in onion. However, application of CIP at 20 °C found effective than the hot fogging. Gamma-irradiation (0.15kGy) inhibit the sprouting, but its effect depends upon pre-harvest growing conditions, seasonal variation, curing period, bulb dormancy as well as storage environment/structures. Pre-cooling at <4 °C for 4-6 hours reported effective for maintaining the quality of onion produce. This can be done with hydro, forced air and vacuum cooling.

Storage environment has significant effect on dormancy and storage life of onion. Two distinct temperature ranges i.e. 0-2 °C and 25-30 °C found suitable for storage of onion, whereas, 10-20 °C is favorable for sprouting. Under, Indian conditions Directorate of Onion and Garlic recommended different ventilated storage structures and needs promotion to install in whole country. The basic is provision of ventilation to the stored bulbs from all sides with 1-1.2 m loading height and protection from rains with waterproof roof. To reduce the storage losses forced air ventilation flow has been suggested @ 114 m³ hr⁻¹ MT⁻¹ of onion bulbs. Keeping all precautions under ambient conditions, about 30% losses are inevitable, which can be reduced with cold storage at 1-2 °C and 55-70% RH. To get maximum storage benefit, bulbs should be fully mature and properly cured with tight neck. The air circulation in the store requires temperature and humidity without condensation of water on the bulb surface. Excessive humidity promotes root development and, higher temperature and humidity favor sprouting and pathological disorders. The controlled atmosphere (CA) storage having 2-4% O₂, 0-5% CO₂, 86-92% RH and 2±1 °C temperature can store onion bulbs for eight months with minimum losses. The onion availability to the consumers can further be enhanced by processing and value addition. It can be in form of pre-sliced fresh onion, dehydrated, powdered, paste, pickle, vinegar, oil and wine.

6. Marketing and Export: Onion showed 8.28% per annum growth in production, 6.01% in area and 2.48% in productivity during the last two decades. However, its growth was exponential for production (14.24%), area (8.84%) and productivity (4.97%) during the last ten years. This made the increase in per
capita availability of onion from 4.56 to 13.97 kg in the country. The per capita consumption growth of 12% indicated remarkable preference of onion by the Indian consumers. No other food crop in India has shown this type of growth in recent past. The increase in income, change of life-style and dietary pattern increased the onion consumption by 53% in urban area. Large expansion of eating joints, outside eateries, snack corners and restaurants enhanced the onion consumption considerably due to main ingredient, particularly in spicy food. There is a high rigidity in consumer demand and is difficult to imagine acceptance of any food without the onion. It has replaced its substitute spices due to their high cost. The low price elasticity of demand for onion implies from the fact that 10% increase in price resulted in 1% decline in demand, whereas, 10% shortfall in supply increase 100% price of onion. Such, situation is exploited by the traders to hike the price. Presently, about 70% of onion production is from Maharashtra, Karnataka, Madhya Pradesh, Gujarat and Bihar. Maharashtra contributes about 30% of the total and in March 2013, due to abnormal weather 4% low production was predicted in the state. Understanding this situation private traders procured onion in a big way at higher price from April to June (24% higher than normal), as a result supply from the farmer dried up after June. Market arrival in July lowered by 17% and in August by 22% than the previous year. Then traders control the supply and price of onion, which was 186 and 293% higher in July and August than the previous year price, respectively. So, decrease in production of onion responsible to a small extent, but predominant part is with drawl of stock from the market. Such shock in onion prices occurs frequently and we usually attribute it to unfavorable weather, rather than to cartelization, hoarding etc. by the traders, which needs solution to avoid their recurrence.

The world trade of onion exports is about 6.77 million tonnes of worth US$ 2,856. India ranked first in export (1.82 million MT), followed by China (0.74), The Netherlands (0.6), Egypt (0.49), Mexico (0.37), USA (0.35), Spain (0.25), Argentina (0.21), Pakistan (0.17) and Turkey (0.12). The onion export in India has risen with 9% growth rate during last decade. Malaysia, Sri Lanka, Bangladesh and UAE are the major and traditional markets for export due to high demand of Indian red onion. Further, penetration in European, American and Japanese markets can be made with the development of big size yellow onions.

Though, horizontal and vertical growth of onion occurred due to increase in demand, high returns, better varieties and improved production technologies,
but hike in prices many times lead to sensitive social, political and economical unrest in the country. Such situation should be handled with strict vigil on the distribution system specially hoarding and black marketing; exploring way to withheld stock with the farmers; extending cultivation to alternative geographic regions than the traditional; developing mechanism for forecasting; strengthening existing storage system; proper distribution system; augmentation with import; developing high yielding varieties/hybrids; adoption of improved production technologies and reducing post-harvest losses.

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Wisconsin, Madison, USA.
Advances in production technology of brinjal

(Solanum melongena L.)

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Globally, brinjal is grown in an area of 1.87 million hectares with a production of about 49.50 million tonnes. China and India are the leading producers of brinjal which is popularly called poor man’s vegetable and about 573000 hectare is annually planted under this crop in India with the production of 12589000 tonnes (FAO STAT 2013). Worldwide, the crop is also popular in France, Italy and United States as the name “eggplant” reveals that the first introductions were small fruited, which look like chicken eggs. In India, West Bengal, Orissa, Gujrat and Bihar are leading states in brinjal cultivation (India Stat 2015). In Himachal Pradesh, it is grown as a cash crop in low and mid hills.

It is valued for its tender unripe fruits that are cooked as vegetable and it has potential as raw material in pickle and dehydration industries. It is quite rich in nutrients and health building substances and can play a significant role in combating mal-nutrition and under-nutrition problems in the country. Oblong fruited varieties contain large amount of free reducing sugars, anthocyanins, phenols, glycoalkaloids (solasodine), dry matter and amide proteins. Long fruited brinjals are rich in total soluble solids whreraes round types have high polyphenol activity and glycoalkaloid contents. Normally, the glycol-alkaloid content in cultivated varieties varies from 0.37 mg to 4.83 mg/100 g and about 20 mg and above quantity causes bitterness. Varieties also vary w.r.t polyphenol oxidase content, which imparts brown discolouration after cutting brinjal fruits. It has also been recommended as an excellent remedy for those suffering from liver complaints (Shukla and Naik 1993).

Depending upon regional preferences, a large number of varieties have been developed in India, which vary in shape (long, oblong, round, oval, etc.) colour (purple (most parts), green(Orissa), white and a blend of colours), and size (small, medium, large and extra large). Selection of a variety/hybrid depends upon market demand and specific regional problems.
The productivity of brinjal in India can be considerably improved by selection of appropriate varieties/hybrids, use of seed from reliable source and raising commercial crop from plants grown in plug trays in soil less media, growing the crop under optimum conditions (climate soil, time, irrigation (trickle) and proper field preparation), plant density, integrated plant nutrient management, weed management, mulches, integrated pest and disease management practices, growing parthenocarpic/OP varieties under net houses, ratooning of Kharif brinjal in northern plains and low hills and timely harvesting. Maturity indices and post harvest handling techniques including value addition can go a long way in reducing the spoilage of fruits after harvesting.

**Varieties:**

A wide array of varieties is available in brinjal on the basis of fruit colour, shape and size and the preference varies both region and season. Selection of an appropriate variety is a prerequisite for commercial production due to specific regional and local preferences. Till date, 48 high yielding varieties and 8 diseases resistant varieties of brinjal have been recommended for cultivation in different zones of the country through All India Coordinated Research Trials. Likewise, more than 39 hybrids have been recommended for different zones through All India Coordinated trials. Long (Pusa Hybrid-5) and round type (Pusa Hybrid-6 and 9) hybrids, developed by IARI, New Delhi (Table-1) offer great promise for cultivation in our country; Northern plains, Central India, non coastal areas of Kerala, T.N., Karnataka and Andhra Pradesh, North and Central India (Pusa Hybrid 6) and Gujarat and Maharasthra (Pusa Hybrid-9). Arka Nidhi, Arka Keshav, Arka Neelkanth (purple long), Hissar Shyamal (purple round), Neelima (hybrid), Soorya (purple oblong), Hartha (green long) and Swetha (greenish white long) are suitable for growing in bacterial wilt prone pockets of the country. Of late, 3 hybrids (PBH-3, PBH-4 and PBHL-52) from PAU and I hybrid (DBHL-20) from IARI, New Delhi also offer promise for early maturity and high yield potential.
Table-1 Promising varieties and hybrids of brinjal

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Name of Variety/Hybrid</th>
<th>Fruit shape and colour</th>
<th>Average yield (q/ha)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Arka Nidhi</td>
<td>Long bluish purple</td>
<td>300</td>
<td>BWR</td>
</tr>
<tr>
<td>2.</td>
<td>Arka Keshav</td>
<td>Long reddish purple</td>
<td>350</td>
<td>BWR</td>
</tr>
<tr>
<td>3.</td>
<td>Arka Navneet(F&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>Round to oval purple</td>
<td>600</td>
<td>Cooking quality</td>
</tr>
<tr>
<td>4.</td>
<td>NDBH-1(F&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>Oblong purple</td>
<td>600</td>
<td>Cluster</td>
</tr>
<tr>
<td>5.</td>
<td>NDBH-6(F&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>Oblong purple</td>
<td>600</td>
<td>Cluster</td>
</tr>
<tr>
<td>6.</td>
<td>Pant BH-1(F&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>Long purple</td>
<td>500</td>
<td>BWR</td>
</tr>
<tr>
<td>7.</td>
<td>Punjab Sadabahar</td>
<td>Long deep purple</td>
<td>350</td>
<td>SFBT</td>
</tr>
<tr>
<td>8.</td>
<td>Punjab -8</td>
<td>Round light purple</td>
<td>300</td>
<td>Early-5</td>
</tr>
<tr>
<td>9.</td>
<td>Pusa Hybrid-5(F&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>Long dark purple</td>
<td>450</td>
<td>-</td>
</tr>
<tr>
<td>10.</td>
<td>Pusa Hybrid-6(F&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>Round purple</td>
<td>450</td>
<td>early</td>
</tr>
<tr>
<td>11.</td>
<td>Pusa Hybrid-9(F&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>Oval round and purple</td>
<td>550</td>
<td>Glossy</td>
</tr>
<tr>
<td>12.</td>
<td>VRBHR-1(F&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>Round light purple</td>
<td>700</td>
<td>-</td>
</tr>
<tr>
<td>13.</td>
<td>Pusa Brinjal-20(DBHL-20)*</td>
<td>Long dark purple</td>
<td>600</td>
<td>High yield</td>
</tr>
<tr>
<td>14.</td>
<td>PBH-3*</td>
<td>Early, small round, purple</td>
<td>-</td>
<td>High yield</td>
</tr>
<tr>
<td>15.</td>
<td>PBH-4*</td>
<td>Early, long, dark purple</td>
<td>-</td>
<td>High yield</td>
</tr>
<tr>
<td>16.</td>
<td>PBHL-52*</td>
<td>Early, long, dark purple</td>
<td>-</td>
<td>High yield</td>
</tr>
</tbody>
</table>

- New hybrids

Keeping in view the high yield potential of hybrid varieties, hybrids should always be preferred. Grafting of brinjal over wild or resistant root stocks provides protection against various biotic and abiotic stresses. Liu et al. (2009) reported that eggplant grafted on to tomato root stock exhibited markedly higher disease
resistance and yield than non-grafted eggplant when challenged with *Verticillium dahliae*.

**Climate and soil:**

It is a warm season, long duration and frost sensitive crop. Temperatures below optimum (21 °C) affect yield and quality and result in deformed fruits. Temperature below 16°C retards growth, pollen germination and fruit development. Cloudy and cool weather also reduce fruit set. It can tolerate drought and excessive rainfall and remains vegetative under high temperature and humidity.

Deep, fertile well drained and organic matter rich soils, having pH of 5.5 to 6.8, are ideally suited for its commercial production. However, heavy clay and saturated soils should be avoided due to increased incidence of root and collar rot.

**Seed treatment:**

Soak seeds in warm water (50°C) for 30 minutes, then rinse in cold water and dry the seeds before sowing. Treat the seeds with thiram or captan or bavastin. Soaking of seeds in GA₃ @ 200ppm and KNO₃ at 4% gave 100 and 80% germination, respectively in Annamalai variety of brinjal having seed dormancy of 2-3 months. Dormancy has also been observed in Arka Nidhi and Arka Keshav varieties of brinjal, which were sown from freshly harvested seed (personal communication).

**Nursery raising:**

The time of nursery raising varies depending upon the temperature, rainfall, region and availability of irrigation facilities. In North India, following schedule of nursery raising is followed for commercial production:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Time of sowing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autumn crop</td>
<td>June-July</td>
</tr>
<tr>
<td>Spring-summer crop</td>
<td>November</td>
</tr>
<tr>
<td>Rainy season crop</td>
<td>March-May</td>
</tr>
</tbody>
</table>

500-750g seed of O.P. varieties and 350-400g seed of hybrid varieties is sufficient for transplanting in 1 hectare of land. On an average, 1 g seed contains about 250 seeds. Of late, transplants which allow field planting without disturbing the root system and require lesser seed quantity, are used in many
countries to raise the crop. In this method, plug trays or containers are filled with peat moss or soil mixture or commercial potting soil or a potting mixture prepared by mixing soil, compost, rice hulls, vermiculite, peat moss and sand. Sterilize the mixture by autoclaving or baking at 150°C for at least 2 hours. Preferably, growing media containing 3 parts cocopeat, 1 part vermiculite and 1 part perlite should be used for high quality production of brinjal transplants. Plug seedlings are raised in green houses and fertilized with water-soluble fertilizers. Seedlings are ready for transplanting in green house within 4-5 weeks after sowing.

The seedlings can be grown in the nursery beds either in the green house or in the open. Apply 150-200 g fertilizer mixture or 100g each of ammonium sulfate, superphosphate and muriate of potash and 10-15 kg of compost or well-rotten FYM per 3 square meter area. Nursery beds should be 15-20 cm high, 1 m wide, and seeds should be sown in rows 5-6 cm apart and 0.5 cm deep. Avoid thick sowing of seeds to avoid damping off. Hardening is another important operation and it should begin 6-9 days before transplanting to minimize transplanting shock by withholding water, removing polythene sheet/nets and exposing the seedlings to stronger sunlight. The crop should be transplanted in the evening hours when the nursery plants are about 15 cm tall having 4-5 leaves. Pressing the soil firmly and light irrigation through flooding or spot watering are important to establish a good root-soil contact. Raised beds, plastic and organic mulches are used in a few counties for commercial production.

**Plant population:**

The plant density varies with soil fertility, season and cultivars. Singh *et al.* (1997) reported that closer planting (45 X 45 cm) of brinjal hybrids BH-1 and BH-2 produced the highest early, marketable and total yield along with maximum dry matter accumulation. Location specific studies are essential for harnessing the real production potential of new varieties/hybrids.

**Manures and fertilizers:**

The manures and fertilizer requirement depends on soil type, growing season and cultivar. Brinjal is a long duration and heavy yielding crop thereby, removing large quantity of nutrients. Soil testing is a pre-requisite for sustainable and optimum returns. The doses of manures and fertilizers differ from state to state and may vary from 100-150 kg N, 80-100kg P and 60-75 kg
K per hectare. Moreover, fertilizer doses may vary depending on the fertility of the soils. Organic manures @ 15-20 tonnes should be applied well in advance whereas full P and K and 1/3rd N are mixed and applied as basal dose. Remaining N should be top desired in two equal doses i.e. 25-30 and 40-50 days after transplanting about 5-10 cm away from the plant. In fact, 30% of the N should be applied before transplanting, 15% in each side dressing (3-4 & 6-7 weeks after TP) and 40% applied during first harvest. Prabhu et al. (2006) at Coimbatore (India) reported that the earliest flowering (37.90 days) was obtained with 175 kg N + 100 kg P + 100 kg K/ha while, the highest mean number of fruits per plant (40.49), individual fruit weight (88.37 g) and yield (56.90 tonnes/ha) were obtained with 200 kg N + 100 kg P + 100 kg K/ha. Maniutiui (2006) in Romania reported that plants trained with 3 branches and supplied with fertilizer weekly exhibited superior growth over the control (untrained plants treated with fertilizer monthly) and other treatments. Higher early yields were obtained when the fertilizer was applied weekly than monthly. Srijaya and Sitaramayya (2006) in Hyderabad (A.P) studied the effect of nutrient management practices on fruit yield and nutrient composition of brinjal (cv. Bhagyamati) in Alfisol of Ranga Reddy district, and revealed that fruit yield significantly increased with the application of RDF+Zn (S.A.) (201.65 q ha-1) with 26.3 per cent over RDF (174.94 q ha-1). Among the organic sources, vermincompost had more additive effect over FYM in realizing more fruit yield and nutrient composition.

Siddiky et al. (2007) in Bangladesh reported that the highest brinjal yield (73.65 t ha-1) was recorded with Zn at the rate of 3.00 kg ha-1, and beyond that the yield declined steadily. The 88% yield increase was also noticed in the same treatment. Interaction effect of B and Zn was found to be highly beneficial to the yield and yield components of brinjal. The highest yield (81.67 t ha-1) was recorded with B-Zn combination at the rate of B 1.50, Zn 3.00 kg ha-1 and 166% yield increase over B-Zn control (B₀ Zn₀). Balliu (2007) at Tirana, Albania conducted an experiment in green house and reported that the growth rate of young aubergine was strongly dependent on the N concentration in the nutrient solution. Deolankar et al. (2007) evaluated the efficiency of liquid fertilizer application through drip irrigation in improving the performance of brinjal cv. Krishna during summer. The NPK liquid fertilizer was supplied in 4 splits at 15-day intervals (20, 20, 30 and 30% of each level of fertilizer dose) and highest yield was obtained under 100% NPK applied as drip

In India, substitution of ammonium sulfate and single super phosphate with diammonium phosphate and urea for increasing vegetable productivity vis-
à-vis inadequate use of organic manures have rendered the vegetable fields deficient in macro, secondary and micro nutrients. Availability of adequate P and K is essential for improving quality and shelf life of vegetables. Application of FYM @ 25 t/ha along with 100% NPK + biofertilizers (Azospirillium & PSB) recorded the highest fruit set percentage (65%), fruit number (26.64) and fruit yield (31.67 t/ha).

**Interculture and weed control:**

Weeds pose serious competition for light, nutrients and moisture and yield losses up to 70 per cent have been reported. These also harbour insect-pests and diseases, which affect yield and quality of the produce. *Solanum nigrum* is a host for brinjal shoot and fruit borer. *Vicia sativa* (common vetch) provides shelter for *Helicoverpa armigera* whereas *Ageratum* spp and *Lantana* spp provide shelter to white fly. The weed management studies reveal that weeds should be controlled early in the growing period and sustained until the vegetable crop is able to compete with the weeds. Therefore, regular weeding and hoeing are required at 3 weeks interval.

Pre-sowing irrigation, crop rotation and intercropping, drip irrigation, mulches (black and saw dust), solarization for 4-6 weeks, chemical control (soil fumigants and herbicides) are a few strategies, which should be followed for effective weed control in brinjal.

Pre-mergence application of Pendimethalin @ 1 Kg/ha + two hand weedings after 30 and 60 DAT is the most effective, practical and economical method for getting high yield and better quality fruits (Razia, 2001). She further reported that Alachlor 50 EC (LASSO) (PP) fb 2HW, Trifluralin 48 EC (Treflan) (PPI) fb 2HW and metolachlor 50 EC (Dual) (PP) fb 2HW also resulted in effective weed control with high benefit cost ratio in brinjal. Singh *et al.* (2006) in Bikaner, Rajasthan reported that the synthetic and organic mulches conserved 55 and 36% more moisture per 0.15 cm soil depth, respectively as compared to control. Soil temperature was favourably moderate in mulch materials as compared to unmulched treatment. They further reported that plant height, stem girth, plant spread, number of fruits/plant and fruit yield increased with mulch application.

Shivalingapp *et al.* (2014) reported that application of butachlor and pretilachlor at 1.5 kg a.i. /ha were phytotoxic while, pendimethalin at 1.0 and 1.5 kg a.i. /ha was non-phytotoxic to brinjal plants. Total number and total dry weight of weeds were found to be maximum in unweeded control and weed
control treatments decreased these parameters but, the treatment where pendimethalin at 1.5 kg a.i. /ha was applied, total number and total dry weight were the lowest. WCE (%) was highest with the pendimethalin at 1.5 kg a.i. /ha. The yield parameters viz. number of fruits, fruit weight, and fruit yield decreased significantly in unweeded control while weed index was higher. The fruit yield was significantly higher with application of pendimethalin at 1.5 kg a.i. /ha

**Irrigation:**

Irrigation in brinjal depends on the season, soil type and method of transplanting. On an average, 100-110 cm of irrigation water is required during the cropping period to get a successful crop. In general, if soil is light, it needs more irrigation compared to the heavy soil. Similarly in summer season, the irrigation interval is less compared to the winter crop. Rainy season crop requires less or no irrigation depending upon the frequency of monsoon rains.

Drip irrigation system has been found very useful in eggplant cultivation. Besides providing the adequate moisture, this system enables proper aeration in root zone. Relative performance of micro-irrigation compared to traditional system in eggplant is given in table 2.

**Table 2 Relative performances of micro-irrigation and traditional system**

<table>
<thead>
<tr>
<th>Location</th>
<th>Yield (q/ha)</th>
<th>Irrigation (cm)</th>
<th>WUE (q/ha/cm)</th>
<th>Adv. Of MI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surf.</td>
<td>Drip</td>
<td>Surf.</td>
<td>Drip</td>
</tr>
<tr>
<td>Akola</td>
<td>91.00</td>
<td>148.00</td>
<td>168.00</td>
<td>64.00</td>
</tr>
<tr>
<td>Delhi</td>
<td>280.00</td>
<td>338.00</td>
<td>45.00</td>
<td>35.00</td>
</tr>
<tr>
<td>NCPA</td>
<td>280.00</td>
<td>320.00</td>
<td>90.00</td>
<td>42.00</td>
</tr>
<tr>
<td>Pune</td>
<td>225.00</td>
<td>245.00</td>
<td>78.00</td>
<td>51.00</td>
</tr>
<tr>
<td>Rahuri</td>
<td>280.00</td>
<td>280.00</td>
<td>90.00</td>
<td>42.00</td>
</tr>
</tbody>
</table>

In brinjal, highest yield of 42.33 tonnes/ha was recorded in drip irrigation at 75% of recommended N and K with maximum shoot length and number of branches per plant when compared with other levels of irrigation and fertigation (Vijayakumar et al., 2010). At IIHR, the highest yield (1004 q/ha)
along with C:B ratio (6.1) was recorded in tomato, which was grown under drip irrigation at 0.9 PE with black-silver polythene mulch (Anonymous, 2015).

**Growth regulators**

Induced parthenocarpy, increased fruit set, advanced fruit maturation and significant increase in total yield was obtained by the application of 2,4-D at 2 ppm at flowering stage. Though, short styled and pseudo short styled flowers do not normally set any fruit, the application of 2,4-D on pseudo short styled, medium styled and long styled produced a higher percentage of fruit set. Tang *et al.* (2006) in China suggested that ABA could effectively delay the decrease of relative water content in the leaves of aubergine seedling during drought stress, as well as effectively enhance the ability of aubergine seedling resistance to drought stress. Rohokale *et al.* (2007) in Rahuri (Maharashtra) reported that five foliar sprays of 20% methanol at 15 + 30 + 45 + 60 + 75 days after transplanting resulted in increase in nutrient uptake and yield of aubergine.

**Harvesting**

The brinjal fruits should be harvested when they attain a good size, attractive colour and its surface should not loose its bright and glossy appearance. At full maturity, fruits become yellow or dull in colour. It is an indication of over maturity and loss of quality. The maturity can be tested by pressing the thumb on the front skin. If the pressed portion springs back to its original shape, the fruit is too immature. Timely harvesting of tender fruits increases the total growing period and number of pickings and yield. It has been observed that about 3 weeks old brinjal fruits are optimally mature to harvest. Small fruited varieties are harvested more frequently than bigger ones.

**Yield**

The yield of the brinjal fruits depends on the cultivar, growing season, fertility status of the soil and application of manures and fertilizers, etc. Under optimum growing conditions and good management, long, round, oblong and small round varieties produce 50, 65, 60 and 40 t/ha, respectively whereas, F1 hybrids have potential to produce 62.5, 79, 75 and 50 t/ha in these respective groups. On an average, yield of open pollinated varieties varies from 300-500 q/ha whereas hybrids produce an average yield of 600-800 q/ha.
Storage and marketing

Brinjal fruits can be stored for about a week at 8 to 10°C at 85 to 90% relative humidity. Green brinjals have comparatively longer shelf life. Pre treatment with fungicidal wax emulsion and packaging in perforated polythene bag enhances shelf life. Polythene packed fruits (150 gauges) recorded significantly lower values (2%) for physiological loss compared to gunny bags packed fruits (13%) on 10th day of storage under ambient conditions. However, decay loss was significantly less in gunny bag packed fruits.

Conclusion:

Production and productivity of brinjal can be considerably improved by growing disease resistant hybrid/OP varieties, development and cultivation of Bt-transgenics, ensuring availability of quality seed and seed treatment and pro/plug tray nursery production Standardization of cultural practices, irrigation and nutritional requirements of different cultivars under different soils and climatic conditions will ensure better crop stand and higher production. The use of herbicides and mulching practices have potential to suppress the fast growth of weeds in brinjal thereby, producing healthier and better quality produce. The water use efficiency has been increased by 66% using trickle irrigation and also resulted in about 20 -25 % increase in yield. Protected cultivation especially, net house cultivation in suitable locations makes the availability of pesticide free quality brinjal fruits and proved cost effective and eco-friendly for harvesting borer free fruits. Adopting strict IPM schedule against brinjal shoot and fruit borer can be rewarding proposition in commercial production of brinjal. Use of growth regulators induced parthenocarpy, earliness and high yield while different chemical formulations helped in checking of various insect-pest and diseases of brinjal. The grafting of brinjal cultivars on perennial and wild species have potential to increase the yield and availability period of the fruits.
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Trends and Techniques of Cultivation of High Value Vegetables Under Protected Environment

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Since ancient time, mankind has been well aware of the fact that wise modification of environment could improve the productivity of crops. For instance, the fact that light transmitting structure could create a favourable environment was certainly known to Romans as Emperor Tiberius Caesar used to eat a cucumber daily. However, in the present scenario, protected cultivation is considered as one of the core components of precision farming and has a tremendous and multifarious role to play in global horticulture by increasing the availability of quality horticultural produce thereby, ensuring access to year-round nutritious, safe and quality food.

In the last two decades, the green house industry has spread widely around the globe. In fact, there are two basic greenhouse agro-systems (Wittwer and Castilla, 1995). One type is sophisticated and highly controlled i.e. Northern greenhouse agro-system, typical of the high latitudes areas of Europe and North America that developed first in these colder climates because of the obvious inability of the plants to grow outdoors in freezing weather (Albright, 2002). The second type of greenhouse provides minimal or partial climate control, enabling the plants to survive and produce an economical yield (Enoch, 1986). The design of a greenhouse agro-system, in between these two extreme types, can vary greatly depending on whether it is located in a desert, the tropics or a temperate region (Jensen, 2002). India, unlike other countries using greenhouse concept, has six climatic zones ranging from extreme hot deserts to chilly, high altitude regions and a vast coastal region having warm and humid climate (Bansal and Minke, 1988).

After green revolution, our country has become self-sufficient in food-grain production. Now-onwards, we need to redefine our planning and approach to increase availability of high value crops like vegetables which can address under-nutrition and mal-nutrition problems, besides ensuring financial and livelihood security especially, in rural areas. Simultaneously, technological transfer through training and skill enhancement can play a vital role in Indian agriculture thereby, bringing socio-economic transformation among farmers
especially, in the underprivileged areas, for overall economic development of the nation. Although India has become self-sufficient in food-grain production, yet increasing pressure on natural resources coupled with degradation of land and water are posing serious threats to socio-economic, livelihood and environmental security. Thus, at present, biotic and abiotic stresses are the major bottlenecks making farming more risky and challenging. In order to overcome these problems, protected cultivation can play a predominant role in enhancing quality production of wide array of horticultural crops per unit area and time.

**Protected Cultivation- Relevance and Trends:**

Growing high value horticultural crops under protected environment is a vital component of protected agriculture, which necessitates need-based human/automatic interventions that create favourable conditions around the cultivated plants offsetting the detrimental effects of prevailing abiotic and biotic factors. As we are well aware that the plants in open field conditions experience short growing/cropping season, unfavourable climatic conditions/vagaries of weather (cold, hot, dry, wet, windy and cloudy) impairing photosynthetic activities and product quality. Besides, crops in open field conditions are more vulnerable to pests, depletion of soil moisture and plant nutrients. Due to vagaries of weather and ever increasing insect-pest/wild animal incidence in open environments, growing high value crops like vegetables has become risky, unreliable and less remunerative. In protected agriculture, one or more of these factors viz. temperature, air circulation, light, relative humidity, carbon dioxide concentration, wind velocity, irrigation/fertigation and insect-pests etc. are partially or completely controlled/adjusted as per crop requirement, and accordingly, per square meter construction cost of protected structures varies depending upon the level of climate control. Appropriate protected structures are constructed in different locations/areas as per prevailing abiotic and biotic stresses for harnessing optimum growth and yield.

In the changing scenario of increasing population, decreasing cultivable land/water resources, increasing urbanization/industrialization, there is a need to produce more from available land and water (more cop per drop). Further, with globalization of markets and global climate change, the protected cultivation of high value crops has emerged as the single most important technology for ensuring high productivity, improved quality and lucrative returns. Protected cultivation offers great scope to harness the potential of growing the high value crops by achieving independence of climate and weather, and to grow these crops
during off-season and in marginal environments. Globally, there is a need to increase productivity and quality of the produce of the high value crops to meet the demand of ever increasing quality and health conscious consumers. Hence, a breakthrough in production technology of high value crops that integrates market driven safe foods/products quality parameters with the production system by ensuring vertical growth in the productivity, will be required. These crops also have tremendous scope for enhancing profitability and livelihood options.

This technology encompasses all the practices involved in the control of plant growth viz., use of mulch, row cover, plastic low tunnel or poly-tunnel, hot bed/soil trench, substrate culture, hydroponics, greenhouse/glasshouse/polyhouse, soil less cultivation, shade house/screen house, growth chamber and mist propagation chamber etc. The use of covering techniques started with mulching followed by row covers, plastic low tunnels, walk-in tunnels, high tunnels, polyhouses or greenhouses for growing tender crops under protection. All these covering devices were used to overcome various abiotic and biotic stresses since limited areas around the world are endowed with favourable growing conditions for round the year crop production in open environments. However, of late, the locations requiring least energy for greenhouse production of high value crops are preferred, and due to varied climate and topography, our country has tremendous potential for this technology. Protected cultivation being highly skill oriented, knowledge based and labour intensive venture, has the potential to generate employment opportunities in rural and peri-urban areas. After adoption of this technology, there has been paradigm shift in polyhouse grower’s perception from production to productivity and quality with major emphasis on profitability.

At present, the total area under protected cultivation of horticultural crops in India is more than 25,000 ha. Our country has varied agro-ecological situations in different regions, so the cost effective low and medium-cost greenhouses, low tunnels and other related low cost structures need to be developed as per local agro-ecological situations. Protected structures have been built in Ladakh and other cold desert regions mainly for extending the growing season of vegetables due to greenhouse effect (Castilla, 2005). In North-East and other high rainfall areas of the country, such structures act as rain shelters to permit off-season production due to umbrella effect (Garnaud, 1987). The coastal and southern regions require naturally ventilated polyhouses for efficient and round the year cultivation of vegetables and flowers. In deserts and dry
locations, this technology can be harnessed by inducing **oasis effect** (Sirjacobs, 1988). In Northern regions with hot and cold climate, the protected cultivation technology can be efficiently and economically utilized by integrating **greenhouse**, **oasis** and **umbrella** effects depending upon season and location. In the plains, the polyhouses also need cooling (fan-pad) devices thereby, increasing maintenance cost. However, economics as well as effectiveness of cooling for successful production of various crops under these greenhouses is doubtful keeping in view the high ambient temperature w.e.f. April to October. UV stabilized net houses of at-least 50 mesh have been successfully utilized to grow capsicum, tomato, okra, brinjal and beans etc. in low hills and adjoining plains and such greenhouses having cladding with screens (nets) is finding favour in very mild temperature areas (low latitudes) or periods (in medium latitudes during the spring and summer seasons). Various cucurbits (cucumber, bitter gourd, summer squash, musk melon and water melon) can be planted in plains in plastic low tunnels/poly tunnels, and by the time flowering starts, the plastic film is removed mechanically or manually-**temporary transparent shelters**. The farmers can pre-pone the harvest of these crops by 30-40 days. Production of high value crops in greenhouses, however, is an intensive enterprise requiring basic training, skilled man power, regular monitoring and capital inputs.

Protected cultivation has extended to many states and offers vast scope for expansion of greenhouse technology in India. In North western Himalaya, due to varying topography, a few states like Jammu and Kashmir, Himachal and Uttarakhand are also called as natural greenhouses of the country for producing off-season vegetables and flowers. Scattered and small land holdings, difficult terrain, fluctuating and unpredictable weather, prevalence of low temperature during autumn winter and spring and large variation in seasonal and diurnal temperature especially in North western Himalaya offer scope for product diversification, remunerative returns, besides improving food habits of farmers.

In Himachal Pradesh, due to initiation of various Horticulture Technology Mission schemes(HTM I-III, HMNEH and MIDH ) implemented by state Department of Horticulture w.e.f. 2003 onwards and NABARD funded schemes(Pandit Deen Dayal Kissan Bhagwan Samridhi Yojna and Dr Y S Parmar Kissan Swarojgar Yojna), implemented by state Department of Agriculture, the area under protected cultivation has increased to more than 300 hectares (personal communication from Directorates of Horticulture and Agriculture), and the state ranks third in protected cultivation after Maharashtra and
Karnataka. In these schemes, thousands of different polyhouses, including portable low/fixed tunnels have been constructed in almost all the districts of the state since inception of these schemes (table-1).

**Table 1: Status of polyhouses in HP as on March, 2014 under Pandit Deen Dayal Kissan Bhagwan Samridhi Yojna-I for growing high value vegetables/nursery**

<table>
<thead>
<tr>
<th>District</th>
<th>Polyhouse size (Number)</th>
<th>1000 sqm</th>
<th>500 sqm</th>
<th>250 sqm</th>
<th>100-150 sqm</th>
<th>40 sqm*</th>
<th>6 sqm**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilaspur</td>
<td></td>
<td>20</td>
<td>116</td>
<td>190</td>
<td>244</td>
<td>7</td>
<td>549</td>
</tr>
<tr>
<td>Chamba</td>
<td></td>
<td>0</td>
<td>12</td>
<td>107</td>
<td>141</td>
<td>92</td>
<td>345</td>
</tr>
<tr>
<td>Hamirpur</td>
<td></td>
<td>6</td>
<td>53</td>
<td>233</td>
<td>134</td>
<td>127</td>
<td>363</td>
</tr>
<tr>
<td>Kangra</td>
<td></td>
<td>12</td>
<td>120</td>
<td>323</td>
<td>532</td>
<td>178</td>
<td>295</td>
</tr>
<tr>
<td>Kinnaur</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>59</td>
<td>100</td>
</tr>
<tr>
<td>Kullu</td>
<td></td>
<td>0</td>
<td>35</td>
<td>65</td>
<td>43</td>
<td>36</td>
<td>599</td>
</tr>
<tr>
<td>L/Spiti</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>158</td>
<td>127</td>
</tr>
<tr>
<td>Mandi</td>
<td></td>
<td>6</td>
<td>65</td>
<td>342</td>
<td>316</td>
<td>61</td>
<td>1650</td>
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<tr>
<td>Shimla</td>
<td></td>
<td>0</td>
<td>46</td>
<td>168</td>
<td>162</td>
<td>84</td>
<td>419</td>
</tr>
<tr>
<td>Sirmaur</td>
<td></td>
<td>9</td>
<td>80</td>
<td>221</td>
<td>34</td>
<td>48</td>
<td>217</td>
</tr>
<tr>
<td>Solan</td>
<td></td>
<td>4</td>
<td>80</td>
<td>309</td>
<td>162</td>
<td>39</td>
<td>750</td>
</tr>
<tr>
<td>Una</td>
<td></td>
<td>49</td>
<td>135</td>
<td>79</td>
<td>152</td>
<td>2</td>
<td>130</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>106</td>
<td>742</td>
<td>2037</td>
<td>1920</td>
<td>891</td>
<td>5544</td>
</tr>
</tbody>
</table>

*L*Low tunnel

**portable tunnel

Large (1000 and 500 sq m) polyhouses predominate in low hills (Una, Bilaspur, Kangra, Sirmaur and Solan) whereas medium (250 sq m) and small(<150 sq m) predominate in mid and high hills (Mandi, Kangra, Solan and Hamirpur). In Krishi Bagwan Samridhi Yojna Part –I, about 147 ha was covered under polyhouses till March, 2014. However, for commercial cultivation, only big and medium sized polyhouses offer promise. Small sized polyhouses or portable or fixed low tunnels are used by hill farmers either for producing quality nursery of high value crops or growing leafy vegetables, including coriander and other exotic vegetables for self consumption thereby, ensuring their financial, health and nutritional security.
Strategies for Protected Cultivation of High Value Vegetables:

Efficient designing and construction of polyhouses and related structures (location specific) is the pre-requisite for success of greenhouse technology by making use of appropriate and need based cladding material (UV stabilized) that combines the desirable characteristics of various materials (Castrill a et al., 2004). An ideal polyhouse or greenhouse having double door, sufficient side and top ventilation, drip irrigation, fogging/misting facility and 40-50 per cent shade nets may be constructed as per agro-ecological situations in different locations for harnessing the real potential of greenhouse technology.

Use of plastic mulches, portable low/fixed low/high tunnels, shade houses or row covers can be economically practised in different pockets for mitigating influence of various biotic and abiotic stresses. Exclusion of insects-pests through mechanical/physical barriers, hygienic and other means is essential for success of the technology. In dry temperate areas including Leh and Ladakh, polyench (combination of above and under-ground) and Ladakhi type polyhouses are better suited for leafy vegetable production during winter (sub-zero temperature) and growing various fruit vegetables during summer months. The polyhouses in high hills and dry temperate areas should be strong enough to resist snow load, strong cold winds and extremely low temperature. Therefore, as per location and agro-ecological situation, economically and ecologically sustainable protected structures suited to different agro-climatic conditions of India need to be evolved indigenously.

A number of new crops can be introduced, but their possibility to affect significantly the biological structure of protected cultivation appears moderate.

Grafting of Solanaceous and Cucurbitaceous vegetables is practiced extensively in Korea and Japan to mitigate the problem of nematodes and soil borne diseases due to continuous and intensive cultivation in greenhouses, also offers potential in India.

Modern techniques of hydroponics, soil-less cultivation, aeroponics and nutrient film techniques are possible only in greenhouse conditions and these minimize the water and environmental pollution (Tuzel et al., 2004). The use of advanced equipments and innovative methodologies for more correct and judicious quantification of irrigation and fertilizer requirements (fertigation) can drastically reduce the production cost of greenhouse cultivation besides assuring judicious use of critical inputs viz., water and fertilizer.
Production Tips:

The protected cultivation of high value crops has become irreplaceable both from economic and environment points of view. Protected cultivation of high value vegetables is specialized type of farming and essentially requires training, skill development, hygienic conditions and proper prior planning. Therefore, the polyhouse growers should be well versed with the tips and techniques of protected cultivation by following eco-friendly and good agricultural practices so as to ensure high yield, improved quality, product safety and lucrative returns.

At the time of structure fabrication:

Identify crops and markets well in advance; Construct polyhouse in sunny and well drained location along the wind direction; Ensure availability of electricity and water supply to the polyhouse; Construct an ideal polyhouse from reliable company with the basic essential features and maintenance contract; and get the soil health status determined (nutrients/ soil microorganisms/ nematodes) prior to installing the polyhouse.

Prior to planting:

Get the soil tested for macro-, micro-nutrients, pH and organic carbon every year and apply fertilizer based on soil test; Time of planting is most vital for success of the crop and polyhouse growers must follow recommended package; Tall growing high value vegetables offer potential by using vertical space efficiently by growing vegetables viz. capsicum, tomato and parthenocarpic cucumber; Produce during off-season; As per market demand, grow filler crops; Don’t use space between two doors as store or for growing plants in plug trays or pro-trays; Grow hybrid varieties only and procure quality planting material from reliable source; Select appropriate crop/variety(hybrids) as per location and season; Grow disease resistant/tolerant hybrids especially against bacterial wilt and powdery mildew; Prefer plug/ pro tray raised seedlings for raising the crop under insect free structures; Avoid relay cropping/ staggered planting for checking insect-pest and disease incidence.
At the time of planting:

Make raised beds (85-90 cm wide & at least 20 cm high) at 50-60 cm distance especially for tall vegetables; Use vermicompost (1kg/ m²) or well rotten farm yard manure (2kg/ m²); Apply neem cake @ 30g/ planting pit one week before transplanting; Install yellow/blue sticky traps for mass trapping of flying insects one week before transplanting @ 1 trap per 10 m²; Apply 10-12 g complex fertiliser (12:32:16) per m² (2 g per plant); Apply as a soil drench imidacloprid 17.8 SL @ 0.05 ml per plant one day after transplanting. For this, mix 5 ml imidacloprid 17.8 SL in 10 l water and use 100 ml of the solution per planting pit; Use shoe disinfectant at entry.

During plant growth period:

Regulate average temperature (20-25°C) & relative humidity (60-80 %) during the cropping period for high yield & quality produce especially for growing high value summer vegetables; While growing high value crops, keep a strict vigil on temperature and humidity; For winter/filler crops, maintain average temperature (15-20º C) and relative humidity (60-80%); In case of high value summer vegetables, avoid temperature to rise over 35°C by using 50% UV stabilized agro shade nets, frequent fogging/misting and increased ventilation; Foggers/ misters should be run for about quarter (3/4) to one (1) minute only for regulating temperature & humidity; Ventilate polyhouses as per requirement during summer, rainy and winter season. Ventilation is also essential during winter season to avoid grey mould incidence. During winter, opening and duration of the side vent may be adjusted as per prevailing temperature and location.

Irrigation and fertigation:

Start fertigation 21 days after transplanting & withhold 15 days before final harvesting; Apply liquid fertilizer 19:19:19 or 18:18:18 @ 2-2.5 g/m² once or twice depending upon crop growth; Irrigate beds through drip twice or thrice a week. Preferably, irrigate during forenoon.

Pruning, pinching, training and other operations:

Follow timely and need based pinching, pruning and training; Training on four stems in capsicum (one flower & two leaves), two stems in tomato (by de-shooting the auxiliary branches) and single stem in parthenocarpic cucumber
(by de-shooting the auxiliary branches) in naturally ventilated polyhouses ensures high yield, uniform produce and improved quality product; Gentle shaking of tomato plants twice in a day ensures sufficient pollination and high fruit setting; Fertigate/irrigate using drip as per requirement twice or thrice a week.

**Plant protection:**

Adjust sticky traps as per height of the crop and position the traps 5-10 cm above plant canopy;

Follow IPM for minimising powdery mildew incidence; Take preventive and need based curative plant protection measures; Spray neem based insecticides at 10 to 12 days interval for minimizing insect-pest and disease incidence; Apply pesticides during evening hours; Follow eco-friendly plant protection measures; Timely uproot/remove disease infected plants.

**Harvesting:**

Harvest the crop at appropriate time preferably in the evening hours; Send the produce to market after grading and proper packaging.

**Maintenance of soil health and structure**

Practice soil solarization during June In low hills and plains by using 30 micron thick plastic sheets to combat soil borne pathogens and nematodes; Resort to pressure cleaning of UV stabilized sheet and net of the green houses every year for removing dust deposits.

**Follow the principle “Protected Cultivation-Everyday Farming”**

**Conclusion:**

Protected cultivation technology ensures almost year round production with high productivity and improved quality. It offers several advantages to grow high value crops even under unfavourable and marginal environments. However, high training needs of greenhouse growers and trainers, poor greenhouse crop management day-to-day practices, poor quality produce and pesticide residue on crop produce are of great concern. These issues can easily be addressed by integrating various production and protection practices including location specific efficient designing and construction of the polyhouses. The production
of high value crops viz. vegetables, cut flowers, nursery and hybrid seed production etc. in partially controlled protected environments, mainly naturally ventilated polyhouses is input and labour intensive. Adoption of systematic approach based on the involvement of greenhouse engineers, breeders, crop production, crop physiology and protection scientists, and post-harvest technologists will help in increasing the sustainability and relevance of protected cultivation across the country and globe.

Protected cultivation will face an increasing competition of the produce and therefore, now-onwards, crop diversification (product innovation), reduction in production cost, less dependence on energy by constructing area specific ideal indigenous polyhouses, yield increase, product safety by following integrated pest management (IPM) and good agricultural practices (GAP) and minimal environment pollution will be the major issues, which need immediate attention of the greenhouse growers for their long term sustainability in the domestic and foreign markets. Keeping in view the dynamic need of the society for quality and safe horticultural produce, our country looks for the second green revolution through hi-tech interventions in horticulture.

References


Scope of Organic Vegetable Cultivation in Hilly Regions

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Hilly regions of the country, have great potential to regulate year round supply of many vegetables due to varied agro-climatic conditions. The land holdings in these areas are small and scattered with little irrigation facility. The cereal based cropping system is not profitable for their livelihood which lead to migration of rural youth to plains areas. The consistent efforts of state Agricultural universities and other development agencies in educating the rural youth to grow array of vegetables as cash crops resulted in creating great economic activity for self employment. Off-season production of major vegetables find ready market in the plains at remunerative returns since cultivation of these vegetables is not possible in the plains due to adverse climatic conditions. As evident from the table given below, supply of major vegetables is made during the peak periods as off-season from hilly regions.

Table: Availability period of major vegetables in hills and plains.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Availability in hills</th>
<th>Availability in plains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garden pea</td>
<td>April-November</td>
<td>December-March</td>
</tr>
<tr>
<td>Tomato</td>
<td>June-November</td>
<td>April-may</td>
</tr>
<tr>
<td>Bell Pepper</td>
<td>June-October</td>
<td>March-April</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>Year round</td>
<td>January-March</td>
</tr>
<tr>
<td>Cabbage</td>
<td>Year round</td>
<td>January-April</td>
</tr>
<tr>
<td>French beans</td>
<td>May-November</td>
<td>March-April</td>
</tr>
<tr>
<td>Potato</td>
<td>May-November</td>
<td>December-January</td>
</tr>
</tbody>
</table>

From the above table it is clear that hilly regions have vast potential to adopt off-season vegetable cultivation on large scale in view of the ever increasing
demand of these vegetables in the distant markets. Further, due to heavy incidence of diseases and pests, vegetable growers of plain areas make indiscriminate use of pesticides. In hilly regions incidence of pests and diseases is comparatively low hence there is little or negligible use of chemicals.

The consumption of chemical fertilizers is also low as compared to plains. There are many other factors which are favourable for organic cultivation of vegetables in hills that too during off-season under field as well as protected conditions. Some of the major factors creating conducive environment in hills for certified organic production of vegetables are explained hereunder:

- **Availability of organic matter**: In hills due to large population of live stock, there is ample availability of farm yard manure, vermicompost and other bio degradable waste.
- **Long growing season**: Due to mild agroclimatic condition, maturity of vegetables is at slow rate hence they are better in quality and appearance.
- ** Longer availability period**: Due to varied agro-Eco situations the availability periods of major vegetables are long as compared to plains.
- **Easy availability of man power**: Vegetable cultivation is labour intensive. In hills agriculture being major occupation for livelihood family as well hired labour is easily available.
- **Ready markets at remunerative returns**: There is ever increasing demand of organic vegetables in cosmopolitan cities because urban population is more health conscious as compared to hills.
- **Good scope of self employment**: In hills rural youth is already engaged in vegetable production and further educating them to go for organic production shall lead to raise their socio-economic status.
- **Fast crop diversification**: Due to fast pace of diversification to vegetable growing particularly in temperate regions of the country huge quantity of marketable surplus is available for fulfilling the ever growing demand of fresh and organically produced vegetables.
- **Good scope of protected cultivation**: Organic cultivation of vegetables under protected structures in the hills ensures year round supply of major vegetables to the distant markets. The operational cost of poly-house is comparatively low in hills because of low temperature in summers. Protective cultivation of tomato, bell pepper, pathenocarpic cucumber, French beans under organic management is more profitable in hills due to higher yields and better quality. In Himachal Pradesh, state deptt. Of agriculture and horticulture are giving higher subsidy to promote off-season cultivation of vegetables under protected structures.
• Better transportation facilities: Due to better road network in hilly regions, there is quick approach to distant markets for the disposal of fresh and organically produced vegetables during off-season.

• Research and Extension support: There is enough research and extension support by the state agricultural universities and line department to promote organic production of vegetables.

• Rainfed cultivation of vegetables: Due to undulating topography in hills there is great scope of crop diversification particularly off-season vegetable cultivation in rainfed areas under organic system.

• Ample availability of raw materials for the production of different bio-formulations: In hilly regions, large number of herbs are available for preparing bioformulations to control prevailing pests and diseases.

• Higher population of bio-agents: In hills there is more population of natural predators to control harmful insects. Hence, there is less need of chemicals as compared to plains.

• Unexplored potential pockets for organic cultivation of vegetables: In the higher reaches, still farmers grow vegetables organically. As such there is great scope for increasing area under certified organic production of vegetables.
Organic Cultivation of Vegetable Crops

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Due to indiscriminate use of pesticides and their health hazards, consumers are becoming more conscious to health vis-a-vis quality food. Amongst all the agricultural commodities, fresh vegetables available in the market carry the maximum pesticides’ residues. Pesticides consumption in vegetables is 6 to 7 times more than other crops and the period between harvesting and consumption of vegetables is short. This poses a serious health problem besides environmental pollution. However, due to less incidence of insect-pests and diseases the pesticides consumption is less in hilly areas. The produce of many pockets is organic by default. There is a great demand of organic food including fresh vegetables worldwide. Organic farming is a profitable venture as it is a low input requiring farming and certified organic produce fetches higher premium in the market. Majority of the hilly farmers are small and marginal, who can be benefitted by promoting organic farming. Government of Himachal Pradesh has framed ‘Organic Farming Policy’ and it is now on the top priority agenda of the state government. Department of Organic Agriculture, CSKHPKV, Palampur has been identified as one of the Niche Area of Excellence by ICAR in the field of organic farming during 11th and 12th Five Year Plan consecutively. Technologies on cultivation practices of vegetables have been standardized for the last 8 years.

Though, India is the second largest producer of vegetables after China in the world, but the productivity of vegetables in India is much less than the potential productivity or even the world average productivity. India is the largest producer of okra, cauliflower and peas in the world and has a share in total world vegetable production of about 13%. However, due to heavy post harvest losses (approximately 30%) and high pressure of population in the country, the per capita availability of vegetables in the country is only 140g/day. Whereas, as per the recommendations of nutritional experts, a person should consume daily 300g of vegetables including 115g leafy vegetables, 70g root and tuber vegetables and 115g other vegetables. In addition to their role in nutrition, vegetables increase attractiveness and palatability of the diet by providing sensory appeal through their variety of colour and flavour but very less people know about the medicinal properties as these can be used to cure many diseases. To keep pace
with the ever increasing population (1.98% annual growth rate), the estimated requirement of vegetables by 2021 will be 160 million tones. Vegetable farming is more remunerative than cereals and pulses. Vegetables are cheap and rich source of carbohydrates, proteins, vitamins and minerals. Vegetables like, potato, peas, cluster bean, carrot and sugar beet are rich sources of carbohydrates; peas, cowpea, leaves of methi, mustard, spinach, pointed gourd and beans are rich in protein; of proteins, all leafy vegetables are rich in iron, vitamin A & B; carrot and tomato are rich in vitamin A; Brussels sprouts, leaves of coriander, parsley, bitter gourd, chilli, sweet pepper, tomato, cauliflower cabbage and sugar beet are rich in vitamin C and all green vegetables are rich sources of minerals. The productivity of vegetables is much higher as compared to other crops. It is also possible to grow 3-4 crops of vegetables in a year compared to only 2 in cereals. Thus vegetables give more net returns per unit area. Vegetable cultivation provides more employment opportunities due to intensive type of cultivation and requires more labour.

Vegetable cultivation provides joy and aesthetic value to all. Himachal Pradesh has come up in a big way in vegetable production during the last two decades. During 2001-02, the area under vegetable production in HP was 34,150 ha and the production was 6,27,445 MT, which has increased to 68,865 ha area and 13,98,048 MT production in 2012-13. There is a consistent increase in area and production of vegetables in HP and the present share of vegetables in the state economy is now 3.3%. The farmers of the state are now shifting from apple to vegetables as the share of apple in state economy has now reduced from 6% to 3%. The main reason for shifting towards vegetable cultivation in HP is due to more potential in varied agro-climatic regions and sustainability of vegetables in the state.

Vegetable farming is more remunerative than cereals and pulses. Vegetables are cheap and rich source of carbohydrates, proteins, vitamins and minerals. Vegetables like potato, peas, cluster bean, carrot and sugar beet are rich sources of carbohydrates; peas, cowpea, leaves of methi, mustard, spinach, pointed gourd and beans are rich in protein; of proteins, all leafy vegetables are rich in iron, vitamin A & B; carrot and tomato are rich in vitamin A; Brussels sprouts, leaves of coriander, parsley, bitter gourd, chilli, sweet pepper, tomato, cauliflower cabbage and sugar beet are rich in vitamin C and all green vegetables are rich sources of minerals. The productivity of vegetables is much higher as compared to other crops. It is also possible to grow 3-4 crops of vegetables in a year compared to only 2 in cereals. Thus vegetables give more net returns per
unit area. Vegetable cultivation provides more employment opportunities due to intensive type of cultivation and requires more labour. Vegetable cultivation provides joy and aesthetic value to all. Himachal Pradesh has come up in a big way in vegetable production during the last two decades. During 2001-02, the area under vegetable production in HP was 34,150 ha and the production was 6,27,445 MT, which has increased to 68,865 ha area and 13,98,048 MT production in 2012-13. There is a consistent increase in area and production of vegetables in HP and the present share of vegetables in the state economy is now 3.3%. The farmers of the state are now shifting from apple to vegetables as the share of apple in state economy has now reduced from 6% to 3%. The main reason for shifting towards vegetable cultivation in HP is due to more potential in varied agro-climatic regions and sustainability of vegetables in the state.

Vegetable productivity in this hilly state (19 MT/ha) is more than the national average. Organic farming has attracted attention worldwide. The pioneer workers who promoted organic farming were Sir Albert Howard (recognized as the father of organic farming), J.I. Rodale in USA and Lady Eve Balfour in UK. Organic farming is the form of agriculture that relies on techniques such as crop rotation, composting, green manuring, biofertilizers, integration with leguminous vegetables, etc. to maintain soil productivity and use of biological pest control measures on the farm. The use of chemical fertilizers, pesticides, plant growth regulators, food additives, livestock antibiotics, genetically modified organisms and transgenic plants is strictly prohibited in organic farming. IFOAM (International Federation of Organic Agriculture Movements), established in 1972 in Germany is an international umbrella organization has set the standards for organic farming. IFOAM defines the organic farming as a production system that sustains the health of soil, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved. So in simple words “Organic farming is a method of farming system, which primarily aims at cultivating the land and raising crops in such a way, so as to keep the soil alive and in good health.”

The United Nation’s Food and Agricultural Organization (FAO) has expressed favour of organic agriculture. Its report ‘Organic Agriculture and Food Security’ explicitly states that organic agriculture can address local and global food security challenges. Keeping in view the awareness towards pesticide
residues and their ill effects on health, the consumers are willing to pay higher prices for organic produce. Organic farming is highly knowledge intensive, therefore, knowledge sharing among farmers is promoted, natural resources are conserved and there is an increase in production after conversion period and decrease in migration of farming for nitrogen availability in leguminous crops *Rhizobium* and in non-leguminous crops *Azotobacter/Azospirillum* are recommended. PSB is recommended in all types of vegetable crops for increasing phosphorus availability. These biofertilizers can be used as seed treatment, seedling root dip or as soil treatment.

- **Seed treatment:** 200 g of nitrogenous biofertilizer and 200 g of Phosphotika are suspended in 300-400 ml of water and mixed thoroughly. 10 kg seeds are treated with this paste and dried in shade. The treated seeds have to be sown as soon as possible

- **Seedling root dip:** For transplanted crops, like tomato, brinjal, chilli, capsicum, cabbage, cole crops, etc. recommended biofertilizers are mixed in this water and the roots of seedlings are dipped for 30 minutes.

- **Soil treatment:** 4kg each of the recommended biofertilizers are mixed in 200 kg of compost and kept overnight. This mixture is incorporated in the soil at the time of sowing or planting.

**For good response to biofertilizer application, the following suggestion must be kept in mind:**

- Biofertilizer product must contain good effective strain in appropriate population and should be free from contaminating microorganisms.
- Select right combination of biofertilizers and use before expiry date.
- Use suggested method of application and apply at appropriate time as per the information provided on the label.
- For seed treatment adequate adhesive should be used for better results.
- For problematic soils, use corrective methods like lime or gypsum pelleting of seeds or correction of soil pH by use of lime.
- Ensure the supply of phosphorus and other nutrients.

**Mulching:** Mulches are materials which are used to cover the ground surface of cropped area to prevent it from direct exposure. There are different types of mulches used in agriculture. For mulching, leaves, bark, nut shells, weeds, grasses, wood chips, silage, paper, pine & conifer needles, paddy & wheat straw, rice husk, coir dust, saw dust, banana and sugarcane leaf waste, etc., as available in the area can be used. In modern agriculture, the use of plastic mulches is becoming popular, though there are environmental issues related to their production and disposal. Organic standards allow the use of polyethylene,
polypropylene and other polycarbonate-based plastic mulches but only if these are not incorporated into the soil and lifted off and disposed off in an environmentally responsible manner. After lifting the plastic a soil building cycle must be completed to help rebuild soil health. For mulching one-hectare area of any agricultural crop, about 4 -5 tonnes of biomass is required. In most agricultural crops, mulches should be applied uniformly after the first weeding, which generally occurs 2–3 weeks after sowing/transplanting.

**Advantages of mulching:**

1. **Prevent soil erosion:** Mulching protects the soil from erosion and helps to retain soil nutrients: Wind, rain and melting snow can lead to soil erosion and cause a loss of nutrients through run-off. By providing a protective layer between the soil and the elements, mulch helps to retain existing soil nutrients and a healthy soil structure.

2. **Feeds the soil web:** Healthy soil contains an array of organisms, including worms, fungi, and thousands of species of microorganisms. To keep the soil organisms alive and well, they must be provided with organic material to feed on. By mulching with organic materials, such as hay and leaves, this provides the soil organisms with a slow and steady supply of nourishment. The microorganisms will decompose the mulch materials, making the nutrients available to growing plants.

3. **Prevent weeds:** Mulching helps to prevent weed growth. A thick layer of mulch substantially blocks the sunlight from reaching the soil. This inhibits underlying seeds from germinating or young plants from growing, leading to fewer weeds. To ensure that the growing plants have proper access to sunlight, the mulch can be pushed aside in areas where seeds are sown or young plants are transplanted.

4. **Conserve soil moisture:** Mulching keeps the soil moist by reducing evaporation: In rainfed area mulching helps to conserve the moisture.

5. **Improved water retention:** Mulches add an extra layer between the soil and the sun, reducing evaporation and helping to retain water. Water need is considerably reduced or eliminated, and the plants experience more consistent levels of moisture.

6. **Increase in water use efficiency:** Water use efficiency can be doubled with mulching, and the frequency and intensity of irrigation can be reduced drastically.
7. **Moderates soil temperature:** The temperature of the soil changes over the course of the season, during cold snaps and heat waves, and also from daytime to night time. Mulches provide a layer of insulation, keeping soil temperatures more moderate.

8. **Protects perennials and biennials plants during the winter:** The mulch will help to retain snow, which creates insulation for over-wintering plants.

9. **Reduces soil compaction:** The mulch acts as a protective mat over the ground, reducing compaction from footsteps or heavy rainstorms.

**Organic certification**

**Definition:** Certification is the procedure by which officially recognized certification bodies, provide written or equivalent assurance that foods or food control systems conform to requirements of organic operation. All the certified organic products carry the organic labels and certification marks.

**Need of organic certification:** With increasing awareness regarding the residual hazards of the pesticides, there is always a demand from the consumers for healthy and environmentally sound products and for that they are ready to pay a higher premium for organic produce. If the farmers produce according to defined organic standards, they can sell their products at a higher price. Earlier, the organic products were sold only through trust and personnel relationships. However, some of the farmers sold their conventional products by claiming them organic. To maintain the trust of consumers, the certification of produce grown organically is required by some duly accredited inspection and certification agencies. Therefore, organic certification for the products to be sold as organic is required mainly to build trust between consumer and organic producer, to recognize trust worthy organic products in the markets easily and to achieve better prices as compared to conventional products. Organic certification can be used as an important marketing tool in exploring new marketing opportunities.

**TOMATO**

**Organic plant nutrition:** Plant nutrition is maintained through basic manures and liquid manures. Under polyhouse conditions, the basal dose of the manures should be increased 25% than the open field conditions. Polyhouse tomato crop needs frequent feeding with liquid manure. Vermiwash is one of the best sources for liquid nutrient supply. 10% vermiwash @ 100ml per plant should be fed through drip irrigation at weekly interval starting with the initiation of flowering. Fortnightly sprays of 10%*Panchagavya* is also beneficial.

**Diseases of solanaceous crops:**
Damping off

**Causal organisms:** Pythium spp. and Phytophthora spp.

**Organic management:**
- Seed treated with Trichoderma @ 5g/kg
- Drench the nursery with Trichoderma @ 25g in 5L water and drench 40 sq.mts.
- Avoid thick sowing and heavy irrigation
- Treat the nursery beds with Jeevamrit (10%) @ 5L/nursery bed (3 sq.m) one week before sowing of seed.

Buckeye rot:

**Causal organism:** Phytopathora nicotianae var parasitica

**Organic management:**
- Use resistant variety like Solan Vajara
- Mulching of the plants
- Proper water drainage
- Destroy rotten fruits
- Proper staking of the plants
- Application of Panchgavya 10% just before the incidence and repeat at 10 day interval.

Leaf spot and fruit rot

**Causal organism:** Alternaria tenuissima

**Organic management:** Spray with 10% Panchgavya and Tamara lassi 1:20 at an interval of seven days

Late Blight: caused by Phytophthora infestans.

**Symptoms:** Starting from brown to purple black lesions to complete burning of leaves.

**Early Blight:** Caused by Alternaria solani and symptoms resemble to late blight.

**Organic management for early and late blight:**
- Destroy the infected lower leaves of the plants
- Procure the seed from disease free plants
- Spray bordeaux mixture (limited use permitted)
- Use resistant varieties
- Spray Panchagavya at 15 days interval
Bacterial wilt: Caused by *Ralstonia solanacearum* (*Pseudomonas solanacearum*), it is the most serious disease. It causes sudden death of the plants. Vascular bundles turn brown.

**Organic management:**
- Grow resistant varieties like Palam Pink and Palam Pride
- Crop rotation with Paddy
- Hot water seed treatment

Leaf curl virus: Curling of leaves caused by white fly (*Bemisia tabaci*).

**Organic management:**
- Control the insect vector by spraying *Verticillium* or neem or *Ploygonum hydropiper* formulations.
- Destroy affected plants.

Okra (lady finger):

**Varieties**

**P-7:** Evolved from inter-specific hybridization between *Abelmoschus esculentus* x *Abelmoschus manihot*. It was released as resistant to YVMV but resistance has broken down in this variety also.

**Parbhani Kranti:** Evolved from cross between *Abelmoschus esculentus* x *Abelmoschus manihot*. Fruits are 5-ridged and medium sized. This variety is still maintaining resistance to YVMV.

**P-8:** Resistance to YVMV.

**Organic plant nutrition:** Apply either 15t of vermicompost or 20t of well rotten farmyard manure in the soil at the time of field preparation. At the time of first hoeing apply 2t enriched compost/ha. Apply *Trichoderma harzianum*, *Azotobacter* and Phosphate Solubilizing Bacteria (PSB) in the soil. Drenching the crops with 10% aerated compost tea or vermiwash at fortnightly interval starting after one month of sowing

Garden pea (*Pisum sativum L.*)

**Organic plant nutrition:** A healthy population of symbiotic microflora is essential to fix atmospheric nitrogen. Seed inoculation with *Rhizobium* culture @25g/kg of seed helps in quick nodulation on the roots which in turn fix atmospheric nitrogen. Apply *Jeevamrit* (10%) in soil at least one week prior to sowing in the soil at the time of field preparation. Apply 15t farmyard manure or 10t/ha vermicompost at the time of field preparation. Fortnightly sprays of
vermiwash or compost tea (10%) before pod filling stage are beneficial for crop growth and development.

Diseases:

**Root rot/wilt:**

**Causal Organism:** *Fusarium oxysporum f sp. pisi*

**Symptom:** In the beginning, lower leaves appear pale and drop downwards. These symptoms progress upward and the plants give stunted look. Slowly, the entire plant topple down. The vascular systems of upper top root extending up to stem is discolored, yellow to orange brown.

**Organic management:**
Seed treatment with *Trichoderma* @ 5g/kg and *Panchgavya* or beejamrit both @ 10%.

**Powdery mildew:**

**Causal organism:** *Erysiphe pisi*

**Symptom:** The epiphytic growth of powdery mildew fungus appears first on older leaves as diffused specks. These spots radiate on all sides covering large areas. Symptoms appear on tendrils, stem and pods. In general, the foliage looks withered and is covered with powdery mass of spores and mycelium.

**Organic management:**
- Spray with 10% *Panchgavya* + *Heeng* 5g and 10% cow milk at seven days interval

**Insect-pests:**

**Pea leaf miner (Chromatonia horticola):** It infests almost all the pulses, oilseeds, potato, solanaceous, cole and root crops. It remains active during mild climate. The maggots pierce in leaf epidermis, feed on contents and make tunnels within which gives silver zig-zag lines and some dark spots as the maggots are seen.

**Organic management:**
- Crop sown in the 2nd fortnight of November escape its incidence.
- Destroy the infested leaves.
- Spray the crop as prophylactic measure (infestation 5-10%) with *panchgavya* 10% *Melia* 5% or *Eupatorium* 5% or neemastra 5% or *Verticillium lecaniiifungus* at 5-7 day interval.
- Older leaves must be removed time to time.
- Nimbecidine or neembaan @3ml/L of water be applied when the infestation was seen over 20 percent.
Cauliflower:

Organic plant nutrition: Apply Jeevamrit (10%) in soil at least one week prior to sowing at the time of field preparation. Apply either 15t of vermicompost or 20t of well-decomposed farm yard manure at the time of field preparation. Apply 2t/ha enriched compost at the time of first hoeing near to the plants. Spray the crops thrice with 10% aerated/non-aerated compost tea or vermiwash at fortnightly oil treatment with Jeevamrit. IMachal Pradesh are Bonneville, VL-3 and Kinnauri. and development.

Organic plant nutrition: Apply either 10t of vermicompost + 2t enriched compost or 15t of FYM + 2t enriched compost. Apply additional 5t/ha vermicompost at the time of first hoeing up after one month of transplanting.

Plant protection in cole crops

Diseases:
Damping off: Same as discussed for solanaceous crops
Black rot: Infested plant leaves show yellow colouration and increase in size as V shaped without green colouration from bottom to top. Affected heads/curd become black in colour and rot. Organic management:
• Hot water treatment of seed for 30 minutes.
• Spray panchgavya 10% at 15 days interval.
Stalk rot: Shining of leaves destroyed. Stems rot from inside and become hollow. Curd starts rotting and no emergence of seed stalk. Organic management:
• Follow crop rotation with paddy crop
• Destroy infested leaves
• Inoculate Trichoderma with compost. Incubate for one week and apply at the time of transplanting
Insect-pests: There are over 40 insects associated with these crops but the key pests are:

Cabbage white butterfly (Pieris brassicae): The caterpillars are only feeding stagewhich develop from yellow colour clustered eggs on leaves. Initially they feed gregariously on one leaf later disperse on to other parts of plant. Yellowish
larvae are transversely decorated with black lines and have small hairs on their body.

**Organic management:**
- Collection and destruction of eggs and gregariously feeding larvae.
- Specific granulosis virus (GV) of this insect is very effective.
- *Cotessia gallarariae* is an egg larval parasitoid and need to be released @ 30-40 thousand adults/ crop season 2-3 times.
- *Trichogramma chiloris* as Trichocards @ 10 cards/ha should be erected in the crop.
- Spray with *Bt* as the dosage given on the label of formulation would be beneficial.
- A module consisted of one sprays each of Bt, panchgavya10%, *Bt + panchgavya* 10%, neem seed kernel extract 10%, *Lantana* extract 5% and neem oil 0.03% at 10 day interval during the cropping period has proved very effective under organic conditions.

**Diamond black moth (*Plutella xylostella*):** Initially the caterpillars mine in leaves and then feed on the contents. The larval enter in the heads making them unmarketable and unfit for use. It is a tiny moth which can be identified easily when it sits attains a shape of diamond spot on its back.

**Organic management:**
- Monitoring and trapping of this pest using DBM pheromone lure traps.
- Destruction of stubbles, alternate hosts and crop residues.
- Any cole crop or mustard can be used as a trap crop.
- *Melia* 5% or *Eupatorium* 5% extract will be sustainable botanical menace of this pest.
- *Cotessia plutellae* is an effective egg larval parasitoid.

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- Application of specific *GV* during the early infestation and *Bt* in heavyinfestation.
- Neem oil formulations are helpful in managing it by restricting its emergence from pupae.

**Cabbage aphid (*Brevicoryne brassicae*):** It is a key pest of all the cole crops. The aphid in grayish clusters are seen on all parts of plant which exude honeydew
and later sooty fungal appear. They suck the sap and plants turns yellow, wrinkled and topple with the injury.

**Organic management:**
- An extract of *Polygonum hydropiper* (water weed) 5% is very effective.
- Neem formulation or *Melia* 5% or *Eupatorium* 5% aqueous extracts are also helpful in its management at a week interval.
- *Aphidius sp.*, *Dietiella sp.*, *Syrphis spp.* and *coccinellids* are the prominent bioagents for its management.
- Destruction of crop refuges is very important to avoid carry forward infestations.
- Recommended dose of vermicompost or any other compost should be applied.
- All Season, Red Drum Head, Sure Head and Express Mail are aphid tolerant varieties of cabbage

**Cabbage semilooper (Trichoplusia orichalcea):** It is a polyphagous pest and attacks all the vegetables. Young caterpillars feed from under surface of leaves which get an appearance of web or veins are left. It can be identified by its serpentine movement making a loop and caterpillars are greenish in colour.

**Organic management:**
- Collection and destruction of eggs and larval masses in the initial stage.
- Neem oil 0.03% or neem seed kernel extract 10% or *Melia* extract 5% or dashparni 5% can effectively manage it.
- *Trichogramma chilonis* is a prominent bio-agent.

**Bulb Crops**

**Onion:**

**Organic plant nutrition:**

Apply Jeevamrit (10%) in soil at least one week prior to sowing at the time of field preparation. Vermicompost @ 15t/ha or FYM @ 20t/ha is required. Himcompost @ 2t/ha should be applied at the time of first hoeing up. Application of *Azospirillum* as seed treatment, seedling dipping and soil application in onion crop under organic farming conditions is a recommended practice for enhancing nitrogen availability to the crop. Soil drenching with vermiwash or compost tea at monthly interval (30, 60 and 90DAT) are beneficial for plant growth and development. Deficiency of micronutrients
particularly copper, manganese, zinc and molybdenum is often observed in newlyconverted organic fields which is detrimental to quality and quantity of onion. To takeare of these micronutrients in the soil, the compost should be enriched with mineralforms of these nutrients.

**Plant protection in bulb crops:**

**Diseases:**

**Damping off:** Same as for solanaceous and cole crops.

**Purple blotch:** Purple colour spots appear on flowering branches and the branches break from that point.

**Organic management:**

- Spray *panchgavaya* 10% at 10 days interval

**Downy mildew:** Spots appear on affected parts.

**Organic management:**

- Spray *panchgavaya* 10% at 10 days interval

**Dry rot of garlic:**

**Causal Organism:** It is caused due to *Fusarium* and *Pratylenchus* complex.

**Organic management:** Soil treatment with Jeevamrit and seed treatment with Trichoderma 5g/kg or *Panchgavaya* 10% and Beejamrit 10%

**Insect-pests**

**Thrips (*Thrips tabaci*)** : The nymphs and adults suck the sap, the leaves give silvery appearance.

**Organic management:**

- Monitor and manage using yellow sticky traps.
- Sprinkler irrigation helps in dislodging them.
- Fermented butter milk 10% or cow urine 10% or vertisoft 3-5ml/L of water, *P. hydropiper* extract 5%, Nimbecidine 3-5ml/l of water can be an alternate management to synthetic pesticides.

**Onion maggot (**Delia antiqua**):** The maggots make their way in the bulbs which become pithy and rot later. The fly is light brown colored.

**Organic management:**

- *Lantana* 10% dust in the early infestation days.
- Spray with 10% *Panchgavaya* + Ferula (*Heeng*) 5g and 10% cow milk at seven days
interval.

**Potato**: Potato is mainly a cool season crop but on account of varied agroclimatic conditions prevailing in the country, it can be cultivated right from tropical to temperate regions of the country. Potato is a wholesome food. Apart from starch, it provides vitamins, mineral and proteins. It is one of the rich sources of energy to the consumers. However, the nutritive value of potato tubers depends on manuring, water management and other cultural practices. The potato plant possesses a very high production potential, but this can be realized only if due attention is paid to the effective utilization of environment and input level by adopting cultural practices on a scientific line.

**Organic plant nutrients**: Apply *Jeevamrit* (10%) in soil atleast one week prior to sowing in the soil at the time of field preparation. At the time of land preparation or planting, well decomposed farm yard manure or vermicompost should be well mixed with soil. Potato needs heavy manuring. Vermicompost @20t or well decomposed FYM @ 25t /ha along with 2t /ha of Himcompost should be applied at the time of field preparation. Apart from this, drench the crop with a solution of 1L each of *Panchgavya* and Vermiwash dissolved in 30L of water. Apply the solution at 15 days interval.

**Plant protection:**

**Diseases:**

**Early blight**

**Causal organism**: *Alternaria solani*

**Symptoms**: Small dark brown to black scattered spots of 3-4mm diameter appears on the upper leaves. These lesions are well surrounded by chlorotic zone. Concentric ridges appears on the dead lesion giving them target board appearance.

**Organic management:**

- **Seed treatment**: Trichoderma @10g/kg and *Panchgavya* 10%
- **Spray**: Tamarlassi1:20(5%), *Panchgavya* 10% and Himsol 10% at the interval of seven days.

**Late blight**:

**Causal organism**: *Phytophthora infestans*
Symptoms: Leaves show blighted appearance. In severe infestation the entire plant wither with tuber formation.

Organic management:
- Use healthy seed for sowing.
- Follow high ridge culture to avoid tuber infection.
- Seed treatment: Trichoderma @10g/kg and Panchgavya 10%
- Spray: Tamarlassi 1:20(5%), Panchgavya 10% and Himsol 10% at the interval of seven days.

Insect-pests: Over 100 species of insects attack the crop by feeding (*Spodoptera spp.*, *Helicoverpa armigera*, *Trichopplusia orichalcea*, hadda beetles, flea beetles, and blister beetles), sucking sap from leaves (aphids, leafhoppers, thrips, and whiteflies) and by attacking tubers. Tubers are heavily damaged in field and in storage and insects are; white grubs, cutworms, potato tuber moth, termites, red ants, and mole crickets. The information on organic management of some of them has been covered in other crops and the other important insect pests are detailed as under:

Potato tuber moth (*Phthorimaea operculella*): It is a widespread pest of potato plants and tubers throughout the world and is regarded as a major pest of potato. In conventional farming, current means of control prior to harvest comprise several broadspectrum insecticides and cultural methods. The bacterium, *Bacillus thuringiensis*, and the granulovirus of *P. operculella* have been used in certain countries for protection of tubers in storage. Under field conditions, the moth lay eggs in the exposed part of the tubers and infestation then extended to stores. The larvae feed on the contents of tubers, make tunnels within and peculiar pinkish lines of their presence are seen.

Organic management:
- Proper earthing up of plants to ensure the covering of exposed tubers where moth can lay eggs.
- Spray of Nimbecidine 3ml/L of water at 10 day interval.
- Monitor PTM using its pheromone lures.
- Application of Bt @1.5g/L of water soon after the pest monitored.
- Deep setting varieties should be preferred.
- Sprinkler irrigation avoids cracks in soil and manages the pest.
• Spinosyns have also been recommended for this pest.
• PhopGV granulosis virus is an effective measure.
• Cotessia, Trichogramma and Chelonis are the suitable parasitoids.
• Muscodor albus is a recently described endophytic fungus isolated from the cinnamon tree, Cinnamomum zeylanicum, that produces a mixture of volatile organic compounds (alcohols, esters, ketones, acids and lipids) ecome unfit for consumption and optimum temperature for its attack is 20-25°C.
Enhancing Productivity of Allium Vegetables

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Though India ranks first in area (12.04 lakh ha) and second in production (19.40 MT) in general, next only to China, in the case of onion productivity, India is at 90th place with an average yield of 16.10 t/ha. The average onion productivity in China is 22.05 t/ha. The highest productivity of onion is in Ireland (67.33 t/ha) followed by the Republic of Korea (57.03 t/ha) and USA (54.62 t/ha). World's average productivity of onion is 19.47 t/ha (FAOSTAT 2012-13). Like onion the productivity of garlic too has not increased at the same pace and is stagnating at about 569t/ha against world average of nearly 14 t/ha with highest from Tajakistan (30.00t/ha) followed by, USA (24.34 t/ha) and China (23.53).

India is projected to have population of 1.7 billion by 2050. To cater the requirement of this ever increasing population, and keeping per capita consumption, export, processing and losses at existing rate (consumption 7 kg/person/year, export 11%, processing 8% and losses 30%; base year 2012-2013), we will require 23.47 million tonnes of onion in 2050 against 16.81 million tonnes in 2012-13. With the expectations to reduce losses up to 20%, increase export and processing up to 20% each and consumption/person/year may go up to 15 kg by 2050, we have to increase productivity to 50.61 t/ha (271% increase in productivity) to get a production of 83.87 million tones with increase of area by 20% only. Similarly, there is need to increase the production of garlic to 3.68 million tonnes and productivity to 13.48 t/ha i.e. an increase of 165% over the productivity of 5.08 t/ha in 2012-13.

Low productivity of onion and garlic in India is one of the major reasons for the observed shortfall. Though there are many reasons for low yield, including short day length conditions available in India, sub-optimal standards of cultivation, weather vagaries, non-availability of quality seed and use of local low-yielding varieties are important among them.

The substantial estimated required increase in productivity of both onion and garlic over the existing yield levels can be achieved only if innovative
measures are adopted which may be; genetic improvement or better production technology including seed supply and reducing storage losses of this perishable commodity.

A. Genetic improvement

Development of varieties/hybrids

Onion

Systematic breeding programme was started as early as 1960 at Nashik and later at IARI, New Delhi, and 45 varieties of onion (including two F1 hybrids and 6 varieties of multiplier onion) have been developed and released.

Dehydration industries demand white onion varieties with globe shaped bulb and high TSS (>18%). However, Indian stock does not offer TSS range more than 12%. Jain Food Park Industries, however, has developed V-12 with TSS range of 15-18%.

Similarly, in yellow category, which though not preferred in India yet have ready market in yield, only two varieties were developed, viz., Phule Swarna from MPKV, Rahuri and Arka Pitambar from IIHR, Bangalore, however, these varieties are comparatively poor yielder than commercial red onion varieties.

So, there is still enough scope to develop varieties
- with high total soluble solids (TSS) suitable for dehydration,
- short day yellow varieties for export,
- Varieties resistant to diseases and insect pests and suitability in different seasons.

Although India is one of the leading onion producers, yet the efforts to develop hybrids made at IARI, IIHR and other premier institutions could not get momentum in the absence of stable CMS stock under tropical, short photoperiodic environmental conditions of India. Only IIHR, isolated male sterility in cv. Nasik white Globe, and utilized it successfully and released two hybrids namely Arka Kirthiman (MS-65 xSel.13-1-1)’ and Arka Lalima (MS-48 xSel.14-1-1) using cytoplasmic genotypes, so far.
Garlic

Breeding methods for development of garlic are limited to clonal selection and mutagenesis among conventional methods, and somaclonal variation among biotechnological approaches. In India, most varieties have been developed through clonal selection and one or two through introduction. Typical examples of hard neck (long-day varieties –bolt and flower but usually sterile) varieties characterized by big bulbs, less number of cloves (10-15), ease of peeling and, generally, have low storage life are; Agrifound Parvati and Chinese garlic whereas, soft-neck (short-day) varieties which are characterized by small bulbs, more number of cloves (20-45), more aroma and are generally, good storers includes Indian garlic varieties G41, G1, G50, G282, etc.

BIOTECHNOLOGICAL ADVANCES

Diversity analysis and varietal identification

The knowledge of genetic diversity helps in the efficient management of germplasm and selection of parents for crossing. Diversity analysis of seven cultivars of *A. cepa* and single cultivar of Japanese bunching onion, chive, leek and a wild relative of onion (*A. roylei*) by RAPD showed *A. roylei* as the closest relative of *A. cepa*, questioning the current classification of *A. cepa* in the section *Rhizideum* (Susan et al. 1993). Bermis and India-2 were found more dissimilar and Faridpuri and Bhati the most genetically similar through molecular analysis by Maniruzzaman et al. 2010. Similarly, Nashik Red and Poona Red were observed indistinguishable, and similarly N-53 and Bombay Red were quite close in amolecular characterization by Mahajan et al. 2009. Employing SCAR and RAPD markers, Gai and Meng (2010) distinguish between N and S cytoplasm in several welsh onion cultivars, confirmed by Southern blotting.

Meristem tip Culture

This vegetative propagation in garlic leads to accumulation of viruses and it is well established that garlic is susceptible to accumulation of a complex of viruses, notably members of the genera *Potyvirus*, *Carlavirus*, *Allexivirus* and *Potexvirus* (King et al., 2012) that are spread from (vegetative) generation to generation through the bulbs.
Production of virus free garlic plants has been attained through small inflorescence bulbils culture (Ebi et al. 2000), “stem disc dome culture” (Ayabe and Sumi, 2001), meristem tip culture (Wei and We 1992).

**HAPLOIDY**

DH provides an alternative strategy that offers complete homozygosity and phenotypic uniformity along with reduction in the time required to produce inbred lines, considering that onion is a biennial plant that requires up to 10 years to obtained nearly homozygous inbred line by conventional breeding. In India, a preliminary insight into haploid development through in vitro gynogenesis has been achieved by the scientists of DOGR, Pune during 2012.

**Disease & pest resistance**

- Introgression of downy mildew resistance from *A. roylei* into *A. cepa* has been an important example of marker-aided breeding in *Allium*.
- Epicuticular waxes play a significant role in resistant or tolerant cultivars against sucking insect pests (Gent et al., 2006, Diaz-Montano et al., 2011). In recent years, it has been observed that onion has natural variation for the amount and types of epicuticular waxes (Bag et al., 2014, Damon and Havey, 2014). Onion accessions with glossy or semi-glossy foliage have lower wax content, which associated with non-preference to onion thrips.

**Transgenic breeding**

- It involves introduction of an isolated foreign gene into plant cells in such a manner that it is inherited through subsequent generations. Onion is a poor competitor of weeds. Onion growers follow manual and chemical ways to control weeds, measures which are costly and incur adverse environmental affects. Using *Agrobacterium* mediated transformation, an herbicide resistant gene was used to develop glyphosate resistance onions, but these plants have not been released commercially because of issues of bio-safety.
PRODUCTION TECHNOLOGY

Seed quality/seedling transplant:

High seed germination and seed vigor are directly or indirectly related to the success of crop establishment and its further productivity. The quality seeds having good germination may help in reducing the seed rate per hectare from the existing 7 - 8 kg to 4 - 5 kg.

De-Souza et al., 2014 investigated the effects of pre-sowing magnetic treatments on germination, emergence, growth and yield of onion (cv Red Creole) plants under field conditions. In field experiments, the treatments led to a significant increase in seedling emergence, root length, seedling height, seedling dry weight and leaf area per plant. Also, at the vegetative stage, the leaf and root relative growth rates of plants derived from magnetically treated seeds were greater than those of the control plants. At the bulb forming stage, bulb relative growth rates from magnetically exposed seeds were greater than those of controls. At the bulb maturity stage, all magnetic treatments significantly increased mean bulb weight, bulb yield per area, number of tunics per bulb, bulb diameter and dry bulb weight in comparison to the controls.

Since the onion seed loses its viability and vigour rapidly thus the role of seed moisture and packing material is more vital for good productivity of crops. Accordingly, Tripathi and Lawande (2014) studied the effect of different moisture levels i.e. 5, 6, 7 and 8 percent and packing materials i.e. cloth bags, polyethylene bags, laminated aluminum bags and laminated aluminum bags with vacuum packing and stored at ambient condition for 27 months. The results indicated that germination percent and seed vigour Index were higher in seed having 5% moisture than seed having 8% moisture. Among the packing materials, lower seed germination and viability was recorded in cotton cloth bags. The seed packed in cloth bags lost their complete viability and vigour within 18 months of storage. The highest seed germination was observed in laminated aluminum bags with vacuum packing. The seed packed in aluminum laminated bags remained viable for 27 months. Among the various treatments combinations seed having 5% moisture and vacuum packed in aluminum laminated bags remain viable for longer period with percent germination was 61.7% germination 27 months of storage. The seed vigour index was also higher in this treatment than other treatments.
Abdullah et al., 2011 stored onion seeds under a wide range of temperature (5, 15, 25 and 35°C) and relative humidity (RH) (11.3, 22.5, 32.5, 43.2, 58.4, 75.3 and 84.3%) conditions for various storage periods (1, 3, 6, 9 and 12 months) and recorded seeds stored at 5°C had the highest seed germination percentage (SGP) in shortest mean germination time (MGT). Whereas, seeds stored at 35°C had the lowest SGP and the longest MGT. RH up to 58.4% had no significant effect on SGP while higher levels of RH significantly lowered SGP and MGT. The highest RH levels (75 and 84%) showed an obvious decrease in seed quality by lowering SGP and increasing MGT.

Makus, 2004 inoculated onion cultivars Granex 1015Y and Terlingua with mycorrhizae through seedling at transplanting and obtained improved bulb yields and accelerated maturation. Bulbs from mycorrhizal-treated plants were more uniform in diameter. Further, Bulbs stored at 13.2°C for 120 days suffered less soluble solids and weight loss if they were from mycorrhizal-treated plants.

Gabriel et al., 1997 determine combined effects of the seed size (2.000, 2.375 and 2.750 mm dia.) and the gravimetric classification on seed quality and yield components in onion cultivar and observed seed germination increased linearly as seed diameter was greater. Other crop variables such as plant height, commercial yield of bulbs and the percentage of bulb classes 5 and 6 also increased curvilinearly as seed diameter was greater. In the same way, the time from emergence till harvest shortened when seed diameter increased. In addition, the diameter of the bulb neck at harvesting was smaller as the seed diameter increased. According to these results, it is concluded that the performance on onion can be improved classifying the seed lots regarding the seed diameter.

**Weed management**

Season-long exposure of seeded onion to weed competition has been shown to reduce onion yield up to 96 percent (Bond & Burston, 1996). The critical weed-free period for onion is approximately four to six weeks after crop emergence while, the minimum weed-free period required to produce a garlic bulb is 21-49 days from crop emergence.

Excess moisture or waterlogged condition during these stages leads to development of diseases like basal rot and purple blotch. Similarly, continuous
irrigation towards maturity leads to secondary rooting which, in turn, develops new sprouts and such bulbs do not keep longer in storage. Withholding irrigation for two-three weeks prior to harvest in onion is very essential. However, for garlic, some amount of light moisture is necessary at harvest for easy uprooting of bulbs.

- The study at RAU, Muzaffarpur, Bihar observed effective weed control under Oxyfluorfen 23.5 EC before planting + one hand weeding at 40 days after transplanting or combined spray of Pendimethalin 30EC + quizalofop ethyl 5EC at the time of planting and second application at 30 DAT recording significantly highest marketable yield of 211.68 and 202.20 q/ha, respectively (Kumar, 2014)

- At OUAT, Odisha significantly highest total bulb yield was observed through Oxyfluorfen 23.5EC @ 2ml/L before planting and one hand weeding at 40-60 DAT (206.92q/h) with statistical parity by spray of pendimethalin 30EC @ 2.5ml/L and quizalofop ethyl 5EC @ 1.75ml/L at the time of planting and at 30 DAT (190.87q/ha) (Tripathy et al., 2013)

- Another study in JAU, Odisha concluded that the maximum production and profit in rabi onion can be achieved by two HW at 25-30 and 45-50 DAT or under scarcity of labours, we can use oxyfluorfen @ 0.240 kg/ha as PE followed by 1 HW at 45 DAT or oxyfluorfen @ 0.240 kg/ha as PE followed by oxadiargyl @ 0.090 k/ ha as POE at 45 DAT or oxyfluorfen @ 0.240 kg/ha as PE followed by second spray as POE at 45 DAT (Vishnu et al., 2015)

- Application of Oxyfluorfen @ 23.5% EC (1.5 -2.0 ml/L)/ Pendimethalin @ 30% EC (3.5-4ml/L) before transplanting or at the time of transplanting followed by one hand weeding at 40-60 days after transplanting is recommended for efficient weed control. DOGR, 2012

- The combination of oxadiargyl 90 g/ha PE followed by quizalofop-ethyl as POE 50 g/ha applied at 2-3 leaf stage of weeds yielded a B: C ratio of 5.70 in small segmented and 6.73 in large segmented garlic, respectively vis-a-vis 4.7 and 4.1 ratio recorded by weed free plots. (Chopra et al., 2014)

- A study on weed management in garlic at PDKV, Akola, Rahuri revealed that, Pendimethalin @ 1.0 kg a.i/ha before planting and quizalofop ethyl
0.050 kg a.i./ha at 30 DAP beside recording best growth characters (plant height, leaves numbers, bulb size also observed the maximum fresh bulb yield (123.25 q /ha), cured bulb yield (116.44 q /ha) and cost benefit ratio of 1:2.37 (Mohite et al., 2015)

**Water use efficiency**

When water supply is limited, crop management practices that improve water stress resistance can benefit plant growth and improve water use efficiency. Apart from the natural protection systems that plants possess against water stress, Symbiotic association of the roots appears to have a particular significance in this regard. Symbiosing fungi get a protected ecological niche and use plant photo-assimilates, whereas plants earn greater ability for nutrient and water uptake and become more resistance to biotic and abiotic stress. Arbuscular mycorrhizal fungi (AMF) can adapt to a wide range of soil water regimes and can be found in extreme habitats.

Accordingly, Bolandnazar *et al.*, 2007 evaluated the effects of three AMF (*Glomus versiforme, Glomus intraradices, Glomus etunicatum*) species colonization on bulb yield and WUE of onion under various irrigation regimes (7, 9 and 11 days) and elucidated that AM colonization especially *G. versiforme* improved bulb yield and WUE in onion. It seemed that in water deficit condition (longer irrigation intervals) arbuscular mycorrhizal colonization enabled plants to tolerate water stress through improving water and nutrient uptake and thus led to higher yield and WUE comparing to the control.

**Pre- & Post Harvest Management in onion**

In India, presently about 35 to 40 per cent of the onion is estimated to be lost as postharvest losses during various operations including handling and storage. Pre-harvest sprays of growth regulators *viz.*, cycocel, ethylene compounds and fungicides play a crucial role in enhancement of shelf life in onion. The curing techniques like neck cut in onion bulbs and exposure to onion bulbs in gamma radiation for storage are proved to be useful techniques in delaying sprouting and their subsequent deterioration resulting in improved shelf life. Packaging and storage techniques also influence the shelf life of onion bulbs during storage.
Anbukkarasi (2010) applied at 30 days pre-harvest a spray combination of maleic hydrazide @ 2000 ppm + carbendazim@1000 ppm with 2 cm neck length of bulbs later stored in low cost bottom ventilated storage structure.

The above treatment enhanced the shelf life (up to six months), reduced the physiological loss of weight (5.72 and 5.18 %), sprouting loss (0.58 and 0.62 %), rotting, rooting and total loss (6.58 and 6.78 %) and improved the quality parameters like TSS content (17.14 and 17.22 °Brix), total sugar (6.76 and 6.83 %) reducing sugar content (1.44 and 1.49 %) and sulphur content (0.697 and 0.704 %) during the first and second season, respectively.

**Kharif onion:**

Onion is a photo-thermo sensitive crop and thus, time of planting varies from region to region. In Maharashtra, best time of planting for kharif onion is July-August. In northern plains, it is mid or end of August. In Tamil Nadu and Andhra Pradesh, the crop is raised by planting early i.e. April-May, whereas, in West Bengal and Orissa transplanting is done as late as August-September.

Unlike Maharashtra and other major kharif onion growing areas, production of onion bulbs during kharif season through seedlings failed owing to high temperature and heavy rainfall at the time of nursery raising i.e. during June-July. Therefore, the production of bulks during kharif was attempted using alternative planting material i.e. setsmall bulblets). The various studies to standardize the production technology for kharif onion through sets in the low hill conditions of HP, yielded the following results of practical and scientific values;

- The highest sets production (2074g/m²) was obtained when the seeds were sown on March 1 @10m/m²
- The study on vital role of time of seed sowing and seed density on sets production concluded that it requires 20kg of onion seed (Kharif variety) to produce desirable sets for planting over one hectare area. Based on mean weight of bulbable sets produced at most appropriate seed density of 10g/m² and subsequent planting of these sets at a spacing of 15x10cm, it was concluded that 20q of such sets will be required to cultivate one hectare area for bulb production during kharif season.
• August 3rd week planting recorded highest bulb yield of 145.17q/ha, across all sized setts as well as methods of planting.
• The variety B-780 produced luxuriant plant growth and biggest size of bulbs and thus, topped among varieties in term of production (Average yield 200-260q/ha), followed by Agrifound dark Red (160-225q) and N-53 (170-180q/ha).

References:


Ebi M, Kasai N, & Masuda K. 2000. Small Inflorescence Bulbils are Best for Micropropagation and Virus Elimination in Garlic. *HortSci*. **35**:735-737,


Horticultural Congress: Issues and Advances in Transplant Production and Stand Establishment Research


Advances in the Production Technology of Cucurbits

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Cucurbits comprise an important tropical group of vegetable crops *viz.* cucumber, melons, squashes, pumpkins, Asiatic gourds, etc., grown extensively in different tropical and sub-tropical regions of the world. They are consumed in various forms *i.e.*, salad (cucumber, gherkins, long melon), sweet (ash gourd, pointed gourd), pickles (gherkins) and deserts (melons). **Almost all cucurbits are propagated by seeds except pointed gourd, little gourd, kakrol and kartoli.** All the cucurbits belong to the same family cucurbitaceae but to a number of different genera. **Family consists of 117 genera and 825 species. Cucurbits have been originated in Old World, New World and at least seven genera in both the hemispheres.** Most of them are monoecious in nature and a few are dioecious. A number of hermaphrodite and andromonoecious cultivars are also available in some crops. The cultural requirements of all crops in this group are more or less similar. They are a unique group of crop plants having special botanical features, their production technologies recording the highest productivity under sophisticated protected cultivation systems and their utilization includes some significant nutritional and nutraceutical constituents, used in native and traditional systems of Indian medicine and also of other Asiatic and African countries, for human welfare. Most of the members of cucurbitaceae family contain cucurbitacin a bitter glucoside. Though, this bitter principle is not poisonous but even its slight presence affect the taster and quality.

**Types:** There are different types of cucurbits such as;

1) **Annual cucurbits:**
Cucumber

**Gourds:** Bottle gourd, bitter gourd, sponge gourd, ridge gourd, round gourd, snake gourd, and wax gourd.

**Melons:** Muskmelon, watermelon, longmelon and snapmelon.

**Pumpkin and squashes:** Pumpkin, summer squash and winter squash.

2) **Perennial cucurbits:**
Pointed gourd, chayote, kakrol and ivy gourd or little gourd.
Improved varieties/Hybrids:

In India, several research institutes and universities have utilized a number of cultivated and wild species to develop improved varieties and parental lines. About 112 open pollinated varieties of several cucurbits have been recommended for cultivation at national and state levels. Among these, 48 improved varieties in 8 major cucurbits have been identified and recommended through All India Coordinated Vegetable Improvement Project. Similarly, 26 hybrids and 7 disease resistant varieties of major cucurbits have also been developed. Besides these various hybrids of different cucurbits have also been released by the private sector for commercial cultivation.

Agro-techniques:

The main goal of research on cucurbitaceous vegetables in India is to improve productivity on sustainable basis through developing biotic and abiotic resistant varieties/hybrids coupled with quality attributes. The yield potential of cucurbits could be increased by adopting the standardized agro-techniques and plant protection measures. Mulching has been very effective for hybrid crops as it moderate the soil temperatures. During summer and rainy seasons, straw mulch has been found effective. Use the PGR has been proven to be beneficial for earliness, quality and yield in cucurbits. Foliar spray of ethephon (100-500 mg/l), GA (10 mg/l), MH (50 - 150 mg/l) and TIBA (25-50 mg/l) increase the yield in most of the cucurbits. Staking in cucurbits has been found to be very effective in getting maximum yield and better quality of fruits. In this regard, pruning is also beneficial and in cucumber, single stems are allowed to grow with 2-3 fruiting branches, while in melon, lateral branches are removed up to 6-9 nodes, leaving 2-3 fruiting branches. In general, 25- 30 tonnes of farm yard manure as basal dose is sufficient for healthy crop stand in most of the cucurbitaceous vegetable crops.

Recent improvement in different cucurbits

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cucumber</td>
<td>Pusa Uday</td>
</tr>
<tr>
<td></td>
<td>Pusa Barkha (2013)</td>
</tr>
<tr>
<td></td>
<td>Pusa Parthenocarpic Cucumber (2015-16)</td>
</tr>
</tbody>
</table>
### Muskmelon
- Pusa Madhurima (2015-16)
- Pusa Sarda (Sarda Melon) (2015-16)

### Round melon
- Pusa Raunak (2015-16)

### Bottle gourd
- Pusa Santushti (2013)

### Long melon
- Pusa Utkarsh (2015-16)

<table>
<thead>
<tr>
<th>Cucurbits</th>
<th>National level</th>
<th>State level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Muskmelon</strong></td>
<td><strong>Pusa Sarbati, Hara Madhu, Sl-45 (Pusa Madhuras), Arka Rajhans, Arka Jeet, Durgpura Madhu, NDM-15</strong></td>
<td><strong>Punjab Sunehari, Punjab Rasila, Arka Rajhans, Hisar Madhur, RM-43, MHY-3, RM-50, Kashi Madhu</strong></td>
</tr>
<tr>
<td><strong>Watermelon</strong></td>
<td><strong>Durgapura Meetha, Sugar Baby, Arka Manik</strong></td>
<td><strong>Durgapura Kesar, Durgapura Lal</strong></td>
</tr>
<tr>
<td><strong>Bitter gourd</strong></td>
<td><strong>Priya, RHRBG-4-1, KBG-16, PBIG-1</strong></td>
<td><strong>Coimbatore Long, Pusa Do Mausmi, Pusa Vishesh, Punjab-14, Kalyanpur Baramasi, CO-1, CO-2</strong></td>
</tr>
<tr>
<td><strong>Pumpkin</strong></td>
<td><strong>CM-14, Pusa Vishwas, Arka Chandan, Arka Suryamukh, i CM-350, NDPK-24</strong></td>
<td><strong>Co-1, Co-2, Narendra Amrit (NDPK-130), Kashi Harit, Azad Kaddoo-1 (KPS-1)</strong></td>
</tr>
<tr>
<td><strong>Cucumber</strong></td>
<td><strong>CHC-2 (S. Ageti), CH-20 (S. Sheetal), PCUC-28</strong></td>
<td><strong>Japanese long green, Straight-8, Pusa Uday, Himangi, Swarna Poorna, Sheetal, CO-1</strong></td>
</tr>
<tr>
<td><strong>Ridge gourd</strong></td>
<td><strong>CHRG-1 (S. Manjari), PRG-7, IIHR-7 (Arka sumeet)</strong></td>
<td><strong>Swarna Uphar, Co-1, PKM-1, Arka Sujat, Pusa Nasdar, Punjab Sadabahar, Haritham</strong></td>
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<tr>
<td>Vegetable Type</td>
<td>Varieties</td>
<td>Varieties</td>
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<td>------------------------</td>
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<tr>
<td>Bottle gourd</td>
<td>Pusa Naveen, OBOG-61, NDBG-104 (N. Jyoti), NDBG-132</td>
<td>Arka Bahar, Pusa Sandesh, Pusa Summer Prolific Round, Pusa Summer Prolific long, Punjab Round, Punjab Long, Punjab Komal, CO-1, Narendra Rashmi(NDBG-1), Narendra Dharidar, Narendra Shishir, Kashi Ganga</td>
</tr>
<tr>
<td>Sponge gourd</td>
<td>Sel-99 (Pusa Chikni), CHSG-1, JSGL</td>
<td>Pusa Sneha, PSG-9, Rajendra Nenua-1</td>
</tr>
<tr>
<td>Ash gourd</td>
<td>-</td>
<td>CO-1, CO-2 Mudliar, Indu, KAU Local, Kashi Dhawal (IVAG-502), PAG-3</td>
</tr>
<tr>
<td>Long melon</td>
<td>-</td>
<td>Arka Sheetal, Pant Kakri-1</td>
</tr>
<tr>
<td>Round melon</td>
<td>-</td>
<td>Arka Tinda, Punjab Tinda</td>
</tr>
<tr>
<td>Snake gourd</td>
<td></td>
<td>CO-1, CO-2, PKM-1, Kaumudi, Baby, H-8, H-371, H-372, IIHR-16A</td>
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<tr>
<td>Summer squash</td>
<td>-</td>
<td>Punjab Chappan Kaddu-1, Patty Pan, Australian Green</td>
</tr>
<tr>
<td>S. No</td>
<td>Name of the crop</td>
<td>Soil</td>
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<tr>
<td>1</td>
<td>Cucumber</td>
<td>Light to heavy soils with pH 5.5 to 6.8</td>
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<tr>
<td>2</td>
<td>Bottle gourd</td>
<td>Light soils pH 6.0-7.0</td>
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<tr>
<td>3</td>
<td>Bitter gourd</td>
<td>Sandy loam soil</td>
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<tr>
<td>4</td>
<td>Sponge gourd</td>
<td>Wide range</td>
</tr>
<tr>
<td>5</td>
<td>Round gourd or Indian squash</td>
<td>Sandy loam soils</td>
</tr>
<tr>
<td>6</td>
<td>Sanke gourd</td>
<td>Wide range</td>
</tr>
<tr>
<td>7</td>
<td>Wax gourd</td>
<td>Sandy loam</td>
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<tr>
<td>No.</td>
<td>Crop</td>
<td>Soil Type</td>
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<tr>
<td>8.</td>
<td>Muskmelon</td>
<td>Sandy loam, pH 6-6.8</td>
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<tr>
<td>9.</td>
<td>Water melon</td>
<td>Sandy loam, pH 6.5-7.0</td>
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<tr>
<td>10.</td>
<td>Longmelon</td>
<td>Light soils</td>
</tr>
<tr>
<td>11.</td>
<td>Snapmelon</td>
<td>Wide range</td>
</tr>
<tr>
<td>12.</td>
<td>Pumpkin</td>
<td>Heavy and light soils</td>
</tr>
<tr>
<td>13.</td>
<td>Summer squash</td>
<td>Mediu m soils</td>
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<tr>
<td></td>
<td>vegetable marrow</td>
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<tr>
<td>14.</td>
<td>Winter squash</td>
<td>Light soils</td>
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<tr>
<td></td>
<td>(Halwa kadu)</td>
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<tr>
<td>15.</td>
<td>Pointed gourd</td>
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<tr>
<td></td>
<td>(Parwal)</td>
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<tr>
<td>16.</td>
<td>Chayote</td>
<td>Wide range</td>
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<tr>
<td></td>
<td>(Chow-chow)</td>
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<td>17.</td>
<td>Kakrol</td>
<td>-do-</td>
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### Off-season cultivation of cucurbits

Protected cultivation of vegetables provides the best way to increase the productivity and quality of vegetables, especially cucurbits. The yield of some cucurbits like cucumber can be increased manifold compared to their open field cultivation. Normally the economics of protected cultivation directly depends upon the initial cost of fabrication of the protected structure, its running cost and the available market for high quality produce. Therefore, low-cost protected structures, which can generally be fabricated with low cost and the running cost of such structures is also very low, just like naturally ventilated greenhouses, walk-intunnels and plastic low tunnels. These are highly suitable for off-season cultivation of cucurbits and are also highly economical for peri-urban areas of northern plains of India. Naturally ventilated greenhouses are highly suitable for year-round parthenocarpic cucumber cultivation, whereas, walk-in-tunnels are suitable for offseason cultivation of melons. Plastic low tunnels are highly suitable and profitable for off-season cultivation of cucurbits like summer squash, bottle gourd, bitter gourd, muskmelon, watermelon, round melon and long melon in peri-urban areas of northern plains of India. Vegetable growers, for getting higher prices from their offseason produce, often try to send their produce to the market early in the season and also try to extend the growing season for selected vegetable crops for the purpose of obtaining marketing advantage of their off-season produce. For example, crops like long melon, round melon, bottle gourd, bitter gourd, muskmelon summer squash etc. if grown early in spring or early summer often command a greater price on the market. Also producing crop when large quantities of the crop produce are not available (considered as “off-season”) can also command greater prices and increased demand. Off season cucurbit production through nursery management and

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<tbody>
<tr>
<td>18.</td>
<td>Kartoli</td>
<td>Light medium or medium black soils</td>
<td>Rainy season</td>
<td>Rainy season</td>
<td>-</td>
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<td></td>
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<td>FYM 100-150 q N,P 40-60 Kg</td>
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<tr>
<td>19.</td>
<td>Ivy gourd</td>
<td>Sandy loam</td>
<td>Warm and moist</td>
<td>June- July or Feb-March</td>
<td>-</td>
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<td></td>
<td></td>
<td>FYM 100-150 q N- 60 Kg P-80 Kg</td>
</tr>
</tbody>
</table>
greenhouse cultivation has been playing an important role in increasing the profit of the farmers.

**Riverbed cultivation**

Growing of cucurbitaceous vegetables on riverbeds or river basins is a different type of farming. These areas are also familiarly called ‘diara lands' in Uttar Pradesh and Bihar. Presently, river bed cultivation is in practice for production of cucurbitaceous vegetables in off-season in northern parts of our country, although area under river bed cultivation is very limited, which cannot be extended further, but with the use of protective structures such as row covers or low tunnels vegetable crops like muskmelon, watermelon, long melon, round melon, bitter gourd, bottle gourd, summer squash etc. can be grown very early in the spring or summer season.

**Plastic low tunnel technology**

Plastic low tunnels provide the best way for off-season cultivation of cucurbitaceous vegetables during winter season by modifying the microclimate around the plants. Low tunnels also offer several advantages like protection of the crop from frost, hails, and crop advancement from 30-40 days over their normal season of cultivation. This low cost technology for off season cultivation of cucurbits like muskmelon, round melon, long melon, bitter gourd, bottle gourd and summer squash etc., is suitable and may be quite cost effective for the growers in northern parts of the country, where the night temperature during winter season goes below 8 OC for a period of 30-40 days. This technology has been developed for off-season cultivation of major cucurbits for taking full advantage of the prevailing high market prices of the off-season produce. The major steps involved in this technology are as under:

**h) Nursery raising for off-season cultivation of cucurbits**

In India, cucurbits are mainly sown by seeds during their normal season of cultivation. Seedlings of these vegetables cannot be raised through traditional system of nursery raising on soil beds, because these vegetables are not tolerating against slightest damage to their root and shoot system during their uprooting and transplanting. Thereafter, a method of nursery raising was evolved in which off-season seedlings were raised in small polyethylene bags and plastic plug trays by using coco-peat, vermiculite and perlite as soilless media in 3:1:1
ratio on volume basis. This technique is not only efficient in vigorous root development but also suitable to avoid any damage to the roots and shoots of the seedlings at the time of transplanting. This technology is economical and suitable for the cucurbits growers in northern plains of India, because with the introduction of this technique, farmers can grow large number of seedlings as per requirement for off-season cultivation of cucurbits (with various varieties) for fetching high price of their off-season produce. Seedlings of the desired cucurbits are raised in the nursery greenhouse in plastic pro-trays having 1.5” cell size in soil-less media in month of December or January and 28-32 days old seedlings at four leaf stage are transplanted under row covers or plastic low tunnels in the open field from mid January to mid February, when the night temperature is very low in northern parts of the country. Nursery of these crops can also be raised even in polythene bags under very simple and low cost protected structures like walk-in tunnels or in locally available plastic trays in soil less media as per the need of the area.

**Preparation of beds, fixing of hoops, transplanting of seedlings and covering of plastic**

Transplanting of the seedlings is done in a single row on each bed at a planting distance of 50 cm on drip system of irrigation. Distance between the rows is usually kept 1.5 to 1.6 m. Before transplanting of the seedlings on beds, flexible galvanized iron hoops are fixed manually on a distance of 1.5 m to 2.5 m. The width of two ends of hoop is kept 40-60 cm with a height of 40-60 cm above the levels of the beds for covering the plastic on the rows or beds for making low tunnels. Transparent, 30 micron, IR grade plastic is generally used for making low tunnels, which reflects infra-red radiation to keep the temperature of the low tunnels higher than outside field. Now-a-days with the introduction of biodegradable plastic for making low tunnels and for mulching purposes, it is not only eco-friendly but it may be sustainable technology for off-season vegetable production. This biodegradable plastic is available according to the requirement of the duration one want to cover the crop or use as mulch in the crop. After that period the plastic after receiving sufficient sunlight, it becomes brittle. The film eventually breaks down into small flakes and finally completely composted in the soil. The plastic is usually covered in the afternoon after transplanting the desired vegetable like muskmelon, summer squash, bottle gourd, bitter gourd, round melon, cucumber etc. The plastic can be vented or slitted during the growing season as the temperature increase within the tunnels during the peak day time. Generally, 3-4 cm size vents are made on
eastern side of the tunnels just below the top on a distance of 2.5 to 3.0 m after transplanting, and later on the size of the vents can be increased by reducing the distance between two vents with the increase in the temperature and ultimately the plastic is completely removed from the plants in month of February and March depending upon the date of transplanting growth of the crop and prevailing night temperature in the area.

ii) Pollination under plastic low tunnel crops

Most of the cucurbits are monoecious in sex form and needs pollination, which is usually performed by honeybees (*Apis melifera*). When there is complete flowering bees can work in tunnels easily through the vents, made on the plastic. For effective pollination in crops like muskmelon, summer squash etc, one beehive, having 30000-50000 workers is sufficient for one acre area. The beehive box is always kept on the northwest side of the field for effective working of the bees.

iii) Fertigation and plant protection in measure

Fertilizers are applied through drip irrigation. During the first month (i.e. January or February) water can be applied @ 4.0 m$^3$/1000m$^2$ at an interval of 6-7 days. After making fertilizer solution of N: P: K (5:3:5) is applied @ 80-100 ppm per cubic meter of water. During second month 4.0 m$^3$ of water can be applied on duration of 4 days with fertilizer solution @ 120-150 ppm/m$^3$ of water till beginning of flowering in the crop. Thereafter the fertilizer quantity is reduced to 20-30 ppm till the fruits are of lemon size after that the quantity is again increased to 120-150 ppm per cubic meter of water. Before the ripening of the fruits, the quantity of fertilizer solution is again reduced to 50-60 ppm for enhancing the quality of fruits in muskmelon. But in other cucurbit the quantity of Fertigation is always in increasing order, starting from 50 ppm to 300 ppm at the peak fruiting period. The water and fertilizers requirement of crops is usually depends upon the growing season, crop and variety and soil conditions. If required systemic insecticide like confider can be applied through drip irrigation water for control of insects at early stage of the crop when the crop is under plastic tunnels and no foliar spray is possible.
iv) Harvesting and crop advancement

If the crop has been transplanted in first week of February the fruits will be ready for harvesting in third week of April. Fruits from the mid January transplanted crop can be harvested in first week of April, which is normally 30-40 days early than the normal season. Crops like summer squash can be transplanted in first week of December, which are ready for harvesting in the first week of February, and can be treated as complete off-season crop. Different cucurbits can be transplanted from first week of December to first week of February and can be advanced 30-60 days over their normal season of cultivation. Off-season fruits produced under low tunnels can fetch very high price in the market. This technology is quite economical for growing off-season vegetables in peri-urban areas of the northern plains of the country.

2) Protected cultivation technology of high quality cucurbits

The productivity and quality of cucurbits grown under open field conditions is generally low. Cucurbits under open fields are grown in two seasons one in summer and second in rainy season. During winter season, these crops cannot be grown under open field conditions. Keeping in view the biotic and abiotic stresses under open field cultivation of cucurbits, production technology have been developed and standardized for cultivation under two types of protected structures namely, naturally ventilated greenhouse and insect-proof net house. Production of these crops in greenhouse or net house, the use of pesticides is also minimized, which is not possible under open field cultivation. The demand of fresh salad varieties of such crops in increasing and growing these crops under protected conditions is becoming profitable proposition. The production technology of parthenocarpic cucumber has been developed and standardized for its cultivation under naturally ventilated greenhouse conditions. Three crops of parthenocarpic cucumber can be grown over a duration of 10-11 months under naturally ventilated greenhouse conditions with productivity ranging between 120-130 t/ha with very high quality fruits. This technology eliminates stresses due to biotic and abiotic factors and the use of pesticides in both the vegetable crops can be minimized.
Transplanting, crop advancement and expected cost benefit ratio in off-season Cucurbits

<table>
<thead>
<tr>
<th>Crop</th>
<th>Transplanting time</th>
<th>Harvesting time</th>
<th>Crop advancement</th>
<th>Expected cost benefit ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer squash</td>
<td>First week of December</td>
<td>First week of February</td>
<td>60 days</td>
<td>1:3 to 1:4</td>
</tr>
<tr>
<td>Muskmelon</td>
<td>Third week of January to first week of February</td>
<td>Second week of April to last week of April</td>
<td>30-40 days</td>
<td>1:2.5 to 1:3.5</td>
</tr>
<tr>
<td>Bottle gourd</td>
<td>Third week of January to first week of February</td>
<td>Second week of April to last week of April</td>
<td>30-40 days</td>
<td>1:2.5 to 1:3.5</td>
</tr>
<tr>
<td>Bittergourd</td>
<td>Third week of January to first week of February</td>
<td>Second week of April to last week of April</td>
<td>30-40 days</td>
<td>1:3 to 1:4</td>
</tr>
<tr>
<td>Watermelon</td>
<td>Third week of January to first week of February</td>
<td>Second week of April to last week of April</td>
<td>30-40 days</td>
<td>1:2 to 1:2.5</td>
</tr>
<tr>
<td>Cucumber</td>
<td>Third week of January to first week of February</td>
<td>First week of February</td>
<td>30 days</td>
<td>1:3 to 1:4</td>
</tr>
</tbody>
</table>

The technology is highly remunerative for the growers of Jammu and Kashmir (up to Jammu region), Himachal Pradesh (low hills and Plains), Punjab, Haryana, Delhi, U.P., Uttrakhand and (low hills and tarai region), NE states, West Bengal, Maharashtra and Karnataka.
**Harvesting Indices**

Harvesting of crop at right time is very important in cucurbits as in most of the cucurbits, seed development is undesirable. Harvesting stage of various cucurbitaceous vegetables is given as under:

<table>
<thead>
<tr>
<th>Crop</th>
<th>Maturity indices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cucumber, bottle gourd, bitter gourd, round melon, snake gourd, ridge gourd and sponge gourd</td>
<td>Harvest the fruit s when they are still young, tender and hairy and seeds inside the fruits are still soft. Fruits must be harvested before change in fruit color <em>i.e.</em>, from green to yellow.</td>
</tr>
<tr>
<td>Pumpkin</td>
<td>When fruits are full size for the variety; the rind is firm and glossy, and the bottom of the fruit (portion touching the soil) is cream to orange in color.</td>
</tr>
<tr>
<td>Muskmelon</td>
<td>When the fruits slip easily from the vine. Fruit should show changes in color and degree of netting, and a softening at the blossom end. Best eating maturity follows in one to three days; and best flavor is attained if muskmelons are held near 21 °C for this final ripening then chilled for serving.</td>
</tr>
<tr>
<td>Watermelon</td>
<td>Fruits are harvested when they attain full size for the variety, dull in color, and the bottom (portion touching the soil) turns from greenish white to cream in color. At this stage the curly tendril closest to the point of vine attachment is often shriveled or dying.</td>
</tr>
<tr>
<td>Snap melon</td>
<td>Green rind is converted into yellow or orange.</td>
</tr>
<tr>
<td>Summer squash</td>
<td>Summer squash are harvested and eaten while still young and tender, before the seeds ripen, or the rinds harden.</td>
</tr>
<tr>
<td>Winter squash</td>
<td>Winter squash, which is allowed to mature and develop hard rinds, can be eaten after maturity or stored for winter use.</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Ash gourd</td>
<td>Ash gourd is harvested at full maturity when the skin is covered with waxy bloom. Ripe fruits store well it is desirable to wax the stem end for longer storage</td>
</tr>
</tbody>
</table>

**Postharvest management of cucurbits**

**Field packing**

The trend is increasing toward field packing of fruit vegetables. Grading, sorting, sizing, packing, and palletizing are carried out in the field. The products are then transported to a central cooling facility. Mobile packing facilities are commonly towed through the fields for cantaloupe, honeydew melon, cucumber and summer squashes. Field-pack operations entail much less handling of products than in packing houses. This reduces product damage and therefore, increases packout yield of products. Handling costs are also reduced in field pack operations. One difficulty with field packing, however, is the need for increased supervision to maintain consistent quality in the packed product. Loaded field vehicles should be parked in shade to prevent product warming and sun burning. Products may be unloaded by hand (soft rind squashes, some muskmelons, cucumber and watermelon), dry-dumped onto sloping, padded ramps (cantaloupe and honeydew melon) or wet-dumped into tanks of moving water to reduce physical injury (honeydew melon). Considerable mechanical damage occurs in dry-dumping operations; bruising, scratching, abrading and splitting are common examples.

**Cooling**

Various methods are used for cooling cucurbit crops. Forced-air cooling is used for cantaloupe, cucumbers, muskmelons and soft rind squashes. Forced-air evaporative cooling is used to a limited extent on chilling-sensitive commodities such as squashes. Hydro-cooling is used before grading, sizing, and packing of cantaloupe. Sorting of defective products is done both before and after cooling.
Hydro-cooling cycles are rarely long enough during hot weather. The need to maintain a continuous, adequate supply of cantaloupes to the packers often results in the melons being incompletely cooled. This can be remedied if, after packing and palletizing, enough time is allowed in the cold room to cool the product to recommended temperatures before loading for transport to markets. Package-icing and liquid-icing are used to a limited extent for cooling cantaloupe.

**Temporary cold storage**

In large-volume operations, fruits are placed in cold storage rooms after cooling and before shipment. Cold rooms are less used in small farm operations; the products are often transported to central cooperatively owned or distributor-owned facilities for cooling and short-term storage.

**Long term storage**

Cucurbits can have an extended storage life if stored at the correct temperatures and humidity. Optimum storage conditions for zucchinis, button squash and cucumbers are 70°C and 95% relative humidity in an ethylene free atmosphere. Rock melons and honeydew require similar conditions but can be cooled further down to 50°C. Watermelons and pumpkins can be transported in bulk bins without refrigeration.

**Transport**

Some cantaloupe and other muskmelons are shipped in refrigerated railcars, but most cucurbitaceous vegetables are shipped in refrigerated trucks or container vans. Except for the major volume products such as cantaloupe, most are shipped in mixed loads, sometimes with ethylene-sensitive commodities. Among the immature fruit type cucurbits, products such as cucumber and bitter melon are sensitive to ethylene exposure. Among the mature fruit types, watermelon is detrimentally affected by ethylene, resulting in softening of the whole fruit, flesh mealiness, and rind separation.
References:

- http://horticulture.psu.edu/files/hort/extension/cucurbits.pdf
Production Technology of Ginger and Turmeric

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Department of Vegetable Science
Dr Y S Parmar University of Horticulture and Forestry
Nauni 173230 Solan, Himachal Pradesh

Spices are defined as “a strongly flavored or aromatic substance of vegetable origin, obtained from tropical plants, commonly used as a condiment”. Spices were once as precious as Gold. India plays a very important role in the spice market of the world. In ancient times majority of the spices were produced in India and exported world wide. It was then, the spices of India attracted people across the borders and forced them to come to India for Spice trade.

Ginger and turmeric are important spice crops, the production technology of which is discussed as follows:

GINGER

Ginger (Zingiber officinale Rosc. 2n=2x=22), a monocotyledonous plant belonging to the family Zingiberaceae is an important cash crop and one of the principal spice crop all over the country and world. India is the largest producer with more than 50% of the world production and exporter of ginger besides domestic consumption. In India it is grown in a area of 1 32 620 ha with a production of 6 55 060 t i.e. productivity of 4.94 t/ha mainly in the states like Kerala, Meghalaya, HP, WB, Odisha, AP, Karnataka, UK, Sikkim, MP, Mizoram, Manipur, TN, Bihar, Tripura, Gujarat, Nagaland, Assam, J&K, Andaman and Nikobar Islands. Kerala contributes maximum dry ginger i.e. sounth which is marketed internationally under the trade name “Cochin Ginger”. Jamaica and India produce the best quality ginger followed by West Africa. Chinese ginger is usually not exported as a dried spice but preserved in sugar syrup or converted into ginger candy. It has low pungency and aroma and hence can not be used for distillation. Japanese ginger possesses a certain amount of pungency but lacks characteristic ginger aroma.

In HP, the State Department of Agriculture started giving attention to step up the Production of quality ginger and stress was made on investigations on the crop in early sixties at Dadahu in the heart of ginger growing areas of Sirmour district on various aspects of production and breeding. The systematic research
work on ginger was also conducted at Kandaghat and Solan (Shimla Hills) under AICRP on Spices. In HP, the ginger is grown in the area of 3230 ha with a production of 7640 t i.e. productivity of 2.37 t/ha. It is a cash crop of mid and low hills and more than 3/4th of the area and production is mainly from Sirmour district. The other ginger growing areas are Solan, Bilaspur and Shimla and 90% of ginger produced in the state is exported as fresh to the adjoining states like Punjab, Haryana, Delhi, UP and Chandigarh and generate a good income to the farmers of the state. It is marketed in different forms such as raw ginger, bleached ginger, ginger powder, ginger oil, ginger oleoresin, ginger ale, ginger candy, ginger beer, brined ginger, ginger wine, ginger squash, ginger flakes etc. It is useful in gastric, cold and cough.

Climatic requirements: Ginger requires tropical, subtropical, humid climate for its commercial production. The favourable temperature range is 19-28°C, temperature lower than 13°C induces dormancy, higher than 32°C can cause sunburns and poor relative humidity is also unfavourable. The optimum soil temperature for sprouting is 25-26°C and for growth 27.5°C at increased day length (10-16 hours) vegetative growth is enhanced while it is inhibited and rhizome swelling promoted as the day length decreased (16-10 hours). It thrives well under partial shade hence can be grown as an intercrop.

Soil requirements: Ginger can be grown in all types of soils but the ideal one is sandy loam soil, light, loose, friable, well drained and at least 30 cm depth and new soils rich in humus are the best having 5.5-8.5 pH however, rhizome growth is better in slightly acidic soils (pH 6.0-6.5) than neutral soils.

Site selection: The site should be flat with sufficient slope to avoid water stagnation, well drained, rich in humus, organic matter and free from diseases and insect pests. Partial shade conditions are preferred. Ginger crop should not be grown on the same field for at least three years to avoid infection of rhizome disease a serious problem in ginger industry.

Varieties: Differential performance of the varieties in different locations is observed. The cultivars released by AICRP on Spices Varda, Mahima and Rajetha by IISR, Calicut; Surubhi, Suruchi and Suprabha by HARS, Pottangi and Himgiri by UHF Solan, mostly for local state cultivation.

Planting time: It is planted in the month of April, delay in sowing decreases the yield, the early sowing makes sufficient growth that withstands rains and grows
rapidly when there are heavy rains during July-August. In West coast of India, the best time for planting ginger is during the first fortnight of May with the receipt of pre-monsoons. In eastern India planting is done in March. Sowing in HP is according to the altitude i.e. April-May in mid and high hills and May-June in low hills. Burning of surface soil and early planting with the receipt of good summer showers consistently gives higher yield and reduces the disease incidence.

**Land preparation:** The land is ploughed 3-4 times or dug to bring the soil to a fine tilth. Compost or well rotten FYM should be applied at the time of field preparation and mixed thoroughly. Beds of convenient size about 3 m long, 1 m wide and 15 cm raised are prepared with channels of 30-45 cm to avoid stagnation of water. The alignment of the channels should be in such a way that during rainy season these should act as drains for excess water and before and after rainy season as irrigation channels.

**Propagation:** Preserved seed rhizomes are broken or cut into small pieces i.e. bits of 2.5-5.0 cm long weighing 20-30 g each having at least one or two good buds/eyes or growing points. While preparing the seed bits, the hands or the knives used should be washed with detergent powder and the knives be sterilized after some interval to avoid transmission of disease inoculums to the healthy rhizomes of seed ginger.

**Seed rate:** Seed rate vary with the size or weight of the seed bits and may be 18-20 q/ha. Seed bits of 20-25 g having 2-3 eyes are generally recommended. The use of high seed rate may be advantageous if to compensate the high seed cost involved at the time of sowing the farmers can recover the healthy mother rhizomes.
<table>
<thead>
<tr>
<th>Variety/ year of release</th>
<th>Pedigree/ parentage &amp; plant type</th>
<th>Institute/ University</th>
<th>Yield t/ha (fresh)</th>
<th>Salient features</th>
<th>Recommended state/region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suprabha 1988</td>
<td>Clonal selection from Kunduli Local</td>
<td>HARS Pottangi, (OUAT Odisha)</td>
<td>16.6 (22.8)</td>
<td>Plumpy, rhizome, less fibre, wide adaptability, suitable for both early and late sowing, duration 229 days, 8.9% oleoresin, 4.4% crude fibre, 1.9% essential oil and 20% dry recovery.</td>
<td>Odisha and adjoining states</td>
</tr>
<tr>
<td>Suruchi 1990</td>
<td>Clonal selection from Kunduli Local</td>
<td>(OUAT Odisha)</td>
<td>11.6 (23.5)</td>
<td>Profuse tillering, bold rhizome, suitable for rainfed/irrigated conditions, duration 218 days, 10.9% oleoresin, 3.8% crude fibre, 2% essential oil and 23.5% dry recovery.</td>
<td>Odisha, Central and South India</td>
</tr>
<tr>
<td>Surabhi 1991</td>
<td>Induced mutant of Rudrapur Local</td>
<td>HARS Pottangi, (OUAT Odisha)</td>
<td>17.5 (23.0)</td>
<td>Plumpy rhizomes, dark skinned yellow fleshed, suitable for rainfed/irrigated conditions, duration 225 days, 10.2% oleoresin, 4.0% crude fibre, 2.1% essential oil and 22.5% dry recovery.</td>
<td>Odisha, Odisha, Odisha</td>
</tr>
<tr>
<td>V3S1-8</td>
<td>Sodium azide mutant</td>
<td>Dr YS PUHF</td>
<td>29.0</td>
<td>A mutant line moderately tolerant to diseases and pests. Having 10.8% oleoresin, 3.2% crude fibre, 1.3% essential oil and 22.2% dry recovery.</td>
<td>Odisha, AP, WB, UP, Bihar</td>
</tr>
<tr>
<td>V1E1-2</td>
<td>An EMS mutant</td>
<td>Dr YS PUHF</td>
<td>32.9</td>
<td>A high yielding mutant with moderate tolerance to disease and pests. Contains 10.8% oleoresin, 3.5% crude fibre, 1.8% essential oil and 21.4% dry recovery.</td>
<td>Odisha, Odisha, Odisha, Odisha</td>
</tr>
<tr>
<td>Himgiri 1996</td>
<td>Clonal selection from Dr YS PUHF</td>
<td>(OUAT Odisha)</td>
<td>13.5</td>
<td>Best for green ginger, less susceptible to rhizome rot disease, wide ecological adaptability, suitable for both hills and plains.</td>
<td>(OUAT Odisha)</td>
</tr>
</tbody>
</table>

Table 1: Improved cultivars of ginger released in India
<table>
<thead>
<tr>
<th>Selection</th>
<th>Origin</th>
<th>Oleoresin (%)</th>
<th>Crude Fibre (%)</th>
<th>Essential Oil (%)</th>
<th>Dry Recovery (%)</th>
<th>Yield and Quality</th>
<th>Tolerance</th>
<th>Maturity</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Varada 1996</strong></td>
<td>Selection from germplasm</td>
<td>22.6</td>
<td>4.50</td>
<td>1.70</td>
<td>19.50</td>
<td>High yielder, high quality bold low fibre content (3.29% to 4.50%), essential oil 1.7%, oleoresin 6.7% and dry recovery 19.5%, tolerant to disease, maturity 200 days</td>
<td>All over India</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rejatha 2004</strong></td>
<td>Selection from germplasm</td>
<td>22.4</td>
<td>4.00</td>
<td>1.32</td>
<td>20.80</td>
<td>High yielder, plumpy and bold rhizome, 6.3% oleoresin, 4.0% crude fibre, 2.35% essential oil and 20.8% dry recovery, maturity 200 days</td>
<td>Kerala and Karnataka</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mahima 2004</strong></td>
<td>Selection from germplasm</td>
<td>33.2</td>
<td>4.50</td>
<td>1.32</td>
<td>20.00</td>
<td>High yielder, plumpy bold rhizome, 4.5% oleoresin, 4% crude fibre, 1.32% essential oil and 20% dry recovery, maturity 200 days</td>
<td>Kerala and adjoining states</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Seed treatment:** Treat the seed before sowing with a mixture of Dithane M-45 (0.25%) + Bavistin (0.10%) + Chloropyriphos (0.2%) for 60 minutes and dry in shade for 24 hrs as a safeguard against soft rot and to induce early sprouting. Rhizomes for seed are also treated in hot water at 48°C for 20 minutes before planting. Soaking seed rhizomes in water for 24 hours 10 days prior to planting results in good sprouting.

**Spacing:** Depending on the seed rhizome size and weight, agro-ecological situation etc. the spacing ranges 15-20 x 20-30 cm between plants and rows. Generally, closer spacing produces the higher yields. Under AICRP on Spices, general recommendation of spacing for whole of the country is 20 x 25 cm. Seed bit is placed 3-5 cm deep in the soil.

**Manures and fertilizers:** The general recommendation given by the AICRP on Spices is 100, 50, 50 kg NPK/ha. The FYM is applied either by broadcasting or by putting in the hole over the seed and cover with soil. Full dose of P and K applied at the time of field preparation, however, K can also be given in two splits, first half at the time of field preparation and second half 90 days after sowing. N is applied in three splits, first 1/3 at the time of field preparation, second 1/3 one month after germination and third 1/3 one month after second split. The beds are to be earthed up after each top dressing with the fertilizers. In ginger the total period of growth is categorized into three phases: active vegetative growth (90-128 days after planting); slow vegetative growth (129-180 days after planting) and phase approaching senescence (181 days onwards). Marked uptake of NPK is during active growth.

**Mulching:** Preferably locally available material like green or dry grass/ leaves, paddy straw, cane trash, banana leaves, mango leaves, oak leaves, pine needles, FYM etc. can be used. One or two applications can be given; one at the time of sowing and the second 6-8 weeks after sowing. A range of 5-30 t/ha has been tried by different workers and generally 20-25 t/ha is recommended. The first mulching is done at the time of planting or just after planting in 4-5 cm thick uniform layer with green leaves @ 10-12 t/ha or dry leaves @ 5-6 t/ha. Mulching is to be repeated @ 5 and 2.5 t/ha green and dry leaves, respectively, at 40 and 90 days after planting, immediately after weeding, hoeing, earthing up and application of fertilizers. An increase in yield with mulching may be 50-100%. Under low shade mulching may be reduced without affecting the yield.

**Inter-cropping and cropping systems:** Ginger can be planted in young citrus and forest plantations/orchards up to 5-6 years of mango, litchi, citrus, apple, peach, pear, plum, coconut, coffee, areca nut etc. These also provide shade as it prefers partial shade. Annual crops like maize, chilli, okra, *Colocassia,*
amaranths, gram etc are also found to be the best companion crops. Commonly rotated with turmeric, onion, garlic, chillies, other vegetables and maize; and groundnut in irrigated conditions. In NE States, ginger is grown under *jhoom* shifting cultivation system, where ginger rhizomes are planted on a virgin land after preparation and shifting to the new site to make use of the forest land rich in organic matter.

**Shade requirement:** Crop under 25% shade performed better. Maize growing in alternate inter row space has been found beneficial in comparison to sole cropping in terms of tillering and yield. Shade tolerance varies from cultivar to cultivar.

**Irrigation:** The total water requirement of ginger crop ranges between 1320-1520 mm during the complete crop cycle. The rhizomes from rain fed crop has more fibre than irrigated one raised under lower elevations. Studies have shown that sprouting, rhizome initiation (90 DAP) and rhizome development (135 DAP) are critical stages of irrigation.

**Drainage:** The excess water in the field whether it comes from over irrigation or from natural source or rain/ snow water accumulation need to be immediately removed from the field to ensure normal crop growth.

**Earthing-up:** At least two earthing-ups one after 45-90 days and another after 135 days after planting should be done.

**Weed management:** Weeding is done just before fertilizer application and mulching, 2-3 weedings are required depending on the intensity of weed growth. The use of chemical weedicides like Simazine @ 1.5 L/ha or Basalin @ 2.0 L/ha or Attrazine applied immediately after planting as pre-emergence have been reported effective in controlling most of the weeds.

**Recovery of mother rhizomes:** The mother or seed rhizomes utilized as planting material can be removed or detached from ginger sprouts of 4-6 cm height without adversely affecting the further growth of the plant. Separated rhizomes can be used for spice purpose.

**Harvesting and yield:** The stage of harvesting depends upon the purpose for which crop is grown, price trend, variety and agro-climatic conditions. The yield of ginger varies with variety, care and management of crop and agro-climatic conditions of locality, where it is grown. Maximum yield to the tune of 30-40 t/ha has been reported, however, 12-15 t/ha is generally obtained. The yield of dry ginger is 15-25 % of the fresh ginger depending upon the variety and locality.
Storage of rhizome: Conventionally the storage is done above or below ground. In above ground, the rhizomes are kept in heap on sand layer or paddy husk and covered with dry leaves and plastered with cow dung. In below ground, pits of size $1 \times 1 \times 1$ m or as per requirement are made under shade/shed. The walls of this pit are plastered with cow dung with a layer of sand at the base. Healthy and disease free rhizomes treated in solution of Dithane M-45 + Bavistin + Chloropyriphos are placed loosely. Filling is done up to 10-15 cm below from the top. This top is covered with dry grass. The pit is closed with the help of wooden plank. Plaster the space between the planks with soil or cow dung. Keep or place a perforated PVC pipe of 2 inches diameter in the centre of the pit for removal of gases. The material is stored for 3-4 months and taken out from the pits at least 20-25 days before sowing.

a) For green ginger: Green rhizomes harvested after 8-12 months are stored at 12-18°C and 60-80% RH. Fresh ginger can be stored in 200 gauge thick poly-bags of 35 x 25 cm with 125 punch holes each with 4 mm diameter. The ginger is cleaned and dried and sealed with stapler or rubber band. Bags should be kept in cool dry places with air circulation and be inspected at fortnightly intervals. After around 4 months, the weight of 1 kg bag will remain around 700 g.

b) For seed ginger: Fully mature, big, plump rhizomes, free from diseases are selected after harvesting and treated before storage. A drum of 200 litres capacity is filled with 100 litres of water. Few litres of water is taken in a bucket added with 250 g Dithane M-45+100 g Bavistin+200 ml of Chloropyriphos and mixed thoroughly. Then 80 kg rhizomes are steeped in the drum for 30 minutes. Solution is drained off and rhizomes are dried under shade and stored. Rhizomes are best stored by pit method.

TURMERIC

Turmeric (Curcuma longa L. 2n=3x=63) belongs to the family Zingiberaceae and plays a vital role in the national economy. India has a prime position in the world and is largest producer, consumer and exporter of turmeric and accounts for more than 50 % of the world trade. The area under turmeric in India is 2 32 670 ha with an annual production of 11 89 890 t i.e. productivity of 5.11 t/ ha. Out of the total turmeric produced in India 90% is consumed locally and remaining 10% is exported to various countries like USA, UK, Middle East, Japan, Singapore, Malaysia, South Africa, Australia and other countries.
In HP, turmeric has not attained significant status among spice crops probably due to poor yield and being a long duration crop, however, some growers especially in lower hills have started showing interest in the crop and the area is steadily increasing as the crop can be successfully planted under rain fed conditions under minimal care and attention. Moreover, increasing monkey menace and engagement of farmers in other occupations offer better opportunities for increasing acreage under this crop in the state.

**Climatic requirements:** The crop requires a hot and moist climate with a liberal water supply. Turmeric is mostly a tropical plant cultivated throughout India in tropical and sub-tropical humid climate. In the delicate tracts and interior regions of South India and the North Punjab, from sea level up to an altitude of 1500 m with an optimum range of 450-900 m turmeric is cultivated. It tolerates an annual rainfall of 640 to 4290 mm. Moderate rainfalls of 1500 mm at sowing, fairly heavy and well distributed rain during growing period and dry weather about one month before harvest are much suitable. The temperature range of 18.2-27.4°C is optimum. Turmeric cultivated in the hills is reported to be a better quality than that raised in the plains. It is stated that the same variety when grown in the plains and on the hills shows distinct differences in quality and yield.

**Soil requirements:** Turmeric can be grown on various soils but thrives best in well drained, friable, rich sandy or clay loam soils having pH range of 4.3 to 7.5. The crop can neither stand water logging nor alkalinity.

**Varieties:** Some of the popular cultivars are- Duggirala, Cuddapah, Tekurpeta, Sugandham, Amalapuram, Erode local, Alleppey, Wynadan, Moovattupuzha, Rajapuri, and Lakadong. The improved varieties of turmeric are- Suvarna, Suguna, Sudarsana, Prabha, Prathibha, Krishna, Sugandham, Roma, Suroma, Ranga, Rasmis, Rajendra, Sonia, Alleppey, Supreme, Kedaram, Co-1, BSR-1 and BSR-2.

**Planting time:** The time of planting of turmeric varies with the cultivar as well as the agro climatic condition of the area. It is generally planted between mid-April and August. Time of sowing for short duration varieties is second fortnight of May, for mid duration varieties first fortnight of June and for long duration varieties second fortnight of June to second fortnight of July.

**Land preparation:** The land is ploughed 3-4 times or dug to bring the soil to a fine tilth. Compost or well rotten FYM should be applied at the time of field preparation and mixed thoroughly. Beds of convenient size about 3 m long, 1 m wide and 15 cm raised are prepared with channels of 30-45 cm to avoid stagnation of water. The alignment of the channels should be in such a way
that during rainy season these should act as drains for excess water and before and after rainy season as irrigation channels. This space will also help in moving about, while hoeing, weeding, mulching, top dressing and rouging and inspection of the crop. In plains, deep drains should be provided to drain-off excess water during rainy season.

**Propagation:** Turmeric is commonly propagated by rhizomes. Mother rhizomes as well as fingers are used as planting materials.

**Seed rate:** Seed rate vary between 20-25 q/ha. The seed rhizome pieces of 30 g with 2 to 3 eyes are planted.

**Spacing:** Seed rhizomes are planted in small pits made with a hand hoe in the beds in rows with spacing of 30 x 20 cm and covered with soil or dry powdered cattle manure. Germination starts in 10-20 days and will be over by 60 days.

**Manures and fertilizers:** Farmyard manure or compost @ 30-40 t/ha is applied by broadcasting and ploughed at the time of preparation of land or as basal dressing by spreading over the beds or in to the pits at the time of planting. Zinc @ 5 kg/ha may be applied at the time of planting and organic manures like oil cakes can also be applied @ 2 t/ha and in such case, the dosage of FYM can be reduced. Fertilizers @ 60 kg N, 50 kg P₂O₅ and 120 kg K₂O per hectare are to be applied in split doses.

**Mulching:** Preferably locally available material like green or dry grass/ leaves, paddy straw, cane trash, banana leaves, mango leaves, oak leaves, pine needles, FYM etc. can be used. Generally, 20-25 t/ha is recommended. The first mulching is done at the time of planting or just after planting in 4-5 cm thick uniform layer with green leaves @ 10-12 t/ha or dry leaves @ 5-6 t/ha. Mulching is to be repeated @ 5 and 2.5 t/ha green and dry leaves, respectively, at 90 days after planting, immediately after weeding, hoeing, earthing up and application of fertilizers.

**Inter-cropping and cropping systems:** It is recommended as an intercrop in coconut and areca nut gardens. Turmeric can be grown as an inter crop with chillies, colocasia, onion, brinjal, arhar or sunhemp and cereals like maize, ragi, etc. In this way, more income is obtained and risk of loss in case of natural hazards is reduced. It is commonly rotated with onion, garlic, chillies, other vegetables and maize and groundnut in irrigated conditions.

**Irrigation:** The number of irrigations may be varied with the soil types. 15 to 20 irrigations are given for clayey soils and about 40 for sandy loams. During
the period of rhizome development and maturity, frequent irrigations are necessary.

**Drainage:** The excess water in the field whether it comes from over irrigation or from natural source or rain/snow water accumulation need to be immediately removed from the field to ensure normal crop growth, as poorly drained soils not only harm the turmeric crop directly but create various problems in scheduling the mechanical farm operations, invite and promote the development of diseases and pests.

**Earthing-up:** Usually practiced during 45-60 days after planting (DAP) 90-105 DAP, additional if required done on 120-135 DAP. This helps to form and enlarge rhizomes and also protect rhizome from insects.

**Weed management:** Weeding is generally done just before fertilizer application and mulching; while doing hoeing every care should be taken that the rhizomes are not disturbed, injured or exposed. The use of chemical weedicides like Simazine @ 1.5 L/ha or Basalin @ 2.0 L/ha or Attrazine applied immediately after planting as pre-emergence have been reported effective in controlling most of the weeds.

**Harvesting and yield:** Field is irrigated 1-2 days in advance of harvesting the crop. Crop is harvested by ploughing or digging. Rhizomes are gathered by hand picking and cleaned. Rhizomes are washed. Mother rhizomes are separated from the fingers before they are cured. Indian average yield is 20-22 t/ha.

**Processing:** Fresh rhizomes are not useful for marketing. Curing makes fresh rhizomes marketable. Curing involves boiling, drying and polishing.

**Storage of seed rhizomes:** Conventionally the storage is done above or below ground. In above ground, mature, healthy rhizomes are heaped over a layer of 5-10 cm sand under shade of a tree or shed. These are covered with turmeric leaves. Then heaps are plastered with earth mixed with cow dung. The rhizomes are treated with Dithane M-45 @ 0.25% + Bavistin @ 0.10% solution for 30 minutes and shade dried before heaping. Remove rotten rhizomes at the end of storage period. Rhizomes for seed purpose are generally stored by heaping in well ventilated rooms and covered with turmeric leaves. In below ground, pits of size 1 x 1 x 1 m or as per requirement are made under shade/shed. The walls of this pit are plastered with cow dung with a layer of sand at the base. Healthy and disease free rhizomes treated in solution of Dithane M-45 + Bavistin are placed loosely. Filling is done up to 10-15 cm below from the top. This top is covered with dry grass. The pit is closed with
the help of wooden plank. Plaster the space between the planks with soil or cow dung. Keep or place a perforated PVC pipe of 2 inches diameter in the centre of the pit for removal of gases. The material is stored for 3-4 months and taken out from the pits at least 20-25 days before sowing. The seed rhizomes can also be stored in pits with saw dust and sand.

References

Advances in Production Technology of Temperate Vegetables

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The temperate vegetables occupying a significant position may generally include mainly cole crops (cabbage, late cauliflower, broccoli, brussels sprouts, knol-khol, kale and collards). All belongs to family Brassicaceae and having almost similar cultural practices. Similarly, root crops (beet, temperate varieties of carrot, radish and turnip) although belongs to different families, but have similar cultural practices. These crops are also commonly known as European or biennial vegetables.

Production Technology: The improved cultural practices play a crucial role in realizing the maximum yield potential of a variety/hybrid chosen for growing. A brief package of practices for successful cultivation of different temperate vegetables has been summarized as below:

Varieties:

A lot of improvement work has been done, though all of these crops are introduced ones. Popularly grown varieties (open-pollinated) and hybrids (both from public and private sectors) are enlisted in table-1.

Table-1. List of popular varieties and hybrids

<table>
<thead>
<tr>
<th>Crop</th>
<th>Popular varieties</th>
<th>Popular hybrids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cole crops</td>
<td>Early group: Golden Acre, Pride of India, Copenhagen Market, Early Drum Head, Pusa Mukta</td>
<td>Through AICRP: Sri Ganesh Gol, Nath 401&amp; 501, BSS 32 and Quisto</td>
</tr>
<tr>
<td></td>
<td>Mid group: All Head early, Wisconsin, All Green, September</td>
<td>Popularly grown in HP: Varun, Bajrang, Sumit, Bahar Pushkar, Pusa Cabbage Hybrid-1</td>
</tr>
</tbody>
</table>
### Cauliflower

**Late group:** Pusa Drum Head, Danish Ball Head, Late Flat Dutch

**Maturity Group/variety:**

(a) **September**
- Early Kunwari, Pusa Early Synthetic, Pant Gabhi-3, Pusa Meghna
- (Ia) Burkha Early
- (Ib) Shweta Mid

(b) **October**
- Pusa Katki, Pusa Deepali, RC-JOB-1, Pusa Kartik (F₁ hybrid)
- Shweta Mid Suhasini-Late type, Pahuja Takii Snow Crown-Mid-late, Clause Madhuri-Late

(c) **November**
- Pant Gobhi- 4, Agahni, Punjab Giant - 26, Punjab Giant - 35, Hisar – 1, Pusa Sharad, Pusa Hybrid - 2

(d) **December**
- Pusa Shubhra, Pusa Synthetic, Pusa Himjyoti, Pant Shubhra,

(e) **Late (January-February)**
- Pusa Snowball -1, Pusa Snowball K-1, Kt - 25

**B. Sprouts**

- Hild’s Ideal, Rubine

**Knol-Khol**

- White Vienna, Purple Vienna, King of North, Palam Tender and Pusa Virat

**Kale**

- Westo and Khanyari Green

**Root crops**

**Carrot**

- Chantenay, Denver, Nantes, Early Horn, Zeno, Early Gem Imperator, Pusa Yamdagini and Solan Rachna

- Pusa Nayanjyoti (Katrain)

**Radish**


-
Advanced production practices: Since the majority of cole crops are transplanted vegetables, hence raising of healthy seedlings is equally essential. Fungicide ‘Captan’ as seed treatment @ 0.25% followed by soil drench (0.25%) @ 6 litre solution /m² has been reported very effective. About 4-6 weeks old seedlings are transplanted either on flat beds or on one side of the 15-20 cm high ridges especially during wet season for better drainage. Direct seed sowing in rows is also followed by the farmers in north Indian plains. Planting time of different cole crops varies in different agro-climatic zones of India. Some of the crops are being grown throughout the year. The temperature and soil requirement of different crops for different varieties/hybrids varies from germination till harvesting to complete all the stages of growth and development (Table-2). Hence, planting of different crops is required to be adjusted accordingly. In order to ensure optimum plant density, it is advisable to transplant the crops at desired spacing for early, mid and late varieties respectively (Table-3). Majority of cole crops are shallow rooted vegetable and requires more nutrients coupled with earthing up for proper growth and development of plants. All crops are heavy feeder and slightly tolerant to soil acidity but moderate to highly tolerant to soil salinity. Although the exact requirement of manures and fertilizers will depend upon soil test across locations but in optimum doses must be applied. Foliar sprays of urea (1.0-1.5%) in some crops help in saving N-fertilizer on one hand and making its availability to the plants at the earliest possible. Use of non symbiotic biofertilizers viz., Azospirillum and Azotobacter as seed treatment @500g/ha, soil application @5.0kg/ha and seedling dipping @1.0kg/ha has been reported effective in economizing 25-30% of nitrogen requirement. Phosphorus solubalizing bacteria (PSB) @500g/ha as seedling dip and vasiccular arbuscular mycorrhizae (VAM) @ 15kg/ha) as soil application along with recommended/reduced doses of NPK fertilizers have also proved beneficial. As regards irrigation, it is needed at the time of transplanting of the seedlings in the field and thereafter every 5-7 days during relatively warmer period and at 10-15 days interval during relatively cooler period. Besides manual weeding, the application of chemical weedicides has proved effective in keeping the weed growth under check. Notable weedicides are Pendimethalin (Stomp) @ 1.0-1.5kg a.i. /ha as post-planting, Fluchloralain (Basalin) @ 1.5kg a.i. /ha as preplant incorporation, Alachlor @ 2.0Kg.a.i./ha
as preplanting and Trifluralin (Treflan) @ 0.5-1.0 kg a.i. /ha as preplanting (Table-3).

On the other hand, all root vegetables are sown directly in the field. Seeds are usually sown in the shallow furrows of 2 cm depth on ridges. After sowing the ridges are kept moist till the germination is completed. The seed of beet root is multigerm which produces 3-4 seedlings per seed ball, hence thinning is an important operation. Also remove the weak, diseased and insect affected plants to maintain proper distance between the plants within the rows. Root crops can also be seeded precisely with mechanical seeders that prevent the need for subsequent thinning. Time of sowing of any root crop depends upon the type of the variety and location. Further, moisture stress can reduce the crop yields. Plants that wilt intermittently may produce smaller yields, while those which wilt frequently will often die due to irreversible cell damage. Most of root crops require irrigation prior to germination to prevent a crust from forming on the soil which impedes germination. After germination, irrigation is only necessary during drought or on typically dry soils such as sands. Both drip and overhead sprinkler irrigation systems are effective. Manure and fertilizer application is also an important step which decides the productivity potential and quality produce of any crop. Fertilizer program should be based on a soil test. Random soil samples should be collected from the entire field and nutritional status of the field should be checked out before planting any crop. Due to climatic conditions, differing cultural practices, varying soil conditions and other situations, the crop’s response to the fertility program may vary from region to region. Weeds pose a very serious problem in the early stages as growth of seedlings is very slow and they cannot compete with the weeds. Generally, one to two shallow weedings at early stages of crop growth keep the field free from weeds. Moreover, pre-emergence application of Fluchloralin (0.5-1.0 kg/ha) or Pendimethalin (1.0 kg/ha) is also effective to control the weeds in the field of root crops. Soil should be hoed time to time to allow proper aeration. Beside this, organic mulches also help in keeping soil weed free and lower down the soil temperature (Table-3).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Temperature (°C)</th>
<th>Soil type and pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cole crops</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cabbage</td>
<td>15-18</td>
<td>A fertile medium to heavy well drained soil with pH 6.0-6.5 is ideal to grow cole crops</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>10-16</td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>10-15</td>
<td></td>
</tr>
<tr>
<td>Crop</td>
<td>Sowing time</td>
<td>Spacing</td>
</tr>
<tr>
<td>--------------</td>
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<td>----------</td>
</tr>
<tr>
<td>B. Sprouts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knol-Khol</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Root crops</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radish</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turnip</td>
<td></td>
<td></td>
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<tr>
<td>Beet root</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Crop</th>
<th>Sowing time</th>
<th>Spacing</th>
<th>Seed Rate</th>
<th>Manure and fertilizers</th>
<th>Irrigation</th>
<th>Weed management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabba ge</td>
<td>Jan-Feb</td>
<td>45 × 45 cm</td>
<td>Early-500g</td>
<td>FYM @15-20 tons/ha 180:60:60 kg/ha</td>
<td>During bolting and pod formation stage</td>
<td>2-3 manual weeding, Herbicides like trifluralin @ 0.5kg/ha and fluchloralin @0.5 kg/ha used for weed control.</td>
</tr>
<tr>
<td></td>
<td>July-August</td>
<td>60 × 60 cm</td>
<td>Late-200-375g</td>
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<tr>
<td></td>
<td>Sept- Oct</td>
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<td>Oct-Nov</td>
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<td>Nov-Dec</td>
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<td></td>
<td>Dec-Jan</td>
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<tr>
<td></td>
<td>Jan-Feb</td>
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</tr>
<tr>
<td>Cauliflow er</td>
<td>Sept-Oct</td>
<td>60 × 45 cm</td>
<td>375g</td>
<td>FYM @30 tons/ha 90:90:90 kg/ha NPK</td>
<td>Once in a week</td>
<td>Frequent shallow cultivation to kill weeds and provide soil mulch.</td>
</tr>
<tr>
<td></td>
<td>Oct-Nov</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>Oct-Nov</td>
<td>60 × 45 cm</td>
<td>500-500g/ha</td>
<td>FYM @30 tons/ha 90:90:90 kg NPK</td>
<td>Once in a week</td>
<td>Frequent shallow cultivation to kill weeds and provide soil mulch.</td>
</tr>
</tbody>
</table>

Table 3. Standard cultural practices for vegetative crop production in temperate vegetables

**Note:** Root crops prefer deep, loose, well drained, sandy loams or loam soil having pH 5.5-7.0
<table>
<thead>
<tr>
<th>Crop</th>
<th>Planting Time</th>
<th>Size/Spacing</th>
<th>Fertilizer</th>
<th>Weed Control</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Sprouts</td>
<td>Sept-Oct</td>
<td>Large sprouts: 90 × 90cm</td>
<td>FYM @15-20 tons/ha</td>
<td>During bolting and pod formation stage</td>
<td>2-3 manual weeding, Herbicides like trifluralin @ 0.5 kg/ha and fluchloralin @0.5 kg/ha used for weed control.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Small sprouts: 60 × 60 cm</td>
<td>180:60:60 kg/ha</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knol-Khol</td>
<td>September</td>
<td>25×25 cm, 25 × 30cm, 25 × 40cm, 30×45cm</td>
<td><a href="mailto:FYM@12.5t">FYM@12.5t</a>/ha</td>
<td>During bolting and pod formation stage</td>
<td>One hoeing and weeding during Sept-Oct. and one weeding and earthing up during Nov-Dec.</td>
</tr>
<tr>
<td>Kale</td>
<td>Sept-Oct</td>
<td>60 × 45 cm</td>
<td>500-600g/ha</td>
<td>Once in a week</td>
<td>Frequent shallow cultivation to kill weeds and provide soil mulch.</td>
</tr>
</tbody>
</table>

**Root crops**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Planting Time</th>
<th>Size/Spacing</th>
<th>Fertilizer</th>
<th>Weed Control</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrot</td>
<td>Asiatic type: Aug-Nov, European: Oct-Nov</td>
<td>25-30 × 8-10cm</td>
<td>8-10kg</td>
<td>FYM@20-30t/ha 120:60:60 kg NPK</td>
<td>At an interval of 5-7 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Two weeding at 15-20 and 30-35 DAS. Linuron(0.5-1.0kg/ha) Nitrofen(1.0kg/ha)</td>
</tr>
<tr>
<td>Radish</td>
<td>Asiatic: Aug-Jan, European: Sept-Mar.</td>
<td>25-30 × 8-10cm</td>
<td>Asiatic: 10kg European 12-14kg/ha</td>
<td>6-7 days interval and root development and pod formation are</td>
<td>One weeding after 15-20 days, serious problem during early stage of growth,</td>
</tr>
</tbody>
</table>
| Plant | Region | Stage | Plant Protection Measures | Pesticide
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Turnip</strong></td>
<td><strong>North Indian plains</strong>: Sept-Dec, <strong>Lower hills</strong>: July-Oct, <strong>High hills</strong>: July-Sept</td>
<td>30-45x10-15cm, 3-4kg FYM@20-50t/ha 30-40:50:50 kg NPK</td>
<td>At 8-10 days interval Moderate and uniform moisture conditions</td>
<td>Fluchloralin @0.5kg/ha, Two shallow weeding and hoeing <a href="mailto:Fluchloralin@1-1.5kg">Fluchloralin@1-1.5kg</a>/ha and Pendimethali@1kg/ha</td>
</tr>
<tr>
<td><strong>Beet root</strong></td>
<td><strong>North Indian plains</strong>: Sept-Nov, <strong>South Indian Plains</strong>: July-Nov, <strong>Hills</strong>: Mach-July</td>
<td>30-45x8-10cm, 8-10kg 20-25t/ha 30-40:100-120:60-70kg and 20kg Bora×</td>
<td>Field should be kept free from weeds during first 2 month of sowing. Pyrazone @1.5-2.0 kg/ha, Cycloate @ 3-4 kg/ha</td>
<td>Immediately after sowing Lightbut regular irrigation, 4-6 irrigations are required</td>
</tr>
</tbody>
</table>

**Plant Protection Measures**: It is in the interest of the farmers to keep the prevalent diseases and insect-pests under check in getting optimum yields of desired quality. The disease and insect-pest problems of different cole crops are almost similar to each other. The plant protection can be achieved by growing resistant/tolerant varieties/hybrids and pesticides. Seed dressing and soil drenching with Thiride @ 0.2% or Bavistin @0.2% or Captan @0.25% has proved effective in raising healthy nursery. Bavistin sprays @ 0.1% at 15-20 days interval are effective in checking Sclerotinia stalk rot. Mancozeb sprays @ 0.25% at 15 days interval are effective against Alternaria blight disease. Streptocycline as seed treatment @ 100 ppm for 15 minutes followed
by seedling dip in 100 ppm solution for 15 minutes before transplanting and three sprays @ 200 ppm at 10 days interval after 50 days of transplanting was the best to control black rot disease at Bhubaneshwar and Kalyani centres. Four sprays of Plantomycin (500ppm) + Blitox (3000ppm) mixture have proved effective in controlling *Erwinia* soft rot at Katrain. For managing the infestation of diamond back moth, three sprays of Fenvalerate @ 50g a.i. /ha have proved effective at IIHR, Hessarghata. Besides, mustard as trap-crop has also proved effective in reducing the insect population. It is recommended to sow mustard 15 days prior to transplanting of cabbage and give two-three sprays of Dichlorvos @ 0.075% in mustard crop and two sprays of 5% neem seed kernel extract (NSKE) in cabbage.

In root vegetables, seed treatment with captan or Thiram @ 3g/kg of seed before sowing and at an interval of 7-10 days is helpful to control Alternaria Blight in carrot. While, foliar application of copper fungicides or Zineb or Dithane Z-78 is effective against Leaf Spot or Cercospora Blight of carrot. In radish, application of Difolitan (0.3%), Dithane-M-45(0.2%) and Ridomil (0.1%) is advisable to control white rust disease. Mustard Sawfly in turnip can be controlled effectively by foliar application of Malathion or dichlorvos @ 0.05%. While in beetroot, Sclerotium Root Rot can be controlled by drenching the roots with bavistin (0.03%) solution.

**Seed Production of temperate vegetables:**

Seed is one of the most critical inputs for production. A sustained increase in vegetable production and productivity has become dependent upon the development of new improved varieties/hybrids and supply of their quality seed to the farmers. Seed production is very systematic as well as technical programme involving set procedures. Good seed is the basic requirement of all growers. Thus seed producer stands in a position of great responsibility, and to fill his obligation satisfactorily he needs to understand thoroughly many factors which enter into production and processing of good seed.

On the basis of seed production, vegetable crops can be classified into two groups viz., ‘Tropical’ and ‘Temperate’. Seeds of tropical vegetable crops can be easily produced in plains and lower hills of India but the second group of vegetables includes biennial or European vegetables requiring temperate climate for successful seed production.
Suitable areas for seed production

Our country is gifted with a wide range of agro-climatic conditions, which enables the seed production of different vegetable crops throughout the country in one or the other part. The different pockets in the Hindukush Himalaya are suitable for seed production of temperate vegetables. In India, Humid Western Himalayan Region consists of states like Jammu and Kashmir, Himachal Pradesh, Uttranchal and Humid Eastern Himalayan Region with Sikkim, Meghalaya, Manipur, Nagaland Mizoram, Tripura and Arunachal Pradesh. Likewise Pakistan Himalayan Region of Baluchistan, whole of Nepal and Bhutan are suitable for this purpose.

The winter temperature of Kullu and Kashmir valleys is so congenial that neither protection from cold in the field nor provision of storage facilities for over wintering is required. The crops under these conditions can be left in the open for overwintering without any damage. Winter and summers suit to produce seeds of not only temperate vegetables, but also of summer’s vegetables. Besides the Kullu and Kashmir valleys, fulfilling the necessary requirement for seed production of temperate vegetable, there are some other areas viz., Vegetable Research Station, Kalpa, Kinnaur where climatic conditions (severe winters and dry hot spring-summers) are quite congenial for quality seed production of temperate vegetable crops. These areas widen the scope for expending the seed industry not for indigenous consumption, but also for export to even some European and western countries, where seed production becomes expensive day by day with the increase in cost of labour.

Specific requirements for Seed Production of temperate vegetables:

It is greatly affecting the pattern of crop growth in various agro-climatic zones throughout the world, which in-turn is changing the socio-economic conditions of the people. Vegetable production is also not untouched by the changing climatic scenario, it has also affected the seed production of the various temperate vegetables like cabbage, cauliflower, broccoli, brussel's sprouts, knol-khol, kale, European carrots, radish, turnip, beetroot etc. which have specific low temperature chilling requirements. Various marginal areas are becoming unsuitable for seed production of different vegetables viz., late cauliflower, cabbage and other temperate vegetables due to increasing temperature. The problems arise from extreme events that are difficult to predict. More erratic rainfall patterns and unpredictable high temperature spells will consequently reduce crop productivity. Climate change is projected to increase the global temperatures, causes variations in rainfall, increases the frequency of extreme events such as heat, cold waves, frost days, droughts, floods etc. with immense impact on agriculture sector.
Temperate vegetables require temperate climate especially during a specific stage of their growth for successful seed production. During this period these vegetables meet the vernalization (chilling) requirement, a precondition necessary for breaking dormancy of plant, thus stimulating the conversion of the vegetative phase into the reproductive phase i.e. induction of flowering and bolting.

**Table-5. Special temperature requirement**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Edible part</th>
<th>Chilling temperature (°C)</th>
<th>Duration (Weeks)</th>
<th>Phases of Production</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cole crops</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cabbage</td>
<td>Head</td>
<td>4-10</td>
<td>6-8</td>
<td>2</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>Curd</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Head</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>B. Sprouts</td>
<td>Brussels</td>
<td>4-10</td>
<td>5-7</td>
<td>2</td>
</tr>
<tr>
<td>Knol-Khol</td>
<td>Knob</td>
<td>7-10</td>
<td>4-6</td>
<td>2</td>
</tr>
<tr>
<td><strong>Root crops</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td>Root</td>
<td>4-7</td>
<td>4-6</td>
<td>2</td>
</tr>
<tr>
<td>Radish</td>
<td>Root</td>
<td>4-7</td>
<td>4-6</td>
<td>2</td>
</tr>
<tr>
<td>Turnip</td>
<td>Root</td>
<td>4-7</td>
<td>4-6</td>
<td>2</td>
</tr>
<tr>
<td>Beet root</td>
<td>Root</td>
<td>4-7</td>
<td>4-6</td>
<td>2</td>
</tr>
</tbody>
</table>

The seed production is taken in the hills for European types and in the plains for Asiatic types. European/temperate types require high chilling (4-7°C) for a specific period (about 4-6 weeks) in majority of cases as given in table-5. The mild summer and low rainfall of hills especially during flowering and seed setting stages are beneficial. The sowing time should be so adjusted that the roots become available and their stecklings could be set in before chilling months. In heavy snowfall areas where chilling period is long, the roots after uprooting are stored in trenches before the onset of winters and replanting is done in the month of March- April. In such case stecklings are prepared just before planting. The seed is ready for harvesting from July-August to September-October (high-hills) depending upon the weather, crop and cultivar.

**Methods of seed production of cole crops**

**Seed production**

For seed multiplication of different cole crops the following three methods can be followed depending on the suitability, type of seed and stage of multiplication:
1. **Seed-to-seed method**

For foundation and certified seed production, seed-to-seed method is commonly followed by using high quality breeders’ seed. Plants are allowed to grow, overwinter and produce seed in their original position where they were first planted as seedling. This method is again divided into 3 sub-methods for quality seed production of cabbage.

(A) **Head intact method**: This is the most common method in commercial seed raising of cabbage. The plants are allowed to over winter at the place of original planting as seedling. Head may burst from any side to allow the flower-stalk to come out. The heads bursting from lateral sides may result in an injury to the terminal part of the inflorescence stalk. With the suppression of apical dominance, the growth of lateral buds/branches is stimulated and the branches instead of growing upright become decumbent. These are liable to be broken while performing field-operations such as weeding, spraying and strong winds at the full load of mature pods. To facilitate the flower-stalk to emerge easily, uniformly and to grow straight up with the terminal point intact, two vertical cross-cuts with a sharp knife or blade are given to the heads as soon as they start buldging or giving dome-shaped appearance. A care is taken not to injure the central growing point. Cross cuts may be given twice or thrice in the varieties having very compact heads.

(B) **Stump method**: The fully mature heads are decapitated just below the base with a sharp knife keeping the stem with outer whorls of leaves intact. Removal of heads should only be done after ascertaining true to type of mature heads. The stumps thus left throw flowering shoots from the axillary buds during spring. This method may be useful when the selection of heads is based on internal characters like core size particularly in research. The stump of plants selected on the basis of head characteristics can be left either in situ or replanted at other place.

2. **Head-to-seed method**

This method is mostly followed for nucleus seed production. True-to-type compact heads are selected, uprooted and replanted in a separate plot during November-December. Before replanting, the outer leaves are removed and plants are set in the field in such a way that the whole stem below the head is buried in the ground with the head resting just above the surface of soil which prevents tilting of plants due to weight of the heads. The soil around the base of the plant is made firm by pressing and levelled uniformly. There
should be no depression otherwise water will stagnate and may injure the root system. The loosely set plants get tilted immediately after irrigation. Selection of true-to-type heads is possible only in the compact stage. Hence selection in the loose headed stage from seed quality point of view is risky unless there is certainty of the highest quality of the seed stock used.

**Modified Method:** This method is followed in areas like Kalpa-Kinnaur (Himachal Pradesh) where there is a heavy snowfall during winter and the land remains covered with snow for a fairly long time. In such areas planting time is adjusted in such a way that full maturity of the heads occurs just before the onset of winter season and is generally done in May-June. If the planting is done earlier the heads may begin to split and are not fit for storage in the trenches. In the delayed planting, the head may not be compact and fully mature which cannot be stored properly because loosely folded leaves are more prone to desiccation than the tightly overlapped leaves which increase the staying capacity of the heads. The compact true-to-type heads are selected, uprooted and stored in trenches for overwintering after removing the outer whorls of leaves.

Due to extremely low temperature, the heads get vernalized in the trenches. At low temperature, the heads remain dormant and the growth of disease organisms is discouraged. As soon as the danger of frost is over, the heads are taken out from the trenches and are replanted in well prepared field during March-April. Cross cut (3cm deep) is given to the heads before they start bursting. Flowering takes place in June-July and the seed is ready for harvesting in August-September. This method is advocated for nucleus seed raising under insect proof conditions in the screen chambers. It is also suitable for breeders’ seed production. Head-to-seed method provides better scope for inspection of heads (stalk length after removal of outer leaves, head size, shape and colour) and rouging.

### 3. Late planting

Although this method is a modification of in situ method and is followed only under specific circumstances. It can only be followed in early types which when planted late bolt directly in spring after overwintering in the field without forming any typical heads. In the maturing cabbages seed production is not possible because when these are planted late, the immediate onset of winter will prevent the plants from making sufficient vegetative growth necessary for perceiving the low temperature effect required to initiate bolting and flowering. These plants remain in vegetative stage even after the winter is over and start making further growth with the rise of temperature in March. Heading in these plants occurs in May-June. In this method, seed yield is very
high but the quality of seed produced may not be up to the prescribed seed standards. In case this method is to be followed the stock seed used to raise the crop must be of the highest quality otherwise it is quite risky and the subsequent crop raised from this seed is bound to produce plants of inferior quality. The other advantage is that it shortens the period of seed production in early cultivars because in other methods of seed raising, the plants have to be maintained and cared for, for almost a year, which may involve extra expenses.

Methods of seed production in root crops

1. Seed-to-seed
2. Root-to-seed

Both seed-to-seed and root-to-seed methods are employed for seed production in root crops. The former method is not followed unless the seed is of the highest quality. Replanting method (root-to-seed) is preferred for producing nucleus and breeder seeds. When the roots are fully mature, the crop is harvested, true-to-type roots are selected. The selection and roguing are done on the basis of foliage characters and root characters both external and internal (colour, shape, size, flesh colour, core size, pungency, indistinct rings etc.). Undesirable roots are discarded. After selection of true-to-type roots, their tops and tips are cut and transplanted in a well prepared field. The stecklings of roots can be prepared by giving one-third top (shoot) cut and one-fourth to one-half root cut to obtain higher yield of better quality seeds. In case of turnip and beet, after selection the tap root and tops of the roots are trimmed taking care not to injure the crown and planted in a well prepared field.

Bolting, flowering and seed setting: Exposure of plants to low temperature results in transformation of leaf-primordial into floral primordial. As discussed earlier the size of the plant exposed to low temperature is of considerable importance. The larger the plants at the vernalization, greater is their tendency to shoot to seed. The size of the plants varies with different maturity groups. As in cabbage, the major selection criteria are based on the head characteristics, the plant must form heads before the temperature becomes low. With the increase of temperature in February the heads start bulding out as a result of internal pressure. At this stage cuts 2.5-5 cm deep at right angles are given across the heads for easy emergence of the flower-stalks. As soon as the heads burst and growing tip comes out, bolting is said to have taken place and continues till flowering. By second week of April the flower-stalk attains a height of about 1.00-1.25 m and then the process of flowering starts from the lower portion of the main axis and continues till the end of May. The amount of flower-formation depends on temperature, the period of exposure to low temperature and to some extent on the rate of seed
set because the plants with good seed-set cease to produce flowers early than the plants where less or no seeds is set. A single plant covered with a bag continues to flower for longer duration. Lower temperatures within the favourable range of 4.4°C-10°C for vernalization stimulate the plant in less time to bolt quickly and produce flowers in abundance and vice-versa. Number of flower-formation also depends on the age of the plant. Low temperature treatment at the end of juvenile phase produces sparse flowering but when exposure to chilling temperature is subjected for 28-42 days or so profuse flowering takes place.

Rate of opening of flowers is decreased in rainy and cold weather. Moreover, pollination, fertilization and seed-setting are adversely affected. Sunny days are favourable for satisfactory flowering and seed-setting. Cloudy weather results in poor seed-set owing to poor bee-activity. Provision of 3-4 bee-hives/ha ensures good seed-set and thus increased seed yield. The favourable temperature range for flowering and seed-setting is 12.5°C-18.5°C. Sprays of micronutrient formulations like Mcnelf, Agromin, Multiplex, etc. after the emergence of flower-stalk increases proper development of flower-buds and seed-setting. Seed-yield is increased by spraying of ppm boric acid at pre-flowering stage as this enhances pollen germination (Bhagchandani et al., 1982). Proper moisture regime in the soil should be maintained for satisfactory setting, growth and development of seed. Ovules wither and dry under water-deficit conditions in early stages following fertilization. Dry conditions in the later stages of seed development cause shriveling of seeds and forced ripening of seeds with smaller size. Such type of ripening is however, not desirable from seed quality point of view due to sudden suppression of physiological processes going on inside the seed. This reduces the vigour of the subsequent crop. A huge population of aphids on the fully mature but green pods for few days before turning yellow leads to quick drying of branches and pods with the result seed become shrielled.

**Harvesting:** Harvesting is the last of various field-operations and is done at full maturity of the seed. Ripening of pods starts from mid-June onwards when the average temperature is above 25°C at lower temperature, maturity is delayed by 7-14 days. It should neither be done too early to effect proper curing nor, be delayed to cause shattering and damage due to rainy season showers. Pre-harvest rains effect the viability during storage and its subsequent performance in the field. Harvesting should be done in 2-3 lots to avoid shattering losses. When about 7.% of pods on a branch have changed to yellowish-brown colour and seed turns brown it is cut whole with a sharp sickle. With a blunt sickle the plant is shaken and shattering of seed may occur. The shattering losses are greatly reduced when harvesting is done in the morning or early part of the day or on cloudy days. Further, it is prevented
by collecting the cut-seed stalks on a spreading cloth or hessian cloth to facilitate collection of fallen seeds from the dehisced siliques.

**Curing, threshing and seed grading:** An ultimate seed quality is dependent upon the handling of the harvested crop and the care taken during curing, threshing, drying and storage conditions. The harvested crop is piled up in small heaps for curing either on a tarpaulin or cement floor and covered with a tarpaulin or hay to reduce rapid drying of branches. Curing with branches helps the unripened seed to ripen slowly as under normal conditions in the field. Seed ripens at the cost of water and food supply from the branches. Curing improves the colour of the seed, ripening during the process of curing and brings the colour at par with the seed that ripens on the plant under natural conditions. Curing also reduces shattering losses in the field. After 4-5 days the heap is turned upside down and allowed to cure for another 4-5 days. There should be no over or under-curing, otherwise the seed colour and quality will be impaired. If the heap is not turned for many days, the seed in the centre of the heap, germinates due to sufficient heat and moisture there. For this reason it is not advisable to pile in large heaps for curing. Threshing should be done on a clear day for once-over operation. Threshing does not present difficulties as the seeds are readily dislodged from the siliques because of the natural tendency of pods to dehisce. In the morning the crop is spread on a tarpaulin or concrete floor for drying and in the afternoon the seed is extracted by beating with sticks. Seed can be separated from chaff or broken twigs either by winnowing or passing through coarse mesh sieve. Drying of seed to safe moisture levels (7%) should be done rather quickly to preserve vitality and vigour. Freshly harvested seed should not be kept packed in gunny bags for days together otherwise it will heat up due to high moisture in it. Rather the seed should be kept spreading or in small packs as long as it is moist. The other point to remember is that the moist seed should never be put into the bags when warm. It is to be cooled down before filling. Hand-grading of seed is laborious and takes lot of time. Seed-grading machines overcome this difficulty. Seed after grading should contain minimum of 98% pure seed with at least 70% germinability.

The isolation distance may also vary between varieties belonging to the same or the other groups of cabbage on the basis of maturity and head shape. It is beneficial to plan seed production of cabbage according to the following classification for isolation (Hawthorn and Pallard, 1954).

**Isolation and pollination**

All the root vegetables are cross pollinated owing to one or the other genetic mechanisms. Radish, carrot and beet do not cross with cruciferous
crops belonging to genus Brassica. Turnips do not cross naturally with any other member of the sp. *Brassica oleracea* but cross easily with Chinese cabbage (*B. perkinessis* and *B. Chinesis*) and *B. Juncea*. Insects are the main agents to carry out pollination in these crops. Beet (*Beta vulgaris*) is pollinated by the agency of wind however, insects also visit the crop at flowering which may be a source of contamination. Garden beet crosses easily with sugar beet, spinach beet, swiss chart etc. The isolation distance for different classes of temperate vegetable crops are presented in **table-6**. If there are any chances of out-crossing it is better to cover the crop with isolation cages. Nucleus seed production should be carried out in the isolation chambers to ensure to effect pollination in case of carrot, radish and turnip whereas beet being wind pollinated, hand shaking of plants inside the chamber is practiced.

**Table-6. Isolation Distance for different temperate vegetables**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Breeder Seed</th>
<th>Foundation Seed(m)</th>
<th>Certified(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cole crops</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cabbage</td>
<td>3000</td>
<td>1600</td>
<td>1000</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>3000</td>
<td>1600</td>
<td>1000</td>
</tr>
<tr>
<td>Broccoli</td>
<td>3000</td>
<td>1600</td>
<td>1000</td>
</tr>
<tr>
<td>B. Sprouts</td>
<td>3000</td>
<td>1600</td>
<td>1000</td>
</tr>
<tr>
<td>Knol-khol</td>
<td>3000</td>
<td>1600</td>
<td>1000</td>
</tr>
<tr>
<td>Kale</td>
<td>3000</td>
<td>1600</td>
<td>1000</td>
</tr>
<tr>
<td><strong>Root Crops</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td>3000</td>
<td>1000</td>
<td>800</td>
</tr>
<tr>
<td>Radish</td>
<td>3000</td>
<td>1600</td>
<td>1000</td>
</tr>
<tr>
<td>Turnip</td>
<td>3000</td>
<td>1600</td>
<td>1000</td>
</tr>
<tr>
<td>Beet root</td>
<td>3000</td>
<td>1600</td>
<td>800</td>
</tr>
</tbody>
</table>

**Roguing and Selection**

Roguing and selection are the most important operations in seed production and must be carried out at specific stage of crop growth to remover off types and undesirable plants to maintain the purity of the variety. While selecting true to type organ (head/curd/brussels/knob/roots), besides foliage characters, the various traits of organ are of utmost importance and examined thoroughly. A minimum of 3 inspections and roughing are necessary to maintain the purity of a variety.

**Pre-uprooting stage:** Inspection at this stage can be made any time from organs development stage but before pulling of the organ from soil. Rouging based on foliage characters is made as the root parts cannot be examined at
this stage. The amount of vegetable growth, size, shape, colour, and distinction of leaf-lamina are observed carefully. Diseased, unhealthy, weak or very vigorous plants should be discarded.

**Uprooting and replanting stage:** At this stage size, shape, colour, shoulder and typical shape of the organs and root types (stumpy, semi-stumpy, tapering or globe) are examined critically. All the cracked, diseased hairy, deformed heads/curds/roots are discarded. Extremely large or small organs are not desirable. The internal characters viz., pithiness, colour of flesh, core colour and size and presence/absence of blackish tissues in the core of the roots can be observed when stockings are prepared for replanting in case of root crops.

**Bolting and pre-flowering stage:** Consideration is given to remove very early and late bolters. Plants showing poor growth due to disease infection should be rouged out. This inspection should be done before flowering to avoid contamination with undesirable plants. Volunteer plants growing here and there need to be removed before their flowering.

**Seed yield:** It is a function of various interacting factors. Besides agronomical and climatic factors, the yield contributing components of the plants are responsible for its overall seed-yielding potential. These characters are number of flowers produced (product of number of flowering branches and flowers per inflorescence), the percentage of flowers that produce seeded siliqua/pods and the number of seeds per pod, number of ovules per flower/ovary and the number of ovules that mature after pollination/fertilization. The final graded seed weight will ultimately determine the seed yield. The average seed yield of important temperate vegetables is presented in table-7.

**Table-7. Average seed yield of important temperate vegetables**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Seed yield (q/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cole Crops</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cabbage</td>
<td>Golden Acre</td>
<td>3.65</td>
</tr>
<tr>
<td></td>
<td>Pride of India</td>
<td>2.38</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>Pusa Snoball K-I</td>
<td>2.27</td>
</tr>
<tr>
<td>Broccoli</td>
<td>Pusa Broccoli KTS-1</td>
<td>2.50</td>
</tr>
<tr>
<td>B. Sprouts</td>
<td>Hills Ideal</td>
<td>2.01</td>
</tr>
<tr>
<td>Knol khol</td>
<td>White Vienna</td>
<td>8.48</td>
</tr>
<tr>
<td><strong>Root Crops</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radish</td>
<td>Chinese Pink</td>
<td>6.00 to 8.50</td>
</tr>
<tr>
<td></td>
<td>Japanese White</td>
<td>6-50 to7.50</td>
</tr>
<tr>
<td>Crop</td>
<td>RRWT</td>
<td>Carrot</td>
</tr>
<tr>
<td>------------</td>
<td>------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Turnip</td>
<td>PTWG</td>
<td>6.50 to 8.0</td>
</tr>
<tr>
<td>Beetroot</td>
<td></td>
<td>Detroit Dark Red</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crimson Globe</td>
</tr>
</tbody>
</table>

**Minimum Seed Standards:**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Seed type</th>
<th>Pure seed (Min.)</th>
<th>Inert matter (Max.)</th>
<th>Other crop seed (Max./kg)</th>
<th>Weed seed (Max./kg)</th>
<th>Germi-</th>
<th>Moisture (%)</th>
<th>Vapour proof contain-</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>er</td>
</tr>
<tr>
<td><strong>Cole crops</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cabbage</td>
<td>F</td>
<td>98.0</td>
<td>2.0</td>
<td>5</td>
<td>5</td>
<td>70</td>
<td>7.0</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>98.0</td>
<td>2.0</td>
<td>5</td>
<td>10</td>
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**A case study:** It is well known that temperate carrot produces seeds commercially by ‘root to seed’ method in two cropping seasons. Roots produced in the first year require storage at low temperature/vernalization to induce seed stalk and flower initiation. These stored roots are planted the next year/cropping season. Therefore, this method takes 18-24 months for seed production.
The Defence Institute of High Altitude Research (DIHAR), the world’s highest research laboratory working on agro-animal technologies’ under Defence Research and Development Organization, Leh-Ladakh has invented ‘rootlet to seed’, a new technology of high-quality carrot seed production within a year and at a low cost. In this method, seed is sown in November in nursery beds of a 10.0m×3.0 m × 1.0 m semi-underground passive greenhouse and it is covered with 200 mm thick translucent polythene from November to February. After germination, the plants are kept in this passive greenhouse up to February. During this period the plants received naturally available, low-temperature vernalization by manipulating the opening/covering time of the greenhouse by the polythene sheets. Very less irrigation and nutrients are provided so that the plants in the greenhouse just survive and produce small-sized roots called ‘rootlets’. These rootlets (about 12 g each) enter directly in the reproductive phase. The rootlets are harvested and transplanted in the field in March for commercial seed production.

The seed stalk and inflorescence induces 70-80 days after replanting and produced seeds in October during the same year. Therefore, with this technology one phase (root production phase) can be avoided completely using an eco-friendly method and high-quality seeds can be successfully produced in one year. Including the losses during handling and storage for the next season about 2.0 metric tonn carrots can be made available for table purposes; otherwise, these would have been used for seed production in the ‘root to seed’ method.

Higher seed yield per hectare and quality were recorded with ‘rootlet to seed’ compared to ‘root to seed’ method, apparently due to the contribution of maximum seeds from first-and second-order umbels. However, higher seed yield per plant was observed in ‘root to seed’ method, and the third-and fourth-order umbels contribute in seed yield in this method. Seeds produced in the third-and fourth-order umbels are inferior in quality than first-and second-order umbels, because these small-sized seed contain higher levels of carrotal substance which inhibits germination and adversely affects the vigour. Therefore, high germination percentage and seed vigour were observed in the seeds produced using ‘rootlets to seed’ technology.

With the adoption of ‘rootlet to seed’ technology development by DIHAR, food used for seed production as carrot roots (2.0 metric tonne/ha) can be saved and good quality seed can be produced in one year at almost one-third cost in comparison to the conventional method.
Future strategies

Climate change is a serious constraint, which accounts for enormous losses in terms of seed yield and quality of temperate vegetable crops. So, there is an urgent need to focus our attention on studying the impacts of climate change on growth, development, seed yield, and quality of these crops. However, the promotion of modern technology and crop diversification should be tailored according to local conditions. Efforts should be made to uplift the socio-economic condition of farmers through rigorous research and development. Researchers, extension personnel, gardeners, and farmers should be trained on the issues of climate change. Temperate vegetable crops, which are tolerant to high temperatures, flooding, drought, and soil salinity, must be identified from the available resources. The use of biotechnological interventions for introgression of important genes, which are adapted to climatic changes, have been widely acknowledged. Some of simple, but effective adaptations strategies include change in the sowing date, use of efficient technologies like drip irrigation, soil and moisture conservations measures, fertilizers management through fertigation, change of crop/alternate crop, increase in input efficiency, pre and post harvest management of economic produce can not only minimize the losses, but also increase the positive impacts of climate change. All these measures can make the horticultural farmer more resilient to climate change. In conclusion, climate change will decrease crop yields in the long-term, unless one slows climate change and/or adapts new management practices and improved cultivars.

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Indian Horticulture Database (2005). National Horticulture Board, Ministry of Agriculture, Govt. of India.


Seed Quality Enhancement Technologies for the Improvement of Productivity of Vegetable Crops

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Quality seed plays a seminal role in augmenting agricultural productivity as well as production. Only by using quality seeds, productivity can be enhanced to the tune of 15-20% easily and under optimum management the increment may touch up to depending upon the crops since the efficiency and efficacy of all other inputs in the production technology gamut are contingent upon the quality of seeds being used. Since antiquity the importance of quality seed to enhance agricultural productivity is well evident as mentioned in old testimonials, literatures, scriptures, treatises, epics and many other ancient documents. In course of time through critical observation and elaborate experimentations conducted over years across continents, it was observed that there are several seed quality enhancement technologies to enhance germination potential and vigour of seeds thereby producing adequate crop stand and yield.

Definition of seed quality enhancement

Post harvest treatment that improve germination or seedling growth or facilitate the delivery of seeds and other materials required at the time of sowing. It is the term used in scientific literature and seed industry for range of techniques performed on seeds after harvesting & conditioning (e.g. priming, pelleting, pre-germination).

Seed is treated to enhance seed longevity, establish optimum and uniform plant population of healthy plants with reduced seed rate, incorporate tolerance against biotic and abiotic stresses at the time of seedling establishment; and to facilitate in precision mechanical planting. It is of following types

Seed invigoration

- Pre-storage treatments
  - Halogenation
  - Antioxidant treatments
• Mid storage treatments
  Hydration-Dehydration
Pre-sowing treatment
• Germination and vigour augmenting
  Seed fortification/infusion
  Dry permeation or seed infusion
  Seed hardening
  Seed priming
  Irradiation
  Magnetic seed treatment
Seed coating treatments
  Pelleting
  Film coating
  Seed colouring

In this article, the focus will be on pre sowing and seed coating treatments that aims to augment optimum field stand and thereby increase in the production levels.

**Germination and vigour improvement treatments**

**(A) Seed fortification/ infusion:** Process of enriching the seeds with bioactive chemicals viz., micronutrients, growth regulators, vitamins and seed protectants to improve germination and seedling vigour is known as seed fortification.

**Procedure:**
Seed+ 1/3\textsuperscript{rd} nutrient solution
(To the known volume of seeds, one third volume of the nutrient solution is added and allowed to imbibe for short duration)

Kept the solution for 6-24h

Moisture content of seeds raised to 20-25%

Dry the seeds under shade

Soaking of rice seed in 1% KCl for 16 h; soyabean seed in 0.25 M CaCl\textsubscript{2} or 0.2% Molybdenum or 5% NaH\textsubscript{2}PO\textsubscript{4} , ascorbic acid (2%), K H\textsubscript{2}PO\textsubscript{4} (2%) and fungicides (bavistin and thiram 1g/l) significantly improve the germination and seedling vigour.
**Benefits:**
- Low and medium quality seed can be upgraded
- Early flowering and higher yield
- Low cost technology as compare to soil and foliar application

**(B) Dry permeation /seed infusion:** Soaking of seeds in organic solvents to improve the germination and vigour of the seed by infusion of bioactive chemicals into the seed without altering seed moisture content is known as dry permeation. It avoids seed damage caused by soaking of water and provides protective, regulatory and selective functions of the chemicals to improve the performance of the seed.

The seed is soaked in organic solvent using ascorbic acid as a bioactive chemical in the form of acetone, petroleum ether, toluene, hexane, ethanol and dichloromethane with desired hormonal and non hormonal chemicals for 2-3 hrs followed by evaporation of solvent in air.

**Benefits**
- Simple, easy to operate
- Can be used for incorporating chemicals into seed
- Short treatment duration
- Easier drying back
- Rate of deterioration of seed is controlled
- Environmental pollution controlled
- No soaking/hydration injury to seed
- Bioactive chemicals made available to embryo directly

**(C) Seed hardening:** Hydration of seed to initiate the pre-germinative metabolism followed by dehydration to fix the biochemical events is called as seed hardening. It has specialized effect to withstand abiotic stresses at the time of germination and field emergence.

Hydration and dehydration of seed reorganize the physio-chemical changes by initiating the physiological activity in germ (embryo) and associated structure (mainly cotyledon). It results in enhanced elasticity in cell wall and development of a stronger and efficient root system.
Seeds are allowed to take up a certain amount of water, and then they are kept moist at 10°-25°C for several hours before drying in a stream of air. In many crops two to three cycles of wetting and drying are recommended. Different amount of water, concentration of chemicals used, duration of hydration and seed to solute ratio have been standardized for different crops.

**Advantages of Pre-hydration**

- Faster water Imbibition
- Imbibition causes swelling of seeds
- Pre-hydration promotes early germination and good crop stand.

**Disadvantages of Pre-hydration**

- Toxicity of chemicals
- Limited O₂ supply to seed
- Disadvantage in handling large quantity of seed

(D) **Seed Priming:** It is a presowing treatment in which seeds are soaked in osmotic solution that allows the seeds to imbibe water and go through the first and second stage of germination but does not permit radicle protrusion through the seed coat. It is based on the principle of controlled imbibition/hydration through a carrier that permits pre germination metabolism to proceed, followed by dehydration which prevents the actual emergence of radicle.

Primed seed exhibit uniform germination alongwith enhanced rate and speed of germination resulting in fast and uniform seedling growth. The optimal priming effect is often obtained at the least negative water potential that prevents radicle emergence.
For priming seeds are soaked at 10-15°C temperature in a chemically inert, high molecular weight compound solute that does not penetrate the cell wall viz., inorganic salts, sugars and polyethylene glycol (PEG). The duration of priming varies with the crop. Seed priming is of following type

**Hydro-priming**: It is hardening of seed in water. Water is applied in the form of fine mist onto seed for a specific duration depending upon the crop species and later the seed are dried back to permanently fix the metabolic changes brought about during the priming process.

**Osmo-priming**: Soaking of seeds in osmotic solutions viz., PEG, glycerol, mannitol.

**Halo-priming**: Soaking of seeds in salt solutions viz., KNO$_3$, KH$_2$PO$_4$, CuSO$_4$ etc.

**Solid matrix priming**: Seeds are mixed with solid carrier material viz., organic or inorganic carrier such as sand and water in a sealed container for a definite period to bring the moisture content of the matrix just below the level required for radicle protrusion. Carrier holds the water during seed priming and the water is imbibed by the seed upto equilibrium. The seed water potential is regulated by the matrix.
Physiological and Biochemical changes occurring in seed during priming

potential of the seed. The mixture is dried and seeds are separated from the media and cleaned. Materials such as vermiculite, synthetic calcium silicate, calcite clay, sphagnum moss, shale and bituminous charcoal have been widely used.

Bio-priming: Invigorating seed with biological agents like bacteria, fungi etc.

Advantages of Priming
- Controlled water Imbibition
- Imbibition injury prevented
- Halo priming serves to provide essential elements for seed growth and development and bio priming provides protection respectively

Disadvantages of Priming
- Toxicity of chemicals
- Limited O₂ supply to seed
- Disadvantage in handling large quantity of seed

(E) Irradiation: Irradiation of air dried seeds by lower dose of gamma rays for short period before sowing enhances germination and vigour. Germination, field emergence and growth of plants developed from irradiated seeds are significantly enhanced due to the effect of distant irradiation action that results in acceleration of the cell multiplication, enhancement of growth and development and change of organogenesis. Higher dose or time of irradiation may cause mutation.

(F) Magnetic seed treatment: Exposure of seeds to a magnetic field for a specified duration improves germination and vigour. Seed treated under magnetic field respire slowly with higher respiration quotient values that increase activity of enzymes viz., α amylase and nitrate reductase. Germination and vigour of seed are enhanced due to increased activity of enzymes.

Seed Coating Treatment

(A) Seed Pelleting: Enclosing or encapsulation of small seed with inert (foreign) material to produce a globular unit of standard size is known as seed pelleting. More or less spherical units developed for precision sowing, usually incorporating a single seed with the size and shape of the seed no longer evident. The pellet, in addition to the pelleting material, may contain pesticides, dyes or other additives. Pelleted seed helps in
Precision planting
- Mechanical planting
- Easy handling of small and irregular shaped seeds
- Reduced seed rate due to precision sowing
- Maintain plant to plant distance
- Increase in size of seed improves scatter pattern in aerial seeding
- Uniform field emergence

Protection
- Pelleting with fungicides provide protection against soil and seed borne pathogens
- Pelleting with insecticide provides protection from insects at the time of seedling establishment and during storage
- Incorporation of unpalatable substances provide protection against rodents

Vigour
- Enhanced seedling vigour when pelleted with fertilizer by nourishing the young seedling
- Assured germination under abiotic stresses when pelleted with growth regulators and bio fertilizers by promoting rooting and seedling growth

Environmental friendly
- Reduced environmental pollution
- Precise and accurate use of chemicals
- Improved ballistic property

Materials and equipment

<table>
<thead>
<tr>
<th>Pelleting material</th>
<th>Clay, limestone, calcium carbonate, talc, vermiculite</th>
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</thead>
<tbody>
<tr>
<td>Binding agents</td>
<td>Gum Arabic, gelatin, methyl cellulose, polyvinyl alcohol, polyoxylethylene glycol- based waxes</td>
</tr>
<tr>
<td>Seed protectants</td>
<td>Insecticide, fungicide and antibiotics; herbicide and chemicals to enhance resistance against abiotic stresses</td>
</tr>
<tr>
<td>Nutrients e.g.</td>
<td>Diammonium phosphate to stimulate prolific root growth</td>
</tr>
<tr>
<td>Inoculants (bio-fertilizer)</td>
<td><em>Rhizobium, Mycorrhiza</em> etc.</td>
</tr>
<tr>
<td>Coating drum</td>
<td>In this seed can be mixed with other ingredients as cement mixer plant</td>
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</tbody>
</table>
**Procedure:** Seeds are placed in a coating drum and rotated after spraying of water. In this, prescribed quantity of amalgam of pelleting material, seed protectants, nutrients and inoculants are added. By rotation the wet seed is coated with the dry pelleting material. The size of the pellet gradually increases with each turn of coating drum. With the increase in number of rotation the size of the pellet is enhanced with improvement in roundness. At the end of the pelleting process, a binder is added to harden the outer layer of the pellet.

![Pelleting machine at the Department of Seed Science & Technology, UHF Nauni](image)

**Film Coating:** A continuous layer of film or chemical is coated on the surface of the seed without altering the shape and size. The advantage of film coating over other coating process is the minimum emission of dust particles, minimum loss of coated material, high retention capacity of chemical on seed, low quantity of chemical requirement, accurate dose of chemicals with low coefficient of variation, proper availability of nutrients to the seedling, less hazardous to operator and farmer and improvement of seed flow in planting equipment.

Seed is coated with a thin layer of durable water permeable coating usually polymer binder in a slurry coating equipment by spraying or dipping the seed in the dissolved additives followed by immediate drying. Polymer film coating involves application of 1% composition of vinyl acetate + Vinyl chloride + ethylene + acrylate with 30% cellulose ether as a stabilizing substance followed by immediately drying.

Coating of seed with hydrogel polymer helps in obtaining optimum plant population under excessive moisture and drought at the time of seedling establishment due to erratic behavior of monsoon. It absorbs 100 to 200% moisture of its weight and assures supply of moisture at the time of
seedling establishment under drought. Coating of seed with temperature responsive polymer ensures germination only at optimum temperature.

(c) **Seed Colouring:** Precise amount of natural or artificial dyes or pigments is applied directly on the surface of the seed. The colouring agent should not be absorbed in the seed.

### Dyes used for seed colouring

- **Natural dyes**
  - Environmental friendly, non toxic to seed and most of them have medicinal and antimicrobial properties
  - Extracted from leaves, flower, fruits, seeds and roots of plants.

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<th>Amount</th>
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<td><strong>Turmeric (Curcuma longa)</strong></td>
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<tr>
<td><strong>Heena (Lawsonia inermis)</strong></td>
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<tr>
<td><strong>Beet root (Beta vulgaris)</strong></td>
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<tr>
<td><strong>Basella rubra</strong></td>
<td>6-10 ml/5 g</td>
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<td><strong>Marigold (Tagetus erecta)</strong></td>
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<tr>
<td><strong>Hibiscus rosa-sinensis</strong></td>
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<tr>
<td><strong>Opuntia spp</strong></td>
<td>6-10 ml/5 g</td>
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<tr>
<td><strong>Bixa orellana</strong></td>
<td>5-15 ml/5 g</td>
</tr>
<tr>
<td><strong>Jamun (Syzygium cumini)</strong></td>
<td>6-12 ml/5 g</td>
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</tbody>
</table>

- **Artificial dyes**
  - Congo red - 0.25-1.0%
  - Bromocersol green - 0.25-1.0%
  - Jade green - 0.25-1.0%

The purpose of seed colouring are
- Prevent accidental use of treated seeds for food or feed purposes
- Identification of the seeds of parental lines ‘A’ line, ‘B’ line, ‘R’ line
- Brand identification
- Distinct and attractive look
- Improvement in storability
- Enhanced germinability and vigour

### Advantages of Seed Enhancement Technology

- Early emergence and reduced time of emergence under stress conditions
- More competence of seedlings with weeds
- Field stand and uniformity
• Activation of repair mechanism
• Precise placement on target
• Minimize toxicant use
• Supply of growth regulators/nutrients/beneficial microbes
• Reduced seed rate
• Better nursery management
• Direct seeding of conventionally transplanted vegetable seeds.
• Increased production and therefore high turnover

References:


Integrated Nutrient Management in Vegetable Crops

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Integrated nutrient management (INM) is an approach to soil fertility management that combines organic and mineral methods of soil fertilization with physical and biological measures for soil and water conservation. INM adopts a holistic view of plant nutrient management by considering the totality of the farm resources that can be used as plant nutrients.

Integrated nutrient management is based on three fundamental principles:
- Maximize the use of organic material
- Ensure access to inorganic fertilizer and improve the efficiency of its use
- Minimize losses of plant nutrients

Goals of INM

1. To maintain soil productivity.
2. To ensure productive and sustainable agriculture.
3. To reduce expenditure on costs of purchased inputs by using farm manure and crop residue etc.
4. To utilize the potential benefits of green manures, leguminous crops and biofertilizers.
5. To prevent degradation of the environment.
6. To meet the social and economic aspirations of the farmers without harming the natural resource base of the agricultural production.
7. To maintain or enhance soil productivity through balanced use of mineral fertilizers combined with organic and biological sources of plant nutrients.
8. To improve the efficiency of plant nutrients, thus limiting losses to the environment.
9. To improve physical conditions of soils

Research gaps in integrated nutrient management in vegetables
The research gaps include:
- Mismatching of INM practices developed at research stations with the farmers resources and their practices
• INM recommendations for different crops are not based on soil testing and nutrient release behaviour of the manures
• Nutrient balance/flow analysis vis-a-vis soil fertility management practices with special reference to INM at farm level needs to be worked out
• Nutrient release characteristics of farm residues in relation to their quality to develop decision support systems
• Biofertilizers were not included as component of INM in many cases; and
• Integrated Farming Systems approach needs to be encouraged for sustaining livelihood in rural areas particularly for small and marginal farmers.

Basic components of Integrated Nutrient Management

Different components of INM

There are various components of plant nutrients for INM which can be applied in an integrated way. Besides inorganic fertilizers as the major component, others include farmyard manure (FYM), composts, green manure crops, crop residues, crop rotation and bio fertilizers. Fertilization in a balanced way, improved crop nutrition maintain the soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of various plant nutrients in an integrated manner.

i) Chemical fertilizers: Chemical fertilizers are rich in nutrients. They are required in less quantity to supply nutrients as compared to organic manures. But continuous use of chemical fertilizers deteriorates the soil conditions. Therefore, chemical fertilizers should be accompanied by organic / biofertilizers.

ii) Organic manures like FYM in situ, Vermicompost: It improves the bulk density of soil up to a layer of 25 cm. It reduces resistance to penetration and Supplements N up to 50% of the nitrogenous requirement of the crop. Increases available N and P use efficiency when combined with 100% of the recommended quantity of NPK and Biofertilizers.

iii) Industrial waste various practices can be adopted to convert wastes into suitable products Convert all available biomass on the farm into compost instead of burning or wasting it.

iv) Inclusion of legume crops in cropping system to fix the atmospheric nitrogen in the soil.

v) Use of Biofertilizers like azolla, blue green algae, and rhizobium etc.

vi) Crop residues and Make use of cattle excreta as manure rather than as fuel
vii) Green manuring either growing in the same field or incorporating of leguminous plant or leaves.

ix) Crop rotations: It is most important INM strategy which is ignored by the growers that is crop rotation is a very important tool in sustaining nutrient supply. Legumes in rotation restore soil fertility in more than one way viz, some of the N fixed is left in the soil after harvest, improvement in soil properties, lesser disease and pest problem and better weed control.

**Role of biofertilizers in INM**

Different types of biofertilizers available at present among that Rhizobium is relatively more effective and widely used. Considering an average N fixation rate of 25 kg N/ha per 500 g application of Rhizobium, it is expected that 1 tonne of Rhizobium inoculants will be equivalent to 50 tonnes of nitrogen. On the other hand, Azotobacter, which is used in non legume crops, has given inconclusive results. Similarly, Blue Green Algae (BGA) and Azolla have been reported to be effective in certain growing areas in the country. Meanwhile if BGA applied at 10 kg/ha fixes 20 kg N/ha, then 1 tonne of BGA has an equivalent fertilizer value of 2 tonnes of nitrogen. Another important role of biofertilizers is liberation of growth substances, which promote germination and plant growth. Against the total anticipated biofertilizers demand of 1 million tonne in the country, the current supply position is very low (<10 000 tonnes). There are several constraints to effectively utilize and popularize the use of biofertilizers. Some of these constraints are:

- Unlike mineral fertilizers, use of the biofertilizers is crop and location specific. A strain found ideal at one location may be ineffective at another location due to competition of native soil microbes, poor aeration, high temperature, soil moisture, acidity, salinity and alkalinity, presence of toxic elements etc.
- Low shelf life of the microorganisms
- Unlike mineral fertilizers, biofertilizers need careful handling and storage
- Lack of suitable carrier material, for restoration and longevity in actual field conditions

In order to overcome the above constraints and make biofertilizers an effective supplementary source of mineral fertilizers, these aspects need to be critically attended.

**Green manure improves nutrient use efficiency in various ways:**

Using Green Manure and the cover crops which are incorporated into the soil when they are still green are called as green manures. Cover crop are also grown but are grown to protect soil from erosion when the vegetable
grower not growing the crop. Because upper layer of soil is rich in organic matter and nutrient content, controlling erosion is an important method of conserving soil nutrients. Green manures and cover crops are both used to supply nitrogen and increase soil organic matter. Legumes crops such as alfalfa and Beans can fix between 45 kg and 91 kg of nitrogen per acre in one year. The grasses like rye without a legume will not increase the nitrogen content of the soil. These crops are used for increasing soil organic matter content. They can also retain the residual nitrogen from the previous crop and keep it from being lost by leaching. A mixture of both grasses and legumes can be used to obtain the advantages of each. Improved soil tilth from added organic matter improves root growth, which increases the capacity of a crop to take up available soil nutrients. The decision to plant a green manure should take into account the cost of cultural practices and seed, as well as the lost opportunity cost if the green manure is grown instead of a cash crop. Some green manure crops accumulate high levels of phosphorus and are thought to increase phosphorus availability to subsequent crops by returning it to the soil in organic form. Green manuring through Sesbania aculeate (dhaincha) is equivalent to 60 kg inorganic Nitrogen per hactore. Incorporation of mungbean after picking pods results in savings of 60 kg inorganic Nitrogen per hactore. Alley cropping to Leucaena leucocephala, (ku-Babul) Gliricidia sepium and Acacia mangium can provide 100-300 kg N/ha per year. Pruning of Sesbania rostrata planted as hedgerows provides 3-4 t/ha dry matter after decomposition, it releases an average of 70 kg N/ha.

**Besides above, green manure helps in**

- Increasing apparent use efficiency of K when combined with 50% of the recommended NPK.
- Having residual effect on the next crop.
- Minimizing the adverse effects of Fe in acidic lateritic soils.

**Common constraints encountered by the farmers in adoption of INM technology are as follows:**

1. Non-availability of FYM
2. Difficulties in growing green manure crops
3. Non-availability of biofertilizers
4. Non-availability of soil testing facilities
5. High cost of chemical fertilizers
6. Non-availability of water
7. Lack of knowledge and poor advisory services
8. Non-availability of improved seeds
9. Soil conditions
10. Non-availability of credit facilities
How this INM technology different from conventional way of farming?

Integrated nutrient management differs from conventional nutrient management in that it considers nutrients from different sources, notably organic materials, nutrients carried over from previous cropping seasons, transformation of nutrients in soil, in conventional farming, people gave more emphasis on yield through use of chemical fertilizers, use of high yielding varieties and chemical pesticides along with irrigation facilities.

In INM it integrates/combines the objectives of production with ecology and environment, that is, optimum crop nutrition, optimum functioning of the soil health, and minimum nutrient losses or other adverse effect on the environment. Integrated Nutrient Management (INM) has to be considered an integral part of any sustainable agricultural system.

Advantages

1. Enhances the availability of applied as well as native soil nutrients
2. Synchronizes the nutrient demand of the crop with nutrient supply from native and applied sources.
3. Provides balanced nutrition to crops and minimizes the antagonistic effects resulting from hidden deficiencies and nutrient imbalance.
4. Improves and sustains the physical, chemical and biological functioning of soil.
5. Minimizes the deterioration of soil, water and ecosystem by promoting carbon sequestration, reducing nutrient losses to ground and surface water bodies and to atmosphere.

Suggested Readings:


Advances in Production Technology of Tomato and Sweet Pepper

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Nauni 173230 Solan, Himachal Pradesh

Introduction

Tomato and Sweet pepper are important vegetable crops grown throughout the world. Tomato is native to Central and South America. As a fresh commodity and as a processed product, tomato represents a major vegetable source for essential nutrients. Tomato is universally treated as ‘Protective food’ based on its nutritional value and antioxidant properties due to presence of lycopene and flavonoids. Tomato and tomato based products are also used as a preventive strategy against major lifestyle diseases, such as cancer and cardiovascular diseases. Tomato is grown as spring summer and autumn winter crop in many parts of the country. Tomato crop produced during June to September in hills of Himachal Pradesh becomes off season vegetable in the markets of North Indian Plains and provides very remunerative prices to the farmers. Sweet pepper is a high value vegetable crop which was brought to India by Britishers in 19th century. In India, it is mainly cultivated in Himachal Pradesh, UP, J & K, parts of West Bengal, Maharashtra and Karnataka. Nutritionally, sweet pepper is rich in vitamins particularly vitamin A and C. In Himachal Pradesh, it is an important summer and rainy season crop of mid hills. Production of tomato and sweet pepper has increased by adopting advance nursery raising techniques, use of mulches, biofertilizers, using protected structures, soilless culture and adopting grafting techniques.

Nursery raising techniques

Plug trays

Plug trays are filled with growing media (Cocopeat, Vermicompost or FYM) or (Cocopeat, Perlite and Vermiculite). One seed per cell is sown and covered with medium. Trays are irrigated lightly every day depending upon the prevailing weather conditions using a fine sprinkling rose can or with hose pipe fitted with rose. Drenching the trays with fungicides as a precautionary measure against seedling mortality can also be done. Spraying water soluble fertilizers like polyfeed twice (12 and 20 days after sowing) @ 0.3 percent is
practiced to enhance the growth of the seedlings. The seedlings are hardened by withholding the irrigation before transplanting. The seedlings would be ready in about 25-30 days in tomato and 35-42 days in sweet pepper for transplanting to the main field, depending upon the crop.

**Plastic Low Tunnels**

Plastic low tunnels provide a better way for off season vegetable production. Low tunnels protect the crop from adverse climate along with crop advancement from 20-30 days over their normal season of cultivation. Healthy and early nursery can be obtained under low tunnels. The nursery beds are covered with pre-fabricated tunnels of size 3 m long, 1.5 m wide and central height of 1.0 m. The semicircular structure is clad with UV-polythene sheath (200 micron) with 75 percent transmittance. Once the seed sowing, covering and irrigation to field capacity is over, the bed can be covered with the tunnels. Both the openings can be closed if nursery is grown in winters.

**Mulching**

Use of organic and inorganic mulches is common in high value crops like tomato and sweet pepper. These protective coverings help reduce evaporation, moderate the soil temperature and reduce soil run off and erosion, protect the plants from diseases and suppress the weed growth. It can save 20-25% of irrigational water. Use of organic materials as mulch can enhance the soil fertility, structure and other soil properties. Dry grass, black polythene and red polythene are used as mulch in tomato and sweet pepper.

**Biofertilizers**

Biofertilizers are ready to use live formulations of beneficial microorganisms which on application, mobilize availability of nutrients by their biological activity and build up soil health. Yield is increased by 20-30% in tomato and sweet pepper. Bacteria like Rhizobium, Azotobacter and Azospirillum fix the atmospheric nitrogen; Phosphate Solublizing Bacteria make the insoluble phosphorus available to the plants in soluble form and Vesicular Arbuscular Mycorrhiza (VAM) increase the nutrient uptake particularly P, Zn and other micronutrients and also increase the growth of associated plants by producing auxins and antibiotics etc. Azotobacter with phosphate solubilizing bacteria is commonly used in tomato and sweet pepper crop. Commonly used biofertilizers are Azogro (Azotobacter), Phosphobacteria (PSB), Matrix (Azospirillum) and K- Boster (KSB).

**Methods of application**
Seed treatment

Seed treatment is a most common method adopted for all types of inoculants. Seed treatment can be done with any of two or more bacteria like Rhizobium, Azotobacter, Azospirillum along with PSB. Coating is done first with Rhizobium or Azotobacter or Azospirillum, when each seeds get a layer of above bacteria then the PSB inoculant has to be treated on outer layer of the seeds. The biofertilizer is applied at the rate of 100 g per 5 Kg of seeds. Biofertilizer is mixed in water (1:2) with 10% jaggery to form the slurry. The slurry is poured in container with seeds to be sown. The combination is mixed properly such that each seed is coated with biofertilizer. The seeds are dried under the shade and sown.

Seedling dipping

Suspend biofertilizer culture in water (1:5-10) to make the suspension. Make small bundles of the seedlings. Dip the root of the seedlings in the suspension for 15-30 minutes and transplant immediately.

Soil application

Biofertilizer is mixed with carriers like soil, compost, farmyard manure and rice husks etc. (1kg per 25kg of carrier) which should have enough moisture and kept for 24 hours and then directly put in the soil. The applied area needs to be irrigated immediately. Use the mixture as a soil application in rows.

Protected cultivation

Protected structures play an important role in minimizing the impact of environmental factors like, temperature fluctuation, over/under precipitation, fluctuating sunshine and infestation of diseases and pests. Uniform and quality produce is obtained, which can be harvested to longer durations. Resources like land, labour, water, fertilizers, insecticides and fungicides are efficiently used and yield is increased manifold.

Tomato

Tomato is produced round the year in naturally ventilated polyhouses. Two crops are taken in a year, for spring summer season, planting time is February and for autumn winter crop, is July- August. Seedlings are raised in plug trays and transplanted in the evening for better establishment of the plants on well prepared beds in growing media comprising of soil, organic
matter (FYM/Vermicompost) and sand (1:2:1). High yielding indeterminate varieties and hybrids are grown for maximum production and spacing is kept 90 x 30 cm or 70 x 30 cm.

During bed preparation, basal dose of fertilizers is added (Urea @ 21.5 g, SSP @ 62.5 g and MOP @ 16.5 g per sq. m.). In tomato, the irrigation is done through drip system and monitored with the help of soil moisture meters/tensiometers for optimum control. Fertigation is done with soluble fertilizers (having same composition of the N, P and K) @ 200 kg NPK/ha, twice a week starting from 3rd week after transplanting and stopped 10 days prior to the final harvest. If polyfeed (19:19:19 NPK) fertilizer is applied in fertigation, the dose is 2.92 g/sq. m. Mulching is a standard practice during winters and generally black polythene mulch is used. It conserves the soil moisture and keeps the weeds under control. In tomato, it promotes growth, early yield and improves quality of the produce.

Training and pruning is essential operation in greenhouse for tomato crop for better management and providing uniform light to the plants. It also helps in efficient utilization of resource and greenhouse environment by the crop. In tomato, single or two stem training system is followed for longer harvest duration and staking is done with plastic or nylon threads. When fruits start attaining turning stage, are harvested for long distance markets and fruits must be packed in good containers to avoid any damage in transit and storage. For local market fruits are harvested at pink stage. A well managed tomato crop under greenhouse condition is expected to yield 10-12 kg/sq.m. (Package of Practices for Vegetable Crops, 2009)

**Sweet pepper**

Sweet pepper can be cultivated round the year in naturally ventilated polyhouse in mid hills of HP. Crop raised inside the polyhouse has good quality fruits and fetch good prices in the market. Colored sweet pepper varieties are preferred for polyhouse cultivation viz., Indra (green), Orobelle (yellow) and Bomby (red). Basal dose of fertilizers (Urea @ 11 g, SSP @ 32.5 g and MOP @ 8.33 g per sq. m.) is added during beds preparation. Seedlings are transplanted at spacing of 45 x 30 cm on the beds comprising of growing media; soil, organic matter (FYM/Vermicompost) and sand. Planting times are January and July. Irrigation is done through drip irrigation system, every day in summers and on third day in winters. Fertigation is done with water soluble fertilizers (having same composition of the N, P and K) @ 150 kg NPK/ha, twice a week starting from 3rd week after transplanting and stopped 15 days prior to the final harvest. If polyfeed (19:19:19 NPK) fertilizer is applied in fertigation, the dose is 2.22 g/sq. m. Four stem training system is followed in
sweet pepper and staking is done with plastic threads when plants attain a good height. Yield potential of sweet pepper is 65-70 t/ha. (Package of Practices for Vegetable Crops, 2009).

**Soilless culture**

Soilless culture covers all types of planting technologies without soil. The plants are grown in an inert growing medium and the nutrition is applied through nutrient solution (water and fertilizer mixed). In tomato and sweet pepper solid media culture is used for cultivation which includes hanging bag technique, grow bag technique, trench or trough technique. In hanging bag technique 1m long cylindrical structure, white from outside and black from inside thick polythene bags are filled with sterilized media and sealed at the bottom end and tied at the top with small PVC pipe. Bags are suspended vertically and nutrient is supplied through nutrient delivery tube. Planting material squeezed into holes on the side of hanging bags. In trench or trough technique, plants are grown in narrow trenches in the ground constructed with bricks or concrete blocks. Trenches or troughs lined with waterproof material. Depth of trough should be at least 30 cm. Irrigation is done by drip system. Pipe of 2.5 cm diameter placed at the bottom for drainage. In grow bag technique growing media is filled in grow bags and nutrient is supplied through drip system. A good soilless culture media should has the characteristics such as fairly constant in volume, free from weed seeds, nematodes and soil born diseases, should have proper drainage and aeration, should contain sufficient nutrients, possess adequate CEC and low insoluble salts, biologically and chemically stable on sterilization.

**Aquaponics**

It is the practice of raising fish and plants in recirculating systems where waste from fish is recirculated as fertilizer to the containers of the plants where they uptake the nutrients through their roots. Nitrogen fixing bacteria and worms breakdown the fish waste into nitrites and nitrates and are absorbed by the plants. The resulting clean water is then recirculated into aquaculture tank. Tomato and sweet pepper are also being grown by this technique.

**Grafting**

Though grafting has been practiced in fruit trees for thousands of years, vegetable grafting has been only recently widely adapted on a commercial scale. Old records on vegetable grafting can be found in Chinese as well as in Korean and Japanese writings. Commercial vegetable grafting originated in
Japan and Korea. Grafting of tomato plants was started in 1970s. Grafting was introduced to Western countries in the early 1990s and is currently being globally practiced using local scion cultivars and introduced rootstocks. Tomato and sweet pepper are affected by various biotic (diseases, nematodes) and abiotic stresses (cold, heat, water stress, salinity). Great loss in yield is caused by soil borne diseases under continuous cropping system. Chemical control is expensive, not always effective and is harmful to the environment. Losses in production due to different environmental conditions can be minimized by grafting. Grafting a susceptible scion onto a resistant rootstock can provide a resistant cultivar without the prolonged screening and selection required to breed resistance into a cultivar. Furthermore, grafting allows rapid response to new pathogen races and in the short-term provides a less expensive and more flexible solution for controlling soil borne diseases than breeding new resistant cultivars. Grafting is a propagation method where the tissues of two plants are fused together. The bottom part of the plant that contributes roots and support is called the rootstock. The upper part contributing leaves, flowers, fruits and stems is called the scion. Grafting involves the joining together of plant parts by means of tissue regeneration in which the resulting combination of plant parts achieves the union and grows as an independent plant. *Solanum lycopersicum* x *Solanum habrochaites* rootstocks provide tolerance to low soil temperature (10°C to 13°C) for their grafted tomato scions. Many accessions of brinjal are highly tolerant to flooding, thus can be grafted to improve the flood tolerance of tomato using brinjal rootstocks which were identified with good grafting compatibility with tomato.

In India, grafting work has been started in IIHR Bangalore, NBPGR regional station, Thrissur, Kerala and CSKHPKV, Palampur. IIHR Bangalore has identified rootstocks for waterlogged conditions and imported semi-automated grafting machine for grafting. CSKHPKV, Palampur identified more than 22 rootstocks of brinjal, chilli, tomato and cucurbits for importing resistance to bacterial wilt and nematodes.

**Variety selection**

Wise selection of rootstock based on fruit quality is very important. Rootstock is selected based on resistance i.e. resistance to various soil borne diseases, root knot nematode and tolerance to salt, cold and water logging conditions. In some cases rootstock may be selected on the basis of vigorous root system which results in increased vigour of the plant. Scion is selected on the basis of fruit quality i.e. for high TSS, flavour, antioxidants and ascorbic acid content etc. Rootstock and scion varieties must be genetically compatible. Healthy, uniform rootstock seedlings with 2–4 true leaves and a
minimum stem diameter of about 1.5 mm to 2.5 mm are best for grafting. Choose rootstock and scion seedlings whose stem diameters are similar. Mainly cleft, tongue, tube, splice and pin grafting is done in tomato and sweet pepper. Different rootstocks for tomato and sweet pepper have been listed in table 1. Sources for different abiotic stresses in tomato and sweet pepper have been given in table 2.

**Sanitation and Seed treatment**

Minimize the spread of diseases using clean, high quality and possibly treated seed. Keep work spaces clean with cleaning agents, wear gloves while grafting and use clean implements.

**Types of grafting**

**Cleft Grafting**

In Cleft grafting, cut a 0.5 cm long vertical incision into the centre of the rootstock. Cut the scion stem into a 0.5 cm long wedge and insert it into the vertical incision in the rootstock. Place a plastic clip around the graft union to hold it tightly together.

**Tongue approach grafting/ Side grafting**

The grafting cut for rootstock should be made in a downward direction and the scion cut in an upward direction at an angle, usually 30°-40° to the perpendicular axis and deep enough to allow the fusion of as many vascular bundles as possible and then specially designed clips are placed to fix the graft position. After five days, the rootstock top and the scion roots from the grafted plants are removed.

**Tube grafting**

This is the most widely used grafting technique for tomatoes and sweet pepper. The rootstock should be grafted when cotyledons and the first true leaf start to develop (about 7 to 10 days after sowing). One cotyledon and the growing tip are removed. The seedling is cut at a slant from the base of one cotyledon to 0.8–1.0 cm below the other cotyledon, removing one cotyledon and the growing tip. The length of cut on the scion hypocotyl should match that of the rootstock and should be at a 35° to 45° angle. The scion is attached to the rootstock and fixed tightly by a grafting tube or clip.
Splice grafting

In this method, a slant cut is given on rootstock and scion and both are tightly held with clips and then healed and acclimatize.

Pin grafting

Pin grafting is basically the same as the splice grafting. However, instead of placing grafting clips to hold the grafted position, specially designed pins are used to hold the grafted position in place. The ceramic pin developed by Takii Seed Company is about 15 mm long and 0.5 mm in diagonal width of the hexagonal cross-section. The pins are made of natural ceramic so it can be left on the plant without any problem. The price of ceramic pin is fairly high so the alternative methods are being sought like bamboo pins, rectangular in cross-sectional shape, could successfully replace the expensive ceramic pins at much lower price.

Securing graft union

It is done by using glue and clips mainly.

Robotic Grafting

Grafting machines have been developed and commercialized in Korea. The pin grafting robot developed by Rural Development Administration, Korea for solanaceous crops can graft 1200 seedlings per hour. The simple and economic grafting machine was developed and has been very popular in Korea. This machine priced about US $500, has been exported for more than 10 years to many Asian countries and some European countries. This machine can graft up to 600 seedlings per hour by tongue approach grafting. However, an experienced operator is needed to run this machine effectively and efficiently. Recently a multiuse semi-automatic grafting machine has been developed by a private company in Korea (Helper RoboTech) and many growers purchased this machine to graft tomato and pepper seedlings. This machine has also been actively exported to many foreign countries in recent years because of the reasonable price, multiple functions and convenient handling. More recently, a fully automated grafting robot (1000 grafts per hour) has been developed and used commercially for tomato in Netherlands.

Healing and acclimatizing the graft

The healing and acclimatization are very important for grafted plants to survive. A healing chamber is commonly placed in a greenhouse. Increasing
the height too much decreases the ability to maintain consistently high levels of humidity. Both the width and length of the healing chamber should be 5 feet or less to provide easy management when opening and closing and to maintain high humidity throughout the chamber. In healing chambers, the grafts are kept for 5 – 7 days. Open the chamber twice a day to replenish carbon dioxide for the grafts and after 4 days light can be slowly introduced and humidity lowered for 2 days. Grafted plants are also healed and acclimated in a plastic tunnel. Keeping the grafted plants at about 20-30°C and with more than 95% relative humidity for three days of healing promotes the survival ratio. Gradually, the relative humidity is then lowered and the light intensity increased. During healing and acclimatization, it is important to keep a constant air temperature in the tunnel in order to maintain high humidity. If wilting is observed, foliar spraying of grafted plants with water is effective in helping them survive. The shading materials and films should be adjusted according to the daily weather. The grafted plants take 7 -10 days for acclimatization. The plants must be re-acclimated for 3-4 days to the full-sun conditions of the greenhouse environment. Start increasing the light exposure by removing the opaque plastic sheets. Finally, while planting the grafted plants into the production house, it is important to keep the graft union above the soil line, because if the scion roots into the soil, the plant will become susceptible to soil-borne diseases.

**Field management of grafts**

Planting is done on the raised beds covered with polythene sheet in order to minimize the transmission of disease through rain splashes. Raised beds are highly recommended to minimize flooding. While transplanting care should be taken that graft union remain 2.5 cm above the soil line. Timely removal of shoots developed from the rootstock and adventitious roots from scion is very important after transplanting in the field. Grafted plants should be staked three to four weeks after transplanting in tomato. This will prevent the scion stem contacting the soil. Proper water management practices are very important after transplanting to minimize the wilting of the grafted plants.
Table 1. Rootstocks for tomato and sweet pepper for biotic and abiotic stresses

<table>
<thead>
<tr>
<th>Crop</th>
<th>Rootstock</th>
<th>Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>Beaufort</td>
<td>Resistance to root knot nematode (Kubota et al., 2008)</td>
</tr>
<tr>
<td></td>
<td>Maxifort</td>
<td>Resistance to Fusarium wilt (Kubota et al., 2008)</td>
</tr>
<tr>
<td></td>
<td>Robusta</td>
<td>Resistant to Verticillium wilt (Kubota et al., 2008)</td>
</tr>
<tr>
<td></td>
<td>Survivor</td>
<td>Resistance to Tomato mosaic (Kubota et al., 2008)</td>
</tr>
<tr>
<td></td>
<td>VI043614</td>
<td>Resistance to Bacterial wilt (The World Vegetable Centre, 2003)</td>
</tr>
<tr>
<td></td>
<td>VI006378</td>
<td>Resistance to Pythium (The World Vegetable Centre, 2003)</td>
</tr>
<tr>
<td></td>
<td>VI006378</td>
<td>Resistance to Flooding (The World Vegetable Centre, 2003)</td>
</tr>
<tr>
<td>Sweet pepper</td>
<td>PP0237-7502 (chilli)</td>
<td>Resistant to flooding (The World Vegetable Centre)</td>
</tr>
<tr>
<td></td>
<td>PP0242-62 (chilli)</td>
<td>Resistant to Bacterial wilt (The World Vegetable Centre)</td>
</tr>
<tr>
<td></td>
<td>Lee B (chilli)</td>
<td>Resistant to Phytophthora blight (The World Vegetable Centre)</td>
</tr>
</tbody>
</table>

Table 2. List of tomato and sweet pepper lines/genetic sources tolerant to abiotic stresses

<table>
<thead>
<tr>
<th>Crop</th>
<th>Lines/Genetic sources</th>
<th>Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>Solanum cheesmanii, S. chilense, S. lycopersicum var. cerasiforme, S. pennellii, S. peruvianum, S. pimpinellifolium, RF-4A (Spaldon et al., 2015)</td>
<td>Tolerant to drought</td>
</tr>
<tr>
<td></td>
<td>LA-1777, EC-520061 (Solanum habrochaites), Solanum chilense, Solanum</td>
<td>Tolerant to chilling</td>
</tr>
</tbody>
</table>
**Solanum cheesmanii**, *S. pennellii*, *S. peruvianum*, *S. pimpinellifolium*, *Solanum habrochatæs* (Flowers, 2004; Foolad, 2004; Cuartero et al., 2006) Tolerant to salinity

**Sweet pepper**

<table>
<thead>
<tr>
<th>Variety</th>
<th>References</th>
</tr>
</thead>
</table>

**References**


Integrated Weed Management in Vegetable Crops

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INTRODUCTION

Weed is a commonly known as a plant growing at a place where it is not desired or out of place. Our Vegetable fields are usually infested by a wide spectrum of broad and grassy weeds. Weeds compete with the crops for water, soil, nutrients, light and for space thus reduce crop yields up to 37 per cent (Varshney, 2009). They also harbour many microorganisms and insect-pests (Cooper and Harrison, 1973). On an average, weed extract two times more N and Ca and 25 per cent more potassium than the crop (Mallik et al. 1998). Reduction in economic yield of vegetables has been reported to be 6-82 per cent in potato, 25-30 per cent in peas, 70-80 per cent in carrot, 67 per cent in onion, 42-71 per cent in tomato and 61 per cent in cauliflower (Singh et al., 1993). Conventional methods of weed control have become an expensive input in the cultivation of vegetable crops. Owing to high cost and non-availability of labor, in time and no single method of weed control is adequate or cost effective. Integrated weed management is a systematic approach to minimize weed impacts and optimize the land use, by the use of different weed management practices (Aldrich, 1984).

Common weed flora associated with vegetable crops:
In Rabi Season:

<table>
<thead>
<tr>
<th>Botanical name</th>
<th>Common name</th>
<th>Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chenopodium album</td>
<td>Bathu</td>
<td>Chenopodiaceae</td>
</tr>
<tr>
<td>Melilotus indica</td>
<td>Senji Methi</td>
<td>Papilionaceae</td>
</tr>
<tr>
<td>Melilotus alba</td>
<td>Ban methi</td>
<td>Papilionaceae</td>
</tr>
<tr>
<td>Lathyrus aphaca</td>
<td>Maturi, Pipura Pipari</td>
<td>Papilionaceae</td>
</tr>
<tr>
<td>Vicia sativa</td>
<td>Anhta ankari</td>
<td>Papilionaceae</td>
</tr>
<tr>
<td>Convolvulus arvensis</td>
<td>Hirankhuri</td>
<td>Convolvulaceae</td>
</tr>
<tr>
<td>Rumex maritimus</td>
<td>Panbheri</td>
<td>Polygonaceae</td>
</tr>
<tr>
<td>Cynodon dactylon</td>
<td>Bermuda grass, Doob grass</td>
<td>Graminae</td>
</tr>
<tr>
<td>Cyperus rotundus</td>
<td>Motha</td>
<td>Cyperaceae</td>
</tr>
<tr>
<td>Orobanchae spp.</td>
<td>-----</td>
<td>Orobanchaceae</td>
</tr>
<tr>
<td>Spergula arvensis</td>
<td>Bhandhania</td>
<td>Caryophyllaceae</td>
</tr>
<tr>
<td>Euphorbia hirta</td>
<td>Bari Dudhi</td>
<td>Euphorbiaceae</td>
</tr>
</tbody>
</table>
In Kharif Season:

<table>
<thead>
<tr>
<th>Botanical name</th>
<th>Common name</th>
<th>Family</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Trianthema portulacastrum</em></td>
<td>Patharchata, Gadhupura</td>
<td>Azoiaeae</td>
</tr>
<tr>
<td><em>Echinochloa colona</em></td>
<td>Barnyard Grass, Sama grass,</td>
<td>Graminae</td>
</tr>
<tr>
<td><em>Cyperus rotundus</em></td>
<td>Motha</td>
<td>Cyperaceae</td>
</tr>
<tr>
<td><em>Digeria arvensis</em></td>
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<td>Amaranthaceae</td>
</tr>
<tr>
<td><em>Amaranthus viridis</em></td>
<td>Jangli Chaulai</td>
<td>Amaranthaceae</td>
</tr>
<tr>
<td><em>Physalis minima</em></td>
<td>Ban Makaya</td>
<td>Solanaceae</td>
</tr>
<tr>
<td><em>Phyllanthus niruri</em></td>
<td>Haizardana, Jar-Amla, bhuin Anmala</td>
<td>Euphorbiaceae</td>
</tr>
<tr>
<td><em>Commelina benghalensis</em></td>
<td>Kanna, Kena</td>
<td>Commelinaceae</td>
</tr>
<tr>
<td><em>Eleusine indica</em></td>
<td>Malanpuri Kodai</td>
<td>Graminae</td>
</tr>
<tr>
<td><em>Ageratum conyzoides</em></td>
<td>Neela phool</td>
<td>Compositae</td>
</tr>
<tr>
<td><em>Cynodon dactylon</em></td>
<td>Bermuda grass, Doob grass</td>
<td>Graminae</td>
</tr>
<tr>
<td><em>Celosia argentea</em></td>
<td>Safed murge ka phool, Suawari</td>
<td>Amaranthaceae</td>
</tr>
</tbody>
</table>

**Approaches recommended for integrated weed management**

**A. Preventive weed management**

- Use clean seed as many weed seeds get mixed with the main crop and these seeds should be separated before sowing to avoid weeds.
- Clean tillage implements. Many weed seeds stick to the implements used in the previous crops, so before using these implements these should be thoroughly cleaned.
- Avoid use/transportation of soil from weed infested area.
- Prevent reproduction of weeds by removing them in vegetative stage.
- Use weed seed screen filter irrigation water to avoid weed seeds dispersal through irrigation water.
- Restrict live stock movement to non weed infested area. Many weed seeds get stick to live stock and
- Use thoroughly decomposed organic manure, because many seeds remains viable in the cattle dung and if it is used in the fields undecomposed then these weed seeds will germinate.
- Weeds should be removed from the fields before the critical crop weed competition period to avoid yield losses.
Critical stages noted for crop-weed competition in Vegetable crops

<table>
<thead>
<tr>
<th>Crops</th>
<th>Critical Stages (DAS/DAP)</th>
<th>Developmental Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onion/Garlic</td>
<td>30-75</td>
<td>Bulb Initiation</td>
</tr>
<tr>
<td>Cabbage/Cauliflower</td>
<td>30-45</td>
<td>Head Initiation</td>
</tr>
<tr>
<td>Okra</td>
<td>15-30</td>
<td>10-15 cm tall</td>
</tr>
<tr>
<td>Tomato/Chilli</td>
<td>30-45</td>
<td>20-33 cm tall</td>
</tr>
<tr>
<td>Brinjal</td>
<td>20-60</td>
<td>----</td>
</tr>
<tr>
<td>Beans</td>
<td>----</td>
<td>Canopy Formation</td>
</tr>
<tr>
<td>Potato/Radish</td>
<td>25-30</td>
<td>----</td>
</tr>
<tr>
<td>Carrot</td>
<td>15-20</td>
<td>7-10 cm tall</td>
</tr>
</tbody>
</table>

Source: Singh et al. (1993)

B. Cultural practices

- Stale seed bed, Mixed cropping, Land preparation, Mulching, Hand weeding, Burning and flaming, Crop Rotation, Irrigation and Solarisation

Stale seed beds

- Stale (‘false’) seed beds are sometimes used for vegetables when other selective weed-control practices are limited or unavailable. Success depends on controlling the first flush of emerged weeds before crop emergence, and on minimal disturbance, which reduces subsequent weed flushes. Basically, this technique consists of the following:
  - Preparation of a seedbed 2-3 weeks before planting to achieve maximum weed-seed germination near the soil surface.
  - Planting the crop with minimum soil disturbance to avoid exposing new weed seed to favourable germination conditions.
  - Treating the field with a non-residual herbicide to kill all germinated weeds (William et al. 2000) just before or after planting, but before crop emergence.

Crop rotation

Crop rotation was considered for a long time to be a basic practice for obtaining healthy crops and good yields. Classically, crop rotations are applied as follows:
1. Alternating crops with a different type of vegetation: leaf crops (lettuce, spinach, cole), root crops (carrots, potatoes, radish), bulb crops (leeks, onion, garlic), fruit crops (squash, pepper, melon).
2. Alternating grass and dicots, such as maize and vegetables.
3. Alternating different crop cycles: winter cereals and summer vegetables.
4. Avoiding succeeding crops of the same family.
5. Avoiding problematic weeds in specific crops (e.g. *Malvaceae* in celery or carrots, parasitic and perennials in general).

**Soil Solarisation**

Soil solarisation is a preventive method that exploits solar heating to kill weed seeds and therefore reduce weed emergence. Solarization can be defined as a soil disinfection method that exploits the solar energy available during the warmest period of the year. To increase the solarization effect as much as possible, the soil surface must be smooth and must contain enough water to favour heat transfer down the profile and to make reproductive structure of pests, diseases and weeds more sensitive to heat damage. For this reason, prior to solarisation the soil is usually irrigated and a plastic mulch film is laid down onto the soil to further increase soil heating and to avoid heat dissipation to the atmosphere. The soil solarization can only be used in warm climates or under glasshouse conditions in warm-temperate and Mediterranean climates. For example, a significant reduction in weed emergence was observed over the following 12 months after one-month’s solarization in a tunnel glasshouse used for vegetable production in Central Italy (Temperini *et al.* 1998).

**Land preparation and tillage**

When annual weeds are predominant, the objectives are unearthing and fragmentation. This must be achieved through shallow cultivation. If weeds have no dormant seeds deep ploughing to bury the seeds will be advisable. The success of many weed-control operations depends upon the timing of its implementation. The opportunity for mechanical operation is indeed essential. Action must be taken against annual weeds before seed dispersion takes place.

**Hand weeding**

It is very efficient for annual weeds, but not for perennial capable of vegetative reproduction, because root separate from shoot that then produce a new shoot. Hand hoeing control the persistent perennials if it is done often enough. Although efficient and widely used, it takes a lot of time and human energy.
Flaming

Thermal death points for most plant tissue are between 45 – 55°C after prolonged exposure. A flamer directs a petroleum based fuel emitted under pressure and ignited. Plant size at treatment influences efficacy much more than plant density. Required dose increased with plant growth stage and some species of annual weeds are more tolerant than others. The most tolerant species cannot be controlled with one flaming, regardless of dose.

Mulching

It excluded light and prevents shoot growth. Mulches increase soil temperature and many promote better plant growth. Several different materials have been used to mulch, including straw, hay, manure, paper and black plastic. Mulches are used in high value crops.

C. Chemical weed control

Advantages:

- Herbicides are not beneficial but profitable where labour is scarce or expensive.
- Control weeds in crop rows where cultivation is not possible.
- Pre-emergence herbicides provide early season weed control when competition results in the greatest yield reduction and when other methods are less efficient.
- Herbicide reduces the destruction of soil structure by decreasing the need for tillage.
- They reduce fertilizers and irrigation requirements by eliminating competing weeds.

Disadvantages:

- Some herbicide persist in the environment
- Undeniable mammalian toxicity
- Selective herbicides control some weed only
- Are often inconsistent in weed control
- Have phytotoxicity effect
Methods of Herbicide application

Pre-planting/Pre-sowing: the herbicides are applied in the seed-bed or in the field, incorporating in the soil, usually 20-30 days prior to planting or transplanting in the main field, so as to kill most of the weed seeds.

Post-planting: the herbicides are sprayed after planting the crop.

Pre-emergence: the treatment is made prior to the emergence of specific weeds. Mostly contact herbicides are used in this method. The weedicides are applied after the weeds have emerged before the crop emergence and used an efficient herbicide that does not persist in toxic form in the soil.

Post-emergence: the treatment is given after the emergence of specific crop or weed; especially post-emergence of the crop.

Classification of herbicides:

1. On the basis of chemical
   1a. Inorganic

<table>
<thead>
<tr>
<th>Group</th>
<th>Chemical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids</td>
<td>Sulphuric acid, Arsenic acid</td>
</tr>
<tr>
<td>Chlorate</td>
<td>Sodium chlorate, Borax, Decahydrate, Sodium metaborate</td>
</tr>
<tr>
<td>Sulphamate</td>
<td>Copper sulphate, Ferric sulphate</td>
</tr>
<tr>
<td>AMS</td>
<td>Ammonium sulphamate</td>
</tr>
<tr>
<td>Nitrate</td>
<td>Sodium nitrate</td>
</tr>
</tbody>
</table>

1b. Organic herbicides

<table>
<thead>
<tr>
<th>Group</th>
<th>Herbicide Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aliphatics</td>
<td>Dalapon, TCA</td>
</tr>
<tr>
<td>Amides and Anillides</td>
<td>Alachlor, Butachlor, Propachlor, Propanil, Naptalam, Acrolein</td>
</tr>
<tr>
<td>Anilines and Nitrophenols</td>
<td>Dintramine, Nitratin, Triflatulin, Fluchoralin, Nitrofen</td>
</tr>
<tr>
<td>Arsenicals</td>
<td>DSMA, MA, MSMA</td>
</tr>
<tr>
<td>Benzoics and Phenyl Acetic Acid</td>
<td>Chloramben, Dicamba, Fenac</td>
</tr>
<tr>
<td>Carbamate</td>
<td>Diclormate, Asulam, Barban, Propham</td>
</tr>
</tbody>
</table>
Thio-Carbamate | Benthiocarb, EPTC, Diallate, Tra-allate, Molinate, Glyphosate
---|---
Heterocyclic Compounds | Bipyridyelium, Pyridines, Pyridazines, Uracils, Atrazine, Simazine, Propazine, Ametryne, Promatone, Terbutryn, Metribuzin
Hormone | Phenoxy acetic acid, Phenoxy propionic acid, Phenoxy butyric acid
Nitriles | Bromoxynil, Dichlobenil, Loxynil
Substituted Urea | Chloroxuron, Diuron, Fenuron, Fluomruron, Monuron
Alkoxy | Liuron, Chlorbromuron, Neburon
Unclassified | Methazole, Perfluidon, C-288
Nitriles | Bromoxynil, Dichlobenil, Loxynil

Source: Brian (1964)

3. On the basis of selectivity

2a. Selective: those herbicides which affect only certain weeds, leaving certain crops unharmed. But the selectivity depends on the amount of chemical applied and the way they are used.

2b. Non-selective: are used to control a wide range of vegetation indiscriminately because they are toxic to all plants and highly susceptible to living plant tissues.

Commonly used Herbicides in Vegetables:

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Trade Name</th>
<th>Time of application</th>
<th>Rate (kg/1/ha)</th>
<th>Usages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alachlor</td>
<td>Lasso</td>
<td>Pre-emer</td>
<td>2-3</td>
<td>Selective</td>
</tr>
<tr>
<td>Atrazine</td>
<td>Atrataf</td>
<td>Pre-emer</td>
<td>0.5-2</td>
<td>Selective</td>
</tr>
<tr>
<td>Borate</td>
<td>Hibour, Monobar</td>
<td>Soil pre/post</td>
<td>2-3</td>
<td>Non-selective</td>
</tr>
<tr>
<td>Butachlor</td>
<td>Machete</td>
<td>Pre-emer</td>
<td>1-2</td>
<td>Selective</td>
</tr>
<tr>
<td>Fluchloralin</td>
<td>Basalin</td>
<td>Pre-emer</td>
<td>1-2</td>
<td>Selective</td>
</tr>
<tr>
<td>Gluphosate</td>
<td>Round up</td>
<td>Post-emer</td>
<td>1-2</td>
<td>Non-selective</td>
</tr>
<tr>
<td>Metribuzin</td>
<td>Lexone, Sencor</td>
<td>Pre-emer</td>
<td>0.25-1</td>
<td>Selective</td>
</tr>
<tr>
<td>Nitrofen</td>
<td>Tok-E-25</td>
<td>Pre/post</td>
<td>2-5</td>
<td>Selective</td>
</tr>
<tr>
<td>Oxadiazon</td>
<td>Ronstar</td>
<td>Post-emer</td>
<td>0.75-4</td>
<td>Selective</td>
</tr>
<tr>
<td>Paraquat</td>
<td>Gramaxone</td>
<td>Post-emer</td>
<td>0.5-1</td>
<td>Non-selective</td>
</tr>
<tr>
<td>Herbicides</td>
<td>Dose (kg/ha)</td>
<td>Treatment</td>
<td>Crops</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>--------------</td>
<td>--------------------</td>
<td>----------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Pendimathelin</td>
<td>0.65-1.0</td>
<td>Pre-emergence</td>
<td>Transplanted pepper, onion, garlic, spinach brassica crops, umbelliferous crops, legumes and potato.</td>
<td></td>
</tr>
<tr>
<td>Fluchloralin/Trifluralin</td>
<td>1.0-1.5</td>
<td>Pre plant-incorporation</td>
<td>Transplanted tomato, pepper, brinjal, potato, okra, brassica crops, legumes, garlic and umbelliferous crops.</td>
<td></td>
</tr>
<tr>
<td>Oxyfluoren</td>
<td>0.24-0.36</td>
<td>Early post-emergence</td>
<td>Direct seeded and transplanted onion and potato.</td>
<td></td>
</tr>
<tr>
<td>Butachlor</td>
<td>2.0</td>
<td>Pre-emergence</td>
<td>Transplanted tomato &amp; cucurbits.</td>
<td></td>
</tr>
<tr>
<td>Metribuzin</td>
<td>0.2-0.35</td>
<td>Pre or post emergence</td>
<td>Direct seeded and transplanted tomato and potato.</td>
<td></td>
</tr>
</tbody>
</table>

**Selective Herbicides for Weed Control in Vegetable Crops:**

**Biological weed control:**

It is defined as the action of the parasites, predators or pathogens in maintaining other organisms, population at a lower average density than would occur in their absence. The term was used by H. S. Smith.

**Bio-control agents:**

**Classical or inoculative:** It has been used for many years. The earliest record of biological weed control was the release of cochineal insect *Dactylopius ceylonicus* from Brazil to north India in 1795 to control prickly pear cactus.

**Inundative or Augmentative:** E.g. Fungi (*Colletotrichum gloeosporioides*)

**Broad spectrum:** Fish (e.g. White amur or Grass carp (*Ctenopharyngodon idella* Valenciennes), Aquatic Mammals e.g. Sea manatee (*Trichechus spp.*) and Vertibrates e.g. Sheep, goats etc.
Examples of promising bio-agents in weeds:

<table>
<thead>
<tr>
<th>Weed</th>
<th>Bioagent</th>
<th>Reporting Country</th>
<th>Kind of Bioagent</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Chondrilla juncea</em></td>
<td><em>Puccinia chondrillina</em></td>
<td>Australia</td>
<td>Plant Pathogen</td>
</tr>
<tr>
<td><em>Cirsium arvensis</em></td>
<td><em>Septoria cirsii</em></td>
<td></td>
<td>Plant Pathogen</td>
</tr>
<tr>
<td><em>Cyperus rotundus</em></td>
<td><em>Bactra verutana</em></td>
<td>India, Pakistan &amp; USA</td>
<td>Shoot boring moth</td>
</tr>
<tr>
<td><em>Eupatorium riparium</em></td>
<td><em>Entyloma compositarum</em></td>
<td>USA</td>
<td>Plant pathogen</td>
</tr>
<tr>
<td><em>Hydrilla verticillata</em></td>
<td><em>Hydrillaq pakistanae</em></td>
<td>USA</td>
<td>Shoot fly</td>
</tr>
<tr>
<td><em>Orobanche cermua</em></td>
<td><em>Sclerotina spp.</em></td>
<td>USA</td>
<td>Plant pathogen</td>
</tr>
<tr>
<td><em>Parthenium hysterophorus</em></td>
<td>(i) <em>Zygograma bicolorata</em></td>
<td>India</td>
<td>Leaf eating insect</td>
</tr>
<tr>
<td></td>
<td>(ii) <em>Epiblema sternuana</em></td>
<td>Australia</td>
<td>Stem galling insect</td>
</tr>
<tr>
<td></td>
<td>(iii) <em>Conotrachelus spp.</em></td>
<td></td>
<td>Stem galling insect</td>
</tr>
<tr>
<td><em>Rumex spp.</em></td>
<td>(i) <em>Uromyces rumicis</em></td>
<td>USA</td>
<td>Plant pathogen</td>
</tr>
<tr>
<td></td>
<td>(ii) <em>Gastrophysa viridula</em></td>
<td>USA</td>
<td>Beetle</td>
</tr>
</tbody>
</table>

Source: Parsad and Kumar (1999)

Conclusion:

Research work on weed control has to be intensified in important vegetable crops to obtain maximum yield. Greater attention must be paid to integrated weed control practices instead opting for a single practice. A careful watch has to be kept in places where one particular herbicide is being used continuously for a long time, because it may lead to growth of resistant weed species. Herbicide mixtures must be kept handy to control these resistant species. Extension services should be provided to farmers, so that the production system becomes more profitable.

References:


(also available at http://weeds.ippc.orst.edu/pnw/weeds).


Production technology of Exotic and underutilized vegetable crops

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Due to increasing awareness towards health and quality rich foods, the horticultural commodities such as fruits and vegetables have occupied the central stage in human nutrition in the 21st century. Vegetables in particular, being low calorie foods are rated the best in modern times to check obesity and related disorders. Vegetables not only provide essential vitamins, minerals and antioxidants helping to keep oneself young, productive and agile but nutra-ceuticals available through them also ward humans against a number of ailments, which have become now common as a consequence of modern lifestyle.

Exotic or underutilized vegetables represent a spectrum of vegetables generally which are of European or oriental origin but their growing and consumption is still quite limited in India. Their production is being taken up on commercial scale in the hilly regions of the country especially Himachal, parts of Kashmir and Nilgiri hills. More recently these vegetables such as asparagus, lettuce, celery, parsley, broccoli, European carrots, leek, Chinese chive, snow peas, Chinese cabbage, yellow and red capsicum are being included in our food to get full advantage of their protective food value in our health and nutrition as well as bring new flavors and taste to our food.

Globalization and free market trade has promoted the demand and sale of exotic vegetables particularly of European origin in the Indian market. The new vegetables such as Lettuce, asparagus, broccoli, European carrots, red and yellow capsicum, snow peas, leek, Brussels sprouts, parsley, celery, chives and sweet corn have assumed much significance over the last five years. Lettuce is one of the major leafy vegetables consumed in salads worldwide, yet its demand in India picked up only recently after a number of fast food joints came up. Similarly, demand for European carrots known to be rich in vitamin A and sugar remained subdued till these became an essential part of salad in restaurants. European carrots are now successfully cultivated in the hills during summers to make their off-season appearance in the plain markets. Broccoli, an important member of cabbage family is rich in nutrition;
yet Indian consumer prefers cauliflower over broccoli however it has created a niche for itself in the recent times. Brussels sprouts, leek, parsley, red cabbage and asparagus were hardly known to Indian consumer. The demand for yellow and red capsicum picked up due to European tourists and multinational food chains in India.

In view of the increasing demand for exotic vegetables and their nutraceutical value, it is time to take up their cultivation in home as well as in commercial gardens. In the Indian scenario, North Western Himalayas and Nilgiri hills provide excellent climate for the production of most of the exotic vegetables particularly during summer months, whereas most of the vegetables can be cultivated during winters in the plains. The superior quality yellow and red capsicums have been successfully produced under naturally-ventilated polyhouses in the hills. Buy back arrangements with upcoming retail corporate can further ensure adoption of these vegetables by the farmers in their production plans.

The total seed and planting material requirements of exotic vegetables in India at present is not very high and the varieties available from multinational seed companies can be adopted for cultivation. This is the one reason why production of exotic vegetables in India has become feasible because most of the superior planting material is now accessible. Two major strategies can be adopted for production and popularization of these lesser known vegetables and are given below:

**Exotic Vegetables for Home Gardens**

In view of the immense nutritional value as health food and nutraceutical, exotic vegetables have earned a special place in the home gardens. Every household is curious to know more about culture and consumption of exotic vegetables under Indian conditions. The most important aspects regarding culture, storage at home and tips of recipe are given in the present book. The unique advantage of growing vegetables organically at home makes exotic vegetables an excellent choice these are not easily available in the market.

**Exotic Vegetables for Commercial Gardens**

Exotic vegetables are crops those lend themselves well to small scale and part time farming operations. These are a boon for small and marginal farmers. Cultivation of exotic vegetables can be done in the summers in the hills and these can be supplied to plain markets as off-season vegetables. Yellow, red and purple capsicums can be grown successfully in protected
structures. Various marketing alternatives are available for small and marginal farmers. These are wholesale markets, cooperatives, local retailers, roadside stands, processing firms, local restaurants to meet the demand of tourists.

Whether one produces exotic vegetables in home gardens or commercial gardens, their quality maintenance is of utmost importance. Some of the approaches which needs to be adopted for scaling up the production and use of these vegetables are as followed:

- Improved varieties need to be developed suiting to different agro-climates of country for sufficiency in production
- Precision farming
- For more nutritional quality concept of growing under protected conditions
- Exploitation of WTO markets for getting premium prices
- Environment friendly plant protection
- Post harvest handling
- Marketing and storage
Grafting Technique in Vegetable Crops

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Grafting is an age old practice which involves the joining together of plant parts by means of tissue regeneration, in which the resulting combination of parts achieves physical union and grows as a single plant (Janick 1986). The use of graftage overcomes the difficult-to-root problems of many fruits such as apple. Grafting is used for cultivar change, repair, or invigoration of older established fruit trees. Grafting in cucurbits was briefly described in a seventeenth century book written by Hong (1643-1715) in Korea (Lee and Oda 2003)

Vegetable grafting is a horticultural technology that is gaining popularity in many countries around the world. Mostly practiced in Solanaceae and Cucurbitaceae species, vegetable grafting can be a useful and environmentally friendly strategy to mitigate the effects of soil borne diseases and abiotic stress, and is therefore strongly recommended for integrated crop management systems (Colla and Schwarz 2013). Grafting offers various advantages as follows (Oda 1995):

- Reduction of incidence of soil-borne diseases caused by pathogens such as \textit{Fusarium oxysporum};
- Increase of tolerance to low temperature, soil salinity or waterlogging;
- Enhancement of water and nutrient uptake;
- Increase of plant vigour and extension of the duration of economic harvest time;
- Shortening of the breeding period by limiting the breeding objective only for resistance to soil-borne diseases and nematodes in rootstock.

Methods of grafting in vegetables

Grafting methods vary greatly and considerably depending upon the kind of crops, farmers’ experiences and preferences, facilities and machines available, numbers of grafting, and even by the purpose of grafting such as grafting for farmers’ own uses or for sales only by commercial growers (Lee et al 2010).

However, common methods of grafting vegetables are hole Insertion Grafting, tongue approach grafting, splice grafting, one cotyledon splice
grafting, tube grafting, Cleft grafting and pin grafting. The procedure has been shown in a graphic representation by Lee et al 2010.

Major grafting methods in cucurbits and solanaceous vegetables (Lee et al 2010)
(A and B) hole insertion grafting; (C) tongue approach grafting; (D, E and J) splice grafting; (F, G) cleft grafting; (H and I) pin grafting

Grafting Acclimatization

Acclimatization involves healing of the cut surface and hardening for field or greenhouse survival (Lee and Oda 2003). In commercial nurseries, the grafted plants, usually in cell trays of 32–72 cells, are placed on a greenhouse bench and the trays are sealed with a single layer of semi-transparent high-density polyethylene film (0.01mm or thinner) to reduce the moisture loss and kept sealed for 5–7 days without additional irrigation (Lee et al. 2010). Partial shading may be needed during the daytime to avoid excessive heat build-up.

Grafting vegetables to Manage Pathogens, Arthropods and Weeds

The use of grafting in vegetable production systems has expanded to manage a broad range of pathogens including fungi, oomycetes, bacteria, nematodes and viruses. In regards to grafting, two broad approaches have been used to manage biotic problems: intraspecific grafting occurs when rootstock and scion are of the same species. Interspecific and intergeneric grafting uses combinations of rootstock and scion that are of different species or genera, respectively. Use of interspecific and intergeneric rootstock that confers multigenic resistance or nonhost reactions may be broader spectrum and
durable. However, in the absence of other IPM tactics, novel pathogens compatible on the rootstock may emerge (Louws et al. 2010)

**Defence mechanisms in Disease Resistance of Grafted Vegetables (Guan et al. 2012)**

- Inherent resistance within rootstocks as the first line of defence
- Shift of rhizosphere microbial diversity as a result of grafting
- Contributions of vigorous root systems of grafted vegetables to plant defence
- Grafting-induced systemic defence

**Grafting in vegetables crops for salinity tolerance**

Grafting is an effective way to improve the salt tolerance of fruit-bearing vegetables. The grafting process itself has no effect on plant salt tolerance. The increased salt tolerance of grafted plant is due to “the use of salt tolerant rootstock”. Plants grafted onto different rootstocks respond more or less differently to salinity (Estan et al., 2005; Ruiz et al., 2005). Grafting can alleviate ion toxicity by limiting the transport of Na+ and in some cases also of Cl− to the shoot while storing these in the roots, which are typical tissue tolerance mechanisms. The higher accumulation of compatible solutes and osmolytes in the cytosol of leaf cells can increase plant survival and delay leaf senescence of grafted plants. An efficient antioxidant system that reduces oxidative damage plays a key role in enhancing salt tolerance of grafted plants. In addition, induction of hormones may also enable grafted plants to adapt to salinity more efficiently. The rootstock-mediated enhancement of salt tolerance provides an additional motivation for vegetable grafting in modern horticulture (Colla et al. 2010).

**Nutrient deficiency tolerance**

Many rootstocks used to graft vegetables are wild genotypes of the same species as the scion, relatives, or hybrids of them, which are characterized by more vigorous root systems than those of highly productive cultivated varieties (Davis et al., 2008). Öztekin et al. (2009) found a significant increase in the root density by 25.3% on average in tomato plants grafted onto 'He-Man' and 'Beaufort', in comparison with self-grafted plants. The more vigorous root system of the rootstock results in increased nutrient and water uptake, and this may enhance the growth rate and yield performance of the whole plant (Lee, 1994).
Grafting: Effect on Quality

There are many conflicting reports on changes in fruit quality due to grafting and whether grafting effects are advantageous or deleterious. Rootstock/scion combinations should be carefully selected for specific climatic and geographic conditions. Unfortunately, most of the rootstocks available in the market have been selected especially for disease resistance and vigour so breeding program is needed to select rootstock/scion combinations with high fruit quality attributes under the different growing conditions.

Problems in Grafting and Cultivating Grafted Vegetable Seedlings

Various problems are commonly associated with grafting and cultivating grafted seedlings (Lee 1994, Table 1). Major problems are the labour and techniques required for the grafting operation and post-graft handling of grafted seedlings for rapid healing for 7 to 10 days. An expert can graft 1200 seedlings per day (150 seedlings per hour), but the numbers vary with the grafting method.

Table 1: Problems associated with grafting and cultivating grafted vegetable seedlings (Lee 1994).

<table>
<thead>
<tr>
<th>Factors</th>
<th>Category</th>
<th>Possible mitigating measures</th>
</tr>
</thead>
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<tr>
<td>Labor</td>
<td>Grafting operation</td>
<td>Specifically designed knives, grafting apparatus, grafting machines, grafting robots</td>
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<td></td>
<td>Postgraft care</td>
<td>Experience needed and postgraft conditioning chamber may be required for automation</td>
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<tr>
<td>Techniques</td>
<td>Rootstocks</td>
<td>Wise selection of rootstock suitable for type of crops and cultivars</td>
</tr>
<tr>
<td>Management</td>
<td>Fertilizer application</td>
<td>Different field management, especially reduced fertilizer application</td>
</tr>
<tr>
<td>Compatibility</td>
<td>Uneven senescence</td>
<td>Proper timing of growing season and rootstock type and selection</td>
</tr>
<tr>
<td>Growth</td>
<td>Excessive vegetative growth</td>
<td>Reduced fertilizer and soil moisture</td>
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<td></td>
<td>Physiological disorders</td>
<td>Wise selection of rootstocks to reduce excessive water and nutrient uptake</td>
</tr>
<tr>
<td>Fruit quality</td>
<td>Size and shape</td>
<td>Partly controlled with rootstocks</td>
</tr>
<tr>
<td></td>
<td>Appearance</td>
<td>Proper cultural management</td>
</tr>
<tr>
<td></td>
<td>Insipid taste</td>
<td>Cultivar and rootstock selection</td>
</tr>
<tr>
<td></td>
<td>Soluble solids</td>
<td>Proper soil moisture control</td>
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<tr>
<td></td>
<td>Yellow band in flesh</td>
<td>May appear in red flesh of watermelon</td>
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<td></td>
<td>Internal decay</td>
<td>Foliar Ca application and reduced N</td>
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<tr>
<td>Expense</td>
<td>Rootstock seeds</td>
<td>Inexpensive rootstock seeds (domestic or imported)</td>
</tr>
<tr>
<td>Scion rooting</td>
<td>External rooting</td>
<td>Careful management during seedling stage and at transplanting</td>
</tr>
<tr>
<td></td>
<td>Internal or fused rooting</td>
<td>Different grafting methods to avoid scion root development through internal cavity of rootstock hypocotyl, which often cannot be recognized externally</td>
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</tbody>
</table>
**Suggested Reading**


The extent of crop losses in vegetables varies with the crop type, crop location, damage potential of the insect pests involved and cropping season. Insect pest and disease infestation is one of the major limiting factors (Dhandapani et al., 2003) in increasing the yield potential in brinjal, tomato, okra, cucurbitaceous and cole vegetable crops. The crops are susceptible to the attack of various insect pests and diseases in different stages with varying degree of damage which causes considerable losses by reducing potential yield and quality of the produce. In view of the lucrative returns from vegetables in short span, farmers with limited land holdings and resources are forced to follow monoculture and intensive cultivation, which also exacerbates the survival of various insect pests and pathogens from one season to another.

With the introduction of high yielding varieties and hybrids vegetable seeds resulted in dramatic changes in insect pest scenario leading to minor pests assuming the status of major pests. Moreover, the continuous, excessive and injudicious use of pesticides has triggered several ecological consequences like resistance (currently, more than 500 species of insects) and resurgence of insect pests, pesticide poisoning, environmental pollution, destruction and elimination of natural enemies, effect on non target organisms, disruption in food cycle and food web and residues in food commodities (Balasubramanian, 2004). Insects are not only responsible for massive direct losses of productivity but also cause massive indirect losses due to their role as vectors for various plant pathogens. These losses occur despite the extensive use of pesticides and fungicides. In the absence of such crop protection measures losses would be much more serious. This is of special importance in developing countries where, billions of people are living and working in farming areas are exposed to pesticides.

The concept and impetus for IPM grew out of the discontent with using a purely insecticidal approach to insect control in many areas and overuse of insecticides resulted in insects that were resistant to insecticides. So IPM is the integrated approach to manage the pest population. It is the blending of all the suitable control measures against the pest species in as compatible...
manner as possible so as to avoid the pests population in reaching the economic injury level.

- Economic injury level: The minimum pest population which causes economic damage is called as economic injury level.
- The term Integrated Pest Management means:
  Integrated: a focus on interactions of pests, crops, control methods, and the environment rather than on individual weeds, insects, or diseases.
- Pest: a species that conflicts with our profit, health, or convenience. If a species does not exist in numbers that seriously affect these factors, it is not considered a pest. OR pests are plants and animals in undesirable locations according to man’s liking. It may be: insects, mites, snails, birds, weeds, nematodes, and pathogens.
- Management: a way to keep pests below the levels where they can cause economic damage. Management does **not mean eradicating pests**. It means finding tactics that are both effective and economical and that keep environmental damage to a minimum.

This approach considers all available tactics and how they fit in with other agricultural practices.

- Pest: a species that conflicts with our profit, health, or convenience. If a species does not exist in numbers that seriously affect these factors, it is not considered a pest.
- Management: a way to keep pests below the levels where they can cause economic damage. Management does **not mean eradicating pests**. It means finding tactics that are both effective and economical and that keep environmental damage to a minimum.

**DIFFERENT MANAGEMENT PRACTICES**
- Cultural control
- Mechanical control
- Physical control
- Legal control
- Biopesticides
- Chemical control

**Cultural method of control**
- Tillage
- Planting and harvesting time
- Sanitation
- Plant diversity
- Trap cropping
- Crop rotation
- Nutrient and water management
**Physical control**  
Hot and cold treatment  
Light trapping  

**Mechanical control**  
Hand picking  
Exclusion by screens and barriers  
Clipping and pruning  

**Bio pesticides:**  
Bio pesticides of plant origin: Formulations, extracts  
   Neem, plant/plant parts extracts  
Bio pesticides of animal origin:  
   Predators, parasitoids, pathogens  
   Use of sex pheromones for monitoring, mass trapping, mating disruption and auto confusing the target pests.

**Important vegetable crops can be categorized as follow:**  
- Cruciferous crops: Cabbage, Cauliflower, Knol-khol, Broccoli, Brussels sprout etc.  
- Solanceous crop: Tomato, Brinjal and Capsicum  
- Leguminous crops: Pea, French bean  
- Cucurbitaceous crops: Cucumber, Bitter gourd, Bottle gourd  
- Malvaceous crops: Okra

**A brief explanation of the nature of damage of insect pests of important vegetable crops and their management**

<table>
<thead>
<tr>
<th>Sr NO</th>
<th>Bane of the pest</th>
<th>Nature of damage</th>
<th>Management</th>
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<tbody>
<tr>
<td>1</td>
<td>Cabbage aphid</td>
<td>The colonies of the aphid are seen on leave, bud and inflorescence. Damage is caused by nymphs and adults which suck cell sap from plant parts. Due to sucking of the sap curling of leaves takes</td>
<td>Cut and destroy the infested leaves/shoots mechanically as soon as the aphid attack appears. Spray of fine pulverized mica powder @ 0.2 per cent to repel the alates. Apply malathion (500-1000ml/ha) for mustard aphid in cabbage, azadirachtin (0.03%), phosalone (500-1000ml/ha) or quinalphos (500-1000ml/ha).</td>
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</tbody>
</table>
|   | Cabbage butterfly | Damage is caused by caterpillars which in the earlier stage feed in groups and scrap the leaf surface but later on they may eat up the entire leaves leaving only the harder mid rib. | Collection and destruction of the egg masses and early gregarious caterpillars NSKE @ 4.0 %
Need based spraying the crop with insecticides like malathion(0.05%), cypermethrin (0.01%). In nature *Apanteles glomeratus* has been reported as major mortality factor of this pest. |
| 2 | Diamondback moth | Damage is caused by the larvae which in earlier stage mine the leaves and later on feed on the exposed leaf making hole of variable size. | Sprinkler irrigation after every third day in evening hours is effective.
Use of pheromone trap for monitoring.
Spray of neem seed kernel extract (4%)
Spray application of Chlorantraniliprole 18.5% (750-1000 ml/ha), indoxacarb 14.5% SC 200-266 ml in 400-750 l) or Flufenoxuron 10% DC. Same insecticide should not be applied repeatedly.
The population of this pest can be managed by growing paired row of bold seeded Indian mustard as a trap crop at the beginning and
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<tr>
<td></td>
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<td>after every 25 cabbage row. Among the paired rows, the first is sown 15 days prior to cabbage after planting. This attracts upto 80-90% of diamondback moth population.</td>
</tr>
<tr>
<td>4</td>
<td>Cutworm</td>
<td>Soon after transplanting, cutworms attack the tomato seedling. The larvae hide in the soil during day time and come out at dusk and cut seedlings at the ground level. The larvae are voracious eaters. They fell more seedling than</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Do not grow continuously the same crop. In the field where cutworms are known to cause damage in the previous years, drenching with chlorpyripjos (0.04%) should be done in the basin of the plants. Use well rotten FYM.</td>
</tr>
<tr>
<td>5</td>
<td>Tomato fruit borer</td>
<td>Damage is caused by the larva. Feeds on foliage, flowers, buds and fruits. Small green fruits are preferred. The damage is more pronounced during March to June</td>
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<tr>
<td></td>
<td></td>
<td>Deep summer ploughing to expose the pupae to the sunlight and natural enemies. African marigold as trap crop. Marigold used as a trap against tomato fruit borer gave maximum reduction in fruit damage as well as larvae on tomato plants because it does flower synchronously with the tomato with marigold in a 3:1 combination could be adopted for the management of tomato fruit borer.</td>
</tr>
<tr>
<td>6</td>
<td>Greenhouse whitefly</td>
<td>Caused by nymphs as well as adults. Suck the cell sap from leaves. Leaves turn yellow and dry away. Nymphs also excrete honey dew on which sooty moulds develop. Photosynthesis of the plant is reduced.</td>
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<tr>
<td>7</td>
<td><strong>Fruit fly</strong></td>
<td>Damage is caused by larvae which feed inside the fruit on fruit pulp and the fruit is rendered unfit for human consumption. A watery fluid oozes from the puncture. This reduces the market value of the produce. The fruit subsequently rots or becomes distorted and different pathogens develop thus hasten fruit decomposition.</td>
</tr>
<tr>
<td>8</td>
<td><strong>Red pumpkin beetle</strong></td>
<td>Both grubs and beetles are damaging Grubs feed on underground plant parts Beetles damage cotyledons, flowers and tender leaves Adults are very destructive particularly during the initial stage of crop growth Sometimes re-sowing is required</td>
</tr>
<tr>
<td>9</td>
<td><strong>Brinjal shoot and fruit borer</strong></td>
<td>Damages the crop from seedling stage till the harvest</td>
</tr>
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</table>

Removal of weed hosts is important to reduce the incidence.
In young plants, the caterpillars result in dead heart. Later on they bore into flower buds and fruits. Enter from under the calyx, seal the hole with excreta. The damaged flower buds are shed without blossoming. Fruits show circular exit holes.

| Collect all attacked shoots and fruits at regular intervals and burry them deep. |
| Periodic releases of *Trichogramma chilonis* Bt formulations @ 500g/ha |
| NSKE @ 4.0 per cent. |
| Spray cypermethrin (0.01%) |

**REFERENCES:**


Amongst the vegetable crops, solanaceous, leguminaceous and cruciferous vegetables are the most remunerative crops which have ameliorated the economic conditions of the farmers of Himachal Pradesh. The intensive cultivation of these crops year after year also ensures the survival and cumulative build up of the inocula of various pathogens posing threat to the successful cultivation. As the methods of management vary with the nature and cause of individual disease, therefore an accurate diagnosis is essential to prevent waste of time and material inputs. Besides, the information on nature of diseases occurring at various stages during the cycle of a crop is also necessary for developing integrated management schedule of multiple disease for a given geographical area. Thus the adoption of such a schedule which is crop protection oriented, efficient and cost effective is almost essential along with other inputs for the sustenance and realization crops to the extent of the genetic potential. This write up describes the major the diseases affecting tomato, capsicum, peas and cole crops and their integrated management.

Diseases of Solanaceous crops & their management (Tomato, Capsicum and Chillies)

Diseases of Tomato & their Management

DAMPING OFF

It is an important disease especially in tomato and also other vegetable crops like bell pepper, chillies, brinjal, cabbage, cauliflower, broccoli etc. for which nursery is raised for transplanting. The disease is fairly common in poorly managed nursery beds, incited often by the seed and soil borne pathogens. It is responsible not only for the poor seed germination and stand of seedlings but also for carryover of the pathogens to the field where transplanting is done.
**Symptoms**

The disease manifests in two phases

i) Pre-emergence damping-off and ii) post-emergence damping-off.

i) Pre-emergence damping-off:

Failure of seedling emergence from the soil either due to seed rots or killing of young seedlings before their emergence from the soil resulting in patchy appearance of seedlings stands in the nursery in early stages.

ii) Post-emergence damping-off.

Post-emergence damping off is characterized by rapid shrinking of and darkening of cortical tissues, thereby resulting in topping down of infected seedlings.

**Pathogen(s):**

Species of *Pythium, Phytophthora, Fusarium* and *Rhizoctonia solani* Kuhn are the most commonly associated pathogens. High soil moisture, pH 6.0 and heavy soils favour disease development. Pre-emergence damping-off is maximum at 20-25°C while post emergence at 30-40°C. The disease is further aggravated in ill-aerated soils with poor drainage having thick stand of the seedlings.

**Management**

- Change the nursery site every year.
- Either solarize the soil of the bed with transparent polyethylene (25 µm) sheet for 40-45 days during summer months or treat the soil with Formalin (5%) at least 20 days before sowing or apply bioagents like *Trichoderma harzianum* or *T. viride* (40 g/m²).
- Treat the seed with captan (0.3%).
- After seedling emergence from the soil, drench the bed with the mixture of mancozeb (0.25%) and carbendazim (0.1%) and repeat at 7-10 days interval.
- Give light but frequent irrigations.

**EARLY BLIGHT**

This disease is caused by the fungus *Alternaria solani* and is first observed on the plants as small, black lesions mostly on the older foliage. Spots enlarge and concentric rings in a bull’s eye pattern can be seen in the center of the diseased area. Tissue surrounding the spots may turn yellow. If high temperature and humidity occur at this time, much of the foliage is
Lesions on the stems are similar to those on leaves, sometimes girdling the plant if they occur near the soil line (collar rot). On the fruits, lesions attain considerable size, usually involving nearly the entire fruit. Concentric rings are also present on the fruit. Infected fruit frequently drops. The fungus survives on infected debris in the soil, on seed, on volunteer tomato plants and other solanaceous hosts, such as Irish potato, eggplant, and black nightshade.

**Management**

- Collect and destroy the infected plant debris. Follow at least two years crop rotation.
- Select healthy seed and treat it with captan (0.3%).
- Remove the foliage particularly in indeterminate type of cvs/hybrids up to 15-20 cm to avoid moist and stagnant air conditions.
- Spray the crop with chlorothalonil (0.2%) or mancozeb (0.25%) and repeat at 10 to 14 days interval

**LATE BLIGHT**

Late blight is a potentially serious disease of potato and tomato, caused by the fungus *Phytophthora infestans*. Late blight is especially damaging during cool, wet weather. The fungus can affect all plant parts. Young leaf lesions are small and appear as dark, water-soaked spots. These leaf spots will quickly enlarge and a white mold will appear at the margins of the affected area on the lower surface of leaves. Complete defoliation (browning and shriveling of leaves and stems) can occur within 14 days from the first symptoms. Infected tomato fruits develop shiny, dark or olive-colored lesions, which may cover large areas. Fungal spores are spread between plants and gardens by rain and wind. A combination of daytime temperatures in the upper 70s °F with high humidity is ideal for infection.

**Management**

- Stake the plants erect and remove foliage and fruit up to a height of 15-20 cm to avoid moist and stagnant air conditions.
- Collect and destroy the affected fruits regularly.
- Apply pine needle/grass mulch on the field floor to create a barrier between the host and soil borne inoculum.

With the onset of monsoon rains, spray the crop with metalaxyl + mancozeb (0.25%) followed by sprays of either mancozeb (0.25%) or copper oxychloride (0.3%) or Bordeaux mixture (4:4:50) and repeat at 7-10 days interval.
BUCKEYE ROT

Buckeye rot is a disease of the fruit caused by the fungus *Phytophthora nicotianae* var. *parasitica*. Immature fruits (green colour) irrespective of their development stages are susceptible. Water soaked light brown discoloured spots appear which increase readily showing concentric dark brown rings slightly resembling the markings as a buckeye. The lesions rapidly enlarge and within 3-4 days, whole of the fruit surface turns dark brown and feels soft to touch. In warm and humid weather, white flocculent superficial growth of the fungus consisting of sporangia and sporangiophores also develops on the diseased fruits. Later, these fruits may drop off from the plant. The fungus does not affect the foliage. The disease is most common during periods of prolonged warm, wet weather and in poorly drained soils. The fungus survives in the soil and is spread by surface water and rain. Peppers are also susceptible to this disease.

**Management**

- Stake the plants erect and remove foliage and fruit up to a height of 15-20 cm to avoid moist and stagnant air conditions.
- Collect and destroy the affected fruits regularly.
- Apply pine needle/grass mulch on the field floor to create a barrier between the host and soil-borne inoculum.
- With the onset of monsoon rains, spray the crop with metalaxyl + mancozeb (0.25%) followed by sprays of either mancozeb (0.25%) or copper oxychloride (0.3%) or Bordeaux mixture (4:4:50) and repeat at 7-10 days interval.

BACTERIAL WILT

Bacterial wilt or Southern bacterial blight is a serious disease caused by *Ralstonia solanacearum* (formerly *Pseudomonas solanacearum*). This bacterium survives in the soil for extended periods and enters the roots through wounds made by transplanting, cultivation or insects and through natural wounds where secondary roots emerge. Disease development is favored by high temperatures and high moisture. The bacteria multiply rapidly inside the water-conducting tissue of the plant, filling it with slime. This results in a rapid wilt of the plant, while the leaves stay green. If an infected stem is cut crosswise, it will look brown and tiny drops of yellowish ooze may be visible.
Management

- Control of bacterial wilt in infested soil is very difficult as all the commercial cultivars are susceptible and no chemical control is available.
- Follow long crop rotation with non-solanaceous crops.
- Avoid the movement of water from infected plant to healthy plants.
- Shifting of date of transplanting to avoid period of high temperature, heavy rainfall or both.
- Green manuring or biofumigation with *Brassica* spp. may reduce the bacterial inoculum in soil.
- Bacterial antagonists such as *Pseudomonas fluorescens*, *P. glumae*, *P. cepacia* and *Bacillus* spp. have also been known to reduce disease incidence.
- Application of bleaching powder (15 kg/ha) has also been found effective against this disease.
- The disease can also be controlled effectively if dazomet application is combined with soil solarization.
- Seedling dip in Streptocycline (100 ppm) for 30 minutes is also effective to some extent.
- Use resistant cvs./hybrids for cultivation.

**VIRUSES**

Different viruses cause different symptoms on tomato. Symptoms of virus infection may appear as light and dark green mottling of the leaves. With tomato spotted wilt virus (TSWV), plants are stunted, bronzed or spotted, or have prominent purple veins. Fruits may have yellow spots. Tobacco mosaic virus (TMV) causes mottling of older leaves and may cause malformation of leaflets, which may become shoestring-like in shape. Viruses are highly infectious and readily transmitted by any means that introduces even a minute amount of sap from infected into healthy plants.

Management:

- The viral diseases of tomato can be managed effectively through use of virus free seed (ToMV). Rotate tomatoes with crucifers (such as cabbage, broccoli and turnips).
- Remove alternate hosts (TLCV, TSWV). Use insecticides against the vectors and cultivation of resistant varieties / hybrids.
• Seedling bed should be in isolation from ornamental plants and susceptible crops and the surrounding areas should be kept free from weeds.
• Wash hands thoroughly after smoking (the tobacco mosaic virus may be present in certain types of tobacco) and before working in the garden.
• Fine mesh netting may be useful for excluding thrips and other insect vectors.
• Aqueous extracts of neem (3-5ml/litre water) are known to possess strong antiviral substances against ToMV.

Diseases of Capsicum

FRUIT ROT, LEAF BLIGHT, COLLER ROT OF CAPSICUM:

Symptoms of the disease appear as water-soaked bleached spots on any portion of the leaf resulting in premature leaf fall. Small water soaked spots also appear on the fruits and the flesh below the skin become soft and usually there is a distinct line of demarcation between the invaded tissue and healthy. Whitish mould appears on the rotten fruits under humid conditions and completely rotten fruits may fall down on the ground. Symptoms also appear on collar region of adult plants as water-soaked areas with whitish growth of mycelium engirdling the collar region and the point of contact of the soil line. The rot often progresses downwards to the roots in the affected plants and there is sudden drooping of leaves giving the appearance of sudden wilt.

Two species of Phytophthora namely P. capsici Leon and P. nicotianae (Breda de Hann) var. nicotianae Waterhouse have been found associated with the disease. Both pathogens survive in the form of oospores in the soil as well as in infected seed. Presence of abundant rainfall, high RH & warm weather are essential for initiation of this disease. Temperature ranging from 22 -25° C along with high humidity (>80%) favour disease development.

Management:

• Collect and destroy the infected leaves and fruits regularly.
• Drainage of the field should be proper to avoid water stagnation.
• Apply pine needles/ grass mulch on the field floor before the onset of monsoon rains.
• Spray the crop with metalaxyl + mancozeb (0.25%) with the onset of monsoon rains followed by sprays of either mancozeb (0.25%) or copper oxychloride (0.3%) or Bordeaux mixture (4:4: 50) at 7 to 10 days interval.
ANTHRACNOSE AND RIPE ROT

The symptoms of the disease appear in two phases i.e. die-back and anthracnose and ripe fruit rot.

a) Die-back :

Symptoms appear as necrosis of tender twigs from the tip downwards. The entire plant or branch may wither away. The twigs become straw coloured in advanced stages of the disease. Large numbers of black dots (acervuli of the fungus) are seen scattered all over the necrotic parts of the plants.

b) Anthracnose and ripe fruit rot:

The disease is noticed on fully mature green fruits as well as on red ripe fruits. The symptoms are characterized by the appearance of small, circular, yellowish to pinkish, sunken spots on the skin of the fruits which spread in the direction of long axis. As the fruit matures, these spots become brownish to black and severely infected fruits look straw coloured and bear numerous dots like acervuli in concentric rings. The seeds produced in such fruits are discoloured and covered with mycelial mat.

The disease is caused by Colletotrichum capsici. The pathogen survives both in infected plant debris and in the infected seed. The fungus can survive in plant debris in the soil for at least nine months which serve as source of primary infection, whereas secondary infection takes place through wind borne conidia. A temperature of 26° C and presence of free moisture or RH 100 per cent is optimum for disease development and progress.

Management:

- Collect and burn the infected plant debris.
- Remove and destroy solanaceous weed hosts from in and around the field.
- Use seed from healthy fruits.
- Treat the seeds with captan (0.3%).
- Spray the crop with carbendazim (0.1%) or thiophanate methyl (0.1%) or combination of mancozeb (0.25%) and carbendazim (0.05%) and repeat at 10 to 14 days interval.
VIRAL/PHYTOPLASMA DISEASES:

Bell pepper mosaic complex:

Number of different viruses have been found to be associated with mosaic disease complex but main are PVY & CMV. The chlorosis starts from the leaf base progressing along the veins, followed by mosaic mottling, dark green vein banding, puckering and blistering. The infected plant remain stunted. Fruit in the infected plants remain small and deformed. Virus is not seed borne, however, it perenates on perennial peppers as well as on other solanaceous wild hosts. Aphid vectors and *Myzus persicae*, *A.crassivora*, *A.gossypii* and *A.fabae*.

Management:

- Pepper varieties like Punjab Lal, Perennial and Guhati Black are resistant to mosaic viruses belonging to Poty and Cucumovirus groups.
- Planting of maize as barrier crop is also helpful in reducing the mosaic incidence.
- Combined use of yellow traps and insecticidal sprays reduces the population of vectors.

Peas Diseases & its management

Ascochyta Blight

Blight symptoms caused by the three different Ascochyta species *Ascochyta pinodes*, *Ascochyta pisi* and *Ascochyta pinodella*. Early symptoms are most commonly observed under the plant canopy, on lower leaves, stems, and tendrils, where conditions are more humid. Symptoms first appear as small, purplish-brown, irregular flecks. Under continued humid conditions, the flecks enlarge and coalesce, resulting in the lower leaves becoming completely blighted. Severe infections may lead to girdling of the stem near the soil line, which is known as foot rot. Foot rot lesions are purplish-black in colour and may extend above and below the soil line. Foot and stem lesions girdle and weaken the stem, leading to crop lodging and yield loss. Disease lesions develop on pods under prolonged moist conditions or if the crop has lodged. Pod lesions are initially small and dark, but may become extensive and lead to early pod senescence. Severe pod infection may result in small, shrunken or discoloured seed; or alternatively, seed may show no symptoms.
Ascochyta fungi overwinter in seed, soil or infested crop residue. Infested crop residue is the primary source of infection in the main pea production regions. Ascochyta blight is favoured by wet weather, particularly frequent showers. The optimal temperature for infection and lesion development is around 20°C. If the canopy remains dense and wet into the flowering stage, lesions will continue to develop on lower leaves and stems. In the absence of rain, both spore dispersal and lesion growth will be slowed or completely arrested.

**Management**

- Use disease free seeds.
- Disease free seeds can only be produced if the crop is raised in low rainfall areas.
- The soil borne inoculum can be reduced by following long crop rotations and by destruction of the crop refuse by burning either in the field or after threshing.
- Use resistant sources, if available.
- Seed dressing with microbial cultures of *Trichoderma koningii* and *Gliocladium roseum* (4 g/kg seed) was also found effective in protecting the crop against *A. pisi*.
- Treat the seed with fungicides namely carbendazim (0.2%), benomyl (0.1%), thiabendazole (0.1%) + thiram (0.3%) and captan (0.3%).
- With the initiation of the disease spray the crop with fungicides like chlorothalonil (0.2%), carbendazim (0.05%) or combination of both and repeat at 10 days interval.

**Bacterial blight** (*Pseudomonas syringae pv. pisi, P. syringae pv. Syringeae*)

Affects all above ground plant parts. Produces water soaked spots which later become darker and finally necrotic. Mainly seed borne. Disease spread through splashes (overhead irrigation, rains).

**Management**

- Use of clean and disease free seed and resistant variety
- Seed should be procured from arid area
- Soak the seed for two hours in streptocycline solution (250 ppm) before sowing
- Avoid overhead irrigation
- Spray copper oxychloride @0.25% during the disease development period at 7-10 days interval
Powdery mildew (*Erysiphe pisi*)

Formation of white powdery patches on leaves, stems and pods and these white patches soon join together to form larger whitish floury areas. These patches then turn light brown and finally dark brown in colour and later become necrotic. The pathogen perenates through leguminous weeds and flowers viz., *Pisum*, *Melilotus indica*, *Vicia faba*, *Lens*, *Vetches* and perennial tree *Robinia pseudoacacia*. Also survive as perithecia on infected plant debris (dry temperate area). Disease is favoured by dry and high temperature (more than 20°C).

Management

1. Cultural practices like sprinkler irrigation and early sowing
2. Foliar spray of fungicides viz., Sulfex @0.3 % or with Karathane, Bayleton, Topas, Score and Contaf each @ 0.05% at periodic interval of 7-10 days

Diseases of Cole crops

This vegetable group constitutes crops like cauliflower, cabbage, broccoli, red cabbage and knol-khol etc. These crops are grown throughout the country and are attacked by number of diseases which not only reduce the quantity but also quality of the produce. The major diseases, which are of common occurrence, are described in detail as under:

Sclerotinia rot

The symptoms of the disease start appearing with the earthing up of plants. The infection starts from the lower most leaf petiole touching the ground. The infected leaves lose their turgor during day time and droop down to the ground, but regain turgidity during night or early morning. The yellowing starts from tips of the older leaves downwards which shed, prematurely. In most of the cases, mid-rib and petioles at a point touching the soil, show small, discrete to large irregular dark brown to black necrotic lesions. The lesions are covered with fluffy growth of extrametrical fungus under cool and humid weather. Rotting from petioles advances to the stalk where dark brown to black spots are produced which girdling whole of the stem at ground level. The stalk rot progresses towards the curd and occasionally whole of the pith portion up to the forks of curd branching get completely rotten. The pith and the curd also rot, giving way to large cavities lined inside with fluffy mycelium and numerous sclerotia of the causal fungus. Under cool humid conditions, the mycelium emerges out and can be
seen sticking to affected portion of the plant. With the progress of the disease, curds are also affected and show brown to dark brown rotting which may start from any portion of the curd, but generally from the center. The affected tissue becomes soft and mushy bearing numerous sclerotia.

Inflorescence is also affected during the months of April-May in hilly areas. If there are plenty of rains during bolting and seed setting, the fungus progresses fast and engulfs whole of the branches and inflorescence where mycelium can be seen hanging out with sclerotia sticking to it. However, if the weather is dry, the mycelial growth is restricted only up to branches. affected branches become dry and bear shriveled seeds.

The disease is caused by *Sclerotinia sclerotiorum* (Lib.) de Bary. The fungus overwinters in the form of sclerotia in soil as well as in the diseased plant debris. In the presence of proper humidity and light conditions, sclerotia germinate by forming apothecia, which in turn form asci and ascospores. If the spores, upon escaping from the ascus, lodge on a susceptible host, a new infection may originate. Mycelium from sclerotia is also capable of infecting cauliflower. During cool and moist weather fluffy mycelium appears on the host surface and when food is exhausted, the mycelium coagulates and starts forming sclerotia. The fungus can infect the host at a temperature ranging from 0 to 25 °C with an optimum at 15 to 20 °C and high humidity (95-100%) also favours the disease development. Application of nitrogen aggravates the disease.

**Management:**

- Follow long crop rotations with paddy and maize.
- Remove infected leaves at weekly intervals.
- Soil amendment with oil cakes like sunflower and mustard and mulching with pine needles and sunflower inflorescence also reduces the disease incidence.
- Some antagonistic fungi like *Trichoderma harzianum*, *T. viride*, *Gliocladium virens* and *Coniothyrium mimitans* have been found promising in managing this disease.
- These fungi either inhibit the development of new sclerotia or destroy the developed ones by colonizing them.
- In chemical control, sprays of fungicides like carbendazim (0.1%) or thiophenate methyl (0.1%) or mancozeb (0.25%) or combination of mancozeb (0.25%) and carbendazim (0.05%) effective in reducing the disease.
- Initiate sprays immediately after earthing up and repeat at fortnightly intervals.
**BLACK ROT**

Initial symptoms of the disease appear as chlorotic lesions along the margins of leaves which progress in the direction of midrib forming “V”-shaped lesions. The veins and veinlets in the chlorotic area turn black and with the passage of time, the blackening of veins advances to the stem and from there to other leaves and roots. The stem and stalk of infected leaves show blackening of vascular tissues. Due to the systemic infection, black spots appear on flower stalk and siliques.

The heads of cabbage and curds of cauliflower are also invaded and become discoloured. The roots of radish and turnip are also invaded from leaves which show discolouration and internal breakdown.

The disease is caused by *Xanthomonas campestris* pv. *campestris* (Pammel) Dowson. The pathogen survives in infected seeds, diseased plant debris and on cruciferous weeds. The optimum temperature for the disease development is about 26.5 to 30°C, minimum being 5°C and maximum 36°C. Heavy rains have been reported to be responsible for the fast spread of the pathogen and the disease through splashes.

**Management:**

- Follow crop rotation with non-cruciferous crops for at least two years.
- Use disease free seeds and treat them either with hot water (52°C) for 30 minutes followed by same duration dip in Streptocycline solution (100 ppm) or by dipping the seeds in Streptocycline (100 ppm) solution for 30 minutes to eradicate the pathogen.
- In disease prone areas, apply grass or pine needle mulch on the field floor.
- With the initiation of the disease, give fortnightly sprays of combination of Streptocycline (100 ppm) and copper oxyxhloride(0.3%).

**References:**


Integrated Disease Management of Vegetable Crops

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Integrated disease management (IDM) as applied to diseases of vegetable crops means using all the tactics available to the grower (cultural, biological, host-plant resistance, chemical) that provides acceptable yield and quality at the least cost and is compatible with the environmental variations. The five components of an IPM program are prevention, monitoring, correct disease and pest diagnosis, development and use of acceptable thresholds and optimum selection of management tools. The management strategies include genetic control, cultural control, biological control and chemical control. Choice of management strategy depends in part on the particular pathogen. Diseases are mostly controlled by host-plant resistance, cultural practices and chemicals.

For a successful disease management program, one must start with the selection of appropriate varieties, an irrigation system that minimizes leaf wetness, a fertilizer program that results in optimum plant growth, bed preparation, plant density and canopy management that affords optimum air circulation and pesticide coverage when needed, a transplant program which minimizes transplant shock, a clean seedling production program, effective pest monitoring during the season and finally, a harvest and shipping procedure which maximizes shelf life and produce quality. For disease management, it is important to understand the potential of a pathogen to infest and spread in the crop. The three parameters of disease progress are the initial amount of inoculum, the rate of disease increase and the time the crop is grown. These parameters interact in ways to produce a rapid pathogen population increase, manifested as exponential growth in many production systems.

Understanding the biology of the pathogen, host-pathogen interactions and effect of environmental factors on this dynamic process in time and space, is critical for planning and implementing effective and efficient management strategies. These strategies can affect particular aspects of the growth of the pathogen population.
Accurate Diagnosis of Diseases

Proper disease identification is critical for making correct disease management decisions. This will save time, money, and the environment. Effective use of fungicides and other pesticides depends on correct identification of the problem. The accuracy of any diagnosis depends upon the information supplied, the specimen material selected, and the condition of the specimen when it arrives at a clinic. Digital images of the fresh specimen with symptoms and field-view images of the problem might be useful in some cases.

In order to apply disease management practices, there should be knowledge of which pathogens are present or are likely to appear in a particular field or season. Descriptive and pictorial manuals are helpful for identification of diseases. It is important to know the common diseases of a given crop specific to particular area.

Monitoring Pathogens

Monitoring is a critical component of an effective IDM program. Monitoring can be direct (looking for the pathogen or disease) or indirect (recording environmental conditions which affect disease development). Disease distribution within a field is dependent, in large part, on the source of inoculum for the pathogen. If the disease is seed-borne, in many cases the first diseased plants will be more uniformly distributed in the field. If the disease is soil-borne, it may often be found in clusters in the field. If it is transmitted by insects, the distribution may be more random, or a field edge effect may be apparent. Thus, it is important to understand the biology of the disease when developing an appropriate sampling strategy for it.

Prevention and Management Methods

I. Cultural management

i) Infected host eradication

Certain pathogens of annual crops e.g. cucumber mosaic virus overwinters only or mainly in perennial wild plants. Eradication of host in which the pathogen overwinters is sometimes enough to eliminate completely or to reduce drastically the amount of inoculum that can cause infection the following season. It is routinely carried out in nurseries, greenhouses, and fields.
ii) **Crop rotation**

Soil borne pathogens that infect plants of one or few species or even families of plants can sometimes be reduced in the soil by planting non-host crops for 3 or 4 years. In this case, crop rotation can reduce population of pathogen (e.g. *Verticillium*).

iii) **Sanitation**

Sanitation consists of all activities aimed at eliminating or reducing the amount of inoculum present in a plant, field or a warehouse and at preventing the spread of the pathogen to other healthy plants and plant products. Thus, ploughing under infected plants after harvest, such as leftover infected fruit, tubers or leaves, helps cover the inoculum with soil and speed up its disintegration and concurrent destruction of most pathogens carried in or on them.

iv) **Creating conditions unfavourable for the pathogen**

In the production of many crops, particularly containerized stock, using decomposed tree bark in the planting medium has resulted in the successful control of diseases caused by several soil-borne pathogens, e.g. *Phytophthora*, *Phytophthora*, and *Rhizoctonia* causing damping off and crown rot, *Fusarium* causing wilt and nematode diseases of several vegetable crops.

v) **Use of pathogen free material/seeds**

Seed may carry internally one or a few fungi such as those causing anthracnose and smuts, certain bacteria causing bacterial wilts, spots and blights and certain viruses (bean common mosaic virus, lettuce mosaic and squash mosaic).

II. **Physical management**

The physical agents used most commonly in controlling plant diseases are temperature (high or low), dry air, unfavourable light wave lengths and the various types of radiations. With some crops, cultivation in glass or plastic green houses provides physical barriers to pathogens and their vectors and in that way protects the crop from some diseases.

i) **Soil sterilization by heat**

Soil can be sterilized in green houses, and sometimes in seed beds and cold frames, by the heat carried in live or aerated steam or hot water. The soil
is steam sterilized either in special containers (soil sterilizers), into which steam is supplied under pressure, or on the greenhouse benches, in which case steam is piped into and is allowed to diffuse through the soil. At about 50ºC, nematodes, some oomycetes and other water moulds are killed whereas most plant pathogenic fungi and bacteria, along with some worms, slugs, centipedes, are usually killed at temperatures between 60 and 72ºC.

**ii) Soil solarization:**

When clear polythene sheet is placed over moist soil during sunny summer days, the temperature at the top 5 cm of soil may reach as high as 52ºC compare to a maximum of 37ºC in unmulched soil. If sunny weather continues for several days or weeks, the increased soil temperature from solar heat, known as solarization, inactivates or kills many soil borne pathogens, viz., fungi, nematodes, and bacteria near soil surface, thereby reducing the inoculum and the potential for disease.

**iii) Hot water treatment of propagating organs:**

Hot water treatment of certain seeds, bulbs, and nursery stock is used to kill any pathogens with which they are infected or which may be present in seed coats, bulbs, scales, and so on, or which may be present in external surfaces or wounds. In some diseases, seed treatment with hot water was for many years the only means of control, as in the loose smut of cereals, in which the fungus overwinters as mycelium inside the seed where it could not be reached by chemicals.

Treatment of cabbage and cauliflower seeds at 52º C has been recommended against black rot (*Xanthomonas campestris* pv. *campestris*) followed by streptocycline dip (100 ppm) for 30 minutes.

**iv) Hot air treatment of storage organs:**

Treatment of certain storage organs with warm air (curing) removes excess moisture from their surfaces and hastens the healing of wounds, thus preventing their infection by certain weak pathogens. For example, keeping sweet potato at 28- 32ºC for 2 weeks helps the wounds to heal and prevent the infection by *Rhizopus* and soft rotting bacteria.

**v) Disease control by refrigeration:**

Refrigeration is probably the most widely used and the most effective method of controlling post harvest diseases of fleshy plant products. Although
low temperature at or slightly above the freezing point do not kill any of the pathogen that may be on or in the plant tissues, they do inhibit or greatly retard the growth and activities of all such pathogens, thereby reducing the spread of existing infection and the initiation of new ones. Most perishable fruits and vegetables should be refrigerated as soon as possible after harvest, transported in refrigerated vehicles, and kept refrigerated until used by the consumer. Regular refrigeration of especially succulent fruits and vegetables is sometimes preceded by quick hydro cooling or air cooling of these products, aimed at removing the excess heat carried in them from the field as quickly as possible to prevent the development of any new and latent infections.

III. Biological management

Biological control of plant pathogens refers to the total or partial destruction of pathogen population by other organisms. It occurs routinely in nature but manipulations by human being have resulted in enhanced benefits. It is achieved by suppressive soils, reducing amount of inoculum through antagonistic microorganisms or by direct protection by biological control agents.

i) Suppressive soils

Many soil borne pathogens, such as *Fusarium oxysporum* (causing vascular wilts), *Pythium* spp. (causing damping-off) develop well and cause severe diseases in some soils, known as conducive soils, whereas they develop much less and cause much milder diseases in other soils, known as suppressive soils. Many kinds of antagonistic microorganisms have been found to increase in suppressive soils; most commonly, pathogen and disease suppression has been shown to be caused by fungi, such as *Trichoderma*, *Penicillium*, and *Sporidesmium*, or by bacteria belonging to the genera *Pseudomonas*, *Bacillus*, and *Streptomyces*.

ii) Reducing amount of inoculum through antagonistic microorganisms

a) Control of soil borne pathogens:

Several non-plant pathogenic oomycetes and fungi, including some chytridiomycetes and hyphomycetes, and some pseudomonad and actinomycetous bacteria infect the resting spores of several plant pathogenic fungi. Among the most common mycoparasitic fungi are *Trichoderma* sp., mainly *T. harzianum*. It parasitizes mycelia of *Rhizoctonia* and *Sclerotium*, and
inhibits the growth of many oomycetes such as *Pythium*, *Phytophthora*, and other fungi, e.g., *Fusarium*

b) **Control of aerial pathogens:**

Many fungi have been shown to antagonize and inhibit numerous fungal pathogens of aerial plant parts. For example, *Chaetomium globosum* and *Athelia bombacina* suppress *Venturia inaequalis* ascospore and conidia production in the fallen and growing leaves, respectively. *Tuberculina maxima* parasitizes the white pine blister rust fungus *Cronartium ribicola*; *Darluca filum*, and *Verticillium lecanii* parasitizes several rusts.

c) **Control through trap plants:**

If a few rows of rye, corn, or other tall plants are planted around a field of beans, peppers, or squash, many of the incoming aphids carrying viruses that attack the beans, peppers, and squash will stop and feed on the peripheral taller rows of rye or corn. Trap plants are also used against nematodes which are sedentary endo- or ecto-parasites. For example, *Crotalaria* plants trap the juveniles of root-knot nematodes.

d) **Control through antagonistic plants:**

Plants such as asparagus and marigold are antagonistic to nematodes because they release substances in the soil that are toxic to several plant parasitic nematodes.

IV. **Chemical management**

Chemical pesticides have been used generally in plant protection programmes to overcome the diseases caused by various pathogens. Normally, chemical treatments are aimed to eradicate the general inoculum before it comes in contact with the plant hosts. One of the important or common mean of controlling the plant diseases is through chemical compounds which are toxic to the pathogens. These chemicals inhibit the germination, growth and multiplication of the pathogen or are lethal to the pathogen. Depending upon the pathogens they affect, they may be classified as fungicides, bactericides, nematicides, viricides etc. Out of these, some chemicals are broad-spectrum and they are toxic to all pathogens. Most of the chemicals used in plant protection are foliar and are used on the aboveground parts of the plants. Some of them are soil disinfectants, and some are used as protectants on seed, tubers, culms etc. There are some of the chemicals
which are used for curing diseases and are called curative or chemotherapeutants.

V. Host resistance

Host-plant resistance can affect all three parameters by 1) reducing the amount of inoculum via resistance to particular strains of the pest, 2) by slowing the rate of pathogen buildup by reducing its reproductive capacity, and 3) by reducing the total period of exposure in short-season varieties.

Use of resistant varieties in crop cultivation provides undoubtedly the most cost-effective, logistically the easiest, and also the safest of all the methods used for disease control. Both from the economic point of view and the possible health hazards involved in some of the methods used for disease control, this can probably be termed as the “painless method”. This approach costs little to the farmer and is, therefore, suitable for the developing countries like India. Use of resistant varieties not only reduces environment pollution and eliminates hazards to human health, but also checks disease epidemics and thus helps to maintain the biological balance in the ecosystem.

For many diseases like the vascular wilts and those caused by viruses, which are difficult to control effectively by some other means, and others like cereal rusts, powdery mildews, and root rots, which do not appear to be economically practical to be controlled by other methods, the cultivation of resistant varieties provides probably the only means of producing acceptable yields without using toxic compounds. Several other kinds of fungal diseases and also many others caused by bacteria, nematodes, and viruses are best controlled by this approach.

Some examples of resistant varieties

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Disease</th>
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</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>Sun Seed 7711</td>
<td>Bacterial wilt</td>
</tr>
<tr>
<td>Capsicum</td>
<td>Solan Bharpur</td>
<td>Fruit rot and leaf blight</td>
</tr>
<tr>
<td>Chilli</td>
<td>Punjab Lal</td>
<td>Viruses</td>
</tr>
<tr>
<td>French bean</td>
<td>SVM-1</td>
<td>angular leaf spot</td>
</tr>
<tr>
<td>Cucumber</td>
<td>Poinsette</td>
<td>Powdery mildew</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>PSBK-1</td>
<td>Black rot</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>Pusa Shubhra</td>
<td>Alternaria leaf spots</td>
</tr>
<tr>
<td>Cabbage</td>
<td>Pusa Mukta</td>
<td>Black rot</td>
</tr>
<tr>
<td>Pea</td>
<td>Solan Nirog</td>
<td>Powdery mildew</td>
</tr>
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References:


New Approaches in Water Harvesting Technology for Vegetable Production

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Water is a precious natural resource without which no life can be sustained. It is an integral part of man’s environment and the extent to which it is abundant or scarce, clean or polluted, beneficial or destructive, determines to a very large degree, the extent and quality of life. Water is used for a number of purposes and by far, the largest quantity is used for raising crops. A far larger quantity is, however, wasted. Lack of good quality irrigation water for crop production and clean water for drinking would mean inadequate food, ill health, disease, drudgery and discomfort. The socio-economic status and prosperity of farmers are also linked with water availability. It is, therefore, essential to manage and conserve this precious and scarce resource and regulate its use to obtain maximum benefits.

The unprecedented increase in human population, urbanization, industrial activities, etc. is putting enormous stress on limited fresh water availability. Great strides have been made in agricultural production in the country, particularly in areas which have assured irrigation facilities. But 63% of the total cultivated area of 142 m ha is still rainfed. It has been estimated that even after exploiting full irrigation potential through conventional techniques, about 50% of the cultivated areas will continue to remain rainfed. All these facts lead us to realization that our strategy should be to conserve every drop of rainfall and augment water resources by adopting cheap, successful and environment friendly water harvesting techniques.

Rain water harvesting

Rain water harvesting is a process to capture the rain water, store that water above ground or recharge the underground water and use it later. In other words, it is the process of collection, storage and recycling of rain water for domestic, agricultural, industrial purposes, etc. The basic principle of rain water harvesting is to “catch the rain water where it is received”.

Rain is the primary source of all water. There are other sources viz. rivers, streams, springs, wells, lakes, ponds, etc., but all these are ultimately dependent on rainfall. Hence, proper conservation and management of
primary source will also regulate these secondary sources. Rain water harvesting is a broad term and it does not imply harvesting of water received directly from rain only, but also from all other secondary sources as these all draw water from rain and snow itself.

**Need of rain water harvesting and recharging**

- To overcome the inadequacy of water and meet ever increasing demand of water
- To reduce the surface runoff which chokes drains and avoid flooding of roads
- To augment the ground water and productivity of aquifer
- To improve the quality of ground water
- To mitigate the effects of drought and increase the agricultural production
- To improve ecology of the area by increasing the vegetation cover, etc.
- Annual rainwater harvesting potential

The total amount of water that is received in the form of rainfall over an area is called the rainwater endowment of that area. Out of this, the amount that can be effectively harvested annually from the roof tops of campuses/houses or catchment is called as annual rain water harvesting potential.

Annual water harvesting potential \( (\text{m}^3) \) = Annual rainfall \( (\text{m}) \) x collection efficiency x area \( (\text{m}^2) \)

The collection efficiency accounts for the fact that all the rainwater falling over an area cannot be effectively harvested, because of evaporation, spillage, etc. Factors like runoff coefficient for different surfaces and the first flush wastage are taken into account when estimating the collection efficiency. The same procedure can be applied to get the potential for any plot or rooftop area, using rainfall of that area. But, in India rainfall distribution is highly skewed and 80% of the annual rainfall is received during the monsoon period because of maximum recharging and storage and part of the rain water certainly lost as runoff. Hence, actual rain water harvesting potential is 30-40% of annual rainfall received over an area.

**Rain water harvesting is undertaken in two ways**

1. In situ rain water harvesting
2. Ex situ rain water harvesting
1. **In situ** rain water harvesting

Stopping the rain water from being wasted and conserving at the place where it is actually received to produce maximum benefits (catch the water where it is received). This practice is mostly used for meeting the water needs in agriculture and do not involve much expenditure and serves only the purpose of protective and life saving irrigations. Different practices of in situ water harvesting and conservation are tillage, application of mulches, land shaping treatments (land leveling, contour bunding, bench terracing, formation of ridges and furrows inter-row/interplot water harvesting), etc. Among these, mulching is most effective in moisture conservation, temperature moderation and weed control in vegetable production which has been described briefly as under.

**Mulching**

Mulching is the practice for in situ moisture conservation in dry regions by covering the soil surface with extraneous materials. Both grass and black colored plastic mulching are effective in vegetable crops. Effect of mulches in altering soil moisture status is attributed to reduction in evaporation losses and is more pronounced in low rainfall years. It depends upon thickness of mulch layer, soil type and prevailing weather conditions. Crop residue/grass/plastic mulching meet partial irrigation water requirements and save up to 25% irrigation water in fruit/vegetable/cereal crops and as much as 50% in some garden crops. Productivity of most of the fruit and vegetable crops is 20-25% higher under mulching. Mulching registers higher B: C ratio varying from 1.25-1.50 in fruit and vegetable crops.

**Micro-catchment water harvesting**

The flat land is converted into ridge-furrow system and crops are planted in furrows with the objectives of concentrating rainfall in planting area and root zone. Sowing of crops in furrows rather in flat beds helps in harvesting rain water, improves moisture conservation and enhances crop yields.

**Raised-sunken bed technology**

Cultivate high water requiring crops in sunken beds and low water requiring crops on raised beds. Beds are semi permanent in nature and do not require frequent expenditure on their maintenance. Raised beds are also suitable for operators with animal drawn implements.
2. **Ex situ** rain water harvesting

Collection and storage of rain water through various structures such as check dams, roof top water collection, dug out ponds/ storage tanks, nullahs bunding, gully control structures etc. in the vicinity or away from the place where rainfall has been actually received is termed as ex situ rain water harvesting. It is most important because of intermittent nature of runoff and critical time of its use for maximum benefits. Ex situ water harvesting and conservation techniques are location specific and mostly used to avoid large expenditure on water management for meeting domestic and agricultural needs. It makes water available for supplemental irrigations. The ex situ rain water harvesting is taken up on both micro and macro-catchment basis. In micro catchment system, water is collected from land adjacent to the growing area, roof tops, and roads while in macro catchment systems, large flows from rivers, nullahs, kuhls etc. are diverted or stored for supplemental irrigations.

Ex situ rain water harvesting may be undertaken by capturing runoff from:

- Roof tops
- Water springs, seasonal/perennial streams
- Catchments/Watersheds (Conserving water through watershed management)

**Rooftop rain water harvesting**

Rooftop rain water harvesting is defined as the technique through which rainwater is captured from the roof catchments and stored in a reservoir. Rain water available from rooftops of buildings, paved and unpaved areas oftenly goes waste. It can be harvested and utilized gainfully at the time of need for crop production. This approach requires connecting the outlet/ drop pipe from roof of the building to divert the rain water to either existing wells/tube wells/bore wells or specially designed structure. The rain water harvesting system needs to be designed in a way that it does not occupy large space for collection and recharge system.

The rooftop water harvesting system comprises of galvanized iron, aluminum, clay tiles, asbestos sheet or concrete roof as the catchments area, connected by down pipes to a storage tanks/ containers. Underground tank is preferred because it saves space, keeps water cool and checks evaporation losses. The roof top harvested water can be stored in reinforced cement concrete (RCC) tanks or low cost poly-lined ponds, ferro-cement tanks after
some preliminary filtering. Most often these are used for non-potable purposes.

**Rain water harvesting in farm pond** from water springs, seasonal/perennial streams

Rain water may be harvested in farm ponds and used as supplemental irrigation during the lean period. Water harvesting in relatively small ponds (100-200 m$^3$) is ideal for hill farmers who have small and fragmented land holdings. In addition, they do not require elaborate management skills and resources. Different types of farm ponds (shape size, mode of construction) may be constructed at a suitable location in the farm and lined against seepage losses. The ponds may be lined with polyethylene sheet (covered with soil or brick or round boulders etc. to protect it against UV sunlight), silpaulin sheet (UV resistant) bitumen, cement-concrete lining RCC, etc.

**Irrigation potential of ponds**

Ponds of 50-200 m$^3$ capacity are easily constructed on individual farmer basis which are sufficient for vegetable cultivation in about one kanal (400 m$^2$) area. A 100 m$^3$ capacity pond once filled can provide five irrigations through traditional systems each of 5 cm to one kanal area (400 m$^2$). The irrigation potential may be much higher if high-tech irrigation systems are to be used. The life of pond depends upon the longevity of plastic sheet. If pond is constructed with quality materials and workmanship and maintained properly, life of at least 20 years can be expected. The silpaulin sheet, if covered properly with bricks/stones, the expected life of pond may be much more.

**Efficient use of harvested water**

The first decision in rain water harvesting is the intended use of water. Water harvested in limited quantity should be judiciously utilized for raising high value fruit/vegetable/floriculture crops. The harvested water should be used for pre-sowing irrigation or as a life saving irrigation to crops. The irrigation through flooding should be avoided. The water productivity can be increased further if harvested water is used through efficient irrigation systems such drip/micro sprinklers. The productivity of water can be enhanced further if these techniques are integrated with poly house technology. Both these systems save up to 80% of irrigation water over traditional irrigation systems.
Water management in vegetable production

India receives 110 cm of rain annually which produces 400 million-hectare meter (ha-m) of fresh water. This is more than the global average of about 100 cm. But the distribution in time and space is erratic. Rains are confined to the four months of monsoon (90 cm) i.e. June-September in regions of North East India, West Coast and parts of Himachal Pradesh and hills of Uttar Pradesh. The variability result into floods and draughts each year in some parts of the country or the other. For a continuous growth the crop should be irrigated every forth – fifth day in cool seasons. When there is danger of frost, irrigation should be given more regularly, so that irrigations are necessary for obtaining a quick growth of the crop and obtaining more cuttings.

Most of the vegetable crops are shallow rooted, short duration and need assured supply of moisture for normal growth and development. Lack of water is the greatest single factor that lowers vegetable yield. Vegetables are composed of 80-95% of water and they have to produce the remaining 5-20% of their weight through photosynthesis. A plant usually absorbs several times more water than the amount incorporated in its cells. Most of it is lost through the stomata during transpiration.

Vegetable are perhaps the most irrigated crops anywhere in the world. When water is at a premium, vegetable out of all other crops usually get first priority. There are probably three main reasons for this:-

1. Vegetable crops with a few exceptions are usually shallow rooted with roots rarely extending below about 0.6 m.
2. The useful product is usually a leaf, stem, storage organ; fruit or seed sold on the basis of its fresh weight and appearance, attributes which are particularly sensitive to shortage of water.
3. Vegetable production is at higher cost, except in years, when there is a glut, a higher return enterprise.

Water Management is not a function of only crop characteristics, but also of rainfall, soil properties, evaporative demand, topography, depth of water table and quality of irrigation water. With this basic information in view, efficient water management practices for vegetable crop production need to be thoroughly worked out.
In terms of water requirement, vegetables can be classified as follows:

1. **High water use with shallow root system:** Cabbage, Chinese cabbage, cucumber and radish are shallow rooted crops and possess large leaf area and tender tissue, thus they require plenty of water.

2. **Economic water use with deep root system:** Melons, bitter gourd and other cucurbits are deep-rooted crops possess larger leaf area but with hairy lobed leaves to prevent excess transpiration, hence they are slightly tolerant to drought.

3. **Economic water use with shallow root system:** Allium vegetables and asparagus have small and waxy leaves that reduce transpiration. However, they also have poor root system with fewer root hairs for water uptake than most vegetables.

4. **Economical water use with moderate root system:** Solanaceous and root vegetables and legumes, which have less leaf area but with hairy leaves to reduce transpiration. They have a more vagarious root system than crucifers do but lower than that of cucurbits.

**How to irrigate vegetable crops for efficient water management**

Much attention is required for the efficient use of water. As water is becoming a scarce resource, there is a need to use it efficiently for getting economic returns. Efficient methods of irrigation are necessary. For higher vegetable production of better quality, timely application of water in proper quantity at proper intervals is absolutely essential. The important irrigation methods to be used are:

1. **Surface irrigation:** This includes
   1. Surface flooding
   2. Furrow irrigation

2. **Sub-surface irrigation**
3. **Sprinkler irrigation**
4. **Drip irrigation**

Among these, drip method is highly efficient for growing fruit and vegetable crops. The use of harvested water through surface flooding and furrow irrigation should be avoided as there is wastage of irrigation water and uneven distribution.

**Approaches for efficient water management in vegetable production:**

1. By improving irrigation and water use efficacies
2. By adopting optimum irrigation scheduling
3. Application of water actually needed by the crop, always avoid stagnation of water on soil as well as in the root zone
4. Add water through irrigation up to the point approaching the field capacity
5. By adopting water conservation techniques
6. Decide frequency and intensity of irrigation according to type of soil, rooting system (shallow or deep), seasons, kind and variety of crops
7. By adopting the cultivation of vegetable crop having short duration and less water requirement

The range of optimum soil moisture contents or soil water suction at 30 cm depth for scheduling of irrigation in vegetable crops is given Table 2.

**Table 1: Optimum soil moisture contents or soil water suction for scheduling of irrigation in vegetable crops**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Optimum soil moisture tension / per cent available moisture depletion</th>
<th>Soil depth for measurement (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brinjal</td>
<td>20-40% depletion</td>
<td>0-30</td>
</tr>
<tr>
<td>Cabbage</td>
<td>50% depletion</td>
<td>0-30</td>
</tr>
<tr>
<td>Capsicum</td>
<td>20-40% depletion</td>
<td>0-30</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>0.25-0.3 bar</td>
<td>0-15</td>
</tr>
<tr>
<td>Okra</td>
<td>0.5 bar</td>
<td>0-18</td>
</tr>
<tr>
<td>Onion</td>
<td>0.5-0.65 bar</td>
<td>0-10</td>
</tr>
<tr>
<td>Potato</td>
<td>0.3 bar</td>
<td>0-15</td>
</tr>
<tr>
<td>Radish</td>
<td>0.25 bar</td>
<td>0-18</td>
</tr>
<tr>
<td>Sugar-beet</td>
<td>0.20 bar</td>
<td>0-25</td>
</tr>
<tr>
<td>Tomato</td>
<td>40-50% depletion</td>
<td>0-30</td>
</tr>
<tr>
<td>Turnip</td>
<td>0.25 bar</td>
<td>0-18</td>
</tr>
</tbody>
</table>

**Table 2: Water saving and yield enhancement due to micro irrigation**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (q/ha)</th>
<th>Irrigation (cm)</th>
<th>WUE (q/ha/cm)</th>
<th>Adv. of micro-irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surface</td>
<td>Drip</td>
<td>Surface</td>
<td>Drip</td>
</tr>
<tr>
<td>Bittergourd</td>
<td>32.0</td>
<td>43.0</td>
<td>76.0</td>
<td>33.0</td>
</tr>
<tr>
<td>Brinjal</td>
<td>91.0</td>
<td>148.0</td>
<td>168.0</td>
<td>64.0</td>
</tr>
<tr>
<td>Broccoli</td>
<td>140.0</td>
<td>195.0</td>
<td>70.0</td>
<td>60.0</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>171.0</td>
<td>274.0</td>
<td>27.0</td>
<td>18.0</td>
</tr>
<tr>
<td>Chillies</td>
<td>42.3</td>
<td>60.9</td>
<td>109.0</td>
<td>41.7</td>
</tr>
<tr>
<td>Cucumber</td>
<td>155.0</td>
<td>225.0</td>
<td>54.0</td>
<td>24.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Okra</td>
<td>100.0</td>
<td>113.1</td>
<td>53.5</td>
<td>8.6</td>
</tr>
<tr>
<td>Onion</td>
<td>284.0</td>
<td>342.0</td>
<td>52.0</td>
<td>26.0</td>
</tr>
<tr>
<td>Potato</td>
<td>172.0</td>
<td>291.0</td>
<td>60.0</td>
<td>27.5</td>
</tr>
<tr>
<td>Radish</td>
<td>10.5</td>
<td>11.9</td>
<td>46.0</td>
<td>11.0</td>
</tr>
<tr>
<td>Tomato</td>
<td>61.8</td>
<td>88.7</td>
<td>49.8</td>
<td>10.7</td>
</tr>
</tbody>
</table>

Research data on application of irrigation (rain/stream/spring) water, saving in irrigation water and effect on crop yield and water use efficiency are presented in table 2. It shows that micro irrigation in comparison to surface irrigation method could save water ranging between 14 to 84% with enhancement in yield between 13 to 69% and water use efficiency varying 1.30 -15.20 q/ha-cm in different vegetable crops. The higher yield under micro irrigation system is attributed to the fact that during crop growth favorable soil moisture is maintained and the required volume of soil mass is wetted through irrigation water, which provides optimum environment for root growth and nutrient uptake.
Introduction

Crop management over the past four decades in India is driven by increasing use of external inputs. Fertilizers nutrients played a stellar role in improving crop productivity and production. During the period 1969-2010 food grain production more than doubled from about 98M. tons to 212 M. tons in 2001-02, while fertilizer nutrient use increased by > 12 times from 1.95 M. tons to more than 23 M. tons in 2007-08. Notwithstanding these impressive developments, food grain demand is estimated to increase to > 300 M. tons per annum by 2025 for which the country would require about 45 M. tons of fertilizer nutrients (ICAR, 2008). With no scope for further increase in net cultivated area (~142 M. ha), much of the desired increase in food grain production has to be attained through productivity enhancement of major crops like rice, wheat, maize (contribute > 80% to total food production) by 3.0 to 7.5% annually. Increasing genetic potential of genotypes, and more importantly improving use efficiency of resources and inputs like water, nutrients etc. through their efficient management involving conjunctive use of organic and inorganic sources and based on crop demand and location specificity are essential to economize input costs and improve factor productivity. The issue becomes more complex with increasing cropping intensity and cultivation of high yield potential cultures in view of the observed discouraging impacts of green revolution technologies on soil resource quality and its productivity.

The growing concern about impaired soil health, declining / decelerating productivity growth and decreasing factor productivity or efficiency of the nutrients compelling to use increasing levels of fertilizers during the last two decades has raised apprehensions on the productive capacity of the agricultural system. The response to fertilizers use has decreased from 17 kg grain / kg nutrient in 1951 to 5-6 kg grains now, which ideally should be in the range of 18-25 kg/kg nutrient. Data from farmers’ fields (1999 – 2003) showed cereals responding around 8-10 kg grain /kg fertilizer (average). Traditional practices of organic manuring and growing of soil fertility restoring crops have gradually declined while nutrient outflows
through crop production indicated an apparent negative balance of nearly 10 million tons at the national level, which is likely to increase to 16 million tons by 2012. The recovery efficiency of fertilizer nutrients is about 20-40, 15-20 and 40 -50% for N, P and K, respectively while for secondary and micronutrients it is substantially low ranging 5-12%. Major factors contributing to the low and declining crop responses to fertilizer nutrients are continuous nutrient mining from the soil due to imbalanced nutrient use (7:2.8:1 NPK) leading to depletion of some of the major, secondary and micro nutrients like N, K, S, Zn, Mn, Fe, B etc., decreasing use of organic nutrient sources such as FYM, compost and integration of green manures / grain legumes in the cropping systems and mismanagement of irrigation systems leading to serious soil degradation qualitatively. Such decline in soil fertility status (due to negative balance of nutrients) is likely to end with irreversible damage to the nutrient supply system if followed further and could impact production costs with serious environmental consequences. Loss of soil organic carbon has been the important factor for the fatigue in agricultural production which has led to increased atmospheric CO$_2$ from 280 to 365 ppm over the years. Indian pool of soil organic carbon is estimated to be 21 billion tons in the top 30cm soil and nearly 150 billion tons up to 150 cm soil depth. Technological options for soil C sequestration in India include INM, green manuring, mulch farming, conservation tillage, agro forestry / forestation, organic manuring, crop residue recycling and proper choice of cropping systems. The long-term fertilizer experiments in India have shown that balanced fertilization resulted in improved SOC status in the upper 42 cm soil by 8 t / ha at the rate of 0.25 t / ha / year. Current crop production systems are characterized by inadequate and imbalanced use of fertilizers; blanket fertilizer recommendations over large domains with least regard to the variability in soil fertility and productivity. Future gains in productivity and input use efficiency require soil and crop management technologies that are tailored to specific characteristics of individual farms or fields. Recent on farm research demonstrated existence of large field variability in terms of soil nutrient supply, nutrient use efficiency, crop responses etc. Managing this variability is a principal challenge for further increasing crop productivity of intensive rice crop systems. Adoption of precision technologies for more efficient use of resources and nutrients becomes more relevant in the current production scenario. Site specific integrated nutrient management (involving use of inorganic / organic sources) taking into consideration spatial and temporal soil variability, nutrient requirements of the crops and cropping systems, soil capacity to supply nutrients, utilization efficiency of the nutrient and productive capacity of the varieties under best crop management strategies with improved nutrient use efficiency and without deteriorating soil and environmental quality is the most ideal system that needs to be practiced to achieve the targeted goals.
Fertilizer Scenario

India is third largest fertilizer consumer (23 M. tons in 2007-08), though the consumption is highly variable spatially. Consumption ratio of primary plant nutrients (NPK) also shows large variability at district, state and regional levels. Over the time NPK ratio at the national level narrowed down from 8.9:2.2:1 in 1961/62 to 5.9:2.4:1 in 91/92 but after decontrol the ratio widened to 9.7:2.9:1 in 93/94 and currently it is around 6.9:2.6:1 (2003-04). The consumption of nutrients in the north zone is acutely skewed towards N in relation to K (103:32:5.3 kg NPK/ha) compared to south and east zone (60:26:19 and 49:16:11 kg NPK/ha, respectively) while at the state and district levels the problem is more serious. The total fertilizer used in India by five crops (rice, wheat, sugarcane, cotton, rapeseed mustard) account for 68%. On an average farmers applied 126 kg/ha of NPK to rice in 2001-02 in the ratio of 4.3:1.7:1 and 132 kg/ha in the ratio of 24:10:1. In irrigated areas it was about 165 kg/ha for paddy and 143 kg NPK/ha for wheat (96-98%).

Nutrient demands for crop production

Sustainable management involves replenishing of nutrients that are harvested with crops while taking into the consideration other net influxes of nutrients. Indian agriculture is operating at an estimated negative nutrient balance of 10 M. tons. Trends in nutrient use of 23 M tons in 2007-08 is expected to increase to 29.0 M tons (20.7 N, 6.8 P2O5 and 2.1 K2O M. tons) by 2025. However, at the estimated nutrient removal of 37.5 M. tons of NPK (11.9 N + 5.3 P2O5 + 20.3 K2O M. tons), the balance indicate an excess use of N and P2O5 and deficit use of nearly 18 M tons of K2O nutrients which would be alarming. To achieve the projected food grain demand of 300 M. tons by 2025, about 30 M. tons of NPK from various sources are required in addition to 15 M. t. for the commercial crops (total 45 M. t.).

Nutrient uptake by crops and cropping systems

Knowledge of nutrient removal under intensive cropping systems is important for developing future nutrient management strategies. Substantial variation occurs in the nutrient uptake by crops and cropping systems. Rice – Wheat - Cowpea fodder system removes about 270 kg N/ha, 150 kg P2O5/ha and 390 kg K2O/ha (total > 800 kg/ha). Annual removals of NPK could range from 440 - 815 kg/ha under high intensity cropping systems. Production of about 8-12 tons of grain/ha is associated with nutrient uptake of 140-330 kg N, 70-120 kg P2O5/ha and 200-390 kg K2O/ha which provides guidelines for framing nutrient management strategies. Needless to mention that the nutrient needs of individual crops in space and time vary considerably, while the efficiency of soil and applied fertilizer nutrients largely depend on the quality of crop management and farmer’s resources. Harnessing synergistic nutrient interactions operating at higher levels of crop productivity is vital for achieving high productivity targets. For e.g. rice yield could be raised from 4.3
to 6.0 t/ha by extra dose of potassium. Similarly the response ratios to K applications at graded level of N increased for each increment indicating positive N – K interaction. The responses to P application can also be increased with increasing supply of K while the efficiency of zinc increased with K applied @ 60 kg/ha by more than double from 500 kg/ha to nearly 1200 kg/ha. The nutrient requirement of the crops yielding 3.5 t/ha will be certainly be much less (52 N, 29 P\textsubscript{2}O\textsubscript{5} and 83 K\textsubscript{2}O and 20 kg S) than crops targeted to yield 9.5t/ha (218N, 71 P, 309 K and 80 S). Depending on nutrient removal and soil nutrient supply, the difference has to be supplied through fertilizer at the efficiency with which the fertilizer nutrient is absorbed by the crop as determined by the genotype and quality of crop management. Achieving high yield targets are possible only when correct amount of nutrients is supplied at the right time matching with the crops nutrient demand during the season. Efficient nutrient management strategy should aim at maximizing crop uptake of nutrients, utilize crop residues /manures, and adopt good crop management strategies while correcting specific nutrient limitations through use of mineral fertilizers.

**Nutrient use efficiency (NUE)**

The topic of nutrient use efficiency has recently gained more attention with rising fertilizer costs and continued concern over environmental impairment. Nutrient or fertilizer use efficiency can be viewed from different perspectives based on yield, recovery or removal. Among the most common expressions of efficiency is the recovery efficiency (RE) of fertilizer nutrient, defined as the percentage of fertilizer recovered in aboveground plant biomass during the growing season. Fertilizer utilization rate (crop recovery efficiency) under favourable conditions for N is about 50-70%, 10-25% for P (15% average), and 50-60% for K. It was also suggested that efficiency of P and K over time (multiple growing seasons) could also be taken into account for realistic estimate. Nutrients that build-up in soil such as P and K, can certainly be viewed over the long term, while N efficiency is viewed on the short term because of its transient nature. Where there is potential for building soil C reserves, long term N efficiency is appropriate because soil C balance also affects N balance’

**Reasons for low NUE:**

1. Nutrient losses – Erosion, leaching, runoff, volatilization, denitrification etc.
2. Soil fixation of nutrients – P in deficient, highly weathered acid soils (Ultisols and Oxisols), K in highly illitic clay soils and Zn in high clay and calcareous soils. Nutrient interactions - antagonistic interactions between P and Zn, Na and K, Mg and K, Ca and K, Ca and Fe etc.
3. Imbalanced fertilizer use - imbalanced use of a few straight fertilizers results in reduced availability of other nutrients there by reducing their use efficiency.
4. Soil related problems - acidity, salinity; alkalinity, calcareous, acid sulphate soils, poor drainage, texture etc. result in poor availability of nutrient elements.

5. Non-nutrient factors such as lodging, untimely planting, and pest/disease problems limit NUE.

**Strategies to improve NUE**

Judicious use of fertilizer through soil test based approach, fertilization based on nutrient balance (i.e. total Inputs - total outputs; mineral fertilizer, organic manure, atmospheric deposition, biological N fixation, irrigation, rice seedlings, wheat seeds and root biomass are the main sources of nutrient inputs, and nutrients removed through crop uptake, leaching and gaseous / erosion losses of fertilizer and soil nutrients are outputs), water management, selection of variety, crop rotations (nitrate catch crops, N fixing grain legumes, green manures, deep root crops etc), new forms of fertilizers (controlled release coated fertilizers, urease or nitrification inhibitors, incorporation of other essential nutrients, granulation, liquid and suspension forms, chelated forms), precision farming, Integrated nutrient management (INM/IPNS), use of microbial sources (bio fertilisers such as Azolla, Cyanobacteris, Azospirillum, Rhizobium, Azorhizobium, Acetobacter and other heterotrophic N2 fixing bacteria, leguminous green manures, phosphate solubilizing bacteria etc), demand driven nutrient application (especially for N chlorophyll meter / LCC based N application), conservation agriculture, fertigation, site-specific Nutrient Management (SSNM), computer based decision support systems etc.

**Soil Fertility:** It is defined as the inherent capacity of a soil to supply available nutrients to plants in an adequate amount and in suitable proportions to maintain growth and development. It is measure of nutrient status of soil which decides growth and yield of crop.

**Soil Productivity:**

Soil productivity means the crop producing capacity of a soil which is measured in terms of yield (bio-mass). Productivity is a very broad term and fertility is only one of the factors that determine the crop yields. Soil, climate, pests, disease, genetic potential of crop and man’s management are the main factors governing land productivity, as measured by the yield of crop. To be productive, soil must contain all the 13 essential nutrients required by the plants. The total quantity of nutrients is not only being sufficient but they should also be present in an easily “available” form and in “balanced” proportions. Over and above fertility, there are other factors deciding productivity.

“All the productive soils are fertile but not all fertile soils are productive”
METHODS FOR THE EVALUATION OF SOIL FERTILITY:

Several methods are commonly employed to assess the fertility status of a soil. These include:
1. Nutrient Deficiency Symptoms
2. Plant Analysis and Tissue testing
3. Growing higher plants and microorganisms
4. Soil Analysis, and
5. Isotopic Dilution Methods.

1. **Nutrient Deficiency Symptoms:** The deficiencies of nutrient elements in the plants may manifest themselves in the form of complete crop failure at the seedling stage, severe stunting of plants, specific leaf symptoms, internal abnormalities, abnormal maturity etc. A careful observation of the growing plant may be helpful in identifying specific nutrient stresses. The identification of deficiency symptoms, however, requires a high level of expertise since the same type of symptoms could be produced by more than one nutrient, or may be associated with the toxicity or imbalance of the other nutrient. The symptoms may also be confused with the attack of insects, pests and diseases. Also, multiple deficiencies/toxicities may occur simultaneously. The plants sometimes are in need of a nutrient but do not express them in the form of symptoms (hidden hunger) or even the ideal symptoms developed under laboratory/controlled conditions may not be exactly similar under the field conditions. Thus, the Nutrient Deficiency symptoms are only an indicator of a deficiency but do not confirm these deficiencies because of the above mentioned constraints.

Certain plants are particularly sensitive to a nutrient deficiency and are the first to exhibit its deficiency with distinct symptoms. These plants are known as Indicator Plants:

<table>
<thead>
<tr>
<th>Element</th>
<th>Deficiency indicator plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Cauliflower, Cabbage</td>
</tr>
<tr>
<td>P</td>
<td>Rape seed</td>
</tr>
<tr>
<td>K</td>
<td>Potato</td>
</tr>
<tr>
<td>Ca</td>
<td>Cauliflower, Cabbage</td>
</tr>
<tr>
<td>Mg</td>
<td>Potato</td>
</tr>
<tr>
<td>Fe</td>
<td>Cauliflower, Cabbage, Potato</td>
</tr>
<tr>
<td>Na</td>
<td>Sugar beet</td>
</tr>
<tr>
<td>Mn</td>
<td>Sugarbeet, Oats, Potato</td>
</tr>
<tr>
<td>B</td>
<td>Sunflower</td>
</tr>
</tbody>
</table>
2. **Plant Analysis/ Tissue Testing:**

Plant analysis is based on the concept that if the content of a particular nutrient in the plant is greater than its availability in the soil, its availability in the soil is also more. Plant analysis is of two types: **A) Tissue Testing:** In this method, the plant parts are chopped and extracted with reagents. The plant parts are squeezed with pliers on a filter paper and treated with reagents. The intensity of color developed is compared with the standards and used as a measure of nutrient supply. It is a semi-quantitative type of analysis and only the unassimilated pool of the nutrients is estimated. **B) Leaf Analysis:** In this method, both assimilated and unassimilated pools of the nutrients are estimated by digesting the plant samples and estimating the nutrients by different methods. There is a basic relationship between the content of a plant nutrient and growth or yield of plant. **Plant Part and Time of Sampling:** In general, the conductive tissue of the latest mature leaf is used for testing. The most critical stage for plant sampling is at the time of bloom or from bloom to early fruiting stage. The plant part to be sampled and time of sampling, however, differ from crop to crop as per the standardized procedures.

**Interpretation of Plant Analysis:**

The most widely used method for interpretation of results is the **Critical Nutrient Concentration Approach.** It is the concentration that is just adequate for maximum growth or the level below which the growth and quality of the crop is unsatisfactory.
3. **Methods involving growing of higher plants and Microrganisms:**

These methods employ the basic principle of the growth of plants/ microorganisms in the presence of a particular nutrient element. The methods used are:

**A) Higher Plants:**

i) Mitscherlich Pot Culture Method

ii) Neubauer Seedling Method

**B) Microorganisms:**

i) Azotobacter Plaque Method

ii) Aspergillus niger Method

iii) Cunninghamella Plaque Method

4. **Soil Chemical Analysis:**

It is a chemical method for estimating the nutrient supplying capacity of a soil. It does not measure the total amount of nutrient in the soil. It is calibrated in field/ greenhouse nutrient rate studies to arrive at critical concentrations and subsequently used for fertilizer recommendations.

Some of the common extractants used for analysis of soils are:

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Extractant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available P</td>
<td>0.5 M NaH CO₃, pH 8.5 Olsen’s extractant 0.03 N NH₄F + 0.025 NHCl Bray’s No. 1 extratant</td>
</tr>
<tr>
<td>Available K</td>
<td>Neutral normal ammonium acetate</td>
</tr>
<tr>
<td>Available S</td>
<td>0.15 % CaCl₂</td>
</tr>
<tr>
<td>Available Zn, Fe, Cu, Mn</td>
<td>0.005 M DTPA, pH 7.3 Diethylene Triamine penta Acetate</td>
</tr>
<tr>
<td>Gypsum requirement</td>
<td>Schoonover method</td>
</tr>
<tr>
<td>Lime requirement</td>
<td>Shoemaker et al.</td>
</tr>
</tbody>
</table>

The data is then categorized into low, medium and high status according to the critical limits proposed,
### Rating Chart for soil test values

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Acidic</th>
<th>Neutral</th>
<th>Alkaline</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH&lt;sub&gt;w&lt;/sub&gt; (1:2.5)</td>
<td>&lt; 6.5</td>
<td>6.5 - 7.5</td>
<td>&gt; 7.5</td>
</tr>
<tr>
<td>EC (dSm&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>Normal</td>
<td>Critical</td>
<td>Injurious</td>
</tr>
<tr>
<td></td>
<td>&lt; 1.0</td>
<td>1.0 - 3.0</td>
<td>&gt; 3.0</td>
</tr>
<tr>
<td>Org. Carbon</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Avail N (kg/ha)</td>
<td>&lt; 280</td>
<td>280 - 560</td>
<td>&gt; 560</td>
</tr>
<tr>
<td>Avail P (kg/ha)</td>
<td>&lt; 22</td>
<td>22 - 45</td>
<td>&gt; 45</td>
</tr>
<tr>
<td>Avail K (kg/ha)</td>
<td>&lt; 120</td>
<td>120 - 280</td>
<td>&gt; 280</td>
</tr>
<tr>
<td>Avail S (SO&lt;sub&gt;4&lt;/sub&gt;²⁻ μg g⁻¹)</td>
<td>0-10</td>
<td>10-15</td>
<td>&gt;15</td>
</tr>
<tr>
<td>Critical limit for Micro Nutrients (μg g⁻¹ in soil) (rice) (DTPA extract)</td>
<td>Fe</td>
<td>Mn</td>
<td>Zn</td>
</tr>
<tr>
<td>Boron (μg g⁻¹ in soil) (HWS)</td>
<td>Deficiency</td>
<td>Toxicity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 0.50</td>
<td>&gt; 4.00</td>
<td></td>
</tr>
</tbody>
</table>

Based on the contents of available nutrients, soil test values (N,P,K), the soils are grouped into classes such as low, medium and high. In general, the greatest response can be obtained from the low class and the least response from the high class in soil test values.
Declining Soil Health – A Cause of Concern:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>3.19</td>
<td>1.27</td>
<td>-0.72</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>3.10</td>
<td>2.11</td>
<td>0.73</td>
<td></td>
</tr>
<tr>
<td>Pulses</td>
<td>1.61</td>
<td>0.96</td>
<td>-1.84</td>
<td></td>
</tr>
<tr>
<td>All Food grains</td>
<td>2.74</td>
<td>1.52</td>
<td>-0.69</td>
<td></td>
</tr>
<tr>
<td>Oilseeds</td>
<td>2.43</td>
<td>1.25</td>
<td>-3.83</td>
<td></td>
</tr>
<tr>
<td>Non-food grain</td>
<td>2.31</td>
<td>1.04</td>
<td>-1.02</td>
<td></td>
</tr>
</tbody>
</table>

Required Growth to achieve domestic demand by 2020:

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Domestic production 2006-07 (mt)</th>
<th>Growth rate during 1998-99 to 2006-07 (%)</th>
<th>Required growth rate over 2006-07 to meet the demand (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>201.9</td>
<td>0.62</td>
<td>1.9</td>
</tr>
<tr>
<td>Pulses</td>
<td>14.2</td>
<td>0.47</td>
<td>2.1</td>
</tr>
<tr>
<td>Foodgrains</td>
<td>216.1</td>
<td>0.61</td>
<td>1.9</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>23.6</td>
<td>1.96</td>
<td>6.0</td>
</tr>
<tr>
<td>Vegetable</td>
<td>111.8</td>
<td>3.68</td>
<td>0.9</td>
</tr>
<tr>
<td>Fruit</td>
<td>57.7</td>
<td>3.06</td>
<td>2.9</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>315.5</td>
<td>-0.60</td>
<td>0.6</td>
</tr>
</tbody>
</table>
Causes Of Declining Crop Productivity:

- Imbalanced and indiscriminate use of chemical fertilisers
- Occurrence of multi-nutrients deficiency such as Zinc, boron, sulphur etc. besides NPK
- Rain dependent agriculture - About 2/3 area
- Inadequate irrigation facilities
- Continuous fragmentation of land, unfavourable for adoption of technology
- Land holding pattern and Predominance of marginal and small farmers

Fertilizer Management in Vegetable Crops:

Based on the soil analysis values the fertilizer recommendations are made. As per the package of practices available for a crop the fertilizer scheduled have been devised which are applicable to the medium levels of NPK in the soil. For nutrient levels below or above the critical values, the fertilizer schedules are adjusted accordingly. Scientists have also developed Targeted Yield based fertilizer equations on Soil Test basis for Site Specific Nutrient Management.

Table: Fertilizer Schedules of Important vegetable Crops as per the Package of Practices of Dr. Y.S. Parmar University of Horticulture and Forestry, Solan(HP) - Kg/ Bigha

<table>
<thead>
<tr>
<th>CROP</th>
<th>FYM (Quintals)</th>
<th>CAN</th>
<th>SSP</th>
<th>MOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOMATO</td>
<td>20</td>
<td>32</td>
<td>38</td>
<td>7</td>
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<tr>
<td>T. HYBRID</td>
<td>20</td>
<td>48</td>
<td>60</td>
<td>7</td>
</tr>
<tr>
<td>CAPSICUM</td>
<td>16-20</td>
<td>32</td>
<td>40</td>
<td>7</td>
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<tr>
<td>BRINJAL</td>
<td>8</td>
<td>16</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>CHILLI AND LADYFINGER</td>
<td>20</td>
<td>24</td>
<td>38</td>
<td>7</td>
</tr>
<tr>
<td>FRENCHBEAN</td>
<td>16</td>
<td>16</td>
<td>50</td>
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<td>CUCUMBER</td>
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<td>GINGER</td>
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<td>32</td>
<td>25</td>
<td>6.5</td>
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<td>TURMERIC</td>
<td>16</td>
<td>10</td>
<td>15</td>
<td>8</td>
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<tr>
<td>PEAS</td>
<td>16</td>
<td>8</td>
<td>30</td>
<td>8</td>
</tr>
<tr>
<td>Item</td>
<td>N</td>
<td>P</td>
<td>K</td>
<td>Ca</td>
</tr>
<tr>
<td>---------------------------</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>CAULIFLOWER (M)</td>
<td>20</td>
<td>40</td>
<td>38</td>
<td>10</td>
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<tr>
<td>CAULIFLOWER (S)</td>
<td>8</td>
<td>48</td>
<td>50</td>
<td>7</td>
</tr>
<tr>
<td>CABBAGE(M)</td>
<td>16</td>
<td>40</td>
<td>50</td>
<td>7</td>
</tr>
<tr>
<td>CABBAGE (S)</td>
<td>16</td>
<td>40</td>
<td>50</td>
<td>7</td>
</tr>
<tr>
<td>CHINESE CABBAGE AND CELERY</td>
<td>16</td>
<td>32</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>RADISH</td>
<td>8</td>
<td>32</td>
<td>24</td>
<td>5</td>
</tr>
<tr>
<td>CARROT</td>
<td>8</td>
<td>16</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>ONION AND GARLIC</td>
<td>20</td>
<td>40</td>
<td>38</td>
<td>8</td>
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<tr>
<td>PALAK</td>
<td>8</td>
<td>24</td>
<td>25</td>
<td>4</td>
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<tr>
<td>METHI</td>
<td>8</td>
<td>10</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>BROCOLLII / LETTUCE</td>
<td>16/8</td>
<td>40/20</td>
<td>38/20</td>
<td>7/5</td>
</tr>
<tr>
<td>RED CABBAGE</td>
<td>12</td>
<td>38</td>
<td>25</td>
<td>4</td>
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<tr>
<td>ASPARAGUS</td>
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<tr>
<td>PARSLEY</td>
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<td>3.5</td>
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<tr>
<td>LEEK</td>
<td>20</td>
<td>50</td>
<td>30</td>
<td>15</td>
</tr>
</tbody>
</table>

**INTEGRATED NUTRIENT MANAGEMENT**

Since high external input based cropping system has also degraded the soil-water system, depleted soil organic matter/carbon (SOM/SOC) stocks and fertility of soils, these have also led to associated secondary problems viz. salinization and water logging in some canal-irrigated tracts of the country. Consequently, imbalanced fertilization, soil erosion and exclusion of organic sources coupled with overuse of acid forming N fertilizers especially urea compels the crop/cropping systems to exploit soils reserves for other nutrients, thereby creating multiple nutrient deficiencies. Therefore, there is an urgent need for appropriate crop nutrition a key component for higher yield realization and better quality -through integrated approach, called Integrated Nutrient Management (INM) or INM system for supplying crops the essential nutrients.
INM -the concept
The basic concept underlying the integrated nutrient management system (INMS), nevertheless, remains the maintenance and possible improvement of soil fertility for sustained crop productivity on long term-basis and also to reduce inorganic (fertilizer) input cost. The three main components of INMS as defined by FAO, 1998 are:

1. **Maintain or enhance soil productivity through a balanced use of fertilizers combined with organic and biological sources of plant nutrients**
2. **Improve the stock of plant nutrients in the soils**
3. **Improve the efficiency of plant nutrients, thus, limiting losses to the environment.**

Thus, integrated nutrient supply/management (INS) aims at maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of benefit from all possible sources of plant nutrients in an integrated manner.

Requirement of a crop for a nutrient is decided by the rooting behavior and its mining ability, the native soil status, the potential yields as decided by the soil-agroclimatic situations, the targeted yields and nutrient management.

Therefore, an INMS is the most efficient and practical way to mobilize all the available, accessible and affordable plant nutrient sources in order to optimize the productivity of the crops/cropping systems and economic return to the farmer. Three years data collected from 267 sites in India under different crops convincingly show a 22% increase in yield by following INM rather than farmer’s practice.

**Approach/components in INM**

There are various components of plant nutrients for INM which can be applied in an integrated way. Some of these are mentioned below:

i) Chemical fertilizers
ii) Organic manures like FYM in situ, Vermicompost
iii) Farm wastes like paddy straw, wheat straw
iv) Industrial waste
v) Inclusion of legume crops in cropping system
vi) Biofertilizers like azolla, blue green algae, rhizobium
vii) Crop residues
viii) Green manuring either growing in the same field or incorporating of leguminous plant or leaves.

**Balanced fertilization**

Improved crop nutrition aims at maintenance of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimization of various plant nutrients in an integrated manner. Balanced dose of N, P and K is usually applied to the soil in the ratio
of 2:1:1 or 3:1:1 (N:P₂O₅:K₂O). However, imbalanced one viz, high available N possibly shifts the balance between the vegetative and reproductive growth towards excessive vegetative development, thus delaying maturity, reducing yield & promote disease & insect damage. Thus, application of N as basal will have to be reduced under a successful pest’s prevention strategy since schedule and method of application of nutrients, have a lasting influence on the threshold population of pests.

Nitrogen, a growth nutrient is known to positively interact with irrigation, plant density, optimum sowing window, other nutrient elements especially P & K, absence of weeds/pests for higher growth and presence of organics in soil. Management of P & K, however, requires long term strategy for working out the required P & K inputs as biological and chemical transformations don’t add or deplete P & K from the rhizosphere easily. This (strategy) ensures adequate soil P & K supply so that the crop growth is not limited and NUE for N is not reduced.

Farm yard manure

Although the manure is the source of all nutrients, crop response is more evident in presence of fertilizers.

Besides improvement in yield and soil properties, soil microflora is also improved following FYM or INM practice. Significantly greater populations of actinomycetes, fungi, Rhizobia and bacteria in the INM plots compared to that in mineral fertilizer plots which may, in part, be attributed to higher moisture holding capacity and favourable environment under it. Better retention of squares and bolls because of improved soil nutritional status and moisture might be the causal factor for higher yields realization in INM plots.

Green manure

With the increase in usage of fertilizers and intensification of agriculture, alternative source of organics besides FYM like green manure (GM), crop residues/wastes etc. have been increased. Although N additions through GM is in the range of 30-40 kg ha⁻¹, yet this practice is not prevalent even in rainfed areas because of unavailability of sufficient soil moisture and no direct visual/economic benefits. Although a general trend of yield decline is noticed when a GM crop was grown in situ and incorporated as such because of immobilization factor yet yield increases were observed in many locations following its fortification/enrichment.

Crop residues

Usually stalks are poor for quality composting because of their high lignin content, wide C/N ratio, low nutrient especially N content causing N immobilization and often allelopathic effect on the applied crop. Therefore, crop residues need to be converted to bio-composts for its effective conversion and utilization by crop plants.
**Biofertilizers**

The principle involves in rendering unavailable sources of atmospheric N & bound phosphates in decomposed plant residues and other organics into available forms, thus, help enhance soil fertility and crop yields. Crop response to biofertilizers is positive, and there exists a potential to integrate biofertilizers with inorganic fertilizers. Apart from unreliable quality and poor availability in the market, their effects are not consistent as with the fertilizers explaining the reason for unpopularity of these amongst farmers.

For increased availability of P, PSB as soil application @ 5 kg ha-1 in combination with vermicompost (2 t ha-1) and rock phosphate in some crops has been found to be as good as supplying P through SSP. The cheaply available rock phosphate can therefore, be efficiently utilized and should be an incentive to reduce the costs. VAM (vesicular arbuscular mycorrhiza), an obligate symbiont, are also known to improve the availability of P and micronutrients. However, its use is limited because of unavailability in adequate amount and limitation in commercial production. Yet, integration of these biofertilizers has proved to be very useful in many cropping systems.

**Rotational crops**

More often ignored in an INM strategy, crop rotation is a very important tool in sustaining nutrient supply. Legumes in rotation restore soil fertility in more than one way viz, some of the N fixed is left in the soil after harvest, improvement in soil properties, lesser disease and pest problem and better weed control. Legumes rotation can fix atmospheric N to an extent of 135-488 kg ha-1. Therefore, legumes in a cropping system certainly provide a link towards INM.

**Fertilizer equivalents of INM components**

The fertilizer equivalent of different INM components varies in different agroecological regions based on crop response. On an average, 20 to 45 t of FYM or 16.6 t of GM were needed to produce 1 t of seed cotton ha-1 (Blaise, 2004). However, it differs a lot since crop response varies with varying nutrient content of manures, management practices and agro-ecological regions. Thus, its application in huge quantity is not regular due to its unavailability and non-remunerative nature which calls for an appropriate integration of several organic components along with mineral fertilizers for getting the best results.

**Nutrient recycling**

A better example of nutrient recycling in INM for sustainable farming involves application of a set of organic materials/complexes for higher production efficiency with lower nutrient loss from soil (nutrient recharge). Besides direct addition of N to the available soil pool, organics facilitates in the greater multiplication of soil microbes that could convert organically bound N to inorganic form there by help maintaining/restoring soil N status. Similarly, microbial decomposition of organics could form organic complexes.
with sesquioxides and thus, reducing the P fixing capacity of this soil. Moreover, enhancement in K availability is fortified following mineralization of organics and release of K to soil pool due to organic matter-clay interaction & reduction in K fixation. Thus, INM or IPNS has a tremendous role in soil nutrient recharging.

**Nutrient balance and its use efficiency**

The efficiency of fertilizer use (FUE) in a crop/cropping system would be further enhanced through GM, biofertilizers, nitrification inhibitors and even by splitting the fertilizer (mostly N & K) dose. As demonstrated in long term experiment under intensive cropping, the responses to a fixed dose of NPK also decrease with time unless the fertilizer application is balanced by adding other bulky organics in high doses to correct the imbalances.

**Some Other Soil Management Practices For Increased Water and Nutrient Use Efficiency:**

- **Use of Organic Manures/ Residues:** A regular input of organic residues in the farm manures and plant remains to maintain the level of humus, biological activity and plant nutrients. The manures/residues maintain a level of microbial activity sufficient to initiate the decay of organic materials and break down of non-soluble minerals into simple nutrients salts capable of being absorbed by the plant roots. They also create conditions conducive to continued activity of earthworms and other soil stabilizing agents, besides improvement and stabilization of soil structure by production of granular crusts, deep burrowing and incorporation and mixing of the organic matter.

- **Use of Mulches:** Helpful in minimizing water requirement through reducing evapotranspiration, in effective weed management. Mulches are also helpful in minimizing the soil erosion both during summer and rainy season and maintaining optimal temperature in the rhizosphere particularly during adverse weather conditions. Mulching by minimizing evapotranspiration is helpful in better establishment of plants particularly on problem affected lands. Plastic mulches have solarization effect and therefore effective particularly for nursery production. Continuous use of organic mulches over the years are helpful in improving organic matter content, earthworm population and also microbial fauna. Mulching also helps in restricting reflection of cosmic energies from cosmos.

- **Enhancing availability of organic manures:** Recycling and composting/vermi composting of urban, animal and agro industrial waste. About 57MT of urban solid waste is generated per annum with a potential to supply 8MT of good quality compost. The present availability is 383 mt against the moderate requirement of 900 mt / annum (@5 t / ha on gross cropped area of 185 mha).
Promoting Fortified and Coated Fertilizers: The fertilizers to be fortified and coated with micro and secondary nutrients to correct their deficiencies in soils – Zincated urea, boronated SSP & DAP etc

Promoting Fertigation and Water Soluble / Speciality Fertilizers: Fertigation increasing nutrient use efficiency by 40% should be popularized for fruits, vegetables, flowers and plantation crops. It holds a great promise as micro-irrigation is targeted to be expanded on 69 m ha in subsequent plan periods
Precision Farming and Hi-Tech Interventions in Horticultural Crops

R S Spehia
Precision Farming Development Centre
Department of Soil Science & Water Management
Dr Y S Parmar University of Horticulture and Forestry
Nauni 173230 Solan, Himachal Pradesh

In an era of open economy after WTO, it has become increasingly necessary that our produce is competitive, both in the domestic as well as international markets. This demands infusion of technology for an efficient utilization of resources for deriving higher output per unit of inputs with excellent quality of produce. This would be possible only through deployment of precision farming and hi-tech applications.

Precision farming involves the application of technologies and principles to manage spatial and temporal variability associated with all aspects of horticultural production for improving crop performance and environment quality. Precision farming calls for an efficient management of resources through location specific hi-tech interventions. Whereas, hi-tech horticulture is the deployment of modern technology which is capital intensive, less environment dependent, having capacity to improve the productivity and quality of produce. Hi-tech horticulture encompasses a variety of interventions such as micro irrigation, fertigation, protected cultivation, mulching for in-situ moisture conservation, micro propagation, soil less culture etc. Utilization of these interventions orchestrated together having the aim of achieving higher output in given time period leads to precision farming, which is largely knowledge driven.

Precision farming aims to improve crop performance and environment quality. Precision farming is one of the most scientific and modern approaches to sustainable agriculture that has gained momentum in 21st Century. Thus, the precision farming include:

- Variations occur in crop or soil properties within a field
- Theses variations are noted and often mapped
- Management actions are taken as a consequence of the spatial variability within a field

Though, the 20th century agriculture had been characterized by increase in land and labour productivity, the usage of eternal inputs, an increase inefficiency and efficacy of external inputs, it has also been associated with the stimulation of uniformity in agricultural production areas and the
negative side-effects of agriculture. The PF techniques, by appreciating the variability within field and adopting management practices to cater the variability, are serving the dual purpose of enhancing productivity and reducing ecological degradation. The real value from PF is that the farmer can perform more timely tillage, adjust seeding rates, fertilizer application according to soil conditions, plan more crop protection programmes with more precision, and know the yield variation within a field. These benefits can enhance the overall cost effectiveness of crop production, however, the grower must be willing to make adjustments in his management styles to work.

**Developments which prompted PF**

Many technological developments, which occurred in 20th century contributed to the development of the concept of PF were Global Navigation Satellite Systems (GNSS), GPS guided agricultural machinery, geographical information system and remote sensing.

**Constraints in adoption of PF**

PF, though in many cases is a proven technology, but still is restricted to developed countries. The reasons for limited implementation of PF in Asian countries are following:

- Small land holdings
- Cost/benefit aspect of PF
- Heterogeneity of cropping system
- Lack of local technical expertise
- Knowledge and technological gaps

**Economics feasibility of Precision Farming in India on agriculture condition**

- Precision farming is a system, not a single piece of equipment or technology. A GPS by itself has little value to farmer. However, when combined with a yield monitor or a variable rate technology (VRT), it may have value.
- Returns may be positive if costs can be spread over many applications. Specialized equipment, which has limited uses, has greater risks associated with it than equipment that has many uses. A multi-use tractor will likely pay for itself sooner than a new, single-use machine.
- Precision farming may not return on low-valued commodities as it does on high-valued specialty crops i.e. high revenue for vegetables than the wheat and paddy
Apart of these, the major problems for implementing PF in Indian scenario are small holdings and higher investments.

Hi-tech interventions

As PF through GIS etc is still a distant dream in India due to above stated constraints, hi-tech interventions can be used for getting desired results. Main interventions which are being/getting popularized are micro irrigation, in-situ moisture conservation and protected cultivation.

I. Micro Irrigation

Large amount of Water is lost through evaporation and run-off when irrigation is given through flood or surface irrigation. As farmers get their turn to irrigate the field after 10-15 days, they tend to completely fill their fields with water, completely unaware of the fact that the major quantity of water will be lost through evaporation, run-off and percolation before the plant takes it up. Considering all these factors, micro irrigation (drip and sprinkler irrigation) can be helpful in reducing the losses and other benefits.

a) Sprinkler irrigation

In the sprinkler method of irrigation, water is sprayed into the air and allowed to fall on the ground surface somewhat resembling rainfall. The spray is developed by the flow of water under pressure through small orifices or nozzles. The pressure is usually obtained by pumping. With careful selection of nozzle sizes, operating pressure and sprinkler spacing the amount of irrigation water required to refill the crop root zone can be applied nearly uniform at the rate to suit the infiltration rate of soil.

Advantages of sprinkler irrigation

- Elimination of the channels for conveyance, therefore no conveyance loss
- Suitable to all types of soil except heavy clay
- Suitable for irrigating crops where the plant population per unit area is very high. It is most suitable for oil seeds and other cereal and vegetable crops
- Water saving
- Closer control of water application convenient for giving light and frequent irrigation and higher water application efficiency
- Increase in yield
- Mobility of system
- May also be used for undulating area
- Saves land as no bunds etc. are required
- Influences greater conducive micro-climate
- Areas located at a higher elevation than the source can be irrigated
• Possibility of using soluble fertilizers and chemicals
• Less problem of clogging of sprinkler nozzles due to sediment laden water

**Types of Sprinkler Systems:**
On the basis of the arrangement for spraying irrigation water Sprinkler systems are of two major, types:
1. *Rotating head system:*
2. *Perforated pipe system:*

Based on portability, sprinkler systems are classified into the following types:
1. *Portable system:*
2. *Semi-portable system:*
3. *Semi-permanent system.*
5. *Permanent system*

A lot of work has been done in different parts of India showing response of crops to sprinkler irrigation in water saving and yield increase over conventional method of irrigation (Table 1).

Table 1. Response of different crops to sprinkler irrigation

<table>
<thead>
<tr>
<th>Crops</th>
<th>Water Saving, %</th>
<th>Yield increase, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bhindi</td>
<td>28</td>
<td>23</td>
</tr>
<tr>
<td>Cabbage</td>
<td>40</td>
<td>3</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>35</td>
<td>12</td>
</tr>
<tr>
<td>Chillies</td>
<td>33</td>
<td>24</td>
</tr>
<tr>
<td>Cowpea</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>Fenugreek</td>
<td>29</td>
<td>35</td>
</tr>
<tr>
<td>Garlic</td>
<td>28</td>
<td>6</td>
</tr>
<tr>
<td>Gram</td>
<td>69</td>
<td>57</td>
</tr>
<tr>
<td>Onion</td>
<td>33</td>
<td>23</td>
</tr>
<tr>
<td>Potato</td>
<td>46</td>
<td>4</td>
</tr>
<tr>
<td>Sunflower</td>
<td>33</td>
<td>20</td>
</tr>
</tbody>
</table>

Source: INCID (1998)

Just like any other system, sprinkler has certain Limitations also which are mentioned below:
• Requires high operation expenses due to the energy needed for pumping, labour and relatively large investment in equipment: sprinklers and pipes.
• Sensitivity to wind, causing evaporation losses.
• The unavoidable wetting of foliage in field crops results in increased sensitivity to diseases.
• Clean water is necessary in order to prevent clogging of the sprinkler nozzles.
• Some 20% additional water is needed in order to guarantee the net dosage for the entire field.
Drip Irrigation System

Drip irrigation is frequent application of water directly on or below the soil surface near the root zone of plants. It delivers required and measured quantity of water in relatively small amounts slowly to the individual or groups of plants. Water is applied as continuous drops, tiny streams, or fine spray through emitters placed along a low-pressure delivery system. Such system provides water precisely to plant root zones and maintains ideal moisture conditions for plant growths. The main advantages of drip irrigation systems are:

- Greater adaptability than sprinklers to irrigation doses and rates;
- Prevention of evaporation losses, resulting in more precise control over the moisture depth and thus more efficient utilization of the available water.
- Avoiding wetting the foliage reduces the incidence of diseases/pests.
- Wind has no effect, meaning irrigation is possible at all hours of day or night.
- Requires less energy than sprinklers.
- There is no dependence on the topography of the area.
- Facilitates application of fertilizers and pesticides, etc. to the soil via irrigation.
- Irrigation possible over long periods without ongoing labour inputs.
- Suitable for all types of crops at all stages of growth.

The available literature and the results obtained at Precision Farming Development Centres across India report that there is 50 to 70% saving in irrigation water and 18 to 152 % increase in yield of fruits and vegetable crops through drip irrigation (Table 2).

Table 2: Effect of drip irrigation on productivity and Water Use Efficiency of horticultural crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Increase in yield (%)</th>
<th>Yield (q/ha)</th>
<th>WUE (q/ha/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Surface</td>
<td>Drip</td>
</tr>
<tr>
<td>Tomato</td>
<td>20.0</td>
<td>364.3</td>
<td>437.8</td>
</tr>
<tr>
<td>Pea</td>
<td>40.0</td>
<td>121.6</td>
<td>170.3</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>46.0</td>
<td>167.13</td>
<td>244.49</td>
</tr>
<tr>
<td>Capsicum</td>
<td>37.0</td>
<td>100.09</td>
<td>136.17</td>
</tr>
</tbody>
</table>

Source: PFDC, Solan, 2011

Though, drip irrigation system is most effective and productive system of irrigation, still it some limitations like:

- Dripper systems are relatively expensive and require a certain level of professionalism to operate and supervise them.
- Drippers are highly susceptible to clogging and therefore require protective filtration, which is expensive, in terms of cash outlay, maintenance and energy.
• Dripper systems are not very mobile and are therefore more expensive as they are generally stationary for a given crop.
• The pipes in the system are highly susceptible to puncturing by farm machinery.

FERTIGATION
In addition to precise and required amount of water application, drip irrigation system can be used for fertigation. Fertigation is the technique of using soluble/liquid fertilizers to supply essential nutrients to crops through drip irrigation, sprinkler system. It is ideally suited to almost all the horticultural crops.

Advantages of fertigation, compared with application of solid fertilizers
• Savings in fertilizers, fuel, labour and equipment. Various research reports indicate that 25-50 per cent less fertilizers may be used with fertigation, compared with the use of solid fertilizers.
• More frequent applications are possible compared with solid top dressings, especially if an automatic system is used.
• Quick absorption of nutrients from fertilizers into plants.
• Less leaching of nutrients below root zone, when applied little and often
• Less burning of crops, as the fertilizers is applied in diluted form.
• Fertilizers may be applied in conditions which are too wet for tractor operations.
• Less mechanical damage to the crop, when applied via the irrigation system.

From the above written facts, it becomes imperative that drip irrigation be installed where ever possible to get the maximum benefits through conservation and efficient usage of water and fertilizers. In Himachal Pradesh, the use of micro irrigation systems is slowly picking up as most farmers are realizing the importance of efficient irrigation because of erratic behaviour of rains and as a result, reduction of discharge in streams and springs.
In the Precision Farming Development Centre of this department, research trials were conducted on fertigation in tomato and pea for which results are as below:

Table 3. Effect of fertigation on yield of tomato and pea

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (q/ha)</th>
<th>Increase in yield (%)</th>
<th>Saving in fertilizers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conventional</td>
<td>Fertigation</td>
<td>N</td>
</tr>
<tr>
<td>Tomato</td>
<td>389.27</td>
<td>468.32</td>
<td>20.0</td>
</tr>
<tr>
<td>Pea</td>
<td>115.88</td>
<td>162.13</td>
<td>40.0</td>
</tr>
</tbody>
</table>

III. In-situ Moisture Conservation through Plastic Mulch

In situ conservation of water means stopping it from being wasted and conserving at the place where it is received to produce the maximum benefit or collection and storage of rain water where it is received (catch where it falls).

In –situ moisture conservation is needed because:

- Quantity of water available from different sources such as surface water and ground water is insufficient even for drinking purposes
- Difficulty in tapping water from river, spring etc and high cost in carrying the water to the desired site/field
- High cost of installation and maintenance of irrigation schemes
- To increase the effectiveness of various farm inputs
- To enhance the productivity in rainfed agriculture on sustainable basis
- Under such circumstances, it has become imperative to conserve and use all available water resources effectively and efficiently on sustainable basis

As after irrigation, water is lost mainly through evaporation, in-situ moisture conservation through plastic mulch is very effective in:

- Increased soil temperature during winters
- Reduced soil compaction
- Reduced fertilizer leaching
- Reduced evaporation loss
- Increased water-use efficiency
- Cleaner product
- Reduced weed problems
- Earlier crops and Increased growth

Different plastic mulches like black, coloured and transparent polyethylene film are used depending upon the need. Like for mulching only black coloured polyethylene mulch (100 micron thickness for fruit crops, 25-50 micron for flowers and vegetables) is used; when the colour and other
qualities are to be increased, different colours of film can be tried. For soil solarization, transparent polyethylene film is used. In Precision Farming Development Centre, Solan lot of work has been done in plastic mulching alone (Table 4) and in conjunction with drip irrigation (Table 5).

**Table 4. Effect of mulching on per cent increase on yield**

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Crop</th>
<th>Increase in yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Plum</td>
<td>34.00</td>
</tr>
<tr>
<td>2.</td>
<td>Strawberry</td>
<td>55.00</td>
</tr>
<tr>
<td>3.</td>
<td>Capsicum</td>
<td>53.00</td>
</tr>
<tr>
<td>4.</td>
<td>Cabbage</td>
<td>13.60</td>
</tr>
<tr>
<td>5.</td>
<td>French bean</td>
<td>38.61</td>
</tr>
<tr>
<td>6.</td>
<td>Broccoli</td>
<td>19.76</td>
</tr>
</tbody>
</table>

**Table 5. Effect of mulch+ drip irrigation on increase in yield and per cent water saving**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Crop</th>
<th>Increase in yield (%)</th>
<th>Water saving (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Pea</td>
<td>75.80</td>
<td>32.25</td>
</tr>
<tr>
<td>2.</td>
<td>Tomato</td>
<td>94.5</td>
<td>118.80</td>
</tr>
<tr>
<td>3.</td>
<td>Peach</td>
<td>76.20</td>
<td>30.00</td>
</tr>
<tr>
<td>4.</td>
<td>Apricot</td>
<td>43.30</td>
<td>54.00</td>
</tr>
<tr>
<td>5.</td>
<td>Plum</td>
<td>33.9</td>
<td>58.8</td>
</tr>
<tr>
<td>6.</td>
<td>Strawberry</td>
<td>66.74</td>
<td>54.20</td>
</tr>
</tbody>
</table>

Plastic mulching helps in reducing the soil erosion considerably as it stops the splashing effect of rain as well as the run-off effect that occurs after torrential rains. It is also best for stopping the soil erosion and run-offs on the slopes (Table 6).
Table 6. Effect of different conservation practices on run-off, soil loss and yield of broccoli

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Run-off (mm)</th>
<th>Soil loss (t/ha)</th>
<th>Yield (q/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservation tillage</td>
<td>158.3</td>
<td>7.32</td>
<td>187.1</td>
</tr>
<tr>
<td>Conventional tillage (CT)</td>
<td>193.7</td>
<td>8.19</td>
<td>180.7</td>
</tr>
<tr>
<td>CT+Black plastic mulch</td>
<td>56.6</td>
<td>0.54</td>
<td>216.5</td>
</tr>
<tr>
<td>CT+Bi-coloured mulch</td>
<td>56.6</td>
<td>0.54</td>
<td>213</td>
</tr>
<tr>
<td>CT+Grass mulch</td>
<td>59.4</td>
<td>0.57</td>
<td>209</td>
</tr>
</tbody>
</table>

Source: Spechia et al, 2008

IV. PROTECTED CULTIVATION

Protected cultivation is one more such plasticulture application, wherein crops are grown in polyhouse/poly tunnels/shade net house etc. and the soil is protected from erosion as well as water is used in minimal quantity and judiciously. Protected cultivation helps in producing good quality crops all through the year without having any negative effects of the weather on the crop. The yields are increased many fold and the farmer gets good remunerative. The main advantages of protected cultivation are:

- Quality control
- Control over the growing environment
- Potential to better manage diseases and pests
- Reduced water use
- Year round supply of high value produce to markets increasing economic returns
- More predictable yield and quality
- Reduced environmental risks
- No chemical drift from within polyhouse to neighbours polyhouse/field
- Hybrid seed production and Maintenance and multiplication of self incompatible line for hybrid seed production

All these plasticulture applications are highly beneficial in increased production, quality crops, fertilizer saving, cost cuttings of inputs etc. and thereby increasing the economic prospects of the farmers.

V. HYDROPONICS

Horticultural production in most parts of the tropics is extremely difficult due to high rate of infection by the soil-borne diseases. At the moment, utilization of hydroponics systems for the commercial production of
crops is very limited. Although hydroponics is possible for most plant species, a limiting factor is the amount of physical support required. There are several different types of hydroponics system, but all share the same basic method of supplying the plants with nutrients and water. Hydroponics is perhaps the most intensive method of crop production in today’s agricultural industry. It uses advanced technology, is highly productive, conserves water and land, protects the environment and is often capital intensive. Since regulating the aerial and root environment is a major concern in such agricultural systems, production takes place inside enclosures that give control of air and root temperature, light, water, plant nutrition and protection against adverse climatic conditions. Hydroponics offers opportunities to provide optimal conditions for plant growth and therefore, higher yields can be obtained using it compared to open field production. It offers a means of control over soil borne diseases and pests, which is especially desirable in the tropics where the life cycles of these organisms continue uninterrupted and so do the threat of infestation. Thus, the costly and time-consuming tasks of soil sterilization, soil amelioration etc. can be avoided with hydroponics cultivation. Under hydroponics, some plants can be grown closer together than in the field because roots are directly fed. Plants grow faster because they get all the nutrients they need in the proper amounts and proportions. In soil, plants develop a large root system to enable them search for nutrients and water. In hydroponics, nutrients and water are provided directly to the roots. This enables the plants to achieve higher growth of the shoot system, producing more vegetation, larger fruits, flowers and other edible parts. Plants in hydroponics grow up to two times faster with higher yields than with conventional soil farming methods due to high oxygen levels to the root system, optimum pH levels for increased nutrient and water uptake and optimum balanced and high grade nutrient solutions. In addition, a 90% reduction in water use by applying hydroponics culture can be obtained as the same water is used continuously. A study is under progress in the Department of Soil Science & Water management, Dr Y S Parmar University of Horticulture and Forestry, Solan. The initial findings are as under:

Table 7 : Growth, Yield and Mineral Contents of Lettuce Grown under hydroponics (Nutrient Film Technique), Polyhouse and field conditions.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Hydroponics</th>
<th>Polyhouse</th>
<th>Field conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of leaves</td>
<td>27.49</td>
<td>23.38</td>
<td>21.32</td>
</tr>
<tr>
<td>Leaf area (cm²)</td>
<td>2137.89</td>
<td>1753.99</td>
<td>1606.78</td>
</tr>
<tr>
<td>Days to marketable maturity</td>
<td>45.82</td>
<td>69.78</td>
<td>80.78</td>
</tr>
</tbody>
</table>

265
<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yield (kg/m²)</strong></td>
<td>4.25</td>
<td>2.47</td>
<td>2.08</td>
</tr>
<tr>
<td><strong>Carbohydrate content in</strong></td>
<td><strong>leaves/10g</strong></td>
<td><strong>leaves/10g</strong></td>
<td><strong>leaves/10g</strong></td>
</tr>
<tr>
<td></td>
<td>2.56</td>
<td>1.92</td>
<td>1.59</td>
</tr>
<tr>
<td><strong>Carbohydrate content in</strong></td>
<td><strong>roots/10g</strong></td>
<td><strong>roots/10g</strong></td>
<td><strong>roots/10g</strong></td>
</tr>
<tr>
<td></td>
<td>0.71</td>
<td>0.49</td>
<td>0.38</td>
</tr>
<tr>
<td><strong>Protein content in</strong></td>
<td><strong>leaves/10g</strong></td>
<td><strong>leaves/10g</strong></td>
<td><strong>leaves/10g</strong></td>
</tr>
<tr>
<td></td>
<td>1.35</td>
<td>1.18</td>
<td>1.12</td>
</tr>
<tr>
<td><strong>Protein content in</strong></td>
<td><strong>roots/10g</strong></td>
<td><strong>roots/10g</strong></td>
<td><strong>roots/10g</strong></td>
</tr>
<tr>
<td></td>
<td>0.56</td>
<td>0.40</td>
<td>0.35</td>
</tr>
<tr>
<td><strong>Nitrogen (%)</strong></td>
<td>5.67</td>
<td>3.16</td>
<td>3.01</td>
</tr>
<tr>
<td><strong>Phosphorus (%)</strong></td>
<td>0.59</td>
<td>0.32</td>
<td>0.29</td>
</tr>
<tr>
<td><strong>Potassium (%)</strong></td>
<td>4.99</td>
<td>3.02</td>
<td>2.88</td>
</tr>
<tr>
<td><strong>Calcium (%)</strong></td>
<td>2.89</td>
<td>1.78</td>
<td>1.67</td>
</tr>
<tr>
<td><strong>Magnesium (%)</strong></td>
<td>0.85</td>
<td>0.52</td>
<td>0.48</td>
</tr>
<tr>
<td><strong>Iron content (mg/100g)</strong></td>
<td>1.38</td>
<td>1.17</td>
<td>1.12</td>
</tr>
</tbody>
</table>

Spehia and Meera Thakur, 2016.

Lettuce under hydroponic system  Healthy roots are sign of proper growth
**Conclusion**

As in the US, and Europe the development and adoption of precision agriculture in India is a slow process. The small size of farms and fields in most of Indian agriculture limits economic gains from currently available precision farming technology, while the population density, and public concerns for the environment, food safety and animal welfare means that those potential benefits of precision agriculture are being given more attention. Still, there are other hi-tech horticulture interventions such as micro irrigation, in-situ moisture conservation, protected cultivation, micro propagation, high density planting, soil less culture etc. which are being employed for precision farming for increasing production and quality of vegetable crops. In addition, hydroponic system can very well be used in urban areas where land is scarce and difficult to find for agricultural purpose.

**References:**


Recent Approaches in Postharvest Management of Vegetable Crops

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Department of Food Science & Technology
Dr YS Parmar University of Horticulture and Forestry
Nauni, Solan (HP)

Postharvest handling of fresh fruits and vegetables plays a critical role in reducing postharvest losses and facilitating a continuous supply of high quality fresh produce to the consumers. For economic benefits these commodities are being increasingly marketed at greater distances from their centers of production. Being bulky plant organs with high moisture content fruits and vegetables are susceptible to injury and spoilage mainly due to microbial contamination and the ongoing physiological processes eventually leading to their degradation and senescence. Though the fundamentals of postharvest handling: harvesting at proper maturity, minimizing injury, using proper sanitation and temperature management procedures, etc still remain important, many new technologies developed and refined in recent years continue to make possible an even expanding supply of fresh products. The demand from consumers for quality and safe products and global concerns for reducing deterioration of the environment are inducing changes in the way technology is being used to minimize postharvest losses and maintain product quality. These concerns have laid emphasis on development of new technologies that are more environmentally sustainable and economically competitive. The use of more natural chemicals or physical treatments to replace synthetic chemicals and increasing the efficiency of older, more traditional methods in combination with newer bio-control treatments have attracted the attention of researchers, in addition to the genetic control of ripening and senescence during the recent past.

I. Genetic Control:
In recent years, there has been a better understanding of the fact that fruit ripening and senescence are controlled genetically. It has been observed that there is marked increase in protein and nucleic acid (especially mRNA) synthesis during the early stages of respiratory climacteric of fruits including tomato. Additional evidence comes from a series of natural mutants of tomato and variants produced by genetic transformation that exhibit abnormal ripening behavior. A number of non-ripening or slow ripening mutants have been identified that appear to affect ethylene synthesis, perception and/or signal transduction leading to abnormal colouring, lack of softening, etc. These mutants have been extensively used to determine some of the fundamental processes involved in ripening, particularly softening (Wills et
al., 1998) and newer cultivars with better storage potential may be the result of use of such mutants in breeding programmes.

II. Physical Treatments:
Refrigeration, controlled atmosphere and low pressure technologies have been standardised and are being used successfully for the commercial storage of a number of crops. These technologies reduce physiological metabolism to the lowest level and delay consumption of stored metabolites, and hence delay senescence. Among other treatments which are quite well established are the use of postharvest heat treatment (35-50 °C) and ionising radiation (γ rays emitted by Co$^{60}$ and Cs$^{137}$). However, the use of high pressure electrostatic field storage (which mainly adopts high voltage electric field to influence moisture and metabolic process), magnetic field sterilisation technology and ultraviolet radiation treatments are relatively novel technologies. These technologies not only disinfect fruits and vegetables, but can also retain the original colour, taste and nutritive value of treated commodities (Ji et al., 2012).

III. Chemical Treatments:

i. 1-Methylcyclopropene
Among the chemical treatments 1-Methylcyclopropene (1-MCP) appears to be the most effective in influencing storage quality of fresh produce. 1-Methylcyclopropene (1-MCP), a synthetic cyclopropene, is the basis of a new technology that is increasingly being used to improve storage potential and maintain quality of fruits and vegetables. 1-MCP is a stable, non-toxic gas at low concentration (Binder and Bleecker, 2003) that is increasingly being used for improving the storage potential and maintain quality of fruits and vegetables. It acts as an inhibitor of ethylene perception by occupying ethylene receptors, preventing ethylene binding and thus its action (Sisler and Serek, 1997). 1-MCP also influences ethylene biosynthesis by exerting a feedback inhibition on ACS and ACO enzyme expression (Blankenship and Dole, 2003). Effect of 1- MCP on delaying softening of fruit and vegetables has been reported to depend upon the fruit maturity stage at harvest, concentration applied, duration of fruit exposure to 1-MCP, method of application, storage conditions and fruit temperature at the time of 1-MCP application. The U.S. Environmental Protection Agency (EPA) approved use of 1-MCP on floriculture and ornamental products in 1999 and on edible food products in 2002. By 2011, more than 40 countries had approved use of 1-MCP. It is registered for use on a wide variety of fruits and vegetables including apple, apricot, Asian pear, avocado, banana, broccoli, calabrese, cauliflower, Brussels sprouts, cabbage, carrot, cherimoya, cucumber, date, guava, kiwifruit, lime, mango, melon, nectarine, papaya, paprika, peach, pear, pepper, persimmon, pineapple, plantain, plum, plumcot, squash, tomato, and many ornamentals.
The specific products for which 1-MCP is registered in each country vary greatly according to the importance of the crop in that country. For example, 1-MCP can be applied to tulip bulbs in the Netherlands.

Fernandez-Trujillo et al. (2009) treated ‘Setubal’ red pepper fruit with 900 ppb 1-MCP for 24 h at 20°C and packed them in perforated polypropylene bags and concluded that 1-MCP prevented the increase in skin color, and ethylene production. It has successfully been used for storage of cucumber Nilsson (2005), tomato (Paul et al., 2010), egg plant fruit (Massolo et al., 2011), among other crops.

ii. Salicylic acid

Salicylic acid (SA) is considered to be a plant growth regulator which is widely distributed in plants and is now categorized as a hormonal substance, playing an important role in plant physiology. It is gaining importance in maintaining postharvest quality of fruits. It is reported to be directly toxic to fungi as it significantly inhibits fungal growth and spore germination of the pathogen in vitro. It can delay ripening of fruits, probably through inhibition of ethylene biosynthesis or action (Ozeker, 2005). Treatment with salicylic acid is reported to maintain greater firmness, reduce chilling injury indices, and delay membrane lipid peroxidation in fruit during cold storage. Its effect on alleviating chilling injury during cold storage may be attributed to its ability to induce antioxidant systems and heat shock proteins. Exogenous application of salicylic acid or methyl-salicylic acid may also induce the expression of many defense genes during fruit storage. Pre-storage or preharvest application of salicylic acid may provide a useful means of controlling postharvest decay thereby extending storage life (Wang and Shaohua, 2008) and its beneficial effects have been demonstrated in peppers (Elwan and El-Hamahmy, 2009) and Brassica juncea (Fariduddin et al., 2003).

iii. Nitric oxide (NO)

Nitric oxide (NO), a common signal molecule in biological systems has been found to be effective and safe to control insects under ultra low O₂ conditions. Its efficiency is increased with the increase in treatment time, temperature and concentration from 1.0 to 2.0 per cent (Liu, 2013). Postharvest application of nitric oxide is a potential new technology to reduce losses of horticultural produce during handling and marketing (Wills, 2015). Exogenous application of nitric oxide by gas or dipping in a solution of NO-donor compound has been demonstrated to alleviate some of the effects of abiotic stress on a wide range of produce. A key beneficial effect of NO is to reduce the production of ethylene. Other beneficial effects include a reduced rate of respiration, reduced ion leakage resulting from better maintenance of
cellular integrity, reduction in oxidative stress through reduced lipid oxidation and enhanced activity of a range of antioxidant enzymes which have been implicated in defense mechanisms; inhibition of polyphenol oxidase (PPO) activity associated with reduced internal and surface browning; alleviation of chilling injury potentially through enhancing the natural antioxidant defense system which could include endogenous NO.

iv. Hydrogen peroxide ($\text{H}_2\text{O}_2$)

Hydrogen peroxide is an environment friendly compound whose activity is based on oxidation of fungi and bacteria. It is successfully used to control vegetable pathogen during storage (Afek et al., 1999). Hydrogen peroxide treatments significantly reduced weight loss, rot rate index and nitrate content of fruits and significantly increased general appearance, ascorbic acid content and the activity of the antioxidant enzymes such as ascorbate peroxidase and dehydroascorbate reductase. The use of H$_2$O$_2$ for disinfecting vegetables is reported to reduce microbial populations on fresh products and extend the shelf life without leaving significant residues or causing loss of quality (Sapers et al., 2001). Perchonok and French (2005) reported that 0.5 per cent of hydrogen peroxide dip was effective in preventing decay because it strengthens the walls of fruits and vegetables thereby preventing the invasion of the cell walls by disease causing spores. This inhibitory activity of hydrogen peroxide prevents decay, weight loss and also maintains firmness. Dipping of pepper fruits in hydrogen peroxide solutions significantly reduced weight loss, rot rate index and nitrate content of fruits specially with 15 mM hydrogen peroxide (Bayoumi, 2008). Moreover, hydrogen peroxide treatments significantly increased general appearance, ascorbic acid content and the activity of the antioxidant enzymes such as ascorbate peroxidase and dehydroascorbate reductase. Therefore, the use of hydrogen peroxide in postharvest treatments have a good potential to improve the postharvest quality, extend shelf life and maintain nutritional quality as well as inhibit decay development.

v. Ozone:

Ozone (O$_3$) is a good alternative sanitizer for fresh fruits and vegetables, and can destroy micro-organisms through progressive oxidation of vital cellular components (Das et al., 2006). It can also rapidly oxidize ethylene generated by fruits and vegetables, reduce metabolism and prolong storage life (Li, 2005). Ozone treatment is reported to have bactericidal and fungicidal effects on S. enteritidis and Botrytis cinerea inoculated on the surface of tomatoes and can be used for sterilization of fruits before storage.

IV. Biological control

Public and scientific concern about the presence of synthetic chemicals in our food supply and in the environment has been increasing since the
recent past, as a result of which several fungicides have been banned by the US Environmental agency. There is clearly an urgent need to develop new and effective methods of controlling postharvest diseases that are perceived as safe and pose negligible risk to human health and the environment. Considerable attention has been placed on assessing the potential of biological control of postharvest diseases. Two basic approaches are available for using microorganisms to control postharvest diseases: use management of the beneficial microflora that already exists on the fruit and vegetable surfaces or artificial introduction of antagonists against postharvest pathogens (Wisniewski and Wilson, 1992). Various microorganisms which are effective against a wide range of pathogens of fruits and vegetables have been isolated and used commercially. The mode of their action involves a complex syndrome of characters including competition for nutrients and space, attachment of the antagonist to the pathogen, induced resistance, direct parasitism, etc. (Dorby et al., 2009)

V. Waxing and Coatings

Fruits and vegetables have a natural waxy layer that provides protection against drying out, discoloration and other forms of spoilage. This layer may be damaged during postharvest handling and application of coating/waxing material can prolong the shelf life of the commodities. Waxes were initially used to prolong storability of fruits and vegetables during the 1930s and since then a number of substances have been tried for this purpose. More recently however, there has been an emphasis on the use of edible material for coating of fruits and vegetables. Edible coatings consist of a thin layer of edible material applied to the surface of the food products to preserve freshness. Edible films and coatings are generally based on biological materials such as proteins, lipids and polysaccharides. The main polysaccharides that can be included in edible coating formulations are starch and starch derivatives, cellulose derivatives, chitosan, pectin, alginate and other gums. Carboxymethyl-cellulose is a cellulose derivative that has received considerable attention with several examples of applications in many fruits and vegetables. Some polysaccharides have been used as edible coatings to improve the quality of different fresh-cut fruit (Tapia et al., 2007; Rojas-Grau et al., 2007; Rojas-Grau et al., 2008).

The main component of our everyday food i.e. proteins carbohydrates and fats, can fulfil the requirements for edible films. The general rule is that fats reduce water transmission, polysaccharide films control oxygen and transmission of other gasses and protein films provide mechanical stability. Technological advances have given us a tool for formulation of improved edible coatings having specific barrier properties to moisture, O₂, CO₂ etc, so as to suit the requirement of different fruits and vegetables. Inadequate selection
of the material and methods of application can cause anaerobic respiration or desiccation of the product, affecting its overall quality (Perez-Gago et al., 2010).

Raymond et al. (2012) observed the effect of chitosan coating on physical and microbial characteristics of fresh-cut green peppers (Capsicum annuum L.). Green pepper slices were subjected to chitosan coating treatment achieved by dipping, followed by storage at 5°C for a period of 15 days. The effect of various chitosan concentrations (0%, 0.5%, 1.0% and 2 per cent (w/v) chitosan) showed that there was a decrease of surface lightness and the surface green colour was kept under marginal changes as compared to control. On the other hand, a greater reduction of fungal incidence, carbon dioxide concentration and electrolyte leakage of the chitosan treated samples were observed with increased chitosan concentration treatment.

Ochoa-Reyes et al. (2013) studied the effect of different edible coating formulations on shelf-life and quality of green bell peppers. Three different biopolymers (pectin, arabic, and xanthan gums) were evaluated in mixtures with candelilla wax as hydrophobic phase, jojoba oil as plasticizer and a crude extract of polyphenols as source of bioactive compounds. Green bell peppers were immersion-treated and then stored at room temperature. There was a significant reduction in weight loss, color, appearance, pH, total soluble solids and firmness changes which were kinetically determined. All peppers treated with edible-coating showed a significant difference in weight loss compared to control treatment (without edible coating), while a lower level of deterioration was observed in fruits treated with edible coating formulated with arabic gum, but appearance remained similar among fruits treated with different edible coatings. Use of mixtures of biopolymers, candelilla wax, jojoba oil and polyphenols to develop edible and functionalized coatings significantly extended shelf life of green bell pepper. Beaulieu et al. (2009) reported a decrease in weight loss during storage of green bell peppers utilizing oilseed lipid films.

VI. **Plant Extracts and Essential Oils:**

During the recent past, global concern for the protection of the environment has led researchers to investigate non-chemical methods to protect stored commodities and the use of natural flora as one of the sources of treatments for crop protection began to be investigated. Botanicals such as Melia, Mentha, Lantana, Tagetus, Occimum, Azadirachta, etc are known to contain higher amounts of some principal natural components exhibiting growth regulating, fungicidal and insecticidal properties and their extracts have been used advantageously for prolonging storage quality of many fruits including apples (Chauhan et al., 2008). The essential oils or extracts of
Mentha species possess both antimicrobial and antioxidant properties (Daferera et al., 2003).

Application of plant extracts and essential oils have been extensively evaluated for postharvest application on fruits (Tripathi and Dubey, 2004). Saks and Barkai-Golan (1995) reported that application of Aloe vera gel on wounded grapefruit reduced green mould decay by 75 per cent, six days after inoculation with Penicillium digitatum. Shinde et al. (2009) investigated the influence of various plant extract and oils viz., neem leaf extract, bael leaf extract, neem oil and sesame oil; and wrapping material viz., tissue paper and polynet wrapping on mango fruits in order to increase the shelf life and to minimize post harvest losses. Treatment with neem oil (10%) proved to be the most effective as it also exhibited lower physiological loss in weight, slower decrease in ascorbic acid and acidity, slower increase in TSS, retention of higher firmness of fruits, minimized spoilage and the fruits had the highest organoleptic score during storage. Already a number of neem based formulations are available in the market and many more may be available in the near future.

VII. **Novel Modified Atmosphere Packaging Technology:**

During recent years there has been an explosive growth in the market for fresh prepared fruit and vegetable (i.e. produce) products. The main driving force for this market growth is the increasing consumer demand for fresh, healthy, convenient and additive-free prepared product items. However, fresh prepared produce items are highly perishable and prone to the major spoilage mechanisms of enzymic discoloration, moisture loss and microbial growth. Good manufacturing and handling practices along with the appropriate use of modified atmosphere packaging (MAP) are relatively effective at inhibiting these spoilage mechanisms, thereby extending shelf-life. Shelf-life extension also results in the commercial benefits of less wastage in manufacturing and retail display, long distribution channels, improved product image and the ability to sell convenient, added-value, fresh prepared produce items to the consumer with reasonable remaining chilled storage life.

Active packaging is one of the innovative food packaging concepts that have been introduced as a response to the continuous change in current consumers’ demand and market trends. Major active packaging techniques are concerned with substances that absorb oxygen, ethylene, moisture, carbon dioxide, flavors/odors and those which release carbon dioxide, antimicrobial agents, antioxidants and flavors. The increasing demand for fresh and quality packaging, consumer convenience and manufacturers concern for longer shelf life of the food products is driving the market for global active and smart packaging technology for food and beverage market (Vermeiren et al., 1999). Active packaging is one of the most relevant approaches to increase the protection and enhance shelf life of fresh
horticultural crops. Active packaging is a broad concept in which the product packaging material and environment interacts in a positive way to extend the shelf life of the enclosed commodity. Many different active agents can be incorporated into the packaging material to improve its functionality.

The use of O₂ scavengers reduces the level of O₂ within modified atmosphere packages immediately after packaging and reduces respiration rate of the enclosed commodity thereby prolonging its storage life. Oxygen absorbing technology is based on oxidation or combination of one of the following components: iron powder, ascorbic acid, photosensitive polymers, enzymes, etc. (Cruz et al. 2013). Carbon dioxide scavengers can be composed either of a physical absorbent such as zeolite or an active carbon powder, or of a chemical absorbent such as calcium hydroxide, sodium carbonate, etc. (Charles et al. 2006). Ethylene inhibitors are normally used to mitigate harmful effects of ethylene gas in the packaging system and potassium permanganate has been found useful in a number of studies. Potassium permanganate (KMnO₄) is quite effective in reducing ethylene levels by oxidizing it to carbon dioxide and water. It was demonstrated that KMnO₄ retarded the ripening and extended storage life of many fruits (Wills et al. 1998).

The application of novel high oxygen (O₂) MAP is a new approach for the retailing of fresh prepared produce items and is capable of overcoming the many inherent shortcomings of current industry-standard air packaging or low O₂ MAP. The results from recent studies have shown that high O₂ MAP is particularly effective at inhibiting enzymic discolorations, preventing anaerobic fermentation reactions and moisture losses, and inhibiting aerobic and anaerobic microbial growth. Independent research undertaken in the Netherlands, Belgium, Australia, USA and Spain has also shown many interesting and mainly beneficial effects of high O₂ MAP (Day, 2003).

The key to successful retail MAP of fresh prepared produce is currently to use packaging film of correct permeability so as to establish optimal EMAs of typically 3–10% O₂ and 3–10% CO₂. The EMAs attained are influenced by produce respiration rate (which itself is affected by temperature, produce type, variety, size, maturity and severity of preparation); packaging film permeability; pack volume, surface area and fill weight; and degree of illumination. Consequently, establishment of an optimum EMA for individual produce items is very complex. Furthermore, in many commercial situations, produce is sealed in packaging film of insufficient permeability resulting in development of undesirable anaerobic conditions (e.g. <2% O₂ and >20% CO₂). Recently developed, micro perforated films, which have very high gas transmission rates, are now commercially used for maintaining aerobic EMAs (e.g. 5–15% O₂ and 5–15% CO₂) for highly respiring prepared produce items.
such as broccoli and cauliflower florets, baton carrots, beansprouts, mushrooms and spinach. However, micro perforated films are relatively expensive, permit moisture and odour losses, and may allow for the ingress of microorganisms into sealed packs during wet handling situations.

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Vegetables and spices have a great importance in the human diet by making it balanced and supply most important natural elements viz. vitamins, minerals, fibers, carbohydrates and supplementary amounts of proteins and colors. Quality in vegetables as well as in spices is a complex character influenced by both genetical and environmental factors. The quality consciousness in vegetables is increasing in developing countries and will demand more and more emphasis on biochemical attributes along with more yield. This is the need of the hour especially in our country with future plans on globalization of agriculture, increased production and advances in production technology. Following are the important biochemical constituents of vegetable and spice crops:

A. Biochemical constituents of vegetables

Composition of vegetables vary not only for a given kind in according to botanical variety, cultivation practices and weather, but change with the degree of maturity prior to harvest, and the condition of ripeness, which is progressive after harvest and is further influenced by storage conditions. Most fresh vegetables are high in water content, low in protein, and low in fat. Vegetables are also important sources of minerals and certain vitamins, especially vitamins A and C. Vegetables are important sources of both digestible and indigestible carbohydrates and provide roughages important to normal digestion. The important biochemical constituents of vegetables are as follows:

i) Water: Water plays a vital role in the evolution and reproduction cycle and in physiological processes. It has effects on the storage period length and on the consumption of tissue reserve substances. In vegetable cells, water is present in following forms:
- bound water or dilution water which is present in the cell and forms true solutions with mineral or organic substances;
- colloidal bound water which is present in the membrane, cytoplasm and nucleus and acts as a swelling agent for these colloidal structure
substances; it is very difficult to remove during drying/dehydration processes;
• constitution water, directly bound on the chemical component molecules and which is also removed with difficulty.

**ii) Mineral substances:** Mineral substances are present as salts of organic or inorganic acids or as complex organic combinations (chlorophyll, lecithin, etc.), in many cases dissolved in cellular juice. Vegetables are richer in mineral substances as compared with fruits. The mineral substance content is normally between 0.60 and 1.80% and more than 60 elements are present. The major elements are: K, Na, Ca, Mg, Fe, Mn, Al, P, Cl, S. Among vegetables, especially rich in mineral substances are: spinach, carrots, cabbage and tomatoes. Important quantities of potassium (K) and absence of sodium chloride (NaCl) give a high dietetic value to them. Phosphorus is supplied mainly by vegetables and they also contain calcium as in green beans, cabbage, onions and beans which contain more than 0.1% calcium. The calcium/phosphorus or Ca/P ratio is essential for calcium fixation in the human body; this value is considered normal at 0.7 for adults and at 1.0 for children. Even if its content in the human body is very low, iron (Fe) has an important role as a constituent of hemoglobin. Main iron sources are spinach.

**iii) Carbohydrates:** Carbohydrates are the main component of vegetables and represent more than 90% of their dry matter. They are produced by the process of photosynthesis in green plants. They may serve as structural components as in the case of cellulose; they may be stored as energy reserves as in the case of starch in plants; they may function as essential components of nucleic acids as in the case of ribose; and as components of vitamins such as ribose and riboflavin. Carbohydrates can be oxidized to furnish energy, and glucose in the blood is a ready source of energy for the human body. Fermentation of carbohydrates by yeast and other microorganisms can yield carbon dioxide, alcohol, organic acids and other compounds.

**iv) Fats:** Generally vegetables contain very low level of fats, below 0.5%. However, significant quantities are found in tomato seeds (18%).

**v) Organic acids:** Organic acids influence the colour of foods since many plant pigments are natural pH indicators. With respect to bacterial spoilage, most important contribution of organic acids is in lowering a food’s pH. Under anaerobic conditions and slightly above a pH of 4.6, *Clostridium botulinum* can grow and produce lethal toxins. This hazard is absent from foods high in organic acids resulting in a pH of 4.6 and less. Acidity and sugars are two main elements which determine the taste. The sugar/acid ratio is very often used in order to give a technological characterization of some vegetables.
vi) **Nitrogen-containing substances:** These substances are found in plants as different combinations: proteins, amino acids, amides, amines, nitrates, etc. Vegetables contain between 1.0 and 5.5%. Among nitrogen-containing substances the most important are proteins; they have a colloidal structure and, by heating, their water solution above 50°C and one-way reaction makes them insoluble.

vii) **Vitamins:** Vitamins are defined as organic materials which must be supplied to the human body in small amounts apart from the essential amino-acids or fatty acids. Vitamins function as enzyme systems which facilitate the metabolism of proteins, carbohydrates and fats but there is growing evidence that their roles in maintaining health may extend yet further. The vitamins are conveniently divided into two major groups, those that are fat-soluble and those that are water-soluble. Fat-soluble vitamins are A, D, E and K. Their absorption by the body depends upon the normal absorption of fat from the diet. Water-soluble vitamins include vitamin C and several members of the vitamin B complex.

Vitamin A or Retinol is found as such only in animal materials - meat, milk, eggs and the like. Plants contain no vitamin A but contain its precursor, beta-carotene. Man needs either vitamin A or beta-carotene which he can easily convert to vitamin A. Beta-carotene is found in the orange and yellow vegetables as well as the green leafy vegetables, mainly carrots, squash, sweet potatoes, spinach and kale. Vitamin C is the anti-scurvy vitamin. Lack of it causes fragile capillary walls, easy bleeding of the gums, loosening of teeth and bone joint diseases. It is necessary for the normal formation of the protein collagen, which is an important constituent of skin and connective tissue. Like vitamin E, vitamin C favours the absorption of iron. Vitamin C, also known as ascorbic acid, is easily destroyed by oxidation especially at high temperatures and is the vitamin most easily lost during processing, storage and cooking. Excellent sources of vitamin C are tomatoes, cabbage and green peppers. Potatoes also are a fair source of vitamin C.

viii) **Enzymes:** Enzymes are biological catalysts that promote most of the biochemical reactions which occur in vegetable cells. Enzymes have an optimal temperature - around +50°C where their activity is at maximum. Heating beyond this optimal temperature deactivates the enzyme. Activity of each enzyme is also characterised by an optimal pH. In vegetable storage and processing the most important roles are played by the enzymes classes of hydrolases (lipase, invertase, tannase, chlorophylase, amylase, cellulase) and oxidoreductases (peroxidase, tyrosinase, catalase, ascorbinase, polyphenoloxidase).
ix) **Cellulose, Hemicellulose and Lignin**: Cell walls in young plants are very thin and are composed largely of cellulose. As the plant ages cell walls tend to thicken and become higher in hemicellulose and in lignin. These materials are fibrous and tough and are not significantly softened by cooking.

x) **Pectic Substances**: The complex polymers of sugar acid derivatives include pectin and closely related substances. The cement-like substance found especially in the middle lamella which helps hold plant cells to one another is a water-insoluble pectic substance. On mild hydrolysis it yields water-soluble pectin which can form gels or viscous colloidal suspensions with sugar and acid. Certain water-soluble pectic substances also react with metal ions, particularly calcium, to form water-insoluble salts such as calcium pectates. The various pectic substances may influence texture of vegetables and fruits in several ways.

xi) **Pigments**: In addition to a great range of textures, much of the interest that vegetables add to our diets is due to their delightful and variable colours. The pigments and colour precursors of vegetables occur for the most part in the cellular plastic inclusions such as the chloroplasts and other chromoplasts, and to a lesser extent dissolved in fat droplets or water within the cell protoplast and vacuoles. These pigments are classified into four major groups which include the chlorophylls, carotenoids, anthocyanins, and anthoanthins. Pigments belonging to the latter two groups also are referred to as flavonoids, and include the tannins.

**B. Biochemical constituents of spices**

The spices are natural products of plant origin, used primarily for flavouring, seasoning or for adding pungency to foods and beverages. These stimulate secretion of digestive juices and have been known for many different applications from ancient times, like as medicaments, disinfectants, insect repellents, fragrances etc. Spices impart aroma, colour and taste to food preparations and sometimes mask undesirable odours. Volatile oils give the aroma, and oleoresins impart the taste. Aroma compounds play a significant role in the production of flavourants, which are used in the food industry to flavour, improve and increase the appeal of their products. They are classified by functional groups, e.g. alcohols, aldehydes, amines, esters, ethers, ketones, terpenes, thiols and other miscellaneous compounds. In spices, the volatile oils constitute these components. The biochemical constituents and the quality attributes of some important spices are discussed as follows:

i) **Black pepper**: Caryophyllene-rich oils possess sweet floral odours, whereas oils with high pinene content give turpentine like off-odours. The major compounds in fresh pepper are trans-linalool oxide and α-terpineol, whereas dry black pepper oil contains α- and β-pinenes, d-limonene and β-caryophyllene as major components.
ii) Cardamom: The oil has very little mono- or sesquiterpenic hydrocarbons and is dominated by oxygenated compounds, all of which are potential aroma compounds. While many of the identified compounds (alcohols, esters and aldehydes) are commonly found in many spice oils (or even volatiles of many different foods), the dominance of the ether, 1,8-cineole, and the esters, α-terpinyl and linalyl acetates in the composition make the cardamom volatiles a unique combination.

iii) Ginger: Ginger owes its characteristic organoleptic properties to two classes of constituents: the odour and the flavour of ginger are determined by the constituents of its steam- volatile oil, while the pungency is determined by non-steam-volatile components, known as the gingerols. The steam-volatile oil comprises mainly of sesquiterpene hydrocarbons, monoterpane hydrocarbons and oxygenated monoterpenes. The monoterpane constituents are believed to be the most important contributors to the aroma of ginger and are more abundant in the natural oil of the fresh ('green') rhizome than in the essential oil distilled from dried ginger. Oxygenated sesquiterpenes are relatively minor constituents of the volatile oil, but appear to be significant contributors to its flavour properties. The major sesquiterpene hydrocarbon constituent of ginger oil is (-) - α-zingiberene. Australian ginger oil has a reputation for possessing a particular ‘lemony’ aroma, due to its high content of the isomers, neral and geranial, often collectively referred to as citral.

iv) Turmeric: The essential oil contains ar-turmerone and ar-curcumene as major constituents. Curcumin (diferuloylmethane) is responsible for the yellow colour, and comprises curcumin I (94%), curcumin II (6%) and curcumin III (0.3 %). Recently a number of sesqui-terpenes have been reported from turmeric.

v) Cinnamon: It possesses a delicate, spicy aroma, which is attributed to its volatile oil. Volatile components are present in all parts of cinnamon and cassia. They can be classified broadly into monoterpenes, sesquiterpenes and phenylpropenes. The oil from the stem bark contains 75% cinnamaldehyde and 5% cinnamyl acetate, which contribute to the flavor. The minor constituents like methyl amyl ketone, methysalicylate etc., are responsible for the characteristic pleasant odour of cloves. The oil is dominated by eugenol (70–85%), eugenyl acetate (15%) and b-caryophyllene (5–12%), which together make up 99% of the oil. b-Caryophyllene, which was earlier thought of as an artifact of distillation, was first reported as a constituent of the bud oil.

vi) Nutmeg: The volatile oil of nutmeg constitutes the compounds: monoterpane hydrocarbons, 61–88%; oxygenated monoterpenes, i.e. monoterpane alcohols, monoterpane esters; aromatic ethers; sesquiterpenes, aromatic monoterpenes, alkenes, organic acids and miscellaneous...
compounds. Depending on the type, its flavour can vary from a sweetly spicy to a heavier taste. The oil has a clovelike, spicy, sweet, bitter taste with a terpeny, camphor-like aroma.

**vii) Seed spices:** Cumin has a distinctive bitter flavour and strong, warm aroma due to their abundant essential oil content. Of this, 40–65% is cuminaldehyde (4-isopropylbenzaldehyde), the major constituent and important aroma compound, as also the bitterness compound reported in cumin. The odour is best described as penetrating, irritating, fatty and overpowering, curry-like, heavy, spicy, warm and persistent, even after drying out. The characteristic flavour of cumin is probably due to dihydrocuminaldehyde and monoterpenes. In the mature fruit of fennel, up to 95% of the essential oil is located in the fruit, greater amounts being found in the fully ripe fruit. Hydrodistillation yields 1.5–3.5%. Generally, anethole and fenchone are found more in the waxy and ripe fruits than in the stems and leaves. Anethole has flavouring properties and is distinctly sweet, being 13 times sweeter than sugar. As for coriander, in the unripe fruits and the vegetative parts of the plant, aliphatic aldehydes predominate in the steam-volatile oil and are responsible for the peculiar aroma. On ripening, the fruits acquire a more pleasant and sweet odour and the major constituent of the volatile oil is the monoterene alcohol, linalool. Sotolon (also known as sotolone, caramel furanone, sugar lactone and fenugreek lactone) is a lactone and an extremely powerful aroma compound and is the major aroma and flavour component of fenugreek seeds. Among the leafy spices, 45 aroma volatiles of desert parsley have been identified, with the major constituents as myristicin, apiole, β-phellandrene, p-mentha-1,3,8-triene and 4-isopropenyl-1-methylbenzene. Among these, apiole in particular has a desirable parsley odour character. The leaf stems of celery show three main constituents of volatiles, e.g. apiole (about 23%), 3-butylphthalide (about 22%) and sedanolide (about 24%). The last two possess a strong characteristic celery aroma. Limonene (40.5%), β-selinene (16.3%), cis-octimene (12.5%) and β-caryophyllene (10.5%) are some of the volatile oil constituents present in celery leaves from Nigeria.

**Techniques of biochemical analysis**

Biochemical analysis include estimation of solids, acids, solid to solid ratio, starch content, carotenes, vitamins, carbohydrates, proteins etc. Following are some of the techniques to estimate quality characters in vegetable and spice crops:
A. Vegetables:

1. **Tomato:** Important biochemical quality parameters in tomato are TSS (Total soluble solids), Titratable acidity, Lycopene content, Ascorbic acid and pectin hydrolytic enzymes. The methods to estimate these characters are described as follows:

   a) **Total Soluble Solids (TSS):** Total Soluble Solids (TSS) is used to estimate sugar content. Amino acids, organic acids and soluble pectins mainly contribute to soluble solids. They can be estimated in a small sample of fruit juice using hand refractometer.

   b) **Titratable Acidity (TA):** To obtain suitable liquid form of the sample blend, weigh, filter and transfer the pulped material it to the volumetric flask. Dilute this with distilled water. Titrate with 0.1 N NaOH using phenolphthalein solutions as indicator. Appearance of light pink color denotes the end point. Note the titre value and calculate the result as percent anhydrous citric acid.

   c) **Lycopene Content:** Lycopene is a carotene having formula $\text{C}_{40}\text{H}_{56}$ responsible for the red color of tomato. It is measured by observing absorbance in spectrophotometer.

   d) **Ascorbic Acid:** Ascorbic acid or vitamin C is an antioxidant, generally present in all fresh vegetables and fruits. It is water soluble. It is estimated volumetrically.

2. **Capsicum:** Bellpepper is rich in vitamin A and C. Among biochemical quality attributes the fruits have following constituents:

   a) **Capsaicin content:** Capsaicin is an alkaloid which is responsible for hotness or pungency. For table purpose, any cultivar having less than 100 SHU (Schoville Heat Units) is classified as sweet pepper type and the same criterion is applied to the bell pepper. It is estimated using spectrophotometer.

   b) **Chlorophyll:** Many colors of capsicum are available but generally cultivars having dark green colored fruits are desirable. Chlorophyll is extracted in 80% acetone and the absorption is read in a spectrophotometer. Using the absorption co-efficient, the amount of chlorophyll is calculated.

   c) **Vitamin C:** Bell peppers are rich sources of vitamin C among vegetables. Depending upon the cultivar the content of this vitamin varies. Method is same as in tomato.

3. **Chillies:** The pungency in chilli is due to the presence of an alkaloid capsaicin and capsicutin found in the seed along with placental content and pericarp of the fruit. It is secreted by the outer walls of fruit. In addition to yield, chillies contain the following biochemical constituents for quality production.

   a) **Capsaicin content:** The phenolic group in capsaicin reduces phosphomolybdic acid to lower acids of molybdenum. The resulting
component is blue in color and is read at 650 nm. The color intensity is directly proportional to the concentration of capsaicin.

b) **Vitamin A (Carotenoids):** It is an indispensible character especially for red pepper. β- Carotenones the precursor of vitamin-A mainly contribute to the colour and present in good quantity in fresh pepper. The cultivar variations are 0.2 to 2.7 mg/ 100 gram. It is also estimated by using spectrophotometer measuring the absorbance at 450 and 670 nm.

c) **Flavonoids:** They are estimated by using Vanilline reagent and measuring the absorbencies in a spectrophotometer.

4) **Carrot:** Carrots are rich in β- carotene, dietary fibres, antioxidants and minerals. Following biochemical quality attributes can be estimated in the carrots.

a) **Carotenones:** β-carotenones are precursor of vitamin-A, hence their estimation in food stuffs is important from nutritional point of view. Carotenones are separated on a column of calcium hydroxide after their extraction from the experimental material by organic solvent. The individual carotenones are then determined in the column elute spectrophotometrically.

b) **Anthocyanins:** The method described by Swain and Hills (1959) to measure anthocyanin pigment is sensitive and anthocyanin present in sample from standard curve is calculated and the results are expressed as µg /g.

5) **Potato:** Potato is rich in carbohydrates, starch, Vitamin-B₁, Vitamin-B₂, Vitamin-B₃, Vitamin-B₆, Vitamin-C, Ca, Fe, Mg, P and K. The important quality characters of potato are dry matter or carbohydrate content, proteins, glycoalkaloids and vitamin C content.

a) **Dry Matter or carbohydrates:** Their amount should not exceed 0.25 %. Thus sugar content should be lower and starch content should be higher in superior cultivars.

b) **Starch:** Starch, an important polysaccharide, is hydrolyzed to simple sugars by dilute acid and simple sugars and can be measured colorimetrically.

c) **Solanine:** Crush the tissue in 5% acetic acid (20 ml / g tissue) in a blender and pass it through cheese cloth. Warm the filtrate to 70°C in a water bath and add conc. NH₄OH drop wise till the pH is 10. Centrifuge at low speed and discard the supernatant. Wash the residue with 1% NH₄OH and re-centrifuge. Collect the precipitate, dry and weigh the crude solanine for estimation of quality.

**B. Spices:**

**i) Preparation of sample:** Grind laboratory sample as quickly as possible in a grinding mill to pass sieve with 1 mm diameter aperture.
ii) **Determination of extraneous matter and other refractions in whole spices:** Separate extraneous matter and other refractions by hand. Weigh each fraction and calculate percentage.

iii) **Microscopic examination of spices:** A water slide is prepared by dissolving finely powdered sample with a drop of alcohol and then adding one or two drops of glycerol solution (30% in water) before sliding on the cover slip. The water slide is particularly suitable for detecting starch. The presence of starch can be confirmed by adding a drop of very dilute solution of iodine which produces the usual dark blue colour.

iv) **Determination of moisture:** The amount of water is determined by Dean and Stark toluene distillation method.

v) **Determination of total ash:** In 2 g of the prepared sample pour 2 ml of ethanol and ignite it. When the ethanol is burnt off, heat the dish carefully over a small flame to char the material. Then ignite in a muffle furnace at 550±25°C for 2 hours. Cool, wet the ash, evaporate carefully to dryness and heat in the muffle furnace for a further 1 hour. Repeat these operations until the difference in mass between two successive weighings is less than 0.001 g.

vi) **Determination of ash insoluble in dil. HCL:** To the dish containing total ash add 25 ml of dilute HCl and boil covering the dish with a watch glass to prevent spattering. Allow to cool and filter the contents of the dish through an ashless filter paper (medium fine). Wash the filter paper with hot water until the washings are free from HCl as tested by silver nitrate solution, and return it to the dish. Evaporate carefully on a water bath and ignite in a muffle furnace at 550±25°C for 1 hour. Cool the dish in a desiccator and weigh. Repeat the ignition for 1 hr, cooling and weighing till the difference in weight between two successive weighings is less than 0.001 g. Note the lowest weight.

vii) **Determination of cold water soluble extract:** Weigh about 2 g sample, transfer to a 100 ml volumetric flask, add distilled water and make up to mark. Stopper the flask and shake at approximately 30 minutes interval, for 8 hours and allow to stand for 16 hours longer without shaking. Filter the extract through a dry filter paper, evaporate a 50 ml aliquot portion to dryness in the dish on the water bath and heat in an air oven at 103±2°C to constant mass.

viii) **Determination of alcohol soluble extract:** Weigh 2 g of test sample and transfer to a 100 ml volumetric flask and fill to mark with ethanol. Stopper the flask and shake at approximately 30 minutes interval for 4 hours and allow to stand 16 hours longer without shaking. Filter the extract through a dry filter paper, evaporate a 50 ml aliquot portion to dryness on a water bath and heat in oven at 103±2°C to constant mass.

ix) **Determination of non volatile ether extract:** Extract 2 g of ground sample in a Soxhlet apparatus with diethyl ether for 18 hours. Remove the ether by distillation followed by blowing with a stream of air with the flask on a boiling water bath and dry in an oven at 110±1°C till the loss in weight between two successive weighings is less than 2 mg. Shake the residue with
2-3 ml of diethyl ether at room temperature, allow to settle and decant the ether. Repeat the extraction until no more of the residue dissolves. Dry the flask again until the loss in mass between two successive weighing is less than 2 mg. Record the lowest weight.

**x) Determination of volatile oil:** The determination of volatile oil in a spice is made by distilling the spice with water, collecting the distillate in a graduated tube in which the aqueous portion of the distillate is automatically separated and returned to the distilling flask, and measuring the volume of the oil. The content of volatile oil is expressed as a percentage v/w.

**xi) Quality analysis in turmeric:**

a) **Determination of curcumin content:** Grind and weigh 0.1 g of sample, add 30 ml alcohol and reflux for two and half hour. Cool the extract and filter quantitatively into a 100 ml volumetric flask. Transfer the extracted residue to the filter. Wash thoroughly and dilute to mark with alcohol. Pipette 20 ml of the filtered extract into a 250 ml volumetric flask and dilute to volume with alcohol. Measure the absorbance of the extract and the standard solution at 425 nm in 1 cm cell against an alcohol blank.

b) **Determination of starch content:** Starch content is determined by Lane and Eynon Volumetric method.

c) **Test for presence of chromate:** Ash about 2 g of the ground sample. Dissolve the ash in 4-5 ml of dilute sulphuric acid in a test tube and add 1 ml of diphenyl carbazide solution. The development of a violet colour indicates the presence of chromate.

The relative importance of quality is dependent upon the end use of the vegetables and spices. Earlier the quality parameters were appearance, size, shape and presence of extraneous matter. Later, the analytical parameters as described above, biochemical constituents and quality attributes like proteins, vitamins, minerals etc. were added, which depends upon the variety, agro-climatic conditions existing in the area of production, harvest and post harvest operations. Keeping in view the excellent scope for the value added products; development of entrepreneurs with developed technologies, which are commercially viable and infrastructure development and development of human resources are opportunities which can be availed by assuring the quality.

**References**


Role of Biotechnology in Vegetable Production - An Overview

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Introduction

The requirement of fruits and vegetables is increasing proportionally with the increasing population in the country. How do we keep horticultural production on par with the burgeoning population? Although conventional plant breeding techniques have made considerable progress in the development of improved varieties, they have not been able to keep pace with the increasing demand for vegetables and fruits in the developing countries. Therefore, an immediate need is felt to integrate biotechnology to speed up the crop improvement programmes. Biotechnological tools have revolutionized the entire crop improvement programmes by providing new strains of plants, supply of planting material, more efficient and selective pesticides and improved fertilizers. Many genetically modified fruits and vegetables are already in the market in developed countries. Modern biotechnology encompasses broad areas of biology from utilization of living organisms or substances from those organisms to make or to modify a product, to improve plant or animal or to develop micro-organisms for specific use. It is a new aspect which provides new tools and strategies in the struggle against world’s food production problem.

The major areas of biotechnology which can be adopted for improvement of horticultural crops include:

A. TISSUE CULTURE
B. GENETIC ENGINEERING
C. MOLECULAR MARKERS

A. PLANT TISSUE CULTURE:

Plant tissue culture has a great significance in plant biotechnology specially in the crop improvement programmes. The term tissue culture may be defined as the process of in-vitro culture of explants (pieces of living differentiated tissues) in nutrient medium under aseptic conditions. However,
in general, the tissue culture includes the term tissue culture as well as cell culture, organ culture and suspension culture also. G. Haberlandt, a German botanist, in 1902 cultured fully differentiated plant cells isolated from different plants and is aptly regarded as the father of tissue culture. This was the very first step for the beginning of plant cell and tissue culture. Thereafter, there happened some dramatic advances in tissue culture techniques. Further contributions were made by the Cell Doctrine which admitted that a cell is capable of showing totipotency. With the identification of a variety of chemicals like cytokinin, auxin, other hormones, vitamins, etc. and their role in affecting cell division and differentiation, the methods of plant tissue culture developed in a proper manner. The discovery and understanding of role of plant growth hormones in the multiplication of cell also provided an extra aid for the development of in-vitro culture methods of plants.

Different approaches of Plant Tissue Culture used for Vegetable Production

1. Micro-Propagation or In-vitro Propagation

Miniaturized in vitro multiplication of plant material under aseptic and controlled artificial conditions, also known as micropropagation, has been used for decades to speed up the propagation process for several vegetatively propagated crops. This is the case for fruit trees, roots and tubers, vegetables and ornamentals. Many companies and institutions worldwide have invested or specialized in this activity, to provide farmers and growers with high quality and healthy planting material.

2. Somatic Embryogenesis

The embryos formed from the somatic cells of plant in culture under in-vitro conditions are called as somatic embryos. Somatic embryogenesis under in-vitro conditions was first of all observed by Steward et. al. (1958) in carrot (Daucus carota). Thereafter, somatic embryoids have been induced in many plants including vegetable crops like Garlic, Cucumber, Brinjal, Cauliflower, Coriander etc. The development of somatic embryo passes through the stages like globular, heart-shaped, torpedo-shaped and finally giving rise to the cotyledonary stage of somatic embryo.

3. Shoot Culture

A major problem of vegetative propagated crops is transmission of diseases, in particular of viruses, through planting material. Several cultivars of garlic, potato, apple tree, etc., have been known to be totally contaminated
by viruses. In the absence of genetic resistance within the gene pool, meristem culture has been widely used to transform these cultivars into healthy cultivars, free from diseases. The principle is that a meristem (the apical part of a stem) is normally free from diseases. Its association with disease detection methods such as ELISA or PCR techniques makes it a very powerful tool to ensure propagation of healthy planting material.

4. Haploid Production

Using *in vitro* techniques, it is possible to regenerate plants from pollen or ovules. These plants, which contain only one copy of each chromosome, are called haploids. They are not viable. After appropriate chemical treatment, it is possible to restore the normal number of chromosomes and to regenerate viable plants. These plants, called double-haploids, are homozygous for all their genes. Such plants are of tremendous interest to plant breeders, since they allow development of pure line varieties or inbred parental lines much more quickly than through conventional breeding.

Androgenesis (regeneration from pollen) has been successfully used for crops such as eggplant, pepper and wheat. Gynogenesis (regeneration from ovules) is used on barley. In addition, the *in-vitro* production of haploids also aids for: induction of genetic variabilities, disease resistance, salt tolerance, insect resistance, etc. Few examples are Capsicum, Beetroot, *Brassica pekinensis*, *B. chinensis*, etc.

5. Embryo Culture or Embryo rescue

Breeders need access to the largest possible genetic variability. In some cases, variability available within a given species is not sufficient to answer a specific problem (e.g. resistance to some new disease). A solution available to breeders is inter-specific hybridization (crossing plants from separate but related species). However, embryos resulting from such hybridization rarely survive, due to incompatibilities between the embryo and the mother plant. This technique has been used for the introduction of disease resistance into squash, lettuce, tomato, etc. It is used widely in the fields of agriculture, horticulture and forestry for production of hybrid plants. Embryo culture is advantageous for *in-vitro* micro propagation of plants, overcoming seed dormancy and for production of beneficial haploid plants.

6. Endosperm Culture (Triploid Production)

Endosperm tissue is triploid therefore the plantlets originating by the culture of endosperm are also triploid. In majority of flowering plant families
exceptions being Orchidaceae, Podostemaceae, Trapaceae which lack endosperm) the endosperm tissues are present. Endosperm culture has provided a novel strategy for plant breeding and horticulture for the production of triploid plantlets. It is an easy method for production of a large number of triploids in one step. The triploid plants are usually seedless therefore this technique is most beneficial for increasing the commercial value of fruits like apple, mango, grapes, watermelon, etc.

7. SomaClonal Variation

Somaclonal variations may be defined as those variations which occur in the cultured cells/tissues or plants regenerated from such cells *in-vitro*. These are usually heritable for qualitative as well as quantitative characters of plants. Somaclonal variants have proved as an alternate tool to plant breeding for production of improved varieties of plants. Gene mutations and changes in the structure, number of chromosomes are the main causes of production of somaclonal variants. A number of new varieties of cereals, oil seeds, fruits, tomatoes, etc., possessing disease resistance, better quality, better yield etc., have been generated through somaclonal variations. Some of those crop species are Potato, Tomato, Carrot, Oats, Wheat, Rice, Maize, Datura, Soybean, etc.

8. Protoplast culture or Somatic Hybridisation

Somatic hybridization may be described as the production of hybrid cells by the fusion of protoplasts of somatic cells derived from two different plant species/varieties. Fusion of protoplasts is another technique to allow inter-specific hybridization between species that cannot be crossed through conventional breeding, even using *in vitro* embryo rescue. Protoplasts are plant cells that have had their outer walls removed through chemical treatment. While it is difficult or impossible to fuse plant cells, it is possible through various techniques (using either chemical or physical treatments) to merge protoplasts from different crop species or genera, and then to regenerate a whole plant resulting from the fusion process. This technique has been used to introduce traits such as male sterility into rapeseed, or disease resistances in potato. It is immensely helpful for generating new and improved hybrid varieties of plant that may have characters of a completely different species. For example, 'Pomato' is a somatic hybrid which is produced by the fusion of protoplast of somatic cells from potato and tomato which are totally different species.
9. Artificial Seed

In the early 1980s, several organizations investigated the possibility with some crops to use somatic embryos that could be encapsulated with different chemical and biological compounds. These “artificial seeds” would have been planted and treated as seeds. Potential benefits would have been tremendous from a plant breeding, seed production and seed treatment point of view. However, technical and economic constraints have not allowed commercial development of this technology.

10. Cryopreservation

Cryopreservation technique has proved to be one of the most reliable methods for long term storage and preservation of plant germplasm in the form of pollens, shoot-tips, embryos, callus, protoplasts, etc. This technique is used mainly for long term storage of germplasm and thus helps in conservation of nature also. Plant tissues and organs are cryopreserved usually in liquid Nitrogen which has a temperature of 196°C.

B. GENETIC ENGINEERING

Over the last 50 years, the field of genetic engineering has developed rapidly. The term Genetic Engineering is used to describe the process by which the genetic makeup of an organism can be altered using “recombinant DNA technology.” Developing plant varieties expressing good agronomic characteristics is the ultimate goal of plant breeders. With conventional plant breeding, however, there is little or no guarantee of obtaining any particular gene combination from the millions of crosses generated. In contrast, genetic engineering allows the direct transfer of one or just a few genes of interest, between either closely or distantly related organisms to obtain the desired agronomic trait.

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<tr>
<th>Conventional Breeding</th>
<th>Genetic Engineering</th>
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<td>• Limited to exchanges between the same or very closely related species</td>
<td>• Allows the direct transfer of one or just a few genes, between either closely or</td>
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<td>• Little or no guarantee of any particular gene combination from the million of</td>
<td>distantly related organisms</td>
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<td>crosses generated</td>
<td>• Crop improvement can be achieved in a shorter time compared to conventional</td>
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<td>• Undesirable genes can be transferred along with desirable genes</td>
<td>breeding</td>
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<tr>
<td>• Takes a long time to achieve desired results</td>
<td>• Allows plants to be modified by removing or switching off particular genes</td>
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Genetic Engineering is being used to introduce a broad range of new agronomic, processing and nutritional traits into the main agricultural and vegetable crops. It is a very promising tool for the development of new varieties with specific traits that are not present within the crop genepool. Although transgenic tomato “Flavr Savr” was the first transgenic crop to be commercialized, but globally transgenics have been developed in case of many crops but the list dominantly includes Soybeans, Corn, Potatoes and vegetables like Tomatoes, Eggplant, Zucchini and Yellow Squash. Transgenic vegetable crops could make important contributions to sustainable vegetable production in this 21st century. However, countries vary in their market standards of acceptance of transgenic crops. Environmental risks such as cross-pollination with closely related wild relatives of the crop plants and effect of transgene products on human health need to be assessed carefully on a case-by-case basis. Moreover, there are widespread concerns about the use of antibiotic and herbicide resistance genes as selectable markers from the point of view of ecological and human safety. Biotechnology products will be successful if clear advantages and safety are demonstrated to both growers and consumers.

**MARKER-ASSISTED BREEDING**

Markers may be either phenotypic or genotypic, and marker-assisted breeding developed in the 1980s with the evolution of DNA marker technologies. Today, the main DNA markers used in breeding programmes are Random Amplified Polymorphic DNA (RAPD), Amplified Fragment Length Polymorphism (AFLP), Microsatellites (SSRs), and Expressed Sequence Tags (ESTs). Each of these markers has a different set of advantages and limits. Cost and possible automation of the techniques are of particular importance for their adoption.

Use of molecular markers, in association with linkage maps and genomics, offers plant breeders the potential to make genetic progress much more precisely and rapidly than through phenotypic selection. It also offers the possibility of addressing previously unattainable goals. There are many applications for the use of DNA markers in breeding programmes, which fall into four broad groups, based on the purpose of the intervention:

- enhancing knowledge of breeding material and systems, such as better understanding and more effective breeding of Quantitative Trait Loci (QTL);
- rapid introgression or backcross breeding of simple characters, as the number of back-crosses required can be reduced drastically if there are
markers for the character to be introduced and for the genetic background of the recurrent parent;
• early or easy indirect character selection, which is important for genes that cannot be detected at an early development stage, such as high lysine and tryptophan genes in maize; and
• new goals not possible through traditional breeding, including pyramiding of disease resistance genes with indistinguishable phenotypes.

CONCLUSIONS

Plant biotechnology has the potential to be a key tool to achieve sustainable agriculture, through improvement of food production in terms of quantity, quality and safety, while preserving the environment. However, plant biotechnology is not sufficient in itself to achieve this challenge. For instance, biotechnological inventions have no value if not associated with an improved and adapted genetic background. Similarly, if seed distribution networks are not effective, seeds carrying biotechnological inventions will not reach farmers. Therefore, plant biotechnology should be considered in the framework of the agricultural sector at large, taking into account scientific, technical, regulatory, socio-economic and political evolution.

REFERENCES:

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