HORTICULTURE

VEGETABLE SCIENCE
(Vegetables, Tubers & Spice Crops)

Tropical and Sub Tropical Vegetables

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Vegetable growing is an important branch of horticulture. But it is no longer confined to growing in a small garden as vegetables are now cultivated on a large scale commercially. The study of vegetable culture is called as 'Olericulture'. The term vegetable is applicable to the herbaceous plants or parts thereof, which are used for culinary purposes. The term vegetables includes all foods of vegetable origin, but it excludes cereal and dried seeds of pulses, however, it includes grain on the cob, potatoes and other tubers.

Importance of vegetable growing

Vegetables form an indispensable part of daily diet particularly in India, as a large section of people are vegetarian. So for fulfilling the dietary requirements they depend on vegetables. Vegetables are important for our well being because of the following:

1. Vegetables are rich sources of vitamins and other essential nutrients: Vegetables play an important role in human diet and are essential for balanced diet and maintenance of good health. The vegetables are rich sources of protein (Moringa and peas), minerals like calcium (tomato, spinach, peas), Phosphorus (tomato, cucumber), Iron (Spinach, peas, tomato, bitter gourd), Iodine (Okra, Summer squash) Vitamins like Vitamin A (Leafy vegetables, pumpkin), Vitamin B (Peas, Spinach, tomato), Vitamin C (Moringa, chilli, tomato,) and Vitamin K (Leafy vegetables).
2. Vegetables have lots of protective compounds like Cheratin in bitter gourd is effective against diabetes and most of the leafy vegetables and pumpkin are the rich source of beta carotene.
3. Vegetables gave more yield than other traditional crops like wheat and rice. The yield of wheat is about 50-55 qtls per hectare and in vegetables like tomato it is about 250 qtl per hectare. Thus they provide higher quantity of food per unit area.
4. Vegetables gave more farm income than other crops.
5. The cropping intensity in vegetable growing is very high as compared to others. Normally 3-4 vegetable crops can be raised in one year.
6. Vegetables have high export potential.
7. The aesthetic value of vegetables is quite higher than other field crops.
8. The vegetables have given a boon to processing industry as they can be processed to form diverse compounds like sauces, chutneys, pickles etc.

Scope of vegetable growing

In a vast country like India there is an immense scope of vegetable cultivation as mentioned below:

i) Sufficient technical manpower is available in our country and apart from it, there are many unemployed agriculture graduates and post graduate degree holders,

ii) There are varying agro-climatic conditions temperate to subtropical, in different regions of the country and variety of vegetables can be grown all over the country.

iii) There is abundance of rainfall and no scarcity of water for vegetable cultivation.

iv) There is large scope for area expansion under vegetable crops

v) There is high potential for high value low volume crops as purchasing power of lot of population in India is very high

vi) In India the market for processed vegetables is increasing and thus more vegetable production is needed.

vii) The export potential of vegetable crops is extremely high

Tropical and sub-tropical vegetables

The vegetables according to their temperature requirement are classified as tropical, subtropical and temperate vegetables. The tropical vegetables require optimum temperature range of 18-30 ° C for their proper growth and development and the sub-tropical vegetables grow better at temperature range of 12-18 ° C. The subtropical vegetables can be grown on lower temperatures but they cannot withstand frost. In this chapter the emphasis will be laid on the production technology of tropical and sub-tropical vegetables. The major vegetables included in this section are:

S. No.	Common Name	Botanical Name	Family
1.	Tomato	*Lycopersicon esculentum*	Solanaceae
2.	Brinjal	*Solanum melongena*	-do-
3.	Chilli	*Capsicum annuum*	-do-
4.	Bell Pepper	*Capsicum frutescens*	-do-
5.	Okra	*Abelmoschus esculentus*	Malvaceae
6.	Garden Pea	*Pisum sativum*	Leguminoseae
7.	French bean	*Phaseolus vulgaris*	-do-
8.	Cowpea	*Vigna sinensis*	-do-
9.	Dolichos bean	*Dolichos lablab*	-do-
10	Cluster bean	*Cyamopsis tetragonoloba*	-do-
11.	Palak	*Beta vulgaris*	Chenopodiaceae
12.	Spinach	*Spinacia oleracea*	-do-
13.	Moringa (Drumstick)	*Moringa oleifera*	Moringaceae
14.	Amaranath	*Amaranthus viridis*	Amarantaceae
15.	Lettuce	*Lectuca sativa*	Compositae
16.	Watermelon	*Citrullus lanatus*	Cucurbitaceae
17.	Muskmelon	*Cucumis melo*	-do-
18.	Cucumber	*Cucumis sativus*	-do-
19.	Pumpkin	*Cucurbita pepo*	-do-
20.	Bottle gourd	*Lagenaria siceraria*	-do-
21.	Ridge gourd	*Luffa acutangula*	-do-
22.	Bitter gourd	*Momordica charantia*	-do-
23.	Pointed gourd	*Trichosanthes dioica*	-do-
24.	Long melon	*Cucumis melo var. utilissimus*	-do-

25.	Ash gourd	*Benincasa hispida*	-do-
26.	Snake gourd	*Trichosanthes anguina*	-do-
27.	Sponge gourd	*Luffa cylindrica*	-do-
28.	Squash melon	*Citrullus vulgaris*	-do-
29.	Summer squash	*Cucurbita moschata*	-do-

Climate and Soil Requirements

It is the most important factor influencing crop yield therefore for getting proper yields; it is essential to know the climatic requirement of the vegetable crops. Climate is the sum total of the factors such as temperature, light, humidity, rainfall, wind, fog etc. Almost all the vegetables have optimum range of climatic components and beyond those limits vegetables cannot perform up to the mark.

Most of the tropical and sub-tropical vegetables except leafy vegetables like palak and amaranth are the warm season crops. The vegetables under this section cannot stand severe frost. Very low temperature has adverse effects on fruit setting, pigmentation and nutritive value of these vegetables. These crops thrive better in areas with moderate rainfall within the range of 60-120 cm. However, the peas can be grown in relatively cool weather and they grow better in areas where there is a slow transition from cool to warm weather. The temperature requirement for these vegetables is as follows:

S. No.	**Crop**	**Favourable temperature range (°C)**
1.	Tomato	18-27
2.	Brinjal	13-21
3.	Chilli	20-25
4.	French bean, Cowpea	15-25
5.	Garden Peas	5-22
6.	Cucurbits	18-28
7.	Okra	22-30
8.	Lettuce	12-15
9.	Beet leaf	12-30
10.	Spinach	12-30

Soil: Soil is not only the growing medium but it also provides mechanical support, nutrients and water for plant growth. For better development of root system, the soils must contain adequate supply of air and have low bulk density. The soils with high quantity of organic matter and humus are favourable for vegetable production. There should be no hard pan in the land. A layer of calcium carbonate is quite beneficial. Although Vegetables in India are grown in various types of soils but the sandy loam soils are best for growing vegetables as such soil is better in texture and structure, easy to

work, drain away excess moisture quickly and retain necessary moisture. The soil types required for different vegetables are as follows:

S. No.	Soil Conditions	Vegetables
1.	Sandy loam	Tomato, Beans, Cucurbits
2.	Loam	Chili, Okra, Leafy vegetables
3.	Loamy sand	Peas and cowpea

The most favourable pH range for tropical and sub-tropical vegetables is 6.0-7.0. The tropical and sub-tropical vegetables are divided as follows according to their acidity tolerance:

S. No.	Soil Conditions	Vegetables
1.	Slightly acidic (pH 6.0 - 6.8)	Okra, Spinach, Palak, Muskmelon, Lettuce
2.	Moderately acidic (pH 5.0-6.0)	Beans, Pumpkin, Squash melon, Cucumber, Tomato, Brinjal, Pea, Pepper
3.	Highly acidic (pH 4.7-5.0)	Watermelon

Varieties and Hybrids

Many varieties of various vegetables according to size, shape, colour, yield etc are grown throughout the country. The important varieties and hybrids are as follows: -

1.Tomato: Arka Saurabh, Arka Vikas, Pusa Uphar, Hisar Anmol, Hisar Arun, Hisar Lalit, La-Bonita, Pant Bahar, Punjab Chhuhara, Avinash-2, Punjab Kesri, Pusa Early Dwarf, Pusa Ruby, Pusa Sheetal, Roma, Sel 120, Hisar Lalima, Krishna, Matri, Naveen, Pusa 120, Pusa Divya, Pusa Gaurav, Pusa Sadabahar, Rajni, Rashmi, Ratna, S-12, Pant T-3, BT-1, CO-3, KS-2, NTDR-1, PKM-1, Punjab Tropic, PNR-7, TH-2312 and TH-802.

2.Brinjal: Pusa Purple Long, Pusa Anupma, Arka Kusumkar, Jamuni Gola, Pusa Purple Cluster, Arka Navneet, Arka Sheetal, Arka Shirish, Manjari Gota, Mysore Green, Annamalai, Pant Samart, Pusa Kranti, Pusa Bhairav, Pusa Anupam, Pusa Upkar, Pusa Bindu, Punjab Barasti, Pant Rituraj, Aruna, Punjab Neelam, Punjab Sadabahar, Punjab Moti, BH-1, BH-2, Azad Kranti, Hisar Jamuni and Pragati Arka.

3.Chilli: Pusa Jwala, Bhagyalakshmi, Andhra Jyoti, Sindhur, Punjab Lal, Bhaskar, Co-1, Co-2, Arpana Jawahar-218, Pusa Sadabahar, Arka Lohit, Arka Abir, Bhaskar, Masalwadi Selection, CH-1, CH-3, Punjab Gucchedar, Punjab Surkh and Ujjwala.

4.Bell Pepper: California Wonder, Arka Mohini, Arka Gaurav, Arka Basant, Pusa Green Gold, Indira, Hira, Pusa Sanyog and Kt-I

5.Cowpea: Pusa Komal, Birsa Sweta, Pusa Phalguni, Pusa Barsati, Pus Dofasli, Arka Garima, Yard Long Bean, Sel 263, Arka Suman, Narendra Lobia, Pusa Rituraj and Phillipines Early.

6.Dolichos Bean: Deepali, Pusa Early Prolific, Arka Jay, Arka Vijay, Konkan Bhushan and Rajni.

7.Cluster bean: Pusa Mausami and Pusa Sadabahar

8.French bean: Kentucky Wonder, Contender, Pusa Parvati, Arka Komal, TKD-1, KKL-1, YED-1, Bountiful Jampa, Lakshmi, Pant Anupam and Premier

9.Garden Peas: Asauji, Arkel, Jawahar Matar-1, Jawahar Matar-3, Jawahar Matar-4, Bonneville, Arka Ajit, Lincoln, Punjab-87, Punjab-88, Harbhajan, Azad P-1, Hara Bona, Mithi phalli and Mattar Agata-6

10.Okra: Pusa Makhmali, Pusa Sawani, Perkin's Long Green, Pusa-A-4, Arka Anamika, Arka Abhey, Punjab Padmini, Punjab-8, Parbhani Kranti, Gujrat Bhindi-1, Varsha Uphar, Hisar Unnat, Azad Kranti, Punjab-7, Red Bhindi, Varsha, Panchali, Vijay Adhunik, and Panchali.

11.Ashgourd: Mudliar, APAU Shakti and Co-2

12.Bitter gourd: Pusa Do Mausami, Pusa Vishesh, Coimbatore Green, Coimbatore Round, Priya, Konkan Tara, Arka Harit, Harkani, Priya, Priyanka and Phule Green.

13.Cucumber: Japanese Long Green, Straight Eight, Pusa Sanyog, Poinsette, Himangi, Phule Shubbangi, Solan Hybrid, Poonakhira, Sheetal and Arka Jyoti.

14.Muskmelon: Hara madhu, Punjab Hybrid, Pusa Sharbati, Punjab Sunheri, Arka Jeet, Arka Rajhans, Durgapura Madhu, Hisar Madhur, Pusa Madhuras, Hisar Saras Punjab Rasila and Pusa Rasraj

15.Ridge gourd: Pusa Nasdar, Satputia, Konkan Harita, PKM-1, Punjab Sadabahar and IIHR-8.

16.Snake gourd: TA 19, Konkan Sweta and APAU Sweta

17.Sponge gourd: Pusa Chikni, Phule Prajakta, Pusa Supriya, Pusa Sneha and Kalianpura Hari Chikni

18.Squash Melon: Arka Tinda, Tinda Ludhiana, Tinda Tonk, Tamil Nadu Selection and S-48.

19.Watermelon: Asahi Yamato, Sug0ar Baby Arka Jyoti, Arka Bedana, Arka Manik, Improved Shipper, Durgapura Meetha, Durgapura Kesar. New Hampshire, Midget, Pusa Bedana and Special No. –1

20.Bottle Gourd: Pusa Summer Prolific Long, Pusa Summer Prolific Round, Pusa Meghdoot, Pusa Komal, Arka Bahar, Kalyanpur Long Green, Samrat, Pusa Hybrid 3,

Kalyanpur Hari Lambi, Punjab Long, Punjab Komal, Punjab Round, Rajendra Chamatkar and Pusa Hybrid 1.

21.Pumpkin: Arka Chandan, Ambali, Pusa Vishwas Arka Suryamukhi, Pusa Vikas and Pusa Hybrid 1

22.Summer Squash: Punjab Chappan Kaddu, Patty Pan, Early Yellow Prolific, Australian Green and Pusa Alankar

23.Pointed gourd: Mostly local varities called as *Patar* in UP

24.Long melon: Japanese green, Pusa Sanyog, Faizabadi, Lucknow lady long, Laila ki unglian, Majnu ki paslian, Punjab-1

25. Indian Spinach (Palak): All Green, Pusa Palak, Pusa Jyoti, Pusa Harit, Jobner green and Banerjee Giant

26.Spinach: Virginia Savoy, Early Smooth Leaf, Banarasi, Khara Lucknow and Khara Palak
27.Lettuce: Great Lakes, Slowbolt, Chinese Yellow, Imperial 859, White Boston and dark Green

28.Amaranthus: Chotti Chaulai, Badi Chaulai, Pusa Kiran and Pusa Lal Chaulai

29.Drumstick: Chavakacheri Muringai, Chemmurungai , Jaffna Type, Kattumurungai, Kodikalmurungai, Palmurungai, Punamurungai and Yazphanam Muringa.

Cultivation Practices
Most of the tropical and subtropical vegetables are sown directly in field like cucurbits, peas, beans, okra and leafy vegetables whereas the crops like tomato, brinjal and chilli are first sown in nursery beds and later transplanted in field. The cucurbitaceous vegetables like pumpkin, bottle gourd, ridge gourd etc. can be transplanted if the seedlings are uprooted along with a ball of soil without disturbing or exposing the roots. It is beneficial to grow the vegetables in nursery as it is convenient to look after the tender seedlings, seedlings remain in protected place, one gets more time for field preparation and it ensures uniform growth in field.

Nursery raising and transplanting: The vegetables like Tomato, brinjal, chili, and bell pepper give good response to transplanting and these vegetables are firstly sown in nursery before transplanting them to the main field. The nursery land is cultivated to fine tilth and 5 tonnes farmyard manure per $20m^2$ is added. The nursery beds of 1.20-1.50 m width are prepared and they should be raised about 15 cm above the rest of field and should have outward slope. The seeds should be treated with Captan / Thiram @ 3 g per Kg of seed to avoid soil borne infections. The seeds should strictly not be broadcasted in the beds but should be sown in rows spaced 5 cm apart. To raise one hectare of tomato,

brinjal and chilies, the nursery area required is 125 m^2, 67m^2 and 40 m^2, respectively. The seeds should be covered with soil and water should be sprinkled to ensure better germination. The seedlings of tomato, brinjal and chilies should be well taken care of in frosty conditions and protection with sarkanda or polythene sheets is essential. The nursery beds should be watered regularly for proper growth and development of seedlings.

The seedlings are ready to transplant in field when they attain a height of 15-20 cm and have 3-4 true leaves. While transplanting, care should be taken to remove lanky and weak seedlings. It is advisable to irrigate the beds before uprooting the seedlings. The transplanting should be done in evening so that the seedlings can recover from transplanting shock overnight.

Sowing Time: The time of sowing of vegetable depends upon the soil and weather conditions, kind of the vegetable and demand in the market. The vegetables like all the other crops if not sown in time fail to perform to their potential.

S. No.	Vegetable	Sowing Time (Transplanting)
1.	Tomato	October (November), November (February)
2.	Brinjal	October (November), November (February), February-March (April), July (August)
3.	Chili	October-November (February-March), Direct sowing in March-April
4.	Okra	February, June-July
5.	Muskmelon, Watermelon	February-March
6.	Bottle gourd, Bitter gourd, Sponge gourd, Ash gourd, Cucumber, Cow peas	February-March, June-July
7.	Summer squash	January-March, October-November
8.	Garden Peas	November
9.	Leafy vegetables	September-October, February-April

Seed Rate: The quantity of seed required to sow a particular area acre or hectare is referred as seed rate. The seed rate depends upon number of factors like seed viability, plant vigour, soil conditions etc. But the most important factor deciding the seed rate is the planting distance in the field.

The seed rate of important vegetables included in this chapter is as follows:

S. No.	Vegetable	Seed Rate (Kg per ha)
1.	Brinjal	0.5
2.	Tomato	0.5-0.6
3.	Chili	1.5
4.	Bitter gourd, Pumpkin, Watermelon, Cucumber	2-3
5.	Ridge gourd	4
6.	Okra	8-10
7.	Beans	20-30
8.	Garden Peas	60
9.	Palak	15-20

Spacing: Every plant needs a specific space around its vicinity to develop to its full potential. This space varies according to soil conditions, plant vigour, growth habit of plant, inter-plant competition etc. Thus spacing refers to distance between crop rows (inter-row) and between plants with in the rows (intra-row spacing).

The spacing required for the crops being discussed in this chapter is tabulated as follows:

S. No.	Vegetable	Spacing (cm)
1.	Brinjal	60 x 60
2.	Tomato	60 x 45
3.	Chili	45 x 45
4.	Muskmelon, Watermelon	300 x 60
5.	Bitter gourd, Cucumber, Ridge gourd	150 x 45
6.	Okra	45 x 30
7.	Beans	30 x 10
8.	Garden Peas	15 x 10
9.	Palak	20 x 5

Mode of Pollination

There are three modes of pollination in vegetable crops viz., self-pollination, cross-pollination and often cross pollination. The information on the extent of cross-pollination is required to decide the breeding method for the improvement of crop and to maintain the genetic purity of crop. The modes of pollination of important vegetables being discussed in this chapter are as follows:

S. No.	Mode of pollination	Vegetables
1.	Self	Beans, peas, cowpea, tomato
2.	Cross	Cucurbits, palak
3.	Often Cross pollination	Okra, brinjal, chilli

Management of Water

Water is the most critical input for maximization of the yield. In northern and central regions of country, where rains are more or less frequent, supplemental irrigation is required. But in the coastal regions of country and in N-E areas where rains occur more frequently vegetables can be grown as rainfed crops but even then irrigation is needed during winters. The water management in vegetables not only refers to irrigation but also to drain away the excess water, as most of the vegetables cannot withstand the excessive moisture in the root zone. Irrigation in vegetables is done by either flood or furrow irrigation. Now a days drip irrigation is being followed to reduce the irrigation cost and for optimal use of irrigation water.

The irrigation requirements for some vegetables under average soil conditions are mentioned as a guide, which may be increased or decreased according to soil type and climate:

S. No.	Vegetable	Irrigation Schedule
1.	Brinjal	6-8 irrigations. Light irrigation after transplantation and rest at 10-15 days interval. Monsoon crop can be grown without irrigation
2.	Tomato	Light irrigation after transplantation. 5-6 irrigations at 10-15 days interval in winter and 7-8 days interval in summers
3.	Chili	Light irrigation after transplantation. 3-4 light supplemental irrigations between rains.
4.	Cucurbits	Light irrigation after sowing followed by 9-10 irrigations at 8-10 days interval
5.	Leafy vegetables	Pre-sowing irrigation followed by 3-4 light irrigations
6.	Okra	Light pre-sowing irrigation followed by 6-8 irrigations at 7-8 days interval
7.	Peas and Beans	Pre-sowing irrigation followed by 5-6 light irrigations. The beans can be gown without watering during rains

Weed management

Weeds are unwanted plants in gardens that reduce available moisture, nutrients, sunlight and growing space needed by crop plants. Their presence can reduce crop growth, quality and yield. In addition, they can make harvest difficult. Weeds also provide cover for diseases, insects and animals (rodents, box turtles, snakes, etc.). Garden weeds are hard to control because they grow rapidly, produce abundant seeds, and spread aggressively by vegetative structures and/or seeds. There are several methods that should be used in a combined, coordinated effort to control weeds. They include cultural, mechanical and chemical methods.

1. Cultural Methods: Fast growing vegetable crops can effectively suppress weeds by shading. The vegetables like Squashes, Melons, Beans, Pumpkin, Peas, Cucumber and Tomato can suppress the weeds effectively. Mulches can also be used to check weeds and

ultimately reduce time and labour required to remove them. The mulches used are of two types -- **organic mulches,** which are derived from plant material that decompose naturally in the soil, and **inorganic mulches** which do not decompose and therefore need to be removed after increasing soil moisture retention, enhancing soil warming and checking weeds.

2. Mechanical Methods: Weeds can be removed mechanically by hand, weeds can be hand pulled or removed by using hand tools. Several small hand tools like hand hoe, wheel hoe are available that are very effective on small weeds and for working near garden plants.

3. Chemical Methods: Herbicides are another weed control aid that some gardeners employ. Gardeners should be aware that *no single herbicide will do the entire job* of controlling weeds in all vegetable crops. There is also a problem of applying relatively small amounts of the herbicide evenly to the garden surface. Miscalculation of rates or miscalibration of application equipment can cause some areas of the garden to get too much or too little of the herbicide. Under-application will result in poor weed control while over-application will result in damaged plants. Several weedicides like Stomp, Treflan, 2,4-D, Paraquat, MCPB etc. can control the weeds effectively.

Nutrient Management

Nutrients can be supplied to vegetables by organic manures and chemical fertilizers. Organic manures not only add the essential nutrients to the soil but they also improve the soil texture and structure. They also increase the water holding capacity and aeration of soil. The organic manures are needed in bulk as they have little proportion of the nutrients and these nutrients are also released slowly. So the chemical fertilizers are preferred as they are needed in small quantity and release the nutrients quickly.

The requirements of manures and fertilizers by some vegetables on average soil and climatic conditions are stated below.

S. No.	Vegetable	FYM* (t/ha)	Nitrogen (Kg/ha)	Phosphorus (Kg/ha)	Potassium (Kg/ha)	Remarks **
1.	Brinjal	20-25	80-100	50-70	40-60	Apply 25 kg N twice at interval of 40 days after swing
2.	Tomato	20-25	80-150	60-100	100-150	Apply rest of N in 2 doses at 30 days interval after sowing
3.	Chili	20-25	40-60	60-80	40-60	Apply N in 2 split doses after 45 days interval.
4.	Cucurbits	15-35	50-60	30-40	40-60	Apply 30 kg N after 30 days of sowing
5.	Leafy vegetables	10-15	30-50	40-60	40-60	Apply N in 2-3 split doses as top

						dressing after sowing
6.	Okra	12-15	30-50	40-60	30-50	Apply 20-30 kg N as top dressing twice 30 and 60 days after sowing
7.	Peas	15-20	15-30	60-75	40-60	Half N is applied after 40 days of sowing
8.	Beans	12-15	15-30	40-75	30-50	Apply Zinc if necessary

* The FYM should be added in soil during field preparation
** Half of the Nitrogen and full dose of phosphorus and potassium is applied at time of soil preparation and rest of nitrogen is supplied in doses as described.

Plant Growth Regulators

Plant growth regulators (also known as growth regulators or plant hormones) are chemicals used to alter the growth of a plant or plant part. Hormones are substances naturally produced by plants; they control normal plant functions, such as root growth, fruit set and drop, growth and other development processes.

Any substance or mixture of substances intended, through physiological action, for accelerating or retarding the rate of growth or maturation, or for otherwise altering the behavior, of ornamental or crop plants or the produce thereof; but does not include substances intended as plant nutrients, trace elements, nutritional chemicals, plant inoculants, or soil amendments.

The plant growth regulator's class, associated function(s) and practical uses for various vegetables are as follows:

Class	**Function(s)**	**Vegetable crop benefited**	**Practical uses**
Auxins	Shoot elongation	Okra, tomato, brinjal, cowpea	Fruit thinning, increase rooting and flower formation
Gibberellins	Stimulate cell division and elongation	Cucurbits, Tomato	Increase stalk length, increase flower and fruit size
Cytokinins	Stimulate cell division	French bean, Pumpkin	Prolonging storage life of flowers and vegetables, bud initiation and root growth
Ethylene generators	Ripening	Cucurbits, okra, chilli, tomato	Induce uniform ripening in fruit and vegetables
Growth inhibitors	Stops growth	All	Promote flower production by shortening internodes

Harvesting and Yield

Harvesting is the final agricultural operation in field. It depends upon kind and variety of crop, weather, conditions at time of sowing, distance of market and the purpose of marketing. Commercial vegetable growers, wholesalers and retailers are experts at selecting the optimum harvest time and storage conditions to ensure that the vegetables will have the longest possible shelf life.

Harvesting Tips:

1. For best results, the harvesting should be done on the day you plan to market them . Cloudy days, early mornings, and evenings are always best.
2. Sprinkle them lightly with water and store them in a cool place until you are ready to market them.
3. Some vegetables have a short harvest window and should be picked promptly when ripe. Pick all your vegetables in the coolest weather you can
4. Use a clean, sharp knife to cut your vegetables from the plant. Use clean containers to put your crops in. Be gentle when you handle your crops so they don't bruise. Put a clean, dry cloth at the bottom of each container to protect the crops.
5. Keep your containers in the shade as you fill them. Then follow instructions for each vegetable to store it in the right way.
6. If the vegetable needs to be moist when stored, cover it with plastic with slits or holes. Or, if you have a humidifier in your cooler, set it to 95%. Take your crops to the market as soon as you can. Then they will be fresh, healthy, and colourful.
7. Some vegetables are still good a long time after you pick them. That is why it is important to pick and store them

Method of Harvesting

Beans. Pick beans two to three weeks after the plant blooms. Keep them moist and cool, but not cooler than 40° F. Beans will spoil after about one week. Harvest before you can feel the outline of the individual beans. If left too long, shell the beans and discard the pod.

Cucumbers. Pick cucumbers when they are six inches long. Keep them cool but not colder than 40° F. Do not store cucumbers with apples or tomatoes. Cucumbers will spoil after about one week. Harvest before the seeds inside swell.

Brinjal. Pick brinjal when their colour is bright. Keep them cool but not cooler than 50° F. Eggplant will spoil after about one week. Harvest when the fruit is small and glossy. Once they loose their shine they are too old.

Peas. Pick peas while the pods are still tender. Keep them cold and moist. Peas will spoil after about one week. Harvest before the individual peas begin to touch inside the pods. They become starchy and tasteless if left too long.

Chili. Pick them when they are of the size and colour you want. Keep them cool but not cooler than 45 ° F. Peppers will spoil after about two weeks.

Squash (summer). Pick summer squash when they are four to six inches long. Keep them cool. Summer squash will spoil after about one week. Most winter squash should be left on the vine until the bottom is a different colour from the top, and the skin is hard.

Tomatoes (red). Pick red tomatoes when they are pink or red all over. Keep cool but do not refrigerate. Tomatoes will spoil after about five days. It's best to wait until the tomato is ready to eat. A tomato that is picked when is showing any orange or red colour will be superior to a supermarket tomato

Melons They are harvested after 60-90 days of sowing when fruits are fully developed and mature.

Leafy vegetables. The leaves should be tender and succulent at the time of harvesting as hard leaves become bitter

Okra. The tender, green and small (6-10 cm long) pods should be picked in the morning or evening. While picking okra, one should wear gloves or wash his hands thoroughly after picking in order to remove the irritating and stinging effect of the bristles of the fruits.

S. No.	Vegetable	Days to harvest after sowing	Yield (qtl/ha)
1.	Brinjal	70-80	200-250
2.	Tomato	120-150	225-250
3.	Chili	60-90	100-120
4.	Palak	25-30	70-90
5.	Spinach	25-30	80-100
6.	Okra	70-90	100-130
7.	Garden Peas	100-130	50-80
8.	Beans	50-60	30-50
9.	Watermelon	60-90	250-280
10.	Muskmelon	60-90	150-170
11.	Cucumber	60-70	110-120
12.	Bitter gourd	60-80	100-110
13.	Sponge gourd	60-90	100-110
14.	Squash	90-120	240-260
15.	Pumpkin	60-90	250-280

Post harvest Handling

Quality cannot be improved after harvest, only maintained; therefore it is important to harvest vegetables at the proper stage and size and at peak quality. Immature or over

mature produce may not last as long in storage as that picked at proper maturity. Harvest should be completed during the coolest time of the day, which is usually in the early morning, and produce should be kept shaded in the field. Handle produce gently. Crops destined for storage should be as free as possible from skin breaks, bruises, spots, rots, decay, and other deterioration. Bruises and other mechanical damage not only affect appearance, but provide entrance to decay organisms as well. Post harvest rots are more prevalent in fruits and vegetables that are bruised or otherwise damaged. Mechanical damage also increases moisture loss. The rate of moisture loss may be increased by as much as 400 percent by a single bad bruise. Damage can be prevented by training harvest labour to handle the crop gently; harvesting at proper maturity; harvesting dry whenever possible; handling each fruit or vegetable no more than necessary (field pack if possible); installing padding inside bulk bins; and avoiding over- or under-packing.

1. Pre-cooling: Pre-cooling is the first step in post harvest handling. The field heat of a freshly harvested crop—heat the product holds from the sun and ambient temperature is usually high, and should be removed as quickly as possible before shipping, processing, or storage. Pre cooling can be done by any of the following:
Room cooling: Produce is placed in an insulated room equipped with refrigeration units.

Forced-air cooling: Fans are used in conjunction with a cooling room to pull cool air through packages of produce.

Hydro-cooling: Dumping produce into cold water, or running cold water over produce, is an efficient way to remove field heat, and can serve as a means of cleaning at the same time. In addition, hydro-cooling reduces water loss and wilting.

Top or liquid icing: Icing is particularly effective on dense products and palletized packages that are difficult to cool with forced air. In top icing, crushed ice is added to the container over the top of the produce by hand or machine. For liquid icing, a slurry of water and ice is injected into produce packages

Vacuum cooling: Produce is enclosed in a chamber in which a vacuum is created. As the vacuum pressure increases, water within the plant evaporates and removes heat from the tissues. This system works best for leafy crops, such as lettuce, which have a high surface-to-volume ratio.

2. Grading: After bringing form the field, the first operation that usually follows is the removal of unmarketable material. This is because handling of plant material that cannot be sold is costly. This is performed prior to sizing and grading. After removal of the unmarketable products the grading is done. It consists of sorting product in grades or categories of quality. There are two main systems of grading: static and dynamic.

Static systems: These are common in tender and/or high value crops. Here the product is placed on an inspection table where sorters remove units, which do not meet the requirements for the grade or quality category.

The dynamic system: It is probably much more common. Here product moves along a belt in front of the sorters who remove units with defects. Main flow is the highest quality grade. Often second and third grade quality units are removed and placed onto other belts. It is much more efficient in terms of volume sorted per unit of time.

3. Storage: It is essential to store the produce because:

1. Storing ensures the continuous supply even in the off-season.
2. Vegetables remain protected from the fluctuating weather conditions.
3. Stored vegetables can fetch higher price in the market.
4. Storage prolongs the shelf-life.
5. Storage avoids the glut in the market.

Factors affecting storage: The principle factors affecting storage are the temperature, relative humidity, ventilation, cleanliness, packaging type, health of produce, chemical composition of the produce, kind and variety of produce and duration of storage.

Table: Storage temperature and relative humidity for vegetable crops

Vegetable	Cooling Method(s)	Temp. ^{o}F	Freezing Temp^{o}F	Relative Humidity %	Storage Life
Tomatoes	R,F	46-50	31	90-95	1 week
Okra	R,F	45-50	29	90-95	7-10 days
Beans	R,F,H	40-45	31	95	7-10 days
Brinjal	R,F	45-54	31	90-95	1 week
Garden Peas	F,H	32	31	95-98	1-2 weeks
Chilli	R,F	45-50	31	90-95	2-3 weeks
Squash melon	R,F	45-50	31	95	1-2 weeks
Watermelon	R	50-60	31	90	2-3 weeks
Musk melon	H,I	32-40	30	95	2 weeks
Cucumber	F,H	45-50	31	95	2 weeks

Refrigeration is the principal means of extending the shelf life of vegetables after harvest, as it slows down metabolic activity. Vegetables of tropical and subtropical origin show a physiological disorder called Chilling injury if exposed to the temperature below 10°C but above their freezing point. Severity of injury generally increases chilling storage temperature decreases and the duration of storage increases. Chilling storage symptoms may develop during or after exposure. The injury in many vegetables is manifested as discolouration, susceptibility to decay, or failure to ripen; it is progressive with time indication a general degeneration of metabolism.

4. Packaging: Packaging fresh fruits and vegetables is one of the more important steps in the long and complicated journey from grower to consumer. Bags, crates, hampers,

baskets, cartons, bulk bins, and palletized containers are convenient containers for handling, transporting, and marketing fresh produce. Packing and packaging materials contribute a significant cost to the produce industry; therefore it is important that packers, shippers, buyers, and consumers have a clear understanding of the wide range of packaging options available. A significant percentage of produce buyer and consumer complaints may be traced to container failure because of poor design or inappropriate selection and use. A properly designed produce container should contain, protect, and identify the produce, satisfying everyone from grower to consumer.

Points to be kept in mind while selecting packaging material:

1. The produce packaging should be recyclable or biodegradable, or both.
2. The trend is toward greater use of bulk packages for processors and wholesale buyers and smaller packages for consumers. There are now more than 1,500 different sizes and styles of produce packages.
3. The packaging material should boost sales appeal. Multi-colour printing, distinctive lettering, and logos are now common.
4. The produce packaging should be custom engineered for each commodity to extend shelf life and reduce waste.

Diseases and Pests

Most vegetable plants are affected by number of pests and diseases. The diseases are mainly fungal, bacterial and viral. The pests attacking the vegetables are insects, nematodes, cutworms, mites etc.

Table: Major diseases affecting tropical and sub-tropical vegetables

S. No.	Disease	Vegetables affected	Chemical(s) recommended
1.	Powdery mildew	Cucurbits, Peas	Karathane
2.	Downy mildew	Cucurbits	Indofil M 45
3.	Early blight	Cucurbits, tomato	Captan, thiram, Indofil M 45
4.	Late blight	Tomato	Captan, thiram, Indofil M 45
5.	Mosaic	Cucurbits, tomato, chili, cowpea	Rogor, Metasystox
6.	Root knot nematode	Cucurbits, tomato	Nemagon, Rogor
7.	Damping off	Tomato, brinjal, okra, cowpea	Captan, Thiram
8.	Leaf curl	Tomato, chili	Rogor, Metasystox
9.	Little leaf	Brinjal	Malathion
10.	Phomposis blight	Brinjal	Captan, Ziram
11.	Fruit rot	Chili	Indofil M 45, Blitox
12.	Yellow vein mosaic	Okra	Malathion
13.	Cercospora leaf spot	Okra, cowpea, palak	Bavistin
14.	Wilt	Pea	Bavistin
15.	Rust	Pea	Indofil M 45

Similarly there are various insect-pests affecting vegetables like aphids, jassids, red pumpkin beetle, fruit flies fruit borers, spider mites, whitefly, bollworms, pod borer etc.

The incidence of these insect pests and diseases can be minimized by following the integrated pest and disease management strategies such as growing resistant varieties, using disease free seeds, crop rotation, inter-cropping, varying planting dates, bio control predators, soil sterilization, clean cultivation, optimum use of chemical and plant based fungicides and insecticides like neem seed kernel extract.

Physiological disorders: There are some disorders in vegetable crops where there is no pathogen involved and they are more or less due to the unfavourable environmental conditions like nutrition, water, light, soil etc. The major physiological disorders are classified as follows:

S. No.	**Classification**		**Physiological disorder**
1.	Due to Nutrient Deficiency	Calcium	Hypocotyl necrosis of French bean Tip burn of lettuce Blossom-end rot of water melon and tomato
		Potassium	Blotchy ripening in tomato
		Nitrogen	Buttoning in all the vegetables
2.	Due to excessive moisture		Cotyledon cracking in Beans
3.	Due to excessive exposure to sun rays		Sun scald in tomato
4.	Due to high temperature		Blossom drop and ovule abortion in beans Blossom-end rot of water melon and tomato Puffiness and flower drop in tomato
5.	Due to low temperature		Delayed flowering and pod setting in beans Poor fruit setting in tomato and brinjal
6.	Due to water deficiency		Cracking in tomato
7.	Due to deleterious effects of ethylene		Russet spotting in lettuce