STUDENT HANDBOOK

OLERICULTURE-II

Class XII

CENTRAL BOARD OF SECONDARY EDUCATION

Shiksha Kendra, 2, Community Centre, Preet Vihar, Delhi-110 092 India

नया आगाज़

आज समय की माँग पर
आगाज़ नया इक होगा
निरंतर योग्यता के निर्णय से
परिणाम आकलन होगा।

परिवर्तन नियम जीवन का
नियम अब नया बनेगा
अब परिणामों के भय से
नहीं बालक कोई डरेगा

निरंतर योग्यता के निर्णय से
परिणाम आकलन होगा।

बदले शिक्षा का स्वरूप
नई खिले आशा की धूप
अब किसी कोमल-से मन पर
कोई बोझ न होगा

निरंतर योग्यता के निर्णय से
परिणाम आकलन होगा।
नई राह पर चलकर मंज़िल को हमें पाना है
इस नए प्रयास को हमने सफल बनाना है
बेहतर शिक्षा से बदले देश, ऐसे इसे अपनाए
शिक्षक, शिक्षा और शिक्षित
बस आगे बढते जाएँ
बस आगे बढते जाएँ
बस आगे बढते जाएँ.........

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for

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CENTRAL BOARD OF SECONDARY EDUCATION

2, COMMUNITY CENTRE, PREET VIHAR, DELHI – 110092

Olericulture-II for Class XII

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Preface

Vegetable crops established its credibility in improving income through increased productivity, generating employment and enhancing exports. Vegetable cultivation has also marked its significance in high yield potential per unit area and time, high market price, prospects of processing, value addition and export, employment generation, and livelihood improvement.

The vegetable production is getting popular tremendously as a remunerative profession over the past few years in both urban and rural areas of the country. Vegetable cultivation is not only a mean to improve the socio-economic status but may solve the employment problems to a great extent. It is an upcoming business with enormous scope in the various fields like, in its cultivation, processing industry, seed production units etc.

In this endeavour this book entitled **"Olericulture-II"** Student Handbook provides information on different aspects of vegetable production. Keeping the objectives in mind eight lessons have been included in this book which cover modern methods of vegetable cultivation, industrial importance of vegetables, setting up of industry based on vegetable crops, cropping system with vegetables, production technology of important vegetable crops, fertigation in vegetable crops, role of chemicals and growth regulators in vegetable production, seed production techniques and hybrid seed production of vegetable crops. Thus, the manuscript gives an overview of the methodologies and techniques used in vegetable production, their conceptual framework and also entrepreneurship opportunities. The suggested references are provided to encourage students to explore more. During the course of study, student should not only obtain knowledge and skill but also be encouraged to acquire good professional qualities that are based on sound ethical principles which makes one as a real professional.

We hope the students will find the learning material to their reading taste and will be helpful in developing the entrepreneurship skills and will motivate them to choose vegetable production as an enterprise.

Vineet Joshi, IAS
Chairman, CBSE

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भारत का संविधान

उद्देशिका

हम, भारत के लोग, भारत को एक सम्पूर्ण [1]प्रभुत्व-संपन्न समाजवादी पंथनिरपेक्ष लोकतंत्रात्मक गणराज्य बनाने के लिए, तथा उसके समस्त नागरिकों को:

सामाजिक, आर्थिक और राजनैतिक न्याय,
विचार, अभिव्यक्ति, विश्वास, धर्म
और उपासना की स्वतंत्रता,
प्रतिष्ठा और अवसर की समता
प्राप्त कराने के लिए
तथा उन सब में व्यक्ति की गरिमा
[2]और राष्ट्र की एकता और अखंडता
सुनिश्चित करने वाली बंधुता बढ़ाने के लिए

दृढ़संकल्प होकर अपनी इस संविधान सभा में आज तारीख 26 नवम्बर, 1949 ई॰ को एतद्द्वारा इस संविधान को अंगीकृत, अधिनियमित और आत्मार्पित करते हैं।

1. संविधान (बयालीसवां संशोधन) अधिनियम, 1976 की धारा 2 द्वारा (3.1.1977) से "प्रभुत्व-संपन्न लोकतंत्रात्मक गणराज्य" के स्थान पर प्रतिस्थापित।
2. संविधान (बयालीसवां संशोधन) अधिनियम, 1976 की धारा 2 द्वारा (3.1.1977) से "राष्ट्र की एकता" के स्थान पर प्रतिस्थापित।

भाग 4 क

मूल कर्त्तव्य

51 क. मूल कर्त्तव्य – भारत के प्रत्येक नागरिक का यह कर्त्तव्य होगा कि वह –

(क) संविधान का पालन करे और उसके आदर्शों, संस्थाओं, राष्ट्रध्वज और राष्ट्रगान का आदर करे;

(ख) स्वतंत्रता के लिए हमारे राष्ट्रीय आंदोलन को प्रेरित करने वाले उच्च आदर्शों को हृदय में संजोए रखे और उनका पालन करे;

(ग) भारत की प्रभुता, एकता और अखंडता की रक्षा करे और उसे अक्षुण्ण रखे;

(घ) देश की रक्षा करे और आह्वान किए जाने पर राष्ट्र की सेवा करे;

(ङ) भारत के सभी लोगों में समरसता और समान भ्रातृत्व की भावना का निर्माण करे जो धर्म, भाषा और प्रदेश या वर्ग पर आधारित सभी भेदभाव से परे हों, ऐसी प्रथाओं का त्याग करे जो स्त्रियों के सम्मान के विरुद्ध हैं;

(च) हमारी सामासिक संस्कृति की गौरवशाली परंपरा का महत्त्व समझे और उसका परिरक्षण करे;

(छ) प्राकृतिक पर्यावरण की जिसके अंतर्गत वन, झील, नदी, और वन्य जीव हैं, रक्षा करे और उसका संवर्धन करे तथा प्राणिमात्र के प्रति दयाभाव रखे;

(ज) वैज्ञानिक दृष्टिकोण, मानववाद और ज्ञानार्जन तथा सुधार की भावना का विकास करे;

(झ) सार्वजनिक संपत्ति को सुरक्षित रखे और हिंसा से दूर रहे;

(ञ) व्यक्तिगत और सामूहिक गतिविधियों के सभी क्षेत्रों में उत्कर्ष की ओर बढ़ने का सतत प्रयास करे जिससे राष्ट्र निरंतर बढ़ते हुए प्रयत्न और उपलब्धि की नई उंचाइयों को छू ले;

[1](ट) यदि माता-पिता या संरक्षक है, छह वर्ष से चौदह वर्ष तक की आयु वाले अपने, यथास्थिति, बालक या प्रतिपाल्य के लिये शिक्षा के अवसर प्रदान करे।

1. संविधान (छयासीवां संशोधन) अधिनियम, 2002 द्वारा प्रतिस्थापित।

THE CONSTITUTION OF INDIA

PREAMBLE

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a [1]**SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC** and to secure to all its citizens :

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity; and to promote among them all

FRATERNITY assuring the dignity of the individual and the[2] unity and integrity of the Nation;

IN OUR CONSTITUENT ASSEMBLY this twenty-sixth day of November, 1949, do **HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.**

1. Subs, by the Constitution (Forty-Second Amendment) Act. 1976, sec. 2, for "Sovereign Democratic Republic" (w.e.f. 3.1.1977)
2. Subs, by the Constitution (Forty-Second Amendment) Act. 1976, sec. 2, for "unity of the Nation" (w.e.f. 3.1.1977)

THE CONSTITUTION OF INDIA

Chapter IV A

FUNDAMENTAL DUTIES

ARTICLE 51A

Fundamental Duties - It shall be the duty of every citizen of India-

(a) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;

(b) to cherish and follow the noble ideals which inspired our national struggle for freedom;

(c) to uphold and protect the sovereignty, unity and integrity of India;

(d) to defend the country and render national service when called upon to do so;

(e) to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;

(f) to value and preserve the rich heritage of our composite culture;

(g) to protect and improve the natural environment including forests, lakes, rivers, wild life and to have compassion for living creatures;

(h) to develop the scientific temper, humanism and the spirit of inquiry and reform;

(i) to safeguard public property and to abjure violence;

(j) to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievement;

[1](k) to provide opportunities for education to his/her child or, as the case may be, ward between age of 6 and 14 years.

1. Subs, by the Constitution (Eighty-Sixth Amendment) Act. 2002.

CONTENTS

Chapter-1

Different Production System and Modern Methods of Vegetable Cultivation

OBJECTIVES

Students will be able to learn about:-

- Peri-urban vegetable farming
- Truck farming
- Home/kitchen/nutrition garden
- Container garden
- Floating garden
- Precision farming
- Protected cultivation of vegetable crops
- Hydroponics

INTRODUCTION

Diversification in agriculture favouring horticultural crops is to be looked as a means to ensure food and nutrition security as well as higher profitability. As long as production of high value crops remains relatively more profitable as compared to alternatives, it is feasible to promote crop diversification. Vegetable is gaining importance worldwide as it gives more nutritious food per unit area to the human being. Vegetables comprise of a large number of herbaceous plants, mostly annuals, of which different parts like leaf, stem, flower bud, flower, fruit and root etc. are eaten either cooked or raw as principal item during the meals. These are the important sources of carbohydrates, vitamins, minerals and proteins thus, helping in providing nutritional security and combating malnutrition. India has an advantage of producing almost all types of tropical, temperate and exotic vegetables because of varied climatic conditions. In this chapter we will learn about different production systems of vegetable crops existing in India and some modern methods of cultivation to produce high quality vegetables to meet the requirement of quality focused consumers of big cities. Classification of production system of vegetable crops mainly depend upon its objectives, farm size, amount of investment, potential markets /consumers and purpose of marketing like fresh products, processing industry or seed markets. Commercial seed production of vegetable crops is a highly specialized business and it will be discussed later in a separate chapter.

Peri-urban vegetable farming

Peri-urban agriculture is recognised for its potential role in increasing food security, employment and income generation, poverty alleviation, community resource development, waste management and environmental sustainability. With the rapid industrialization, growing urbanization and higher employment opportunities and income level, purchasing capacity is multiplying and awareness for nutrition is also increasing which creates increasing demand of vegetables in urban areas. Peri-urban vegetable cultivation can provide farmers the possibility to cultivate a small piece of land, and obtain an income to meet their essential and basic needs. In recent years, around big cities, green belts are being developed which can provide a very intensive and profitable network of small farms specialised in production of perishable vegetables for consumption by the urban consumers. This is likely to result in a social symbiosis between farmers and city dwellers with mutual benefits and advantages. Large quantity of solid waste is generated in big cities during handling and marketing of fresh vegetable produce and otherwise also which is creating health and environmental hazards which can be used or recycled to produce vermicompost, etc., for use in organic vegetable production. Indian consumers prefer fresh lush green vegetables than processed products which provide a business opportunity to the farmers located nearby the big cities or towns generally referred as peri-urban areas to meet the requirement of consumers and earn higher profit. The nearby market is main focus of this production system and it is also called as market gardening in USA and some other countries. The aim, as with all farm enterprises, is to run the operation as a business and to make a profit. Market gardening is often oriented toward local markets, although production for shipment to more distant markets is also possible. The most important consideration is to develop a clearly focused marketing plan before any vegetable crops are planted. Having marketing in mind before planting helps to ensure but will not guarantee that most of what you plant will be sold, thus eliminating wasted time, space, produce, and money. Many farmers try to maximize their income by selling directly to consumers, thus bypassing wholesalers and other middlemen. Farmers stall in weekly vegetable market, roadside stands and sale agreement to restaurants, modern retail stores are common marketing strategies which can be adopted. The use of information and communication technology (ICT) tools like internet can also be thought for direct marketing with consumers. This is a highly intensive form of production enterprise. Sometimes, organically grown produce typically commands higher prices in the marketplace. Farmers may choose to grow their crops organically but they need to get their farm and produce accredited through certifying agency for organic products which will provide their produce an added advantage in the marketing.

Market gardening is the commercial production of vegetables, fruits, flowers, and other plants, on a scale larger than a home garden, yet many of the principles of gardening can be applied.

Considering the high cost and small size of farm land in the vicinity of a city and high cost of labour, water and energy, it is necessary for the farmer to have high productivity per unit of land area. Diversified crops are grown in peri-urban vegetable farms. Diversified crops may also include specialty vegetables, like baby corn, sweet corn, gherkin, red and yellow coloured sweet pepper, leek, bunching onion, broccoli, Brussels sprouts, celery, parsley, endive, chive, pak-choi, asparagus, artichoke and a few others. The specialty vegetables are becoming popular to meet the demands of consumers, restaurants and hotels in big cities. The other important considerations are choice of vegetables adapted to soil and climatic conditions, facilities of labour, water for irrigation and transport, proximity to market, and preferences of market and consumers. It is often profitable to have intercropping, succession of crops, relay cropping, mixed cropping and early maturing cultivars for continuous supply and for obtaining high price by bringing early produce in the market. The vegetables of peri-urban areas are transported to market by trucks, auto rickshaws, cycle rickshaws, tractor trolley and small tempo carriers. Peri-urban production is either fast diminishing or moving farther from the city because of expansion of urban areas.

Truck Farming

Large scale production for transportation by trucks to distant markets is an extensive farming system. It involves only a few vegetables grown often in rotation with other crops, like cereals and pulses. It is also for off-season supply of a particular vegetable to markets away from the growing areas The well-known examples of distant marketing and off-season supply include onion and tomato from Maharashtra and Gujarat to north India (Delhi, Chandigarh), tomato from Kolar (Karnataka) to Kolkata, watermelon from Andhra Pradesh to Delhi and other northern markets during winter months, peas from Haryana and Punjab to Bangalore, Chennai and other areas of South, off-season pea from Lahul- Spiti, Shimla and other areas of Himachal Pradesh to Delhi in summer months, pointed gourd (parwal) from Bihar and West Bengal to north-western and southern regions, early cauliflower and muskmelon from Rajasthan to Delhi and Chandigarh, cantaloupes from Amritsar (Punjab) to Srinagar in summer, cabbage, cauliflower, peas and carrot from Ooty to Bangalore and Chennai, potato from Jalandhar (Punjab) to southern states (Hyderabad. Bangalore, Chennai) and eastern region (Kolkata, Bhubaneswar, Cuttack), potato from Bihar to Kolkata, tomato from Solan (Himachal Pradesh) to Delhi and Chandigarh, late cauliflower from Himachal Pradesh to Delhi during May to July and several kinds of vegetables from Ranchi (Jharkhand) to Patna, Jamshedpur and Kolkata. Recent developments in infrastructure, like roads / highways, rapid transport trucks and rail, and storage have facilitated truck farming. Nowadays cultivars or hybrids of high value crops like, tomato, cantaloupes, and capsicum suitable for long distance shipping have also contributed to expansion of truck farming system. It is thus not necessary now to grow only those vegetables, which are less perishable than others, like potato, onion, pumpkin, chillies, bottle gourd and pointed gourd (parwal).

Cooperative Farming

A few cooperative societies of enterprising farmers in Maharashtra have undertaken production of tomato for supply to distant markets in northern region, mainly Delhi and Chandigarh. There are not many instances of cooperative farming of vegetable crops in the country. The National Dairy Development Board (NDDB) has assisted in setting up cooperative societies of vegetable growers in Uttar Pradesh, Rajasthan, Haryana and Punjab. The farmers' cooperative societies supply vegetables at a pre-fixed price to NDDB which collects and transports the vegetables from cooperative farms and sells them at their vegetable and fruit booths / outlets established at several locations in Delhi city. A few other cooperative societies have undertaken marketing of fresh vegetables in other parts of the country.

Contract Farming

Contract farming is a partnership between agribusiness/marketing firms and farmers. For agribusiness firms, contract farming is an important means to have an assured access to desired products or a quantitative and qualitative control over material supplies without actually engaging itself in farming. Firms may provide inputs, technology and services to farmers as a part of contract. If a firm were to produce its raw material requirements itself, using own or rented land and hired labor, the costs towards wages, social benefits, training and supervision could be very high. Through contract farming, the firm can shift and/or share some of these responsibilities with farmers, and secure supplies at a lower cost. Contract farming thus enables agribusiness firms to optimally utilize their installed capacity, infrastructure and manpower, and respond to food safety and quality concerns of the consumers. For farmers, contract farming serves as an assured market for their produce at their doorsteps, reducing marketing and transaction costs and also price risk. Availability of an assured market also acts as an incentive to farmers to use quality inputs, adopt improved technologies and scale up their production systems. In circumstances when farmers face problems in accessing inputs, technology, information and services, firms provide these as a part of contract and hence reduce uncertainty in their availability, quality and prices for the farmers. Further contract farming is often practiced in high-value perishable commodities that are riskier and require a different set of production and management practices, while farmers, particularly smallholders, are risk averse and may not venture into production of such commodities without technical assistance. To enable farmers to cope up with risks, firms provide them inputs, technology and services, impart training in production management and share risks.

The case of successful contract farming in vegetables relates to the Mother Dairy Fruits and Vegetables Limited (MDFVL) - a wholly owned subsidiary of the public sector unit, National Dairy Development Board (NDDB). Horticultural production in India is geographically dispersed; only about 15 percent farm households grow vegetables and 5 percent grow fruits. This means high transaction costs to the firm in securing supplies from scattered producers. To reduce these costs, the MDFVL secures supplies of fruits and vegetables from growers' associations promoted by it. The firm provides technical guidance, services and inputs to association members to ensure that farmers follow best production and marketing practices. MDFVL (earlier called SAFAL) is an organized retail chain and was started in 1988 in Delhi. As of now, the MDFVL secures its supplies from around 300 growers' associations spread throughout the country, and has almost an equal number of retail outlets in Delhi. SAFAL is the brand name for MDFVL products. Some of the private companies have also entered in contract farming mainly to meet the requirement of processing industry like Pepsi for tomato cultivation to meet requirements of its processing plant in Punjab and production of potato varieties suitable for processing for its potato chips industry. With the modernization of retail industry, many companies will enter into contract farming for fresh and specialized vegetable cultivation like seedless watermelon, baby corn, lettuce and many others.

A few seed companies in India undertake contract production of vegetable seeds with farmers for export and also for domestic market. Hybrid seed production of vegetables is now a global enterprise of many leading seed companies of the USA, Japan, Holland, France, Denmark, Sweden, Germany and few others. Several thousand small farmers are involved in production of vegetable seeds in Karnataka, Maharashtra, Andhra Pradesh, Tamil Nadu, Haryana, Punjab, Uttar Pradesh, Himachal Pradesh and Jammu and Kashmir. Private seed companies produce hybrid seeds of tomato, capsicum, cucumber, melons, cabbage, cauliflower, okra, and a few other crops under contract with the farmers. However, the seeds produced and supplied by the contract farmers have to meet the requirements of seed quality standards, like germination percentage, genetic purity, hybridity percentage, seed size and colour etc. The price and quantity of seeds required to be produced are intimated to the farmer before he undertakes the production on the agreed terms and conditions. The Indian seed companies undertaking contract production for foreign seed companies have also to follow certain mutually agreed terms and conditions with regard to price, seed quaintly, time of seed supply and seed quality standards. Seeds of the parental lines of the hybrids to be produced are supplied by the importing seed company. A few seed companies export also seeds of their branded hybrids. Hybrid seed production generates not only high income to the farmers but also provides employment opportunities to rural youths and to some extent helps to check their migration to urban areas. Techniques of hybrid seed production will be discussed later in chapter 8.

Activity 1

Make a plan to visit of market/truck garden in nearby areas and discuss with farmers about production techniques, marketing and price realization by them in cultivation of different vegetables. Prepare a report by identifying most profitable and less risky vegetable crops.

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Home/kitchen garden/nutrition garden:

Availability of fresh green vegetable and providing nutrition to the family is the main consideration for this type of vegetable cultivation in the smaller area located in the house premises. In urban areas where home space is limited, vegetable garden may be confined to backyard, hence sometimes called backyard garden. In rural areas, where houses used to bigger, home garden may be located as part of home or may be situated some distance away from the house. The size of area occupied by vegetables may range from few square meters to hundred or even more. Many people enjoy raising vegetables in home garden and consider it as a pleasant way of exercising and economizing on food costs. Its main purpose is to provide a supplementary source of essentially nutrients and variation in the diet for the family. Beneficiaries of home garden may be extended family members or sometimes neighbors also. Vegetables can be grown in combination with fruit trees and ornamentals. Vegetables which can tolerate some extent of shade can be grown under taller plants. Climbing plants like Cucurbits, Dolichos bean etc. can be trained on fences or roofs. Water loving plants can be grown in drainage ditches. Kitchen wastes can be utilized for making of vermi-compost which will provide source of nutrients to vegetable crops. Family members generally meet the labour requirement of home garden.

Fig 1: Different winter vegetables being grown in a kitchen garden

Community/School Garden:

Mid day meal is provided to school children of younger age group and problem of malnutrition or under nutrition is more prevalent in this group. Growing fresh vegetables in a common area of village belonging to community or school may be helpful for providing nutritious foods to school going children. Protein rich vegetable like mostly legumes and vegetables rich in Ca and Fe like beet leaf, amaranthus, Vitamin A rich vegetables like carrot, beet leaf should be preferred for reducing the hidden hunger prevalent in the society. The techniques of growing vegetables is similar to home garden and objective is mainly to provide nutrition to a larger community instead of a small family. School garden can be a place of experimental learning about techniques of vegetable growing and a motivation for getting better nutrition through diversified foods. This type of activity creates sense of cooperation, discipline and responsibilities among school children as well.

Fig 2: View of a well planned vegetable garden

Container gardening:

In urban areas mainly in big cities, land is a big constraint for home/kitchen garden,many types of vegetables can be grown well in containers and space available in backyard, terrace, varandah, balcony can be utilized for this purpose where sunshine is easily available. Start with large enough pots. The 14 inch pots are plenty large for brinjal and cucumber and the 20-inch pots worked out well for tomatoes. The large soil mass helps anchor the pots in the wind and provides enough volume for the large root systems of fruiting vegetables, and with so much fruit and foliage, the large volume is needed so the pots hold enough water to get through sunny days. Your pots should have plenty of drainage holes in the bottom and are nearly as tall as they are wide. Use the right potting media. Ccontainers or pots should be filled with a mix of soil and well decomposed farm yard manures (FYM). One of the real challenges in keeping plants in pots for a long time is the breakdown of the potting media. Some peat moss is good, but mixes made primarily of peat moss are much better for producing young plants for replanting. Water-retaining crystals (polymers) may be helpful as they will hold water that can be available on those hot summer days when plants go through water quickly. There is a business opportunity to provide good pot mixture for cultivating vegetables in pot in urban areas. Liquid fertilizers combining N,P and K in a proper ratio is also being popular for providing nutrients to plants. Generally we should grow those vegetables which facilitates multiple harvest like tomato, leafy vegetables etc. instead of single harvest like cabbage or cauliflower etc.

Fig 3: Different vegetable crops being grown in container/pot

Activity 2

Make a group of 5-7 students and prepare different plots of school/community/nutrition garden and grow different kind of vegetables in their plots. Different plots designed by various groups should be compared for learning good points from each group activity.

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Floating garden:

Floating garden is a kind of small artificial island constructed on a freshwater lake in order to facilitate early production of vegetables and increase the availability of land for agriculture. The lake irrigates the island and provides it with fresh organic material, resulting in an incredibly fertile growing environment. The floating garden of the famous Dal lake were known to have supplied Srinagar with much of its vegetables during the mid 17th century reign of Aurangzeb's governor. Cultivation of vegetables on the floating gardens in Dal lake is an interesting feature which is a centre of attraction for tourists. This is a kind of low input agricultural production system which is sustaining without much intervention of modern agricultural practices or technologies. Floating gardens of Dal lake facilitate early arrival of different fresh vegetables and their acceptability among consumers is very high due to better quality produce from an organic culture. Floating gardens are usually of a long strip of 40-60 ft with a width of 6-8ft. The floating base is prepared with a special kind of typha grass. The matted roots of typha grass is cut from underneath, allowing a thickness of about two and half feet and whole mass floats up. Typha shoots are cut from top twice or thrice till it is strong enough to bear the weight of a man. Rotten weeds and mud are extracted from the lake and placed on the floating base and it is levelled. These strips of floating garden are movable from one place to another place inside the lake and to avoid their movement, they are tied at four corners with poles. The surface soil is basically a decomposed product of weeds and other biological excreta of lake and adjoining areas and highly rich in organic matter and other nutrients. The rich organic soil along with readily available moisture create very favourable environment for growing of several vegetables. The vegetable cultivation inside the lake on floating garden is basically organic in nature without much use of chemical fertiliser or pesticides. Even the seeds used by farmers are generally saved from their previous crops and modern superior varieties or hybrids are not very common. Mixed farming and cropping system is followed. Maize is planted with beans, tomato, potato and other cucurbits. Maize provides protection from chilly wind to many vegetables and cucurbits in their early plant stage. Cucurbits are generally trained on the artificial structure erected with bamboo and other local woods around the periphery to harness the vertical space. Irrigation to the crop is provided whenever they feel its need. Micro climate of floating garden is mild in temperature and high in humidity which is very congenial for early and enhanced production of female flowers in cucurbits. Very few pest and diseases are observed due to modest temperature and chemicals are generally not required for protecting the crops.

Fig 4: Farmers from Myanmar's Intha tribe pick tomatoes from a floating garden in the famous Inle Lake. Khin Maung Win/AFP/Getty Images

Diara land /Riverbed Cultivation

Several cucurbits, like bottle gourd, bitter gourd, long melon, muskmelon, watermelon, pumpkin, ash gourd, pointed gourd *(parwal)* etc. are grown in river beds or river basins in many states. The river bed areas are called 'diara' land in Uttar Pradesh and Bihar. River bed cultivation of cucurbits is practiced along the river Yamuna, Ganges, Gomti, Sarju and other distributaries in Haryana, Uttar Pradesh, and Bihar, Banas river in Tonk (Rajasthan), Narmada, Tawa and Tapti rivers in Madhya Pradesh and Maharashtra, Sabannati, Panam, Vartak and

Orsung in Gujarat, Tungbhadra, Krishna, Hundri and Pennar rivers in Andhra Pradesh, and Parnba and Manimala river beds in Kerala. The soil in river beds contains mostly sand and moisture is seeped from the adjacent river. The fresh silt and clay deposits every year during monsoon months makes the lands of the river banks suitable for growing vegetable crops. Cucurbitaceous vegetables being long tap rooted crops are well adapted for growing in diara land during Novermber to March in Northern plains. Cucurbit seeds are pre-soaked in water and kept covered in wood ash in muslin cloth bags till germination is initiated. These sprouted seeds are sown either in trenches, about one meter deep and spaced 2-3 m. apart or in pits at 4 m. spacing in November-December in north and north-west regions. Organic manure, like farmyard manure, cowdung manure, compost, or oilcake is mixed with sandy soil in the trenches, before seed sowing. Plants are protected from cold temperature by planting *Saccharum* grass which is later cut and spread over the sand in between the rows of plants when the vines grow big and cover the sand. It is a general practice to have mixed cropping of cucurbits like watermelon, muskmelon, pumpkin, bottle gourd, ridge gourd and sponge gourd. In Andhra Pradesh germinated seedlings of cucurbits are transplanted and in Bihar rooted cuttings of parwal are planted. Bottle gourd and other cucurbits become ready for harvest in March and muskmelon and watermelon in April-May. There is a continuous early harvesting of cucurbits from March to June in river bed cultivation which fetch high price in the market.

Fig 5: Cucurbits cultivation in riverbeds of Yamuna around Delhi

Precision farming:

The conventional agronomic practices follow a standard management option for a large area irrespective of the variability occurring within and among the field. For decades now, the farmers have been applying fertilizers based on recommendations emanating from research and field trials under specific agro-climatic conditions. Since soil-nutrient, characteristics vary not only from one region to another, but also from field to field, even within a field, there is a need to take into account such variability while applying fertilizers to a particular crop. Consideration of in-field variations in soil fertility and crop conditions and matching the agricultural inputs like seed, fertilizer, irrigation, insecticide, pesticide, etc. in order to optimize the input or maximizing the crop yield from a given quantum of input, is referred to as precision farming or precision agriculture or precision crop management. The term "precision farming" means carefully tailoring the soil and crop management to fit the different conditions found in each field. It is defined as the application of technologies and principles to manage spatial and temporal variability associated with all aspects of agricultural production. It is also referred to as "prescription farming", "site specific farming" or "variable rate technology." Precision farming can improve the productivity or reduce the cost of production and diminish the chance of environmental degradation caused by excess use of inputs.

Protected Cultivation:

It refers to agriculture with human interventions that create favourable conditions around the cultivated plants offsetting the detrimental effects of prevailing biotic and abiotic factors. Plants in open field conditions experience short cropping season, unfavourable climatic conditions (too cold, too hot, too dry and cloudy ambient) impairing photosynthetic activities, vulnerable to predators, pests, weeds, depleted soil moisture and plant nutrients. In protected agriculture one or more of these factors are controlled or altered, to the advantage of plants, where usually factors such as temperature, $C0_2$ concentration, relative humidity, access to insect and pest etc., are controlled to desirable limits. The factors controlled and range of control is decided by devises chosen and fitted on the structure. For economic reasons, protection or control is provided against the most significant stresses. Structures and environment control measurers employed isolate this cultivated space allowing cultivation in unfavourable ambient conditions in reasonably close to optimal conditions.

Advantages of protected cultivation:

- Crop production with high productivity under unfavourable agro-climatic conditions.
- Productivity levels could be significantly higher (sometimes two-three times of that in open field cultivation).
- Quality of produce is usually superior because of isolation and controls.
- Higher input use efficiency.
- Income per unit area significantly increases.
- Year-round production

The Netherlands (Holland) has a long tradition of protected cultivation under glass shielded greenhouses growing flowers/ ornamentals and vegetables in equal proportion. Globally there are about 20 M ha under protected cultivation and is still on the rise. However, in Europe, Spain is the leader with 51,000 ha mostly under low cost polyhouses, about 150,000 ha under plastic mulches and over 20,000 ha under low tunnels and floating covers. In Asia, China has the largest area under protected cultivation; over 2.5M ha under polyhouses/greenhouse, 9.6M ha under plastic mulches, 0.9M ha under low tunnels and floating covers. Japan has about 54,000 ha under greenhouses/polyhouses of which about 11,000 ha are under fruit crops. Brinjal, tomatoes, cucumbers, pumpkins, green pepper, strawberries, water melons, and lettuce are grown in greenhouses in Japan. India is way behind. Declining landholdings demand greater attention towards protected cultivation particularly low cost polyhouses (currently only 2,000 ha), low tunnels and plastic mulching. Production of crops under protected conditions has great potential in augmenting production and quality of vegetables, in main and also during off season and maximizing water and nutrient use efficiency under varied agro climatic conditions of the country. This technology has very good potential especially in peri- urban agriculture, since it can be profitably used for growing high value vegetable crops like, tomato, cheery tomato, coloured peppers, parthenocarpic cucumber, healthy and virus free seedlings production in agri-entrepreneurial models.

Principles:

Basic principles involved in protected agriculture are greenhouse effect for heating cultivated space using sunrays and ventilation for cooling and air CO_2 regulation. Cultivated area is isolated and covered with plastic film or glass which is transparent to incoming short wave radiation from the sun impinging on outer surface but opaque (partially) to emergent long wave infrared radiation from soil, plant and structural surfaces, thereby trapping the heat. As a result enclosed space maintains higher temperature than the ambient. However, trapped heat is gradually dissipated through conduction, convection/ventilation and radiation. By incorporating heat sinks, reduced ventilation and application of radiation shields either rate of cooling is slowed down or a supplemental heat source placed inside. In summer months when sun is too bright and ambient too hot, shading, natural /forced ventilation, evaporative cooling prevent excessive temperature build up. The major protected cultivation methods being practiced in India are discussed below.

Mulching

It is a practice of covering soil around cultivated plants to make conditions more favourable to the plants by conserving soil moisture, maintaining higher soil temperature, controlling weeds and keeping root zone more friable allowing soil aeration conducive to soil microflora and root growth etc. Covering materials could be natural, like leaves, straw, sawdust, peat moss, compost, gravel etc or synthetic, like polyethylene and PVC of different colours (generally black) and thickness depending upon ambient conditions and effects desired Plastic mulches have several advantages:

- Soil moisture is better conserved.
- Weeds are effectively controlled by blocking sun light.

- Soil fumigation is more effective.
- CO_2 enrichment around plant root zone.
- Permits cleaner crop produce.
- Early crops, higher yields and more income.

A large variety of crops could be brought under plastic mulches. Different vegetable crops have been successfully mulched with plastic films. In China, even maize and rice are plastic mulched. Significant yield advantages (10 - 100%) are reported by mulching. Used plastic mulches are collected for recycling and obtaining heat energy for power generation etc. Alternatively, photo and biodegradable plastic mulches are under development to avoid disposal problem.

Fig 6: Tomato cultivation with black polythene mulch

Polyhouse / Greenhouse

It is a framed or inflated structure using transparent or translucent cover that creates greenhouse effect, allowing at least partial control on crop microclimate and is large enough to permit a person to work inside. The air temperature rise inside a polyhouse/greenhouse during winter and it is utilized to grow nurseries, planting materials and crops without supplementary heat. The enclosed space through controlled ventilation permits enrichment of air inside with higher CO_2 concentration which enhances crop productivity. Relative humidity and temperatures can be raised or lowered than ambient through shading and evaporative cooling or air-conditioning. If economics permits, practically any crop can be grown in greenhouses/polyhouses. However, off season vegetables, and nurseries are found quite remunerative. It is a very intensive method of cultivation that has very high productivity, per unit area, yields superior quality exportable produce with higher market prices.

Zero energy naturally ventilated greenhouses for high value vegetable cultivation

Naturally ventilated greenhouses are the protected structures where no heating or cooling devices are provided for climate control. These are simple and medium cost greenhouses which can be erected with a cost of Rs. 650-700 per sq. meter and these greenhouses can be used successfully and efficiently for growing year round parthenocarpic slicing cucumber, off season muskmelon, tomato and sweet pepper crops for the duration of 8-9 months. These structures have a manually operated cross ventilation system as and when required. Looking to the year round, increasing demand of high quality parthenocarpic slicing cucumber in up markets of the metro and other big cities of the country, this is one of the most suitable and profitable crop for cultivation under naturally ventilated green houses in peri-urban areas of the country. Three successful crops of cucumber can be grown in a naturally ventilated greenhouse in one year. Muskmelon is the second crop, which can be successfully cultivated for its complete off-season availability, which can fetch very high price of the off-season produce in the up markets of the metro and other big cities of the northern parts of the country.

Similarly high value vegetables like standard tomatoes, cherry tomatoes and coloured peppers are three crops which can be grown for long duration (8-10 months period) under naturally ventilated greenhouse conditions. In metro cities like Delhi there is year round demand of these high quality vegetables in the up markets viz. five star hotels, shops of embassies or high commissions of various countries situated in Delhi. They are ready to pay very high price for the high quality produce; therefore, it may be a profitable venture only if this technology adopted around metro cities of the country. Greenhouse vegetable production is a highly intensive enterprise requiring substantial labour and 24 hour-a-day commitment, which restricts the adoption of this technology. But now the time has come when the vegetable growers in various parts of the country can use naturally ventilated green house technology for cultivation of high value vegetables for high profits.

Table 1 : Vegetable cultivation schedule and economics under zero energy naturally ventilated greenhouse (1000m²)

Crop Schedules	Crop and Duration (months)	Expected Yield (q/1000 m²)	Expected Cost : Benefit Ratio
1.	Tomato (July - Mid May)	150-180	1:2.25-2.50
2.	Capsicum (August - Mid May)	30-40	1:2.00-2.25
3.	Parthenocarpic Cucumber (Mid July - Mid May) three crops	100-120	1:2.50-3.00

Cold Arids: Cold arids of Ladakh, Lahol and Spiti experience freezing temperatures during winter months accompanied with strong winds making open field cultivation too difficult. Low cost mud-walled polyhouses have come in use. DRDO and SKUAST-K have developed, demonstrated and popularized trench type polyhouses using transparent film during day time and black film during night for collection and conservation of solar energy at the same time providing protection from winds. Wooden, bamboo and G.I. pipe framed low cost polyhouses have also been successfully tried. Protected cultivation of vegetables is possible even during winter months like leafy vegetables, cucurbits, cabbage, cauliflower, knol-khol, turnips, broccoli etc. Plastic mulching using black polyethylene is also possible for cole crops, tomato, capsicum with advantages of higher productivity, water conservation, weed control and early harvest. It also enables cucurbit cultivation in open field.

Fig 7: Tomato cultivation under low cost polyhouse

Fig 8: Tomato cultivation under naturally ventilated polyhouse

Low Tunnels

Low tunnels generally cover rows of plants in the field providing protection against low temperatures and frost, winds and insect pests. Low tunnel provides a passive control of plant microclimate. Plastic mulches and drip irrigation in conjunction with low tunnels have better effect. Plastic low tunnels are flexible transparent coverings that are installed over single or multiple rows of vegetables to enhance the plant growth by warming the air around the plants in the open field during winter season when the temperature is below 8°C. Plastic low tunnels are often used to promote the growth of plants during the period of winter season. Low tunnels are supported above the plants by using hoops of GI wire and a clear or transparent plastic of 20-30 micron is covered stretched over the hoops and the sides are secured by placing in soil. The plastic is vented or slitted during the growing season as the temperature increase within the tunnels. Plastic low tunnel technology is a simple and profitable technology for off-season cultivation of cucurbits during the winter season in northern plains of our country. Crops like summer squash can be grown as a complete off-season crop, whereas other cucurbits like muskmelon, round melon, bottle gourd, cucumber, bitter gourd, watermelon can be advanced by 30-40 days over their normal growing season. The farmers can grow different varieties of summer squash (round fruited, long fruited) which is an emerging crop along with cultivation of netted muskmelon varieties in place of traditional varieties. Bitter gourd and round melon are two other crops with increasing demand and which usually fetches very high price during off-season and can be grown successfully by using the plastic low tunnel technology. This technology is highly suitable and profitable for the farmers living in northern plains of India.

Fig 9: French bean cultivation under low tunnel

Fig 10: Summer squash cultivation under low tunnel

Off season vegetable cultivation under walk in tunnels

Walk in tunnels are the temporary structures erected by using G.I. pipes & transparent plastic. Walk in tunnels are used for complete off season cultivation of vegetables like bottle gourd, summer squash, cucumber etc. during winter season (Dec.- mid February) the basic objective & utility of walk in tunnels is to fetch high price of the complete off season produce to earn more profit per unit area. The ideal size of a walk in tunnel of 4.0 m width and 30m length (120m^2) and total cost of fabrication may be Rs.12000-14000/-.

Objectives & utility of the walk in tunnels

1. Off season cultivation of vegetables for earning more income.
2. Walk in tunnels are only erected over the crop during the peek winter months of December – mid February and there after the structure is removed from the crop.
3. Since, the plastic is used only for two months (Dec.-mid February) therefore; life of the plastic can be 8-10 years.
4. These temporary plastic structures are suitable for off season vegetable cultivation in northern plains and low hills.

Table 2 : Expected yield and economics of off seasons crops grown under walk in tunnels

S.No.	Crop	Crop Duration	Yield (t/ha)	Expected cost : benefit ratio
1.	Summer squash	Mid November-Mid February	40-50	1:2.0-2.5
2.	Bottle gourd	Mid October - Mid February	25-30	1:2.5-3.0
3.	Cucumber	Mid October- 30 February	15-20	1:2.5-3.0
4.	French bean	Mid October - December	6-8	1:2.5-3.0
5.	Tomato	Mid October - Mid February	20-25	1:2.0-2.5

Vegetable cultivation under shade nets

Shade nets are perforated plastic materials used to cut down the solar radiation and prevent scorching or wilting of leaves caused by marked temperature increases within the leaf tissue from strong sunlight. These nets are available in different shading intensities ranging from 25% to 75%. Leafy vegetables and ornamental greens are recommended to be grown under shade nets whose growth rates are significantly enhanced compared to un-shaded plants when sunlight is strong. The basic objective of shade net is to reduce radiation and temperature up to some extent during critical summer months (May-September). Black colour shade nets are most efficient in reduction of temperature compared to other colours like green, white or silver etc. as the black colour is the maximum absorbent of heat. Mostly leafy vegetables like beet leaf and green coriander are preferred to be grown under shade nets, but it is also suitable for growing early cauliflower and radish cultivation during June to September months.

Insect proof net houses for safe vegetable cultivation

Usually the farmers are growing their vegetable crops like tomato, chilli, sweet pepper, okra etc under open fields. But during rainy and post rainy season it is very difficult to grow these crops successfully in north Indian plains due to leaf curl and yellow vein mosaic and other viruses, respectively. These viruses are mainly spread by insect vectors like whiteflies, aphids, thrips, jassids and sometimes also by hoppers. The population of white fly after onset of monsoons is very high and it remains in the open environment up to end of October depending upon the temperature. The farmers are using several insecticides for several sprays to control these vectors, even they could not control these vectors and their tomatoes, chilli or okra crops are highly infected with viruses. The second most common and most severe problem in tomato, brinjal and okra is the fruit borer against which the growers are using huge amount of insecticide even then they are unable to control this insect. The only way to manage the virus and fruit borer is to put a mechanical barrier between the crops and open environment and this is possible with the use of insect proof net of 40 or 50 meshes in form of net houses or insect proof net covered walk in tunnels. By this way the grower can directly reduce the use of insecticides and they can grow virus free crops of tomato, chilli, sweet pepper and okra during rainy or post rainy season. But for growing these crops under insect proof net houses, it is pre-requisite to raise virus free healthy seedlings of these crops either in the greenhouse or by covering the nursery beds with insect proof net. The farmers can erect these insect proof net houses by using half inch size GI pipes after bending them in half circle shape. Other insect proof net houses can also be made by covering all sides and top with insect proof net of 40 or 50 meshes, but the net should be UV stabilized. Under these net house crops like sweet pepper, tomato, chilli or okra can be grown successfully without infestation of viruses or other insects like fruit borer etc. and the growers can save the huge amount spent on pesticides. Insect proof net houses can also be fabricated in greenhouse design for maximum utilization of the space through vertical growing of high value vegetables. These structures can be fabricated with a cost of Rs. 250-300/ m^2 Such structures can be covered with 40-50% shading nets during critical summer months (April-June) and with plastic during critical winter months (Dec-Feb) with transparent plastic under arid and semi-arid climatic conditions. High value vegetables like tomato, cherry tomato (crop duration 7-8 months), two crops of parthenocarpic cucumber (summer and post rainy season) and capsicum (crop duration 7-8 months). The basic objective of insect proof net house vegetable cultivation is to minimize the use of pesticides in fresh vegetable cultivation for producing safe vegetables.

Hydroponics:

If you have ever placed a plant clipping into a glass of water in the hopes that it will develop roots, you have practiced in a form of hydroponics. Hydroponics is a branch of agriculture where plants are grown without the use of soil. The nutrients that the plants normally derive from the soil are simply dissolved into water instead, and depending on the type of hydroponic system used, the plant's roots are suspended in, flooded with or misted with the nutrient solution so that the plant can derive the elements it needs for growth. The term hydroponics originates from the ancient Greek "hydros," meaning water, and "ponos," meaning work. As the population of our planet soars and arable land available for crop production declines, hydroponics will offer us a lifeline of sorts and allow us to produce crops in greenhouses or in multilevel buildings dedicated to agriculture.

The science behind hydroponics

Before we can take a look at how hydroponics works, we must first understand how plants themselves work. Generally speaking, plants need very little to grow. They can subsist on a simple blend of water, sunlight, carbon dioxide and mineral nutrients from the soil. Plants are able to transform light energy into chemical energy to form sugars that allow them to grow and sustain themselves. Thus, plants convert carbon dioxide, water and light into sugars and oxygen through a process called photosynthesis. The photosynthesis process requires that the plant has access to certain minerals, especially nitrogen, phosphorus and potassium. These nutrients can be naturally occurring in soil and are found in most commercial fertilizers. You should note that the soil itself is not required for plant growth. The plant simply needs the minerals from the soil. This is the basic premise behind hydroponics, all the elements required for plant growth are the same as with traditional soil-based gardening. Hydroponics simply takes away the soil requirements. It is also referred as soilless cultivation in which plants can be grown in an inorganic substance (such as sand, gravel, perlite, rockwool) or in an organic material (such as coconut fiber, pine bark or saphagnum peat moss) and periodically watered with a nutrient solution.

Vegetable cultivation in space:

With the advent of long-duration space laboratories such as Mir and the International Space Station (ISS) it has become clear that more emphasis needs to be placed on improving the human habitability of these environments. The Vegetable Production System (Veggie) is a deployable plant growth unit capable of producing salad-type crops to provide the crew with a palatable, nutritious, and safe source of fresh food and a tool to support relaxation and recreation. The Veggie provides lighting and nutrient delivery, but utilizes the cabin environment for temperature control and as a source of carbon dioxide to promote growth.

Nutrient Film Technique (NFT)

It is a water-based system that requires no soil or mediums. Plants are grown with roots contained in a plastic film, trough or PVC pipe. Nutrient-laden water is re-circulated through the system, bathing the roots. This system is still popular for short-term crops, such as lettuce and leafy vegetables, where the plants are sold with the roots intact. This system was also popular in the 1990s for several small-farm tomato operations in western countries. Because of the risk of root pathogens being spread throughout the greenhouse once an infection starts, most tomato growers are no longer using recirculating systems unless the system includes some means of sterilizing the water.

Ebb and Flow Systems

It requires a medium, such as perlite, which serves no purpose other than to provide stability for the plant's roots. The plant derives no nutrients from the medium itself. Ebb and flow systems include a tray in which the plant is placed in a medium; below the tray in a separate container is a reservoir containing water and mineral solutions. The water from the reservoir is periodically pumped up into the tray. This floods the tray and allows the plants to absorb water and nutrients. Gradually, the water drains back into the reservoir due to gravity. Ebb and Flow systems work best with small plants like herbs and are typically used in smaller hydroponic setups, such as those in the home.

Drip Systems

It is set up almost identically to an ebb and flow system, although instead of water being pumped through one large tube, it is pumped through many small tubes and drains onto the top of the plants. This system is ideal for plants that do not yet have a developed root system, and like an ebb and flow system, works best with smaller plants.

Aeroponics

It is another water based system, which, like NFT, requires no medium. Plants are suspended on a tray, with their roots freely dangling below. The entire tray is placed into a box that has a small amount of water and nutrient solution in the bottom. A pump system is used to draw the water up, where its sprayed in a fine mist onto the entire plant and root in a continuous manner. This system is the most difficult to set up and manage, but it has great potential for large commercial uses.

Advantages:

1. Crops can be grown where no suitable soil exists or where soil is contaminated with disease.
2. Labour for tilling, cultivating, fumigating, watering and other cultural operations is eliminated.
3. Maximum yields are possible so that system may be economically feasible in high density and expansive land area.
4. Soil borne plant diseases are more easily controlled.
5. Complete controlled environment (root environment, timely nutrient feeding or irrigation) and in greenhouse (light, temperature, humidity and composition of air) is possible.
6. All the applied nutrients are readily available to the plant.
7. Lower concentration of the nutrients can be used.

8. The pH of nutrient solution can be controlled to ensure optimal nutrient uptake.
9. No loss of nutrients due to leaching.
10. Conservation of water and nutrients leading to reduced environmental pollution.

Disadvantages:

1. High construction cost
2. Requires trained manpower for all operations.
3. Introduced soil borne diseases and nematodes may spread quickly.
4. There is the threat of power failure, which can cause pumps to stop working and ruin crops.

CHECK YOUR PROGRESS

Give answer in few words

1. Which type of cucumber variety can be grown in protected condition?
2. Which type of tomato varieties should be grown in polyhouse?
3. Name vegetable crops suitable for truck farming.
4. Name suitable crops for low tunnel cultivation.
5. Name commonly grown vegetable crops in riverbeds.

Short answers:

1. Floating garden
2. Nutrient film technique
3. Truck farming
4. How mulching is useful for vegetable cultivation?
5. Discuss a successful model of contract farming in vegetables.
6. How hydroponics is useful for higher productivity of vegetables?

Long answers

1. Periurban vegetable farming is a kind of symbiotic relationship between urban and rural population. Justify the statement

2. What are the different structures for vegetable cultivation under protected condition?

3. What are the main advantages of protected cultivation of vegetable crops?

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★★★

Chapter-2

Industrial Importance of Vegetables and Setting up of Industry Based on Vegetable Crops

OBJECTIVES

Students will be able to learn about :-

- Importance and current scenario of vegetable based industries.
- Export potential of vegetable crops.
- Different vegetable based industries such as seed industry, processing, preservation and value addition in vegetable crops
- Future prospects of vegetable industries and export.

INTRODUCTION

India produces a wide range of fruits and vegetables in substantial quantities making it the second largest producer of these perishable, but nutritionally essential, crops in the World. Vegetable crops play a major role in Indian agriculture by providing food, nutritional and economic security. Vegetables are usually consumed as an auxiliary dish with starchy staple food to add flavour and taste variation to a meal. It includes a large number of species, mainly used as an essential complement to the daily diet, providing vitamins, minerals, fibre, specific amino acids and other health promoting phytochemical. Increasing consumption of vegetables is generally considered to offer healthy benefits in all dietary situations. Vegetable crops being rich sources of various health building substances, especially vitamins and minerals, offer unique advantage for food and nutritional security, tackle malnutrition and dietary deficiency diseases. Besides, their high yield potential per unit area and time, diverse varietal wealth, labour intensiveness, high market price and prospects of processing, value addition and export, they play an important role in employment generation, and livelihood improvement.

Importance and current scenario

The share of high value crops especially fruits and vegetables in the gross value of agricultural output has been increasing during recent years which is evident from compound annual growth of 6% for fruits and vegetables, against 1.4% in food grains during 1992-93 to 2002-03 and the same trend is continuing in this decade also. The growth of Horticulture was 4.7 per cent in comparison to 3.1 per cent of food grains during the eleventh plan period (2002-2007). As long as production of high value crops remains relatively more profitable as compared to alternatives, it is feasible to promote crop diversification. Generally, staple foods are not high value commodities, because the necessity of their consumption leads to demand and supply equilibrium at a relatively low price. For meeting the new demands on agriculture, including healthy foods, environmental services and for addressing concerns like rural employment, higher farm income generation and checking rural exodus, strengthening of institutions and organizations linked with high value agriculture is important. Shift of small farmers to high value agriculture depends much on knowledge transfer, development of physical and institutional infrastructures, marketing linkages and credit support.

Vegetable crops in India occupy only 2.8% of the total cultivated land producing 156.33 million tones of vegetables annually including potato from an area of 8.98 million hectare during 2011-12. India shares about 15% of total world production of vegetables with a productivity of about 17.2 tons per ha. The present production is not sufficient to meet the requirement of 300 g of vegetable on an average per capita per day. The production as well as productivity of vegetable crops will have to be continuously improved upon to secure nutrition for ever increasing Indian population. With increasing purchasing power of people in the country, the demand for vegetable crops has increased enormously leading to sharp increase in their prices and it has been the dominant factor for high inflationary pressure in Indian economy during recent years. Vegetable production is a form of intensive agriculture. Large volumes of produce can be obtained from very small areas of land, so long as the plants are provided with adequate water, nutrients and pest and disease management. Vegetables can make a significant difference to livelihoods of small and marginal farmers. Vegetable production needs only a small area of land, with minimal capital outlay and not only provide access to a valuable food under subsistence conditions, but also has the potential to provide an initial step towards establishing an income base for poorer households.

Vegetable cultivation and processing is considered as one of the major component in agro-industry. In general the vegetable industry has major stake in export of value added products in national and international trades. India is the second largest producer of vegetables in world after China. Amongst different vegetables, India is the largest producer of ginger & okra and ranks second in production of potato, onion, cauliflower, brinjal and cabbage. Cultivation of vegetable crops involves intensive cultural operations starting from sowing to marketing. This result in a round the year practice and provides more and regular employment opportunities in rural areas. The perishable nature of vegetables demand comprehensive planning for movement, storage, processing and distribution of vegetable products. The growth of vegetable industry as a commercial proposition largely depends on mainly allied enterprises like storage, processing, marketing and maintenance and service enterprises to encourage vegetable growing. Per acre yield of vegetables is very high so they are an important source of farm income and also have high aesthetic value.

Vegetables are sold at a higher rate than other crops. It provides regular as well as good source of income in addition to the income from the agronomic crops. Most vegetables are short duration crop and as compared to other crops and it can be raised throughout the year. Vegetable production on a small scale is accessible to many. The cost of entry is fairly low and typically the major input required is family labour. The cost of starting vegetable production is not excessive provided that land is available. Water and access to it is often the key factor in vegetable production as without irrigation, it is not possible to exploit the income potential of the dry season when returns are at their highest.

Export potential of vegetable crops

The vast production base in India offers tremendous opportunity for export in fresh as well as preserved products from vegetable crops. India is also a prominent exporter of fresh vegetables in the world. According to report from The Agricultural and Processed Food Products Export Development Authority (APEDA), India exported vegetables worth Rs. 3263.45 crores during the year 2012-13. India's share in world exports of fresh and processed fruits and vegetables was quite insignificant being just 1 per cent. Onions, okra, bitter gourd, green chilles, and potato contribute largely to the vegetable export basket. Many non-traditional vegetables like asparagus, celery, bell pepper, sweet corn, green pea, cucumber, cherry tomato, gherkin and lima beans and organically grown vegetables are also being increasingly exported and having good export potential. The major destinations for Indian fruits and vegetables are Bangladesh, UAE, Pakistan, Malaysia, Sri Lanka, UK, Saudi Arabia, Kuwait, Netherland, USA and Nepal.

Besides the fresh vegetable production, food processing adds value to the produce. The Indian food processing industry is primarily export oriented. India's geographical situation gives it the unique advantage of connectivity to Europe, Middle East, Japan, Singapore, Thailand, Malaysia Korea, and Gulf region. India exported dried and preserved vegetable worth Rs. 835.57 Crores in 2012-13. The prominent processed items are dehydrated vegetables, canned vegetables, frozen vegetables, pickles, vegetable curries.

The vegetable processing industry in India is highly decentralized. A large number of units are in the cottage/ home scale and small-scale sector. Presently, the processing of fruits and vegetables is estimated to be around 2.2% of the total production in the country. Almost 45% of the processed vegetable products are exported. Of the remaining 10% is consumed by the household segment and 45% by the defense and institutional segments.

Specific requirements of vegetables for export

The uniformity in size and colour are considered to be general quality traits of universal acceptance for any crop apart from several other specific qualities for the external market. The specific requirements of some of the vegetables for export are given here.

Big onion

- 4-6 cm diameter, light to dark red colour, round shape
- Strong pungency for gulf market and south east Asia
- Yellow brown colour, 7-10 cm, round or spindle shape for European and Japanese market

Small onion

- 2-3cm size bulblets of bright red color

Multiplier onion

- 2.5-3.5cm size bulblets of bright red color

Garlic

- White round 5cm and above, bigger cloves of 10-12cm and above with 10-15 in number for Bangladesh and Sri Lanka, 4-5cm size bulbs are also acceptable.

Chillies

- Green, tender, 6-7 cm long.

Okra

- Green, tender, 6-9 cm long, In Europe 5 -7 cm long.

Bitter gourd

- Green, 20-25 cm long having short neck.

Bottle gourd

- Light green, straight cylindrical in shape, 25-30cm long.

Tomato

- Medium size, dark red color, intact bunch

French beans

- 10-12 cm long, straight, round and green pods in the beans.
- Flat beans having 12-13cm length and straight pods are also in demand in European markets

Cluster beans

- Green tender, 7-10cm long

Health benefits of vegetables

Vegetable crops being rich sources of various health building substances, especially vitamins and minerals, offer unique advantage to food and nutrition security, tackle malnutrition and dietary deficiency diseases. Vegetables play a major role in supplying the essential minerals, vitamins and fiber, which are not present in significant quantities in staple starchy cereal crops. Vegetables are usually consumed as an auxiliary dish with starchy staple food to add flavour and taste variation to a meal. Although they are consumed because they are tasty, healthy and supply both proteins and carbohydrates, vegetables are most important as a source of nutraceuticals (vitamins and minerals) and as protective nutrients for human health. For example, tomato fruits contain lycopene (a valuable anti-cancer and anti-cardiovascular chemical), carrots contain carotene (precursor of the essential vitamin A), and many fresh vegetables contain vitamin C.

Fresh vegetables are an important part of the human diet and surplus vegetables usually find a ready market, and have the potential to provide a valuable new source of family income. In the short term, growing vegetables provides poor families with the opportunity to eat a much healthier diet than one based solely on cereals. A better diet will also enable a much healthier prospect for the family.

Fruit and vegetables are important components of a healthy diet, and their sufficient daily consumption could help prevent major diseases, such as cardiovascular diseases and certain cancers. Approximately 16.0 million (1.0%) disability adjusted life years (DALYs, a measure of the potential life lost due to premature mortality and the years of productive life lost due to disability) and 1.7 million (2.8%) of deaths worldwide are attributable to low fruit and vegetable consumption. Moreover, insufficient intake of fruit and vegetables is estimated to cause around 14% of gastrointestinal cancer deaths, about 11% of ischemic heart disease deaths and about 9% of stroke deaths globally. A recently published WHO/FAO report recommends a minimum of 400g of fruit and vegetables per day (excluding potato and other starchy tubers) for the prevention of chronic diseases such as heart disease, cancer, diabetes and obesity, as well as for the prevention and alleviation of several micronutrient deficiencies, especially in less developed countries.

Apart from containing micronutrients such as carotenoids, B-complex vitamins, minerals such as iron, calcium, zinc, potassium, vegetables contain fibers, bioactive phytochemicals or phytonutrients which prevent degenerative processes. For example carotenoids are present in tomato, carrot, pumpkin; indoles, polyphenols & glucosinolates are present in Cruciferous vegetables; osothiocyantes are present in *Brassica* vegetables. There is ample evidence that diets high in vegetables protect against cancer, coronary artery disease, cataract, and diabetes through its antioxidants, micronutrients and phytochemical composition. As most vegetables provide low calories and are bulky in nature, they improve satiety and are helpful for prevention of obesity, which is central to several chronic diseases. The following table gives the list of nutrients and their availability in vegetables.

Nutrients	**Availability in Vegetables**
Carbohydrates	Potato, Sweet potato, Dry beans, Yam, Tapioca, Sweet corn
Protein	Pea, Indian bean, French bean, Cowpea, Cluster bean, Amaranth, Broad bean

Vitamin-A	Carrot, Beet leaf, Amaranth, Pumpkin, Fenugreek, Coriander, Parsley, Green pea, Chilli, green Onion, Paprika
Vitamin-B	Pea, Indian bean
Vitamin-C	Drum stick leaves, Sweet pepper, Green chilli, Bitter gourd, Cauliflower, Knol-khol, Tomato, Leaves of Radish, Amaranth, Brussels sprout, Parsley, Fenugreek, Beet leaf
Calcium	Beet root, Amaranth, Leaves of turnip, Coriander, Ash gourd, Onion, Tomato, Sem, Cauliflower, Carrot, Cabbage, Pea
Potassium/ Potash	Sweet potato, Potato, Bitter gourd, Radish, Indian bean, Onion, Green Leafy Vegetables
Phoshphorus	Garlic, Pea, Bitter gourd, Potato, Carrot, Tomato, Cucumber, Beet leaf, Cauliflower
Iron (Fe)	Bitter Gourd, Amaranth, Fenugreek, Mint, Poi, Beet leaf, Pea, Cabbage, Indian bean, Tomato

Do you know?

- *The highest amount of vitamins and nutrients are contained within the vegetable's skin and the layer directly underneath it*
- *Vegetables are generally very low in fat and calories - excellent for healthy diets!*
- *Vegetables can provide benefits to our skin, teeth, nails, hair and even help to prevent signs of ageing*

Post Harvest Handling of Vegetable Crops

After harvesting the produce at right maturity, it should be handled carefully to ascertain maximum profit by selling good quality and fresh produce to the consumers. The following operations should be carefully undertaken:

Pre-cooling: Harvested vegetables should be pre-cooled at the field itself to reduce their field heat. Cold air or cold water (hydro-cooling), or by evaporation of water from the product under a partial vacuum (vacuum cooling) may be done for this purpose. If such facilities are not available, the produce may be kept under the shade of a tree for some time to reduce the field heat.

Sorting: The harvested vegetables may have disease or insect infection and may be over mature. This may result in spreading of the infection to healthy produce during transportation or storage, and huge postharvest losses may occur. Thus, it is essential to remove such produce from the healthy one.

Washing: Most produce carry soil or residues of various insecticides and pesticides sprays done in the field. Therefore, all traces of soils and pesticides must be removed from produce before packing. It can be done by washing the produce mechanically. This process makes the vegetables attractive.

Skin Removal/ Peeling: Some vegetables require skin removal. This can be done in various ways.

1. **Mechanical:** Depend upon the characteristics of the vegetables, different types of equipments for skin removal/peeling are used.
   - A machine with abrasion device (potatoes, root vegetables)
   - Equipment with knives (potatoes etc)
   - Equipment with rotating sieve drums (root vegetables)
2. **Chemical:** Skin can also be softened from the underlying tissues by submerging vegetables in hot alkali solution. Lye may be used at a concentration of about 0.5-3 %, at about 93°C for a short time period (0.5-3 min).
3. **Thermal:** Vegetables with thick skin as beets, potatoes, carrots and sweet potatoes may be peeled with steam under pressure (about 10 atm) as they pass through cylindrical vessels. When the pressure is suddenly released, steam under the skin expends and causes the skin to puff and crack. The skins are then washed away with jets of water at high pressure (up to 12 atm.).

Grading: After sorting, the healthy produce should be graded according to size, shape, colour, and firmness. Generally, produce is graded as A, B or C as per size, shape and colour. Better grade produce fetch better price in the market. Tomato fruits are graded into four groups based on its size e.g. super A, super, fancy and commercial. Similarly, potato tubers are graded into large, medium and small tuber sizes. Low grade produce can be utilized for making value added products like pickle or ketchup, sauce etc. In cauliflower, compact, medium sized and snow white curds with small stalk are the best. Grading can be done manually or by machine.

Packing: After grading, the vegetable produce is packed in containers. In India, the vegetables are packed in gunny bags or polyethylene bags which are not appropriate packing materials and result in huge losses by lowering the quality on account of bruises and non-availability of air. Other packing materials used are plastic crates, plastic field boxes, wooden field boxes, CFB boxes, bamboo baskets, and nylon nets etc.

Transportation: After packing, the produce has to be sent to market for sale. This is the most neglected area in our country because very less attention is paid for transporting vegetables from the production area. Vegetables are transported by loading in the rickshaws, carts, jeeps, rails and trucks. As a result, bulk of produce is lost during transportation. However, now producers are paying attention on this aspect and even refrigerated vans are used for transporting fresh vegetable produce.

Processing, Preservation and Value Addition in Vegetable Crops

Post harvest losses in vegetable crops are usually very high (20-40%). About 10-15% fresh vegetables shrivels and stale result in lowering their market value and consumer acceptability. Food processing aims to make food more digestible, nutritious and extend the shelf life. Due to the seasonal variations high levels of wastage or shortages can arise if adequate measures are not taken to preserve and store the foods. Food processing offers an opportunity for the creation of sustainable livelihoods and economic development for rural communities. Food processing has come a long way in the last few decades. The ever changing lifestyles, food habits and tastes of customers' globally have altered the dynamics of the industry.

Preservation means just protect the foods against the spoilage, but scientifically it may be defined as a science which deals with the process for prevention of decay or spoilage of the food is called preservation. There are three main principles on which methods of preservation are based:

1. Prevention or delay of microbial decomposition
    - By keeping out microorganisms (asepsis)
    - By removal of microorganisms e.g. filteration
    - By hindering the growth and activity of microorganisms e.g. by low temperature, drying, anaerobic conditions or use of chemicals
    - By killing the microorganisms e.g use of heat or radiation
2. Prevention or delay of self-decomposition of the food
    - By destruction or inactivation of food enzymes e.g. blanching
    - By prevention or delay of purely chemical reactions e.g. prevention of oxidation by means of an antioxidant
3. Prevention of damage caused by insects, rodents, mechanical damage etc.

Preservation by Canning:

Amongst the several techniques employed to conserve vegetables, canning is considered to be the foremost. It is aimed at preservation by killing of spoilage organisms (bacteria, fungi, yeasts, moulds) and inactivating the enzymes that cause metabolic degradation. Toxins like botulotoxin produced by bacteria *(Clostridium botulinum)* is also destroyed by the heat treatment at high temperature and high pressure. The actual canning is preceded by preliminary steps including washing, sorting, grading, soaking, peeling, coring (remove the tough central part), trimming, slicing or cutting. Washing is accomplished by high pressure water sprays and aids in removing dirt and mud that greatly reduces the efficiency of steam, lye (NaOH) peelers. Sorting and grading are mainly intended for size and maturity of crops such as tomato, potato, sweet potato, beans, beets, carrots, peas and okra.

Potatoes, green beans, okra, carrot, drum stick and other should be trimmed, while whole tomatoes and cabbage need to be cored in order to remove decay or undesirable portions. Vegetables for canning are prepared in various sizes and shapes. The whole canned commodities include potatoes, tomatoes, beans, peas; cut like green beans, okra, and cauliflower; sliced or diced as carrots, beets, sweet potatoes and other as desired. The canning process include blanching, filling exhausting and sealing, heat processing and subsequently cooling and storage.

Blanching

The special heat treatment to inactivate enzymes is known as blanching. Blanching is exercised for : (i) inactivation of enzymes, (ii) removal of air and gases, (iii) setting the colour, (iv) improvement in texture, (v) arresting changes in flavour, (vi) leaching of water soluble sugars, and (vii) wilting or softening of vegetable to ease filling of cans. The two most common methods of blanching are: hot water blanching and steam blanching. Blanching is usually carried out between 75 and 95 °C for 1 to 10 minutes, depending on the size of individual vegetable pieces. Blanching in hot water at 70 to 105 °C has been associated with the destruction of enzyme activity. This heat treatment depends upon the specificity of vegetables, the objectives that are followed and the subsequent processing / preservation methods. Blanched vegetables should be promptly cooled down to control and minimize the degradation of soluble and heat-labile nutrients.

Filling

The use of sterile containers and brine are of vital importance. The vegetables may be filled in cans by hand or machine in hot brine or hot water plus tablets of salts. If necessary, other flavour, texture or colour improving ingredients are added. The recommended brine concentration is about 2%.

Exhausting and Sealing

The purpose of exhausting is to eject gases from the product and to increase the product temperature. Exhausting is affected by allowing open cans to pass through a steam box which injects steam into head space. A partial vacuum is also created in the head space which is necessary in extending the storage life of products and preventing distortion of cans at high altitudes. Cans may be pre-vacuumized mechanically and sealed under vacuum.

Heat processing

The basic principle of canning is the destruction of spoilage organisms by sufficient heat treatment, yet not too in excess to cause the heat damage of the heat sensitive nutrients, primarily vitamins. Conventionally, the cans that are hermatically sealed after vacuuminzing are sterilized with steam in retort or cooker. The mode of heat transfer is convection, conduction or combination of both.

Cooling, Lebelling and Storage

The processed cans are liable to over-cooking from internal heat if allowed to cool slowly. Rapid cooling can be accomplished in the cooker under air pressure or in a rotary cooler equipped with a cold water spray.

Spoilage of cans in storage

The spoilage of cans in storage is revealed by bulging of can ends which may be caused by microbial, chemical or physical changes in storage. Under severe conditions, the can likely to explode. Before this condition occurs, can passes through various intensities of spoilage termed as flipper, springer, soft swell and hard swell. Hydrogen swell results from the action of the can content of the container. Production of carbon dioxide leads to chemical swell.

Vegetable drying / dehydration:

Dehydration preserves vegetables in two major ways: (i) it removes moisture necessary for growth of micro-organisms and enzyme activity and (ii) by removing water increases the concentration of sugars and acids, creating a chemical environment unfavourable for growth of many organisms. Actual dehydration process is preceded by preliminary steps such as washing to clean the vegetables, peeling and slicing of root vegetables, sulfating to maintain colour, nutrients and lessen the danger of scorching, and blanching to inactivate enzymes, reduce drying time and retain certain vitamins.

Amongst the techniques sun-drying is the most ancient and cheapest one but goes to the risk of losses due to inclement weather and difficulty of maintaining a high degree of sanitation. The other techniques include: (i) dehydrofreezing and dehydrocanning, (ii) osmotic dehydration (sugar syrup treatment, glycerol treatment), (iii) reverse osmosis (diffusion membrane), and (iv) hot-oil immersion (deep-fat fried snack foods, freeze leaching for quality improvement, chips).

Dehydrofreezing reduces about half of the vegetable weight by warm air drying before freezing. Dehydrozen peas have been successful market item. After preliminary operations (cleaning, grading, blanching, sliting), 70% of the initial water in peas is removed by combining belt-through drier and concentric double drum drier. The dried product soon drops into a freezing belt where it is quickly frozen. The product could be equal in quality as fresh product. Due to reduction in weight and size, there is considerable saving on packaging, transportation and storage. Dehydrocanning is similar to dehdrofreezing in producing a canned product. Dehydrocanned vegetables are dried to half their original weight prior to canning.

Vegetable pieces can be osmotically dried by removing a percentage of moisture by placing it in contact with osmotic agent such as sugar syrup. The product can be further processed in vacuum dryers. Juices can be concentrated by diffusion membrane where water in juice diffuses through a semi-permeable membrane and is then evaporated by warm air. Dehydration of vegetables by 'hot-oil immersion' is comparatively recent technique and the drying is faster than conventional hot dehydration. Deep-fat fried snack foods from potatoes, sweet potatoes and peas are well known. The oil absorption into product can be minimized by incorporating surface freezing of potato strips and subsequently leaching sugars into water prior to frying (freeze leaching for quality improvement

All dried vegetables are prepared by soaking and cooking. Good quality dried products, after cooking and if properly treated should be similar to cooked fresh produce. The following soaking/cooking methods are recommended:

i) **Quick method:** Cold water is added to the dried product ten times the weight of dry product.

ii) **Slow method:** Cold water is added to the dry vegetable and is left to soak for 1 to 2 hours before cooking. The product is then cooked in the same soaking water and actual cooking time is shorter than that for the quick method.

Some of the example explains the simple methods of dehydrating vegetables.

Dehydrating methi

Step 1: Wash methi and remove the stems.

Step 2: Put on a cloth in the sun, cover it.

Step 3: Cool to room temperature and store in air tight tins.

Potato chips

Step 1: Wash and peel potatoes. Cut in thin round slices.

Step 2: Put in boiling water for 3-4 minutes.

Step 3: Make a solution in cold water with 4 tea spoon (tsp) salt, ¾ tsp potassium metabisulphite (for 4 kg potato).

Step 4: Put the blanched potato chips in this solution for 10 minutes.

Step 5: Spread each chip separately on a plate in the sun. Cover with a thin cloth.

Step 6: When dry, cool and store in air tight containers.

Dried onions

- Varieties with pungent flavour are the most appreciated; both coloured and white onions may be used.
- After removing the tops, roots and outer integuments, onions are washed thoroughly and then cut into slices of 3 mm thick. After cutting onion slices are carefully washed. Blanching is not practiced (it makes the onion lose its flavour).
- The use of preservatives is not necessary; therefore, after washing and draining, the slices are spread evenly on the trays of a dryer. The onions are dried till raw material to dry product is become about 9:1 (moisture content about 5%).
- Cooling, packing, labelling and storage of the dried product
- The dried product may be ground into powder (which tend to agglutinate without any anticaking agent).

Dried tomatoes

- For the preparation of dried product, tomatoes should be ripe, of good red colour and should be firm.
- Tomato pigments are stable because they are rich in carotene; therefore, pre-processing, such as blanching is not necessary.
- Washing and sorting are followed by cutting in halves lengthwise to eliminate the liquid and the seeds. The seeds as well as the ones from tomato pulp processing can be used again as seeds if they have not gone through a heat treatment.
- Empty the tomatoes and then cut them lengthwise into slices of 6 to 8 mm thickness and place them in dryers.
- The tomatoes are dry when the raw material / dry product ratio is about 25:1. On an average, 40 g of dried products are obtained from 1 Kg of fresh tomatoes. The yield depends on the dry tomato residue and the degree of drying.
- Cooling, packing, labelling and storage of the dried product

Dried carrots

- Roots with red cores and not woody are good for drying.
- After removing the stalks and tips, wash the carrot, scrape, then cut into slices of about 5-6 cm thick using stainless steel knives. All green parts, if any, have to be removed.
- For blanching, the slices are dipped for 3 minutes in boiling water containing 50 g salt per litre of water, followed by cooling in running water.
- The product is then evenly spread on the trays of a dryer. The carrots are dried when the prepared material/ dry products ratio is about 12:l (moisture content about 6%).
- Cooling, packing, labelling and storage of dried products are performed according to same recommendations as for the other products.

Processing into other value added products

Vegetables can be protected by processing them into more durable products like juices (tomato, watermelon) jams (tomato, watermelon, muskmelon), jellies (watermelon), pickles (chilli, carrot, cucumber, cabbage, pumpkin, cauliflower turnip, beet root), chutneys (tomato, turnip, carrot, cauliflower), soups (tomato, soya bean), purees (tomato), preserves and candied items (carrot, ash gourd, beet root), powders, chunks and discs (potato).

The vegetable to be processed should be firm enough to withstand the necessary treatment. The raw produce should be of uniform maturity and colour. Quality of raw material governs the viscosity or consistency of the processed product which is of vital importance and determines the keeping quality of the product. The initial steps in the manufacture of most products are rather similar and include washing, grading for uniformity, peeling, pitting, slicing and cutting and are performed manually or mechanically. Some of the examples of value added products are:

1. Juicy drinks/Vegetable juices

Juicy drinks are the most favoured products and preparation of type of drink depends on the extent of raw material in the finished product. Juice may be without any alternation (pure juice), undergone alcoholic fermentation (fermented beverages), clarified sweetened juice (cordial), clarified juice artificially flavoured or as juice squash consisting moderate quantities of pulp with cane sugar added for sweetening. The products are made durable by pasteurization, addition of sugars, freezing or by addition of chemicals.

2. Jams and jellies

Jams and jellies are important class of preserved products. However, except few vegetables such as tomato, watermelon and muskmelon, most vegetables are not suitable for these products. Jam is prepared by boiling the fruit pulp with sugar to a reasonably thick consistency, firm enough to hold the fruit tissue in position and should contain not less than 68.5% solids when cooled. Jelly is prepared by boiling the fruit pulp with or without water, straining, adding sugar and again boiling the mixture to a stage to set a clear gel, which should be transparent, well set but not stiff and should have original flavour of the fruit. In jam and jelly, the sugar used acts as preservative allowing no free water and the heating of the product kills the organisms. The setting of the product is governed by sugar, acid and pectin composition of the product.

3. Preserve

A preserve (for example, petha from ash gourd or carrot candy) is made by cooking matured product, whole or pieces, in a syrup of increasingly heavy concentrations until it becomes tender and transparent. Many times, the raw material is initially cooked in water or punctured for absorption of sugar syrup. The concentration of syrup should be such that it penetrates entire body without causing it to become tough or shrink. Hence, cooking in heavy syrup initially is avoided. Instead, the pieces are first boiled in 30° brix (per cent) syrup. It is desired to have cane sugar and invert sugar in equal proportion.

4. Chutneys, sauces and pickles

Chutneys, sauces and pickles have standard recipes for each commodity which can be modified to suit the local taste. Besides raw material, spices and condiments such as onion, garlic, clove, black pepper, cardamom and others are added for flavour whereas salt, sugar and vinegar serve as preservatives. In chutney preparation, the raw material is cut into pieces and slowly cooked below boiling point until they are soft. Onion and garlic are added initially and spices are added as powder or vinegar extract. Chutneys are cooked to thick consistency of jam. The sauces mainly consist of vinegar extract of flavouring material like spices and herbs. The pickling is basically preservation by fermentation, and vinegar and salt act as preservative. Spices and oils are usually added under Indian conditions. Usually, no heat is applied in pickling but the preservation is by making the conditions unfavourable for growth and multiplication of organisms. This is achieved by vinegar, salt or lactic acid, singly or in combination. The acidity takes care of putrefactive bacteria. But yeasts and moulds can grow. At high salt concentration (15 to 20%) moulds and even lactic acid forming bacteria do not grow. In low sugar vegetables, since fermentation is of limited importance, salt concentration is kept high. Faulty pickling preparations may lead to shriveling (cucumber) due to directly placing in salt, bitter taste (strong vinegar or prolonged cooking with spices), blackening (iron contamination) and softness or slipperiness (inadequate covering with brine).

5. Tomato pulp

For the preparation of tomato pulp, fully ripe but not spoilt tomatoes are used. After washing, the tomatoes are drained in order to eliminate the water on the surface. Sorting is done before the tomatoes are cut into halves to facilitate crushing and to detect any possible disease or decay inside. A manual or electrical juice extractor is used to separate the pulp from the seeds and the skin. The pulp is transferred to a pot and heated until 8-9° Brix of solids by refractometer is obtained. While still hot, the pulp is bottled with the help of a ladle and a funnel (previously "boiled" for few minutes in water). Acid correction is done with a small spoon of lemon juice. The bottles are closed with a capper. The pasteurization is performed within the same duration as the jars of peeled tomatoes and under the same conditions. Cool it overnight. Washing and labelling are the last stages before storage.

6. Ketchup

Tomato ketchup is popular condiment all over the world. Clean, wholesome tomatoes of intense red colour and of meaty, not watery texture are used for sauce making. High acidity and a rich tomato flavour are additional desirable qualities. Steps involved in preparation of tomato ketchup are as follows:

- Select ripe and fully red tomatoes. Wash them thoroughly in running water. Remove the green and blemished portions and discard them.
- Cut tomatoes into small pieces. Collect the cut pieces in an open pot and crush them thoroughly with a wooden ladle.
- Cook the crushed mass for about 5 minutes. Strain it through 1 mm stainless steel sieve by rubbing with the bottom of a mug.
- Discard the skin and seeds of tomatoes.
- Weigh the juice and store for further use.

- To the pulp, add 1/3 of the total sugar. The spices are tied loosely in a muslin cloth bag. Place the bag in the pan during boiling of pulp.
- Heat the pulp till it thickens and reduces to about 1/3 of its original volume.
- Remove the cloth bag and squeeze it well to extract the aroma and flavor of the spices. Add salt, remaining sugar vinegar.
- Heat the mass for few minutes so that the volume of the finished product is about 1/3 of the original pulp.
- To a small quantity of finished product, add sodium benzoate at the rate of 0.25gm/kg of finished product and mix thoroughly.

7. Freezed product:

It is highly advanced method. It can be used to dehydrate sensitive vegetables such as peas, sweet corn, etc.

Freezing of Peas

Method

Step 1: Select about half a kilogram of fresh, tender peas and shell them.

Step 2: Take enough water in a stainless steel pan in which the peas can be completely immersed. Add 1 teaspoon of salt for half litre of water dissolve and bring the solution to boil.

Step 3: Completely immerse the peas in the boiling solution for about 2 minutes.

Step 4: Drain the peas immediately on o a stainless steel sieve and let it cool for 10-15 minutes.

Step 5: Pack the peas in polythene bags, remove the air by pressing and seal the bags.

Step 6: Put the packets of peas into a freezer.

Note: *Similarly other vegetable such as cauliflower, beans, carrots etc can also be frozen.*

Using Frozen Vegetables

1. Take out the frozen packet from the freezer on and a half hours or two hours before use and let it thaw to room temperature. Put peas in a sieve and keep under tap water for a few minutes. Drain and use.
2. Frozen vegetables can be stored up to six months in a freezer.

Precautions while freezing Vegetables

a. Packaging material, that is, polythene bags should be strong enough to withstand expansion of food material on freezing.

b. The food once brought out of the freezer and up to room temperature should not be refrozen.

c. Small packets should be prepared, as food once thawed must be consumed. So there is less chance of the unrequired food material being spoilt. This also helps to avoid refreezing of the unutilized food material.

d. Exclude the air carefully and completely from the package before sealing.

e. The freezer should not be opened too frequently.

8. Vegetable powder:

This technology has been developed in recent years with applications mainly for potatoes (flour, flakes, granulated), carrots (powder) and red tomatoes (powder). Drying of vegetables down to final water content below 4% followed by grinding, sieving and packing of products.

9. Pickles and salted vegetables

There are a wide variety of pickled vegetables. Different types include:

i. Fermented pickle, made by submerging vegetables in dilute brine (2-5% salt). Naturally occurring bacteria grow over 1-2 weeks to produce lactic acid, which then prevents the growth of food poisoning bacteria and other spoilage microorganisms. The amount of added salt controls the type and rate of the fermentation. Sugar (2-5%) can be added to increase the rate of fermentation or to make the product sweeter.

ii. 'Salt stock' pickle is produced using a more concentrated brine (up to 16% salt), and is preserved by the salt and not by fermentation. Fruits and vegetables can be preserved in this way to spread production throughout the year.

iii. Vegetables may be packed in vinegar (acetic acid), salt and sometimes added sugar to produce a variety of pickled products that have a different flavour and texture to fermented pickles. They are usually pasteurized by heating.

iv. Sweet pickles are made from fruits or mixtures of fruits and vegetables. They are preserved by a combination of lactic or acetic acid, sugar and spices.

v. Salted vegetables are made in a sealed drum by building up alternate layers of chopped or shredded vegetable such as cabbage, with layers of salt. The salt draws out water from the vegetables to form concentrated brine. The products are washed to reduce the high levels of salt before they are eaten.

vi. *Preserved Gherkins:* India has today emerged as the origin of the finest gherkin cultivation, processing and exporters to the every-growing world requirement. Gherkin industry in India is today fully export oriented and its exports are mainly of two categories:-provisionally preserved (preserved in vinegar, acetic acid and brine) and preserved in vinegar. Preserved in vinegar are ready to eat gherkins which are in smaller packs of jars and cans. Gherkin industry in India is very well established with exports reaching 2,25,000 metric tones per annum. Exports are to all major countries like USA, France, Germany, Australia, Spain, South Korea, Canada, Japan, Belgium, Russia, China, Srilanka, Israel, Estona, Russia. In India there are about 51 major companies producing and exporting gherkins in drums and ready-to-eat consumer packs.

The pickle should be covered at all times during production to stop insects from contaminating it with moulds and yeasts, which spoil the product during storage. Glass jars are the most common packaging. Sealed polythene bags or plastic pots can also be used provided that they can be properly sealed to avoid leakage of product, which damages paper labels and attracts insects.

ACTIVITIES:

1. Make group of 5-10 students and visit to local vegetable mandi (market). Identify few vegetable sellers and interview them. List out advantages and constraints in marketing of vegetable crops.
2. Collect 5 different canned products of vegetable and note down the ingredients and instructions written on can/container.

Pigments and natural dyes from vegetables

The increasing demand of vegetable/natural dye in the whole world has replaced the use of chemical dyes. Vegetable dye is used in textile as well as food industries. Flowers, leaves, roots, fruits of many native plants can be utilized for extracting dyes. Several synthetic dyes are being banned for human consumption as well as for cosmetic use, thereby the demand for natural vegetable dyes has increased to a great extent. Setting up of vegetable dye plant can be highly beneficial in the present scenario. Natural vegetable dyes that are safe and eco-friendly.

Many fruits and vegetables have characteristic colors due to the presence of strong pigments. Examples include quercetin, from yellow onion skins, and anthocyanins, from red cabbage. Anthocyanin group is responsible for the color found in radishes (pink colour), eggplant (purple colour), beet (violet colour), carrot (black and red colour). Cholorophylls can be extracted from french bean, cabbage, cauliflower, cucumber fruit, garlic sprout, lettuce head, okra pod, onion leaves, chillies and spinach. Carotenoids are present in asparagus, bitter gourd, french bean, broccoli, cabbages, cauliflower, carrot, tomato, pepper, watermelon.

Seed Industry

Indian seed market, estimated at US$1.1 billion, is the 6^{th} largest in the world. Public sector involvement in the seed industry on a national scale began at the beginning of the "green revolution" with the establishment of the National Seed Corporation (NSC) in 1963, which was charged with the responsibility of promoting seed industry development from production through processing, storage and marketing, and establishing a system of quality control. The State Seed Corporations (SSC) was established later with support from the

World Bank. The NSC and SSCs work closely together to coordinate procurement and sales prices as well as variety demand and supply. Their presence is considered necessary by the government to ensure the availability of reasonably priced seeds of major crops throughout the country and to make sure that private sector seed companies do not enjoy and exploit unreasonable market power.

The public sector seed organizations are public research institutions, under the aegis of Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs) for their breeder seed requirements. Private sector accounts for 80% turnover in seed. Almost 1/3 companies have a global technology/ financial partner. The composition of the seed industry, by volume of turnover, has reportedly reached a ratio of 60:40 between the private and public sectors. The private seed sector now comprises some twenty or so large players (with sales turnover exceeding Rs 200 million), several medium companies (sales turn over between Rs 200 million and 20 million), and a large number of small, unorganized players (sales turnover less than Rs 20 million) with local presence.

The private seed industry is now undergoing a transition following the Indian government's focus on biotechnology research, as a means of increasing agricultural production and also driven by trends in the domestic and world seed market. Intensifying international competition, increasing R&D costs, and the complexity of biotechnology have lead to increased consolidation of the Indian seed industry with several of the large and medium companies merging or being taken over by multinational seed companies. Most large multinational seed companies now have their presence in India (either as a joint venture or with 100 percent equity) with their main focus on biotechnology. These include Monsanto, Bayer Crop Science, Syngenta, Advanta, Hicks-Muse-Tate, Emergent Genetics, Dow Agro, Bio seed Genetics International Inc., Tokita Seed Co, and Nunhems Zaden BV. The public sector concentrates on seed production of mostly large volume low value crops, whereas, private sector deals with mostly improved hybrids and high value, low volume seeds. Vegetable seeds account for about 18 % of the total production of certified seeds. Most of the seed production is mainly carried out in the farmer, fields under a contract system and ensures better returns for the seed growers.

Vegetable seed industry in India:

India is endowed with several advantages making it competitive for production of open pollinated varieties and hybrid vegetable seeds for domestic and foreign companies and meeting international seed quality standards. Reasons for India's success in hybrid seed production include availability of skilled labour (pollinators and growers) at inexpensive rates, skilled supervisors and favourable climate for production of major crops like tomato and cucurbits over an extended production season. Systems to import parent seeds and export of hybrid seeds are in place. The Government has been supportive of export-oriented activities. The state of Karnataka produces nearly 90% of the total hybrid vegetable seeds; new untapped areas should be explored indigenously for production of seeds of tropical as well as temperate vegetable crops. Rural folk should be encouraged and trained in seed production of vegetable varieties and hybrids. With low cost labour availability and environment suitability for quality, vigorous and bold seed production, all kinds of vegetable seeds can be produced in India for domestic and export markets which will not only save foreign exchange instead earn it besides empowering rural poor with skill, generate employment & income.

Hybrid seed production in tropical vegetables is highly remunerative. Usually a small family handles a unit area of 0.25 to 0.75 acre each in cucumber, gourds and melons and 1 acre each in watermelon and okra for hybrid seed production. The cost of hybrid seed production varies from Rs. 8.5 thousand to Rs. 29 thousand-per unit area depending upon the crop. Hybrid seed production in sweet pepper is highly remunerative generating an average income of Rs 136 thousand per 0.75 acre, followed by chilli realizing average net profit of Rs. 41.5 thousand per 0.25 acre. In remaining crops, the net income varies from Rs. 22 thousand to 38 thousand per unit area.

Finally, there is a great scope for development of the vegetable seed industry and hybrids in India. The market is immense and the farmers are eagerly looking for improved seeds. There is a need for strong public private partnership to further strengthen the seed sector for healthful green India. The public sector research started ground work in most developing countries in order to uplift the technical and managerial level of the farmers, by developing and disseminating (slowly) improved agricultural practices. The private sector has also contributed considerably to the overall growth of the vegetable industry, by developing and making available superior hybrids and quality seeds to the farmers, the demand for quality seed and hybrids is steadily increasing with the improving technological skills of the vegetable farmers.

Future prospects of vegetable based agro-industry

Business opportunities in the area of seed production, storage and processing would increase steeply for vegetable crops. Several private enterprises have already ceased this opportunity and are increasing their capacity for quality seed production. The perishable nature of vegetables necessitates its post harvest storage under refrigerated condition. Although chain of conventional refrigerated storage structures is available in the country, there is a need to refine the storage technology to economize energy consumption as well as to ensure better quality of stored produce. Similarly, opportunities in the area of post harvest processing would increase many folds in near future. Most of the multinational companies dealing with processed vegetable products have already established their links in India. Business opportunity in this area is also going to be increased at a high rate in near future. Besides, latest concepts and business opportunities in the area of contract farming, crop insurance, consultancy, mechanization, high-tech farming, procurement, packaging, retailing, etc. would be favoured in vegetable crops compared to other food crops. The need for supermarkets to keep their shelves filled with homogeneous products the whole year round leads to worldwide sourcing of foodstuff. This trend opens up production possibilities for everybody.

CHECK YOUR PROGRESS

Subjective Questions

1. Discuss about health benefits from vegetable.
2. Write notes on export potential of vegetable crops. What are specific requirements of vegetables for export?
3. Discuss Processing, preservation and value addition in vegetable crops.
4. What are dried products from vegetables? Discuss with examples.

Write short note on the following

1. Principles of preservation
2. Preservation by canning
3. Vegetable dehydration
4. Value added product from vegetables
5. Pigments and natural dyes from vegetables

Fill in the blanks

1. Vegetable crops in India occupy ……… of the total cultivated land producing ……… million tones of vegetables.
2. An average per capita per day requirement of vegetable is……… and in India per capita availability is around ………. g per day.
3. India is the …………….. largest producer of vegetables in world.
4. As per dietician, daily requirement of vegetables is ……… of green leafy vegetables ………of other vegetables and ……. of roots and tubers with other food

5. Prevention or delay of microbial decomposition by keeping out microorganisms is called…………..

Further readings and references

1. Handbook of Horticulture, ICAR, New Delhi
2. www.mofpi.nic.in
3. Handbook of Agriculture, ICAR, New Delhi
4. www.apeda.gov.in
5. Postharvest management and processing of fruits and vegetables by SK Sharma. New India Publishing Agency, New Delhi.
6. Handling, transportation and storage of fruits and vegetables by SK Chattopadhyay. Gene-Tech Books, New Delhi.

★★★

Chapter-3

Cropping System with Vegetable Crops

OBJECTIVES

Students will be able to learn about :-

- Crop rotation
- Sequential cropping
- Relay cropping
- Intercropping
- Vegetable based cropping sequence

INTRODUCTION

The ultimate objective of a farmer is to get maximum production of crop and earn higher profit from his piece of land per unit time. The demand for vegetable is growing continuously and to meet the ever increasing targets as per the demand, productivity needs to be raised further and/ or more area needs to be brought under vegetable cultivation. There is enough opportunities of introducing vegetables in prevailing cereal based cropping systems by introducing short duration vegetable crops between two cereal crops or by replacing less profitable crop with high value vegetable crops. Vegetable crops will enhance the productivity and profitability and it will pave the way for nutritional security and healthy society.

Role of vegetables in cropping systems

Crop diversification has been well recognized as an effective strategy for achieving the objectives of food and nutritional security, income growth, poverty alleviation, employment generation, judicious use of land, water and other natural resources, sustaining agricultural development and environmental improvement. Long growing seasons, small landholdings, and high labour-land ratios make multi crop production systems advantageous in India. Multiple-cropping maximizes land productivity per unit of time. Due to their diversity and relatively short maturity, vegetables can be easily incorporated into many cropping systems. Therefore, multiple-cropping predominates in intensive vegetable production areas. Vegetables are grown as sole crop or multiple cropped with sequential cropping or intercropping systems. Cultivation of many vegetables, like tomato, onion, chillies, capsicum, peas, okra, cauliflower, cabbage, melons and watermelon etc. is taken up as sole crops on large scale for transport to distant markets. Off-season vegetables are also cultivated as sole crops. Multiple cropping involves more than one crop grown either together or in a sequence in a year on the same land. In general, multiple cropping increases cropping intensity and intensifies vegetable cultivation. Multiple cropping is commonly adopted in peri-urban areas where farmers undertake intensified vegetable production with diversified crops. Often higher cropping instensities give higher profits. However, market value / price is more important than higher cropping intensity. Sometimes, a lower cropping intensity may be better when the market value is high for a speciality vegetable.

Advantages of including vegetables in cropping systems:

- Higher quantity of produce per unit area and time.
- Total amount of nutrients produced is higher.
- Multiple crops can be grown on the same piece of land in a year.
- Diversity of crops minimizes weather and pests risk involved.
- Better employment opportunities due to round the year cultivation.
- Improvement in physical, chemical and biological health of soil.

What is a crop rotation?

A crop rotation is a series of different crops planted in the same field following a defined order (i.e. maize-cotton- sunnhemp or maize-soyabeans). Monoculture is the repeated planting of the same crop in the same field year after year.

What problems occur with monocultures?

In monocultures, increases in crop-specific pests and diseases are often observed over time. Continuously growing the same crop will tend to exploit the same soil root zone which can lead to a decrease in available nutrients for plant growth and to a decrease in root development.

What are the advantages of crop rotations?

- Many crops may have positive effects on succeeding crops in the rotation, leading to greater production overall.
- Rotations are used to reduce pests and diseases in the cropping system and to control weeds by including smothering crop species (e.g. cowpeas) or green manure cover crops.
- Rotations may also give benefits in terms of improved soil quality (more or deeper roots; root exudates), better distribution of nutrients in the soil profile (deep-rooted crops bring up nutrients from below) and to increased biological activity.
- Through rotations, peak labour times may be reduced and labour better distributed throughout the year, if planting and harvest times are different.
- Crop rotations may decrease risk as bad seasons, or bad parts of a season, may affect some crops more than others.

- Crop rotations can balance the production of residues by alternating crops that produce few and/or short-lived residues with crops that produce a lot of durable residues.

However, above all the rotation needs to address the needs of the farmer, whether it be for cash income or subsistence.

Sequential Cropping

Sequential cropping involves two or more crops grown in sequence in a year on the same land. It is the planting of two or more crops, one after another, in the same field to maximize land productivity. Double cropping of cowpea and tomato and also French bean and tomato were found to be better than sole crops. Similarly triple cropping of brinjal-turnip-muskmelon and cauliflower-tomato-okra were more remunerative than the crops grown alone. Multiple cropping may be based on cereals, pulses, oilseeds or other field crops. The rice-based cropping systems successful in West Bengal are rice-tomato-rice-mung, rice-watermelon-rice and jute-rice-pumpkin. The wheat or millet based cropping systems recommended include, (i) maize-potato-onion, (ii) cauliflower-wheat-tinda, (iii) bajra-potato-okra, and (iv) maize-potato-pumpkin. In Indo-Gangetic plains the remunerative potato-based cropping systems are (i) rice-potato-wheat, (ii) rice-potato-onion and (iii) rice-potato-green gram. Multiple cropping system suited to Bangalore (Karnataka) conditions were (i) sunflower-cabbage-tomato, (ii) maize-tomato-watermelon and (iii) paddy-peas-tomato. Cropping intensities (percentages) in different multiple crop rotations are 200 in double cropping, tomato-onion, 300 in triple cropping, brinjal-peas-bitter gourd, 400 in quadruple cropping, okra-palak-potato-muskmelon and 500 in crop sequence of okra-radish-cauliflower-squash-cowpea. The combined crop of ragi and hyacinth (Dolichos) bean sown in equal proportions gave the best returns under rainfed conditions. Double croppings of cowpea-tomato and French bean-tomato were also more profitable than sole crops under rainfed conditions.

When planning a sequential cropping system, crops which can be transplanted should be grown in the nursery before the current crop is harvested. This shortens the growing period of the succeeding crop. Crops should be carefully selected, taking into account their most favourable planting date. Early-maturing crops are generally preferred to allow the growing of more crops per year. Crops belonging to the same family should not be planted in succession to prevent accumulation of pests. For example, eggplant should not follow tomato or pepper because this may build up bacterial wilt, a soil-borne disease that affects all of these crops. Radish should not follow cabbage because both are hosts to diamond back moth, an insect pest that is very difficult to control. Some crops produce root exudates which may remain in the soil and harm the next crop. Decomposed residues may also cause damage to the next crop. To make full use of soil nutrients from different strata, deep-rooted crops should be grown in rotation with shallow-rooted crops.

The advantages of sequential cropping are the following:

Pest control - Weeds are controlled effectively when the farm land is used continuously for growing crops. A prolonged fallow or rest period between crops increases weed population, particularly in areas with an even rainfall distribution, because this condition favours the growth and multiplication of weeds. This problem is less severe in areas that are extremely dry during the fallow period. Proper sequencing of crops, so that two successive crops do not share the same disease or insect problem, can effectively break the life cycle of pests. This eventually reduces pest population and makes control easier. In a rotation system with rice, the flooded condition in the rice crop effectively reduces soil-borne diseases which may affect vegetables. It is also an important factor in the control of dryland weeds.

Full use of residual soil moisture and nutrients- After the wet-season paddy rice crop, residual soil moisture is usually adequate to support the establishment of another crop. In rainfed conditions, the residual moisture is not sufficient to support a second rice crop but may be enough for a short-season vegetable crop, such as mungbean. Fertilizers applied on the previous rice crop can also be utilized by a succeeding vegetable crop. Futhermore, fertilizers applied on the vegetable crop can also be used by the succeeding rice crop. With irrigation, two short-season vegetable crops may be grown between two rice crops with the use of early maturing rice varieties.

Sustained soil fertility- The balance of nutrients in the soil can be maintained by rotating crops of different nutrient utilization patterns. Leguminous vegetables can fix atmospheric nitrogen and return some of these to the soil at the end of the season.

Multiple Cropping

Multiple cropping is influenced by climate, varieties, crop rotation and farmers motivation. Both crops and varieties selected for multiple cropping should be suited to the local climate, (temperature, relative humidity, sunlight and rainfall) and soil conditions. Short duration and thermo or photo insensitive varieties are preferred. Short day onion varieties are not suitable for growing at high altitudes where long day types are adapted. The crop rotation should be adapted to climate and soil and crops involved may have high market value. In crop rotation non-host crops may be included instead of the crops of the same botanical family in order to have better protection against diseases and insect pests. Multiple cropping is labour intensive requiring constant and careful management which may discourage some farmers to adopt it. However, increases in production and net profit may motivate the farmers to undertake it.

Crop intensification through vegetables

Vegetables crops are of shorter duration and they can be fit well in different cereal based cropping system prevalent in different regions of our country. Inclusion of vegetables will diversify the existing cropping system and increase the total profit manifolds. Three or more vegetables can be grown on the same piece of land in a year, which will enhance the cropping intensity, productivity and thereby profitability. Short duration vegetable varieties can produce higher yield per unit area, per unit time and enhance the system productivity in whole.

Table 1: Short duration vegetable varieties for enhancing productivity

Crops	Varieties	Days to first picking	Crop availability	Av.Yield (q/ha)
Summer Squash	Pusa Alankar	45	Feb-March	400
	Australian Green	45-50	Feb-March	350
Radish	Pusa Chetaki	40	Aug-Sept	170
	Pusa Desi	50-55	Sept-Oct	175
	Pusa Himani	50-55	Feb-March	250
	Japanese White	55-60	Nov- Dec	250
Tomato	Pusa Sadabahar	80	Dec-Jan	275
Turnip	Pusa Sweti	40-45	Oct	250
	Pusa Chandrima	50-55	Dec	350
	Pusa Swarnima	50-55	Dec	350
Pea	Arkel	55-60	Nov	90
	Pusa Pragati	60-65	Nov	90
Cabbage	Golden Acre	60-65	Nov	250
Knol khol	White Vienna	40-45	Nov	250

Year round vegetable production through suitable varieties

Radish

Radish is one of the important salad vegetable crops required through out the year. A single variety can not be used for growing roots through out the year. Different cultivars developed at IARI having specific growing requirements can be grown under north Indian plains for sowing right from August and continued for the entire year so as to make fresh radish available to the consumers.

Table 2: Improved radish cultivars for year-round production

Sl. No.	Cultivars	Period of sowing	Period of harvesting	Av. Yield (q/ha)
1.	Pusa Desi	Middle of August to Middle of October	Mid-September to Mid-December	175
2.	Pusa Mridula	First fortnight of September to Mid-November	2nd fortnight of October to 1st fortnight of January	180
3.	Japanese White	Mid-October to 2nd fortnight of December	Mid-December to 1st fortnight of March	250
4.	Pusa Himani	2nd fortnight of December to end of February	Mid-February to 3rd week of April	250
5.	Pusa Chetki	First week of April to mid-August	First fortnight of May to 2nd fortnight of September	170

Cauliflower

In earlier days, cauliflower was used to be grown only during winter season because only Snowball types were available during those days. But, with the evolution of heat tolerant, tropical types, popularly known as Indian cauliflower, it has become possible to grow cauliflower during the hotter part of the year also. Based on temperature requirement for growth and curd development, cauliflower varieties have been developed and now it has become possible to grow cauliflower for almost all the year-round.

Table 3: Improved Cauliflower varieties and hybrids for different seasons of the year

Maturity group	Varieties and hybrids	Sowing time	Availability period	Av. Yield (q/ha)
Early I(a)	Pusa Meghna, Pusa Kartik Sankar	End of May	End of August-October	110 110
Early I(b)	Pusa Deepali	June	Oct.-Nov.	120
Mid Early II	Pusa Sharad, Pusa Hybrid-2	End of July-August	Nov.-Dec.	250 200
Mid Late III	Pusa Paushja, Pusa Shukti	End of August-Sept.	Dec.-Jan.	325 320
Late	Pusa Snowball K-1, Pusa Snowball K-25	Sept.-Nov.	Jan.-March	350 320

Carrot

Improved carrot varieties have been developed which can be grown round-the-year and the availability of fresh carrot can be ensured.

Table 4 : Improved carrot varieties and hybrids for different seasons of the year

Variety	Sowing time	Availability	Yield (q/ha)
Pusa Vrishti	July to October	October to December	180-200
Pusa Rudhira,Pusa Asita	September to October	November to January	300-350
Pusa Yamdagini, Pusa Nayanjyoti	September to March	November to April	270-320
Pusa Vrishti	March to April	May to June	150-160

Vegetable based cropping systems

Some important vegetable based cropping systems and their expected profitability have been presented below. Vegetable cultivation will also be beneficial in improving the physical, chemical and biological health of soil if legumes are included in the crop rotation. Similarly, different cropping systems by including the vegetables can be much profitable and must be adopted by the farmers/entrepreneurs for enhancing productivity and profitability. The net returns from a cropping system is an estimated indicative value and it largely depends upon the selling price realized by farmers for different vegetables in the market, hired labour cost, amount of family labours, prevailing climatic condition and incidence of pest and diseases during cropping season, place of cultivation, cost of transportation, methods of marketing etc and some other existing situations.

Table 5: Vegetable based cropping systems

Region	Cropping System	Yield (q/ha)	Net Returns (Rs/ha)
Northern Plains	Early Cauliflower (July-October)	110-125	60,000-75,000
	Peas (October-January)	70-80	50,000-60,000
	Tomato (January-June)	400-450	90,000-1,10,000
	Total returns		**2,00,000-2,45,000**
	Okra (June-September)	130-140	35,000-40,000
	Carrot (October-December)	250-300	45,000-60,000
	Cauliflower (December-March)	250-300	37,000-52,000
	Radish (April-May)	140-150	36,000-40,000
	Total returns		**1,53,000-1,92,000**
	Cucumber (July-September)	120-130	30,000-45,000
	Potato (October-December)	160-180	34,000-42,000
	Onion (January-June)	225-250	60,000-65,000
	Total returns		**1,24,000-1,52,000**

North-eastern	Cauliflower (June-August)	100-110	60,000-70,000
	Peas (September-November)	70-80	36,000-44,000
	Radish (December-January)	200-220	40,000-46,000
	Sweet pepper (January-May)	150-160	90,000-1,00,000
	Total returns		**2,26,000-2,60,000**
	Green Chilli (June-September)	110-120	42,000-50,000
	Broccoli (October-December)	110-120	80,000-90,000
	Radish (January-February)	150-160	30,000-33,000
	Bottle gourd (February-May)	300-325	50,000-58,000
	Total returns		**2,02,000-2,31,000**
North-Western Hills	French Bean (July-September)	100-110	45,000-53,000
	Knol khol (September-November)	150-160	35,000-39,000
	Peas (November-April)	100-110	55,000-62,000
	Sweet pepper (April-July)	150-160	90,000-1,00,000
	Total returns		**2,25,000-2,54,000**
	Tomato (June-September)	350-400	70,000-90,000
	Cabbage (September-November)	200-220	45,000-52,000
	Turnip (November-February)	200-210	30,000-33,000
	Potato (March-May)	250-300	60,000-80,000
	Total returns		**2,05,000-2,55,000**

Table 6: Vegetable and cereal based cropping systems

Cropping System	Yield (q/ha)	Net Returns (Rs/ha)
Basmati Rice (June-November)	35-40	45,000-55,000
Cauliflower (November-January)	250-300	37,000-52,000
Vegetable Cowpea (February-April)	70-80	20,000-25,000
Total Returns		**1,02,000-1,32,000**
Basmati Rice (June-November)	35-40	45,000-55,000
Peas (November-March)	70-80	40,000-50,000
Bottle gourd (March-May)	300-325	50,000-58,000
Total Returns		**1,35,000-1,63,000**
Basmati Rice (June-November)	35-40	45,000-55,000
Cauliflower (November-January)	250-300	37,000-52,000
Onion (January-May)	225-250	52,000-62,000
Total Returns		**1,34,000-1,69,000**

Rice (June-September) Carrot (September-December) Wheat (December–April) **Total Returns**	55-60 250-300 35-40	57,000-65,000 45,000-60,000 25,000-30,000 **1,27,000-1,55,000**
Rice (June-September) Cauliflower (September-December) Wheat (December–April) **Total Returns**	55-60 150-200 35-40	57,000-65,000 50,000-65,000 25,000-30,000 **1,32,000-1,60,000**
Okra (June-September) Radish (September-November) Wheat (November–April) **Total Returns**	130-140 150-200 45-50	35,000-40,000 25,000-40,000 35,000-40,000 **95,000-1,20,000**
Brinjal (June-September) Palak (September-November) Wheat (November–April) **Total Returns**	350-400 150-175 45-50	70,000-90,000 30,000-37,000 35,000-40,000 **1,35,000-1,67,000**

Intercropping

Intercropping is the practice of growing two or more crops in the same field at (or about) the same time. Broadly multiple cropping also includes intercropping of vegetables. Intercropping system in vegetable crops is useful in respect of (i) better utilization of natural resources of sunlight and water and increased land use efficiency, (ii) efficient fertilizer management with better residual, direct and cumulative effects on crops, (iii) improved nitrogen economy when a leguminous vegetable (peas or beans) or any other legume is included in intercropping, (iv) higher nutritional potential, (v) diversification of crops and varieties and (vi) less risky and insurance against crop failure because of aberrant weather. Intercropping in vegetables may be either with vegetables or other field crops and cereals. *Palak* and methi intercropped in cabbage, spinach and beet in cabbage and mustard in cabbage gave higher economic returns. The last one (mustard + cabbage) proved useful for control of diamond back moth in cabbage because mustard acts as a trap crop to attract the diamond back moth. Palak, methi, coriander or radish intercropped in cauliflower, onion in chillies, and palak, radish or onion in tomato are also more profitable than sole crops. Vegetables can be usefully intercropped in cereals and other field crops. Onion is the best intercrop in sugarcane and in some areas sugarcane can also be grown with potato. A few important examples of intercropping of vegetables with cereals and other crop include, radish in potato, potato with maize, peas with maize, onion with maize, vegetables (radish, turnip, carrot, beet) in mustard crop, green onion, radish, turnip in tuber crops (tapioca, yarn, cassava), cassava intercropped with onion followed by radish, onion as an intercrop in cotton, and green onion and turnip in chewing tobacco. There can be also sequential intercropping, such as, (okra + French bean) - (capsicum + onion) - (muskmelon + radish) which is better than sequential sole crop system of okra-capsicum-muskmelon. In Maharashtra, the most profitable onion based cropping system was Aster (*kharif*)-Onion (*rabi*). The vegetable based intercropping systems in Ranchi (Jharkhand) found to be profitable were cabbage + coriander, cabbage + fenugreek and tomato + onion.

Relay-cropping

> Land Equivalent Ratio (LER) is commonly used to indicate the biological efficiency of an intercropping system, and is defined as the relative land area required by single crops to produce the same yield as in intercropping.

This is the planting of a second crop before the first crop is harvested. Relay-cropping is done to 1) reduce the time that is necessary to grow several crops in the same piece of land, 2) utilize the residual soil moisture and fertilizer, 3) protect the seedlings of the second crop from intense sunlight, and 4) utilize solar radiation fully by increasing the ground cover between consecutive crops. Although relay-cropping may reduce the yield of the first crop, the benefit from this practice usually outweighs the loss in yield. To succeed in relay-cropping, certain conditions must be met. The land should be prepared thoroughly for the first crop; so that, it will serve the needs of the two crops. In a relay-cropping scheme, it is difficult to prepare the land for the second crop without causing damage to the first crop, especially if the latter is closely spaced. The first crop must also be planted and evenly spaced in straight rows to facilitate field operations during planting and initial growth of the second crop. Weeds should be controlled more thoroughly during the first crop to avoid harm to the second crop. The relay crop must be shade-tolerant; otherwise, the population of the first crop must be reduced to minimize shading effects on the relay crop. If the relay crop will not be irrigated, it must be drought-tolerant, too. Relay cropping is also practised in some cases, like planting of rabi onion seedlings in the standing crop of cabbage which may be almost reaching maturity for harvest. Vegetables are also grown as cover crops in an established fruit orchard or a newly planted orchard of mango, ber, coconut, oilpalm or rubber. Peas, garlic, onion and cabbage have been successfully grown in ber plantations in rain fed areas. Tomato has been found to be a useful vegetable crop to be grown in young plantations of Poplar trees in Tarai region of Uttarakhand. Tomato plants get full sunlight during winter months when Poplar trees shed their leaves and in spring/summer the new leaves on Poplar trees provide protection from sunscald to tomato fruits on the plants. Later in spring-summer season a good crop of cabbage can be taken in Poplar plantations when partial shade helps to reduce the damage by high temperature (heat) to cabbage during summer months.

Sequential and Multiple Cropping with Intercropping

Sequential cropping and intercropping have been beneficial in fertilizer management and plant protection against diseases and insect pests and provide higher nutrition. The crop rotation of peas-tomato-radish has high potential for vitamin C and similarly tomato-okra-spinach (palak) for vitamin A. Beet root, peas and knol khol intercropped with okra and capsicum provide better nutrition. In multiple cropping, residual, direct and cumulative effects of fertilizer applied depend on the crop grown in sequence. The yield of onion bulb increased due to high N and K fertilizer application to the preceding potato crop. Similarly NPK fertilizer applied to the preceding okra and brinjal crops resulted in higher yields of the subsequent radish crop. Crop combinations of okra with French bean and okra with radish have better utilization of NPK nutrients than the sale crops. The crop rotations of rice-cabbage-tomato and French bean-cabbage-okra had utilized phosphorus more efficiently in sequence cropping system than the crops grown alone. It has been observed that cabbage, radish, carrot and brinjal mobilised the potash (K) in the soil but okra could not mobilise it.

Multiple cropping including intercropping has been found to be beneficial for the control of insect pests and diseases. Mustard intercropped in cabbage controls diamond back moth by attracting the insect pests as a trap crop. Similarly intercropping of mustard with potato can control mustard aphids which will not transmit any of the potato viruses. The crop rotations of tomato with cowpea-maize-cabbage and okra-cowpea-maize were found to be best control of bacterial wilt. The best crop rotations for control of bacterial wilt in brinjal were maize-okra-radish, maize-cowpea-maize, okra-cowpea-maize and ragi-brinjal-French bean. Tomato crop taken after maize was less affected by root-knot nematode. Cabbage intercropped with tomato planted 30 days later had significantly less number or cabbage larvae *(Plutellu oxylostella).*

Activity 1

Visit some farmer's field known for vegetable cultivation. Make a list of different vegetables grown on his field during the year and find out the cropping intensity of his field.

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Activity 2

Plan two or three different vegetable based crop sequence for whole year to be followed in school/ community/ kitchen/home garden and calculate the comparative profitability of different sequences after one year of cultivation.

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CHECK YOUR PROGRESS

Objective types

1. Name radish variety which can be sown during July-August.
2. Name cauliflower variety with curd maturity during October in North Indian plains.
3. Name heat tolerant carrot variety.
4. Name few vegetable crops which can fix atmospheric nitrogen.
5. Name cauliflower variety for curd availability during March.

Write short notes on following:

1. Year round cultivation of radish
2. Relay cropping
3. Intercropping
4. Off season cultivation of vegetable with suitable varieties.

Long answers

1. What do you understand by crop rotation and how it is useful in vegetable cultivation?
2. Vegetable based cropping sequence enhances the profitability of per unit land. Justify the statement with examples.
3. What are the main advantages of sequential cropping with vegetables?

Further readings and references

1. Hazra P and Som MG. Technology for Vegetable Production and Improvement. Naya Prokash.
2. Kalia P, Choudhary H and Kumar A. 2012. Role of vegetable crops in enhancing cropping systems profitability and sustainability. Indian Farming 62(8):30-34.
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Chapter-4

Production Technology of Important Vegetable Crops

OBJECTIVES

Students will be able to learn about :-

- Importance of a particular vegetable
- Production technology to raise healthy crop of different summer and winter season vegetable crops
- Management of important insect-pests and diseases of different vegetable crops
- Post-harvest handling

INTRODUCTION

You have studied the production technology of solanaceous and cucurbitaceous vegetable crops in the XI class. In continuation, we will study the production technology of different winter and summer season vegetable crops in this chapter. As of now, you have understood that vegetables play a very important role in human health and can be taken as an entrepreneurship. We consume different vegetables as cooked or as salad or as dessert. Vegetables in general are consumed when they are immature but tender and crisp. Have you ever tried to know how can we grow a healthy crop of different winter and summer season vegetable crops? Which variety(ies) is suitable for different areas of the country? At what time we should go for their sowing/planting? How much seed is required and how can it be grown? At what spacing different vegetables should be grown? What approach should be taken up to control different pests including weeds, insects and diseases? What are the critical stages for applying irrigation to harness maximum yield potential of different vegetable crops? At what stage, a particular winter or summer vegetable should be harvested? How it should be handled after harvesting? This chapter briefly gives you an idea about different cultural practices to be adopted to raise a healthy crop of different winter and summer season vegetable crops except solanaceous and cucurbitaceous vegetable crops.

What is the necessity to follow agronomic practices?

You have learnt about the importance and necessity of different agronomic practices which are adopted to raise a healthy vegetable crop in chapter VII of XI class, let us revise it. Every crop has a specific requirement of season/environment to grow. The first and the foremost requirement is a suitable variety for a particular area and its quality seed. A good variety and its quality seed determine the success of cultivating a healthy and economic crop. Therefore, always select a variety which is recommended for cultivation in a specific area/

region since each variety cannot be productive everywhere. Always procure seed from a reliable source as it is the most costly input. Optimum sowing/planting time is also important and critical factor in determining the environmental conditions at planting, flowering and fruit development stage and thus has direct impact on the successful cultivation of vegetable crops.

A vegetable crop should be planted/sown at recommended spacing between and within rows. The closer planting results in overcrowding which ultimately hinder the access to proper sunlight and aeration. Further, due to closer planting, humidity gets increased and thus the plants become more vulnerable to the attack of diseases and insect-pests. Wider spacing accommodates less number of plants per unit area which ultimately result in low production per unit area than what we have expected by following recommended spacing. The use of chemical fertilizers to enhance soil fertility and crop productivity has often negative effect on the complex soil-biological cycles. For example, fertilizer use can cause leaching and run-off of nutrients under irrigated conditions/high rainfall areas, especially nitrogen (N) and phosphorus (P), leading to environmental degradation. The potential way to decrease negative environmental impacts resulting from inefficient use of chemical fertilizers is to follow integrated use of organic manures and synthetic fertilizers. This will in turn help to meet out the nutrient requirement of the crops as well as sustain vegetable productivity and soil health.

You have studied in the previous class that management of weeds, diseases and insect-pests at appropriate growth stages is very essential as they individually cause losses to crop yield to the tune of 30-60 per cent. Optimum irrigation at critical growth stage is very crucial to exploit maximum production potential of different vegetable crops as they cannot withstand prolonged dry conditions. Appearance, colour, tenderness and crispiness determine the harvesting stage of a particular vegetable crop to get high premium in the market. So, attention should also be paid to the post-harvest handling of vegetable crops. With this background, let us discuss the production technology, management of pests, harvesting and post harvest handling of different vegetable crops to harness their maximum potential.

Potato

Botanical Name : *Solanum tuberosum* L.

Family : Solanaceae

Origin : Peru and Bolivia in South America

Importance and uses: Potato is the staple food in many European countries of the world and has proved its worth in feeding the nation in emergency. It is an

> ***Do you Know about Irish Potato Famine?***
>
> *As name suggests, a famine was caused by the sudden outbreak of late blight disease during 1845 in Ireland which led to the death of one million people as one third of the population of Ireland was entirely dependent on the potato for food.*

important source of starch. It is a rich source of body building substances such as carbohydrates, vitamins (B_1, B_2, B_6 and C), minerals (Ca, P and Fe) and protein. It contains all the dietary substances except fat.

Soil: It can grow in almost all types of soil. The well drained clay loam soil is considered as ideal for its cultivation. On sandy loam soil, crop can be successfully grown provided manuring is done heavily and the crop is irrigated properly and timely. It produces best when soil pH is 6.0-6.5.

Climate: It is a cool season crop and can tolerate moderate frost. It requires 20°C soil temperature for better germination. Young plant growth is good at 24°C but later growth is favoured by a temperature of 18°C. No tuberization takes place when the night temperature exceeds 23°C. Maximum tuberization occurs at 20°C. Tuber formation stops completely at about 29-30°C.

Varieties: The varieties of potato are categorized into three groups on the basis of their maturity. The important cultivars recommended for cultivation in different parts of India are as under:

Early varieties: These varieties are ready for harvest in 70-80 days such as Kufri Ashoka, Kufri Chandermukhi, Kufri Jawahar, and Kufri Lauvkar.

The Central Potato Research Institute (CPRI) is the premier institute working on research on potato and is situated at Shimla in Himachal Pradesh. The varieties released from CPRI have 'Kufri' as their first name.

Main season varieties: They are ready for harvest in 90-95 days. Among the white coloured varieties, Kufri Jyoti, Kufri Sutlej, Kufri Pukhraj, Kufri Megha, Kufri Badshah, Kufri Anand, Kufri Bahar, Kufri Sadabahar, Kufri Deva, Kufri Sherpa, Kufri Swarna, Kufri Shailza, Kufri Surya, Kufri Himalini, Kufri Girdhari and Kufri Khyati are important.

Late varieties: Kufri Jeevan, Kufri Neelamani, Kufri Khasigaro, Kufri Naveen

Kufri Sindhuri and Kufri Lalima are red coloured main season varieties.

Varieties for processing: Kufri Chipsona 1, Kufri Chipsona 2, Kufri Chipsona 3, and Kufri Himsona

AGRONOMIC PRACTICES:

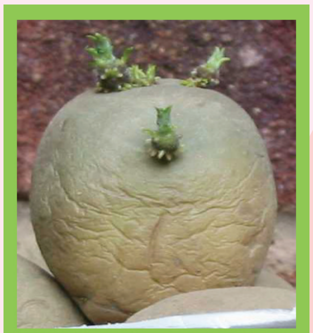
Soil preparation and planting: A well prepared soil provides favourable environment for the development of tubers and also helps to retain moisture. The fields are ploughed to a depth of 20-35 cm first with soil turning plough and afterwards by 4 to 5 ploughings with country plough/disc harrow. Clods must be broken to make the field well pulverized and levelled.

Planting time

Region	Season	Planting time	Harvesting time
North western hills			
Very high hills	Summer	April-May	Sept-Oct
High hills	Summer	Mid-March-April	Sept-Oct
Mid hills	Spring	Jan-Feb	May-June
North central high hills	Summer	Mid Feb-March	August-Sept.
North eastern high hills	Spring	Mid Dec-Mid Jan	July-August
Shillong hills	Summer	March-April	July-August
	Winter	Jan-Feb	May-June
North western plains (Jammu, Punjab, Western U.P., Haryana, Rajasthan, Plains of M.P)	Early	Mid-Sept	Mid Nov-Dec
	Autumn	Mid-Oct	Feb-March
North Central Plains	Winter	Mid-Oct	Feb-March
North eastern plains			
Bihar	Winter	Oct end to 2nd week of Nov.	Jan-Feb
W.B.	Winter	Early Nov	Jan-Feb
Orissa	Winter	Early Nov	Jan-Feb
Plateau regions	*Kharif*	June-July	Sept-Oct
	Rabi	Oct-Nov	Feb-March

Seed rate : 25-35 q/ha

Potato is traditionally propagated through tubers. The eyes on the tuber surface contain axillary buds. The tubers have a dormancy of nearly 8-10 weeks after harvesting. The axillary buds on the tubers start germinating by producing sprouts only when this dormancy is over. The sprouted tubers put up fast and vigorous growth when planted in the soil.



Sprouted tuber

Breaking of dormancy: Hill tubers can not be used for autumn crop immediately because of dormancy period of 2-3 months in tubers. This dormancy can be broken by using any of the following chemical treatments:-

- ✓ Thiourea (Sodium Potassium thiocynate) @ 1-2% solution which is used as a treatment to cut tubers for one to one and half hours and about 1 kg of thiourea is sufficient for 10 quintals of seed tuber.
- ✓ Tubers are kept in 5ppm solution of GA_3 for 10 seconds.
- ✓ Treat the tuber with aqueous solution of thiourea for one hour followed by dipping in 2 ppm solution of GA for 10 seconds.
- ✓ The tubers from cold storage are warmed up at 16°C for 10-14 days before sowing which sprout quickly and give good germination stand.

Seed size and spacing: Proper combination of seed size and spacing is essential to get the required number of stems per unit area. It can be obtained by planting 40-50 g tuber with 40-50 mm diameter at a spacing of 45-60 cm between rows and 20-25 cm between the tubers with in the rows. Large tubers are cut into pieces and each should contain atleast 1-2 eyes. Tuber cutting is not recommended especially for the production of a seed crop as it transmits viruses and bacteria.

Treatment of cut seed tubers

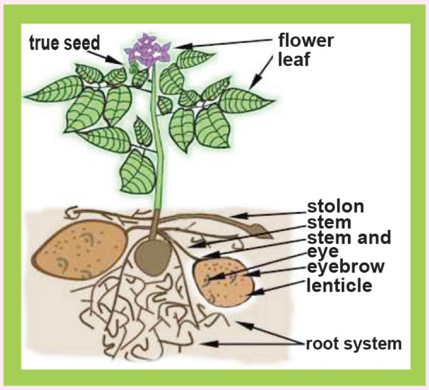
- ➢ Cut tubers should be treated with 0.2% solution of Dithane Z-78 which help in improving tuber size and crop yield.
- ➢ The cut pieces should be allowed to heel at 18-21°C and 85-90% relative humidity for 2-3 days which prevents rotting of cut tubers as seed (this process is known as suberization/healing).
- ➢ Do not treat the tuber with any of the chemicals if sprouts are coming out.

Methods of planting: Ridge and furrow method is the most popular method carried out manually or mechanically. Care should be taken that seed tubers should not come in direct contact with fertilizers. In mechanical method, furrows are made with the help of tractor drawn 2-4 row marker cum fertilizer drills so as to apply fertilizer in one sequence. This is followed by planting of tubers with the help of 2-4 row planter-cum-ridger.

Manures and fertilizers: Apply farmyard manure @100q/ha at the time of field preparation. Fertilizer dose varies depending upon the fertility of the soil. However, fertilizers are applied @ 120:80:60 kg N: P_2O_5: K_2O/ha, respectively. Full dose of farmyard manure, phosphorus and potassium and half of N should be applied at the time of planting. Remaining part of N should be top dressed at the time of earthing up for effective utilization by the crop.

Interculture and weed control: Mulching helps in conserving soil moisture, reducing soil temperature and inducing quick germination. Local available materials such as pine needles or leaf litters are quite effective in controlling run off losses and conserving moisture. Weeds are effectively managed by cultural or chemical methods or combination of both methods. Weeds can be managed by hoeing and weeding when the crop is about a month old followed by earthing up. Pre-emergence application of fluchloralin@ 1 kg a.i. per ha or alachlor @ 1 kg a.i. per ha or pendimethalin @ 1.8 kg a.i. per ha or atrazine @ 1.0 kg a.i. per ha can effectively control the weeds. Post emergence application (only 5-10% plant emergence) of paraquat @ 0.36 kg a.i. per ha is also effective. Application of Tok-e-25 @ 2.5kg a.i. per ha as post emergence application at about 2-3 leaf stage is also helpful in managing the weeds.

Irrigation: Pre-planting irrigation is advantageous for uniform germination. Second irrigation is given after about a week and subsequent as and when required. Light and frequent irrigations are better than heavy and less frequent irrigations. Water is applied effectively and economically at critical stages in crop development i.e. stolon formation, tuber initiation and tuber development stages of the crop. Irrigation is stopped about 10 days before harvesting of crop to allow firming of tuber skin.



Harvesting: The crop is harvested when it is fully matured which can be characterized by yellowing of haulms and no pulling out of skin on rubbing of tubers. At the time of harvesting, field should not be too wet nor too dry. Tractor operated potato diggers are also available for digging the tubers from the fields.

Yield:

Early varieties	200 q/ha
Main season / late varieties	300 q/ha

Post harvest handling

Grading: The tubers are generally categorized into 3 grades according to the size and weight of the tubers.

1. **Grade A (Large):** Tuber weight more than 75g
2. **Grade B (Medium):** Tuber weight between 50-75g
3. **Grade C (Small):** Tuber weight less than 50g

Marketing: The factors which make marketing of potato a complicated process and result in high fluctuation of prices and often glut situation are created.

- Transportation to long distances is problem as potatoes are semi-perishable and bulky.
- Often potatoes rot during transit because of high temperature at the time of transport.
- Problem is further compounded due to shortage of transporting wagons.

- Total cold storage capacity in the country is inadequate which can store only 35-40% of the total production of the country.
- Functioning of cold storage many a time is not upto the mark and is marked by various mal-practices.

PHYSIOLOGICAL DISORDERS

1. **Hollow Heart:** It is caused by rapid growth of tubers. Tubers become oversized and remain empty with in leading to the formation of cavity in the centre with the death of the small area of pith cells. This results in adjacent cracks and hollowness as the centre expands during the growth of the potato.

   Management: Maintain soil moisture conditions to the optimum level. Avoid over fertilization particularly nitrogen. Grow those varieties which are less prone to this defect.

Hollow Heart

2. **Black Heart:** It is caused by sub-oxidation conditions under potato tuber storage as there is no aeration in the centre of the piles. Due to high temperature and excessive moisture, blackening of tissues in the centre occur. The appearance of the tuber affect the consumers otherwise there is no decay.

   Management: Provide proper ventilation. Keep potato tubers in layers. Do not store tubers in the heap.

Black Heart

3. **Greening:** The various factors which increase the glycoalkaloid contents are mechanical injury, premature harvest, and excessive application of fertilizers or exposure of tubers to sunlight. High glycoalkaloid contents lead to solanin production which is slightly poisonous.

   Management: Proper earthing up of tubers as the tuberization takes place. Store tubers in darkness after digging up.

Greening

4. **Knobbiness:** It occurs due to uneven growth of tuber cells/tissues. Uneven watering conditions lead to an obstruction in tuber growth. Heavy irrigation after a long dry spell leads to fast growth of some cells and as a result knobs are formed.

   Management: Ensure frequent and optimum irrigation.

Knobbiness

5. **Cracking:** It is due to boron deficiency or uneven water supply

   Management: Application of Borax @ 20kg/ha. Ensure frequent and optimum irrigation.

6. **Sun Scalding:** It occurs, generally, in the autumn crop when both the temperature and sunshine are high. Emergence of sprouts and leaflets is drastically affected at that time leading to tip burn. It appears when temperature is more than 30°C.

   Management: Water should be passed through the furrows to lower the soil temperature.

7. **Black Spot:** It means the internal browning of potato tubers. It occurs in vascular tissues within 3 days of mechanical injury. Phenols are related to black spot in potato tubers.

   Management: Genetic make up of the varieties. Provide proper storage and growing conditions.

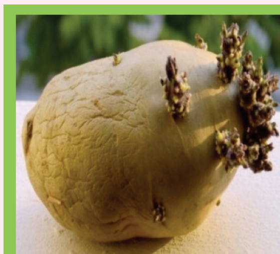
Black spot

8. **Freezing Injury:** It occurs due to the exposure of tubers to freezing temperature during or after harvest. It takes place at -1.5°C or below temperature. There is discolouration of the tissues and affect the vascular tissues at the ring and this is called as ring necrosis and when fine elements or cells of vascular ring are affected, then it is called as net necrosis. Freezing injury render tubers unmarketable. Tubers show more damage towards proximal end.

   Management: Avoid exposure of tubers to freezing temperature during storage or harvest.

9. **Sprouting:** It is often a serious problem in storage.

   Management: It can be inhibited by spraying borax or iron sulphate @ 1000-1500 ppm about 2-3 weeks before harvesting. Chemicals like Chloro IPC (N-tetra chloro isopropyl carbonate) @ 0.5% also help in inhibiting sprouting.



Sprouting tubers

Activity 1

Visit some market and collect samples of potato from different shops carrying some symptoms of physiological disorders. Make a list of them and discuss the possible reasons for these disorders.

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Diseases:

1. **Early Blight *(Alternaria solani)*:** Concentric rings of brown to black colour are formed on the leaves. Heavily infected leaves fall off after drying. Spots also appear on stems.

   Management: Destruction of crop debris by burning. Spray Ridomil MZ @ 2g/l or 0.3% Blitox or 0.25% Dithane-M-45/Dithane-Z-78 at fortnight intervals 3-4 times. Grow resistant varieties e.g. Kufri Naveen, Kufri Jeevan.

Early Blight

2. **Late Blight *(Phytophthora infestans)*:** Lower leaves are infected having cottony growth. Water soaked lesions appear on the margins. Tubers decay under severe infection.

   Management: Use disease free seed. Spray Ridomil @ 2g per litre of water. Grow resistant varieties like Kufri Jawahar, Kufri Himsona, K. Jyoti, K. Swarnima, K. Kanchan.

Late Blight

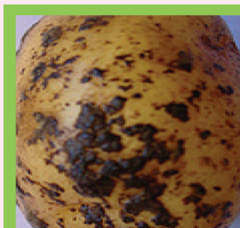
3. **Brown Rot *(Pseudomonas solanacearum)*:** Wilting and stunting of plants occur. The disease is soil and seed borne.

   Management: Crop rotation with maize and wheat. Use disease free tubers.

Brown Rot

4. **Black Scurf *(Rhizoctonia solani)*:** Sprouts are killed before emergence. Cankers cause wilting of plants. Black crust on tubers gives ugly appearance.

   Management: Seed tubers should be treated with Aratan-6 or Tefasan 0.2% or keep the tubers for 5 minutes in Aglal-3 @ 0.5% or Aglal-6 @ 0.2%. Follow crop rotation. Soil treatment with Brassicol @ 20-30 kg per ha.



Black Scurf

Other Common Diseases

Disease	Management
Common Scab	Seed treatment with 0.5% Agalol-3 for 30 minutes. Grow scab resistant varieties.
Verticillium Wilt (Soil borne)	Use disease-free seeds. Follow long crop rotations.
Charcoal Rot	Surface disinfection with some fungicides.

Wart disease	Soil sterilization by steam, mercuric chloride, copper sulphate or 5% formalin. Grow resistant varieties–Kufri Jyoti, Kufri Sherpa and Kufri Kanchan.
Black Leg and Soft Rot	Use disease-free seeds. Long crop rotations.
Bacterial Soft Rot	Remove diseased tubers from healthy ones before storage. Treat seed tubers with 0.5% solution of Agalol-3/Aretan-6/Emisan-6 before storage for 30 minutes
Viral diseases	
Latent Mosaic	Virus is mechanically transmitted (PVX, PVS or PVM). Use disease free seeds. Local quarantine
Mild Mosaic	Use disease free seeds. Grow resistant varieties.
Rugose or Vein-banding Mosaic	Use disease free seeds. Grow resistant varieties.
Purple top leaf roll	It is transmitted by leaf hopper. Use of certified disease-free seed. Control insect vectors by spraying systemic pesticides

Rot knot nematode: Keep land fallow for a quite long time. Follow crop rotation. Nematicides like DD mixture @ 225 l/ha should be injected in the soil. Place between the rows EDB (Ethylene dibromide) @ 175 kg/ha 2 weeks before planting.

Insect-pests:


Cut worms

1. **Cut worm *(Agrotis ipsilon)*:** Creamy white, dome-shaped eggs, laid singly on lower surface of the leaves. Newly emerged young larva is yellow in colour. Dark brown pupae are found in earthen cells lying underground in the potato fields. Adult moth is dark with some grayish patches on the back and dark streaks on the fore wings.

Symptoms of damage

- Young larvae feed on the epidermis of the leaves.
- Older larvae come out at night and feed young plants by cutting their stems
- They also damage the tubers by eating away part of them.

Management

- Flood the infested fields.
- Hand pick and destroy the larvae during morning and evening hours on cracks and crevices in the field
- Plough the soil during summer months to expose larvae and pupae to avian predators
- Set up light trap @ 1/ ha

- Pheromone traps @ 10/ ha to attract male moths
- Spray insecticide chlorpyriphos 20EC @ 1 lit/ha or neem oil 3% @ *5.0ml/ lit.*

2. **Potato tuber moth *(Phthorimaea operculella):*** Eggs are laid singly on the ventral surface of foliage and exposed tubers. Larva is yellow coloured and caterpillar has dark brown head. Pupation occurs within a cocoon among the trash and clods of the earth in the field. Adult is small narrow winged moth with greyish brown fore wings and hind wings are dirty white.

Potato tuber moth

Symptoms of damage

- It is a pest of field and storage
- Larva tunnels into foliage, stem and tubers
- Galleries are formed near tuber eyes

Management

- Select healthy tubers
- Avoid shallow planting of tubers. Plant the tubers at depth of 10 - 15 cm.
- Install pheromone traps@ 15 in numbers/ha.
- Collect and destroy all the infested tubers from the field
- Do earthing up at 60 days after planting to avoid egg laying on the exposed tubers
- Spray NSKE @ 5% or quinalphos 25 EC @ 2ml/lit of water to manage foliar damage
- Spray *Bacillus thuringiensis* @ 1 kg /ha at 10 days interval
- Store the tubers under 3 cm thick layer of sand
- Fumigate the stores with carbon disulphide

Activity 2

Collect plant samples which are affected by different diseases and insect-pests. Try to diagnose the diseases and pests.

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CHECK YOUR PROGRESS

State true or false:

1. Optimum temperature of potato tuberization is 18-21°C.
2. Late blight is a serious disease of potato.
3. Headquarter of CPRI is at New Delhi.
4. Cracking is caused due to the deficiency of boron.
5. Kufri Chipsona-1 is suitable for chips making.

Fill in the blanks:

1. Optimum temperature for germination in potato is_________________.
2. The seed rate of potato is _________________________.
3. _______________ is a serious disease of potato.
4. _____________ and _______________ are the critical stages for the application of irrigation in potato.
5. Seed dormancy in potato tubers can be rectified by treating it with________________.

Short answers

1. Spacing in potato
2. Critical stages of irrigation
3. Weedicides recommended for the control of weeds
4. Disorder caused due to sub-oxidation condition
5. The disease that led to Irish famine

Long answers

1. Write in brief the climatic and soil requirements for potato cultivation
2. What do you mean by seed dormancy in potato? How would you overcome this problem?
3. Enlist five physiological disorders and five diseases of potato and elaborate the symptoms and management of any one of these.
4. Describe the following with respect to potato cultivation
   a) Planting time in north Indian plains
   b) Intercultural operations
   c) Harvesting
   d) Marketing problems
   e) Late blight disease

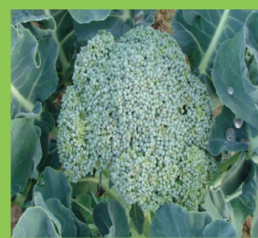
COLE CROPS

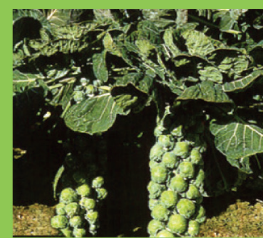
This group of vegetables includes cauliflower, cabbage, broccoli, knolkhol, kale and Brussels' Sprout. The word "cole" seems to have derived from the abbreviation of the word "caulis" meaning stem. It is a group of highly differentiated plants originated from a single wild ancestor *Brassica oleracea* var. *oleracea (sylvestris),* commonly known as wild cabbage. Cole crops are the most popular vegetables grown during winter season and among these, cauliflower and cabbage are the important ones. Broccoli is also gaining popularity due to its high medicinal value.


Cauliflower


Cabbage


Kale


Broccoli


Brussels' sprout

Cauliflower

Botanical Name : *Brassica oleracea* var. *botrytis L.,*

Family : Brassicaceae

Origin : Mediterranean region

Cultivars: Cauliflower cultivars grown in India can be classified into two broad groups:

1. Indian Cauliflower/tropical/hot weather/heat tolerant.
2. European types/ Early temperate type known as Snowball or late cauliflower

Indian Type	European Type
Annual growth habit and tolerant to heat	Biennial growth habit and not tolerant to heat
Curd formation takes place at and above 20°C.	Curd formation takes place at 5-20°C
Curds are yellow to creamish, loose and have strong flavour.	Curds are snow white with very mild or no flavour (better quality curds).
Early in maturity	Late in maturity

Soil: Cauliflower can be grown in all types of soil with good fertility and good water holding capacity. The mid season and late crop grow very well in medium, medium heavy and heavy soils. For early crop, a light to light medium soil should be preferred so that the drainage is easier in the rainy season. The water stagnation checks the growth, which leads to disappointment to the growers. It prefers a soil reaction ranging from pH 6 to 6.5.

Climate: Climatic factors play an important role during transformation from vegetative to curding and curd development stages. Temperature 10-21°C is good for germination. It is highly sensitive to temperature i.e. temperature influences growth from vegetative to reproductive stages. Transformation from vegetative to curding takes place when plants are exposed to 5°C to 28-30°C, depending upon the cultivar of a particular maturity group. Optimum temperature for growth of young plant is 23°C in initial stages while for growth in later stages, favourable temperature range is 17-20°C. Plants continue to grow vegetatively without any curd formation if temperature remains higher than optimum for curding. Late group cultivars require 15-20°C for optimum growth but the same temperature would cause curd formation in the early cultivars. Temperature should not fluctuate too much during curd initiation phase, otherwise curd quality deteriorates.

The part of cauliflower which we eat is called curd. So, it is a cool season vegetable grown for its white and tender curd formed of undifferentiated flower parts or pre-floral apical fleshy meristem.

Temperature higher or lower than optimum for curding results in physiological disorders like riceyness, leafyness, blindness, loose and yellow curd. Accordingly, varieties of cauliflower have been divided into four different maturity groups (I-IV) on the basis of their temperature requirement for curd formation under the northern Indian plains

Maturity group	Nursery sowing	Transplanting time	Opt. temp. range for curding	Varieties
Early I (A) Sept. maturity (mid Sept-mid Nov.)	Mid May	July beginning	20-25°C	Early Kunwari, Pant Gobhi-3, Pusa Meghna
Early I (B) Oct. maturity (Mid Oct-mid Nov)	May end to Mid June	Mid July	20-25°C	Pusa Katki, Pusa Deepali, Pant Gobhi-2, Pusa Kartik Sankar
Mid Early (II) Nov. maturity (Mid Nov-mid Dec)	July end	Sept beginning	16-20°C	Improved Japanese, Pusa Hybrid-2, Pusa Sharad, Pant Gobhi-4
Mid late (III) Dec maturity (mid Dec-mid Jan)	Aug end	Sept end	12-16°C	Pusa Synthetic, Palam Uphar, Pant Subhra, Pusa Himjyoti, Pb Giant 35, Pusa Paushja, Pusa Shukti

Late (IV) Snowball (Jan-March)	Sept end to mid Oct	Oct end-mid Nov	10-16°C	Snowball 16, Pusa Snowball-I, Pusa Snowball K-1, Pusa Snowball KT-25,Dania, Ooty-1,

Seed rate: The seed requirement for raising nursery for one hectare area is as under:

Early varieties	600-750g
Mid-early season varieties	500g
Mid-late varieties	400 g
Late varieties	300g

Soil preparation and transplanting: The soil should be well prepared by ploughing first with soil turning plough and afterwards with 4 to 5 ploughings with country plough. Ploughing should be followed by leveling and bringing the soil to a fine tilth. The manure should be applied at the time of field preparation. Drainage is a problem for early and some times for mid season crop when rains coincide with cropping period. Therefore, early crop should be transplanted on ridges or raised beds while the mid and late cultivars can be planted on flat beds. Seedlings become ready for transplanting in 4-6 weeks time. Seedlings of 5mm in diameter and about 10-12 cm in length are appropriate for transplanting in the field as they have better crop stand with low mortality.

Transplanting should be done during late afternoon to avoid losses due to sun heat.

Spacing:

Early varieties	45cm × 30cm
Mid and late season varieties	60cm × 45cm

Manures and fertilizers: Manures and fertilizer requirements in cauliflower depend upon fertility of soil. Mix 200-250 q/ha farmyard manure thoroughly at the time of field preparation. Application of nitrogen, phosphorus and potash @ 120-180: 75-80: 60-75 kg per hectare, respectively is required to raise a healthy crop of cauliflower. Full dose of phosphorus and one-third of N and half of potassium should be applied at the time of transplanting. Remaining part of N should be top dressed at an interval of one month each while half of potassium is to be applied alongwith N during second top dressing.

Interculture and weed control: Cauliflower is a shallow rooted crop, so it is essential to do shallow hoeing to remove weeds and to avoid any injury to the roots. Regular hoeing operations keep crop weed free and provide aeration to the root system. Earthing up is important in rainy season as roots get exposed after every shower and should be done after 4-5 weeks of transplanting. Critical period for crop- weed competition is between 30-50 days after transplanting. Use herbicides in initial stages followed by hand weeding in later stages of plant growth along with fertilizer top dressings. Application of Alachlor (Lasso) @ 2kg a.i./ha before transplanting is beneficial for controlling annual and broad leaved weeds. Pendimethalin (Stomp) @1.2 kg a.i./ha or Oxyflurofen (Goal) @ 600 ml/ha) can also be used before transplanting if there is problem of annual weeds only.

Irrigation: Cauliflower needs very careful irrigation that should be applied at right time and in sufficient quantity as both over watering and insufficient irrigation are harmful to the standing crop. First light irrigation is given immediately after transplanting of the seedlings. Regular maintenance of optimum moisture is essential during growth and curd development.

India commands the largest area under cauliflower in the world.

Harvesting: The harvesting of curds is to be done as soon as the curds attain prime maturity and compactness. It is better to harvest little early than late if there is any doubt about the maturity. Delayed harvesting leads to the elongation of flowering stalk, loose, ricey, fuzzy and over matured curds which deteriorates the quality of the curd. Such curds should be eliminated from the consignment to be sent to the markets as they wilt rapidly and spoil the appearance of the consignment. The curd should be cut-off with stalk along with sufficient number of jacket leaves to protect the curd. Severe trimming of leaves is to be done after unloading or before marketing.

Yield (q/ha):

- Early varieties: 100-150
- Mid and late season varieties: 150-300.
- Snowball group may produce yield upto 400 q/ha.

Pre and post harvest handling: Harvesting should be done preferably in the late evening or early morning so that the product remains turgid and fresh. The freshly harvested plants should be put in the truck or cart in such a way that the bruising of the curd is minimum. The bruised portions of the curd become blackish and unattractive for the fresh market.

Packing and packaging material: Generally packaging material is not used for transportation or storage of cauliflower in India. Freshly harvested plants with most of the leaves intact are loaded in cart/truck keeping the curd downward. By doing this, the curds are not exposed to the sun and the leaves protect the curd from bruising and impact damage. This practice is for the market situated nearby. They are sent in gunny bag packings or in crates to distant market.

Physiological disorders:

1. **Buttoning:** It means development of small curds or buttons. The general basis is that any check in the vegetative growth of the seedlings may induce buttoning. Planting of over-aged seedlings which do not get sufficient time to initiate growth before transformation to curding or selection of wrong cultivars means planting early variety late or root injury by insects or diseases result in buttoning.

2. **Riceyness:** A premature initiation of floral buds or elongation of peduncle stalk of inflorescence is characterized by riceyness. The curds are considered to be of poor quality for marketing. Temperature higher or lower than the optimum required for curding or high application of nitrogen result in riceyness.

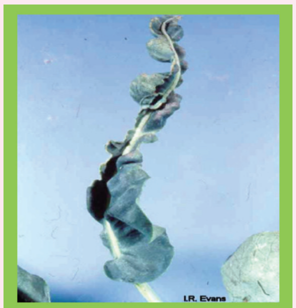
   Management: Proper management of soil moisture and fertility during the development of head or curd.

3. **Blindness:** Blind plants are those, which are without terminal bud. They do not form curd. It is due to poor fertility of the soil or damage to the terminal portion during handling at the time of planting or by insects, diseases etc.

   Management: Healthy and vigorous seedlings with terminal portion intact should be planted.

5. **Whip tail:** It is caused by the deficiency of Molybdenum (Mo). Young plants become chlorotic and turn white particularly along the leaf margins. In older plants, the lamina of the newly formed leaves is irregular in shape and leaves have only a large bare midrib. This is because of this condition, the disorder is called as “Whip tail”.

   Management: Application of molybdenum @ 1kg/ha.



Whip tail

Source: www1.agric.gov.ab.ca

6. **Browning (Red or Brown rot):** It is caused by boron deficiency. The stem become hollow with water soaked tissues surrounding the walls of the cavity. In more advance stages, a pinkish or rusty brown area develops on the surface of the curd and hence is known as red or brown rot.

   Management: Application of borax @20kg/ha

Activity 3

Grow one variety each from early, mid and late season group of cauliflower at the same time. Observe the growth and analyze the effect of temperature on curd formation. Make a list of disorders which will appear in your crop and interpret your observations.

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CHECK YOUR PROGRESS

Fill in the blanks

1. Cauliflower is highly sensitive ________________.
2. In Indian cauliflower, ______________________ formation takes place at and above 20°C.
3. Temperature higher or lower than optimum for curding result in _______________ disorders.
4. Spacing for early varieties of cauliflower is _____________.
5. Regular maintenance of optimum moisture supply is essential during ____________ and ____________ development.
6. Critical period for crop- weed competition is between ___________ days after transplanting
7. It is better to harvest curds little ___________than late if there is any doubt about the maturity.
8. _________________ is caused due to deficiency of molybdenum.
9. Plants without terminal bud result in ___________________ in cauliflower.
10. In India, cauliflower curds are packed in _____________ or ____________ to send for distant market.

Multiple choice questions

1. Botanical name of cauliflower is __________

   a. *Brassica oleracea* var. *capitata* b. *Brassica oleracea* var. *italica*

   b. *Brassica oleracea* var. *botrytis* d. *Brassica oleracea* var. *gongylodes*

2. The development of small curd, when the plants are young is called as ________

   a. Buttoning b. Miniature cauliflower

   c. Multiple curd d. None of these

3. The edible part of cauliflower is
   a. Head b. Curd
   c. Sprouts d. None of these
4. The cultivars of……………group of cauliflowers are self blanching in habit.
   a. Early season b. Mid season
   c. Late season d. None of these
5. Seed rate (g/ha) of early season cultivars of cauliflower is
   a. 300-400 b. 500-800
   c. 400-500 d. 800-1000

Long answers

1. Enlist the physiological disorders of cauliflower and discuss one each which is influenced by climatic abnormalities and nutrient deficiency.
2. What is the effect of temperature in curd formation of cauliflower?
3. Discuss the production technology of cauliflower with reference to manures and fertilizers requirement, spacing, seed rate, interculture and weed management, irrigation and harvesting.

CABBAGE

Botanical name : *Brassica oleracea* var. *capitata*

Family : Brassicaceae

Origin : Mediterranean region

Varieties: White cabbage cultivars are divided into three groups on the basis of maturity of heads after transplanting. These are as under:

Early Group: It takes 55-70 days for maturity. The commonly grown varieties are Golden Acre, Pride of India, Copenhagen Market, Pusa Ageti, Pusa Mukta, Pusa Cabbage Hybrid-1 (KGMR-1).

Mid season Group: The cultivars fall between early and late maturity groups. September, and Pusa Drum Head are the common varieties from this group.

The cabbages are classified into three broad groups:

1. **White cabbage:** It is the most commonly cultivated. Pointed, round and flat or drum-head is the shapes.

2. **Red cabbage:** Leaves have distinct coat of wax and tolerant to diamond back moth.

3. **Savoy cabbage:** Blistered leaves and the shape is pointed round and flat.


Late Group: It takes about 85-130 days for maturity e.g. Late Large Drum Head

Soil: The soil requirement for cabbage is almost same as that of cauliflower. On heavy soils, plant grows slowly and the keeping quality is improved because of compactness. Most cabbages are some what tolerant to salt.

Climate: It can withstand extreme cold and frost better than cauliflower. It thrives best in a relatively cool and moist climate. The optimum seed germination is obtained at 12.6-15.6°C soil temperature. The optimum temperature for growth and head formation is 15-20°C whereas, the growth is checked above 25°C.

Planting time: In the northern Indian plains, transplanting of different varieties can be done from October –January.

The economic part of cabbage which we eat is termed as "Head".

Seed Rate: For raising nursery for one hectare area, early season varieties needs 600-800 g/ha whereas the seed requirement for main season varieties is 200-500 g/ha.

Soil preparation and transplanting: Prepare the field for transplanting in the same manner as described for cauliflower.

Spacing: The spacing depends upon the head size to be produced as per the demand in the market. For getting small sized heads, transplanting is done at closer spacing while plants are transplanted at larger spacing for producing big size heads. General spacing which is recommended is as under:

Early varieties : 45 cm × 30 cm or 30 cm × 30 cm (round & smaller heads)

Late varieties : 60 cm × 45 cm or 60 cm × 60 cm

Nutrient management: Manures and fertilizer requirements in cabbage depend upon fertility of soil. Mix 200-250 q/ha farmyard manure thoroughly at the time of field preparation. Application of 120-180 kg nitrogen, 75-80 kg phosphorus and 60-75 kg potassium per hectare is required to raise a healthy crop of cabbage. Half quantity of nitrogen and full quantity each of phosphorus and potash is applied at the time of transplanting. Remaining quantity of nitrogen is applied after 30-45 days of transplanting.

Intercultural operations: Similar to cauliflower, cabbage is a shallow rooted crop, so it is essential to perform shallow hoeing to remove weeds and to avoid any injury to the roots. Regular hoeing operations keep crop weed free and provide aeration to the root system. Crust formation in medium heavy and clay soils hinder water and air penetration in root system. The crust should be broken otherwise it adversely affects plant growth. Earthing up is important in rainy season as roots get exposed after every shower and should be done 4-5 weeks after transplanting. Critical period for crop-weed competition is between 30-50 days after transplanting. Use herbicides in initial stages followed by hand weeding in later stages of plant growth along with fertilizer top dressings. Application of Alachlor (Lasso) @ 2kg a.i./ha or Trifluralin@ 0.5 kg/ha or Fluchloralin @ 0.5 kg/ha before transplanting is beneficial for controlling annual and broad leaved weeds. Pendimethalin (Stomp) @1.2 kg a.i. /ha or Oxyflurofen (Goal) @ 600 ml/ha) can also be used before transplanting if there is problem of annual weeds only.

Water management: Cabbage is very sensitive to soil moisture. Maximum growth and yield can only be obtained when sufficient quantity of water is available to the plants. First irrigation is given just after transplanting of seedlings. Irrigation may be applied at 10-15 days interval according to the season and soil but optimum soil moisture should be maintained regularly. Cabbage is usually irrigated by furrow method of irrigation. Heavy irrigation should be avoided when the heads have formed, as it results in cracking of heads.

Harvesting: In general, the heads are harvested when they are firm and solid. The heads are cut with a knife, frequently attached with some non-wrapper leaves. These non-wrapper leaves give protection to the heads from bruising injury.

Yield (q/ha): Early varieties: 250-300, Late season varieties: 400-500

Pre and post harvest handling: Harvesting should be done preferably in the late evening or early morning so that the product remains turgid and fresh. Trim diseased, damaged, rotten and discoloured leaves. Avoid direct contact of heads with the soil and exposure to direct sunlight. Proper packing is to be done to avoid bruising.

Activity 4

Visit a field of farmer where harvesting of cabbage has to be taken up. Harvest yourself the cabbage crop and prepare heads for marketing

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CHECK YOUR PROGRESS

Fill in the blanks:

1. Golden Acre variety of cabbage belongs to _______________ maturity group.
2. The optimum growth and head formation of cabbage is checked above temperature_______.
3. Cabbage is a ____________ rooted crop,
4. Heavy irrigation at head formation stage results in _____________of heads.
5. In general, the heads of cabbage are harvested when they are _______________.

Short answers:

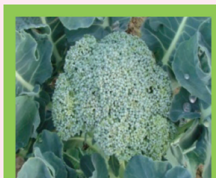
1. List different kinds of cabbages
2. Spacing for cabbage planting
3. Planting time of cabbage in north India
4. Recommended dose of NPK
5. Herbicides recommended for weed management
6. Critical stages of irrigation

BROCCOLI (*Brassica oleracea* var. *italica* L.)

Morphologically, broccoli resembles cauliflower. The plant forms a head consisting of green buds and thick fleshy flower stalks. The terminal head is rather loose, green in colour and the flower stalks are longer than cauliflower. Besides, the main head in the sprouting broccoli, long slender small heads (called spears or sprouts) are developed in the axil of the leaves. These become ready for harvest after removal of main head. Both terminal head and the sprouts with bud clusters are consumed as salad or cooked vegetable.

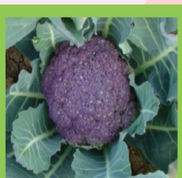
Broccoli needs fertile soil with good moisture holding capacity for its cultivation. It is mainly grown as a winter crop in most parts of the country, however in high hills it may be grown as a spring summer crop. It is sensitive to temperature as bud clusters grow loose quickly and give rise to bracts under warm weather conditions. Light frost causes considerable damage to the buds, though vegetative growth is not affected to that extent. An optimum temperature of 12-18°C is suitable for proper head development. The important varieties recommended for cultivation in India are Palam Samridhi, Palam Haritika, Palam Kanchan, Palam Vichitra, Pusa Broccoli Kt Selection-I and Punjab Broccoli-I. The crop is planted during mid August to mid September in north Indian plains. Seed rate of 400-500g/ha is required to raise a crop of broccoli. The seedlings are transplanted at 45 cm between the rows and also within a row. The field preparation, nutrient management, intercultural and weed management operations, and irrigation practices are similar to those followed in cauliflower. It is important to harvest the broccoli heads at correct time i.e. before the buds open and when the bud clusters are compact. The heads are cut along with stalk (around 15cm) in case of sprouting broccoli. After cutting, part of the foliage is removed from the harvested shoots. Average yield of broccoli is around 150-200q/ha.

Broccoli is highly nutritive and is a rich source of vitamins, minerals, protein etc. It contains about 130 times more Vitamin A contents than cauliflower and 22 times more than cabbage. It is also a rich source of sulphoraphane, a compound associated with reducing the risk of cancer.



Palam Samridhi

Palam Kanchan



Palam Vichitra

Knol Khol *(Brassica oleraceae* var. *gongylodes)*

Knolkhol is characterized by the formation of tuber, which arises as thickening of the stem tissue above the cotyledons. This tuber or knob develops entirely above the ground. It is this portion that is used for vegetable, though young leaves are also used.

In India, mainly two types of cultivars are commonly cultivated. The most common cultivars of knolkhol are Whilte Vienna, Purple Vienna and Palam Tender Knob. It can be grown on all types of soil. However, good soil condition and fertility favour growth in a uniform manner. It is mainly grown as a winter vegetable crop and thrives well in relatively cool moist climatic conditions. Seeds germinate well at 15-30°C. Optimum temperature requirement for its growth is between 15-25°C depending upon cultivars. Planting time under north eastern plains is September-October. Seed rate of 800-1000 g/ha is required to raise the crop. The seedlings are transplanted at 30-40 cm between the rows and at 20-25 cm between plant-to-plants in a row. Proper moisture should be maintained during its growth. Pre-planting application of herbicides followed by hoeing and weeding in the later stages keep the crop free of weeds. Any check in the growth results in the development of fibrous knobs. Mix 200-250q/ha farmyard manure thoroughly at the time of field preparation. Application of nitrogen, phosphorus and potash @ 75-100: 60-80: 60-80 kg per hectare, respectively is required to raise a healthy crop of knokhol. Half quantity of nitrogen and full quantity each of phosphorus and potash is applied at the time of transplanting. Remaining quantity of nitrogen is applied after 30 days of transplanting. Tubers are harvested before they are fully developed as delayed harvesting make tubers fibrous. Generally bright colour tubers of 5-8 cm diameter along with the foliage are favoured in the market. For its marketing, the main root is cut off and the enlarged stem along with the leaves are tied up. Individual tuber may weigh 200-250 g while the yield may vary from 125-250 q/ha under Indian conditions.

The cultivation of knolkhol or Kohlrabi in India is not very popular except in Kashmir, West Bengal and some parts of the south.

Activity 5

Visit some vegetable garden where cultivation of different kinds of cole crops has been taken up. Critically observe all the cole crops and discuss their distinguishing features and prepare a list of these characters.

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CHECK YOUR PROGRESS

Fill in the blanks:

1. An optimum temperature of ___________°C is suitable for proper head development of broccoli.
2. The seed rate recommended for cultivation of broccoli is _________________ g/ha.
3. The planting time of broccoli in north Indian plain is ___________________.
4. Palam Samridhi is a variety of_____________________.
5. ________________ is the most popular variety of knolkhol.
6. The spacing recommended for raising broccoli is _______________ and that for knolkhol is _________________.
7. The edible part of knolkhol is known as ___________________.
8. Delayed harvesting in knolkhol makes tuber _________________.

Diseases and Insect-pests of cole crops

The important diseases and insect-pests of cole crops are described as under:

1. **Black leg: *(Phoma lingam):*** It occurs in areas with continuous rainfall during the growing period. It is a seed borne disease and hence infest crop plants at an early stage. Stem of the affected plant when split vertically shows severe black discolouration of sap stream. Whole root system decays from bottom upwards. Often, the affected plants collapse in the field.

Black leg

Management:

- Hot water treatment of seed before sowing
- Spray the seed crop with copper oxychloride or with an organomercuric compound,
- Variety, Pusa Drum Head of cabbage is tolerant under field condition.

2. **Downy mildew *(Pernospora parasitica):*** It causes serious damage at all stages of plant growth. Discolouration occurs in the young seedlings and in severe cases whole plant perishes. In adult plants, purplish leaf spots or yellow brown spots on the upper surface of the leaf appear, while fluffy downy fungus growth is found on the lower surface. During bolting stage, the seed stalk show blackish patches and in severe cases whole curd is spoiled.

Downy mildew

Management:

- Spray Ridomil MZ 72 @ 0.5 g/litre of water at 10-15 days intervals or with Dithane-M-45 @ 1.5-2.0 g/litre of water.
- Chinese cabbage and kale are resistant to downy mildew while other cole crops are susceptible.

3. **Rhizocotonia *(Rhizoctonia solani):*** causes damping off, wire stem, bottom rot, head rot or crown rot

Rhizoctonia rot

Management:

- Grow resistant varieties and soil application of Brassicol @ 20-30 kg/ha.
- Foliar sprays of Dithane-M-45, Difolatan 80 or Daconil (Kavach) @ 1.5 – 2.0 g / l at an interval of 15 days for 2-4 times.

4. **Black spot *(Alternaria spp.):*** Light brown spots appear on leaves. The infected leaves become yellow and fall down when mature.

Black spot

Management:

- Treat the seeds with Thiram @2.5 g/kg seed or spray at 15 days interval as needed.

5. **Watery soft rot or *Sclerotinia* rot:** Disease first appears as wet soft lesions on cauliflower head and leaf. Later lesion enlarges into a watery rotten mass of tissues that is covered by white silvery appearance.

Sclerotinia rot

Management:

- Spray Bavistin (1g/l) or Dithane-M-45 (2g/liter of water) after appearance of disease or at an interval of 15 days if required.

6. **Black rot *(Xanthomonas campestris):*** The tissue at the leaf margin becomes yellow; chlorosis progresses towards leaf center creating a V-shaped area at the mid rib.

Black rot

Management:

- Spray Streptocycline @ 5g and Blitox @ 100g per 10 litre of water after transplantation.

7. **Bacterial soft rot *(Erwinia carotovora):*** A weak parasite which penetrates the plants through damaged tissue e.g. lesions caused by other pathogens. In the field, it occurs only after rot or mechanical injury to nearly mature cabbage

Bacterial soft rot

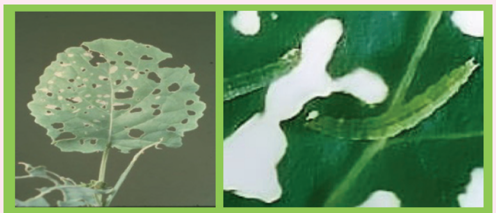
head. High humidity favours development of disease. The affected plants show a soft, slimy, bad smelling rot that under favourable conditions rapidly spreads throughout the plant.

Management:

- Control of other diseases and prevention of damage to cabbage head can check the development of disease.
- Spray 100-200 ppm streptocycline or plantomycin combined with copper oxy chloride (0.3%) at 15 days interval.

Insect- pests:

1. **Diamondback moth:** Spindle shaped pale yellowish green caterpillars feed on the lower side of leaves but later feed on the exposed leaves and enter the head/ curd affecting the produce as well as quality.



Diamondback moth

Management: Indian mustard is effective as a trap crop in suppressing the incidence of diamondback moth and cabbage aphid. Release *Trichogrammatoidea bectrae* @ 0.5-0.75 lakh eggs per ha at weekly intervals for its effective control. Spray of malathion (0.05%), deltamethrin (0.028%), cypermethrin (0.0075%) and fenvalerate (0.01%) can be used for effective suppression of caterpillar complex.

2. **Cutworms:** They damage the seedlings of the newly planted crop. Stems are chewed near the soil level during night.

Cut worm

Management: Use of well-decomposed manure helps in reducing the incidence. Collect and destroy the larvae after flooding of fields/ beds. Soil drenching with chlorpyriphos (0.04%) or spray of cypermethrin (0.0075%) on foliage and soil surface reduces the incidence.

3. **Aphids:** It causes serious damage to cole crops. Seed setting stage is seriously affected.

Aphids

Management: Foliar application of malathion (0.05%) with the appearance of the pest and repeating every 15 days. Stop spraying atleast 7 days before harvesting. On seed crop, apply phorate granules @ 1.5 kg a.i./ha as side dressing during mid February to early March or spray methyl demeton (0.025%) or dimethoate (0.03%) or phosphamidon (0.03%) as soon as aphid population is above 50 aphids per plant.

4. **Cabbage butterfly *(Pieris brassicae):*** Damage is caused by caterpillars. The white winged butterflies deposit yellow coloured eggs in clusters on the under surface of leaves.

Management: Collect and destroy yellow egg masses and early stage larvae of cabbage butterfly. Biological control by *Cotesia glomeratus* which parasitizes the larvae. Spray of malathion (0.05%)/ deltamethrin (0.0028%)/ cypermethrin (0.0075%) and fenvalerate (0.01%) can be used for effective suppression of caterpillar complex

Cabbage white butterfly

5. **Snails and slugs:** They damage the growing tips of plant and also the surface of curd in cauliflower. They are problematic when crop is irrigated with sewerage water.

   Management: Baiting with metaldehyde and bran (1: 25 in 12 litres of water) is effective for their control. As a repellant, alum may be sprayed @ 2% solution.

Slug

Activity 6

Collect plant samples of cole crops which are affected by different diseases and insect-pests. Try to diagnose the diseases and pests.

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CHECK YOUR PROGRESS

Fill in the blanks:

1. ____________________ disease causes serious damage at all stages of plant growth.
2. _______________________ damages seedlings in the newly planted crop.
3. Seed setting stage is seriously affected by ___________________.
4. ______________________deposit yellow coloured eggs in clusters on the undersurface of leaves.
5. _____________________is effective as a trap crop in suppressing the incidence of diamondback moth and cabbage aphid.
6. ______________ disease causes chlorosis creating a V-shaped area at the mid rib.
7. Kale is resistant to _______________________ disease.

Long answers

1. Make a list of important diseases of cole crops and describe the symptoms of black rot and downy mildew.
2. Describe the control measures for diamondback moth and cabbage white butter fly.

GARDEN PEA

Botanical Name : *Pisum sativum* L.

Family : Fabaceae

Origin : Central Asia, the near East, Abyssinia and the Mediterranean resion

Uses:

- Pea is highly nutritive containing high percentage of digestible protein (very valuable for the vegetarians) alongwith carbohydrates and vitamins A and C.
- It is also very rich in minerals Ca and P.
- It is an excellent food for human consumption taken either as a vegetable or in soup.
- Large proportion is processed (canned, frozen or dehydrated) for consumption in the off-season.
- Being N fixing legume, it is recognized as a soil building crop
- Pea is being used in a growing snack market.

How is garden pea different from field pea?

Garden pea has white coloured flowers and wrinkled seeds whereas field/pulse pea bears purple flowers and round seeds. Garden pea is sweater having high sugars while field pea has more starch contents.

Varieties recommended for different regions :

1. **Early wrinkle seeded:** Arkel, Pusa Pragati, Matar Ageta 6, Azad P3, Pant Sabzi Matar 3 (PSM-3), VL Ageti Matar 7 (VL-7), Vivek Matar -10, Kashi Nandini (VRP-5) , Kashi Uday(VRP-6), Palam Triloki
2. **Main season wrinkle seeded varieties:** Bonneville, Lincoln, Azad P-1, Punjab-89, Palam Priya, Vivek Matar-6, Vivek Matar -8, Vivek Matar -9,Arka Ajit
3. **Edible poded peas:** Sylvia, Punjab Mithi Phali, Arka Sampoorna.


Azad P-1

Soil: Pea can be grown on all kinds of soils but the best crop can be taken from well drained and fertile loam soil. Light soils are good for early crop whereas heavy soils are suitable for main season crop. The soil pH 6-7.5 is the best for its proper growth and development.

Climate: Pea is a cool season crop and requires frost-free weather particularly at flowering and pod formation stage though vegetative growth is not affected by the frost. The optimum temperature for its germination is about 22°C and that for better growth and yield is 13-19°C. High temperature reduces the pod quality as sugars in the seeds changes to hemicellulose and starch. Temperature above 27°C shortens the growing period and adversely affects pollination.

AGRONOMIC PRACTICES

Sowing time

Area	Early varieties	Main season varieties
North India	September	First fortnight of October – end November
Peninsular India	June-July	Adverse effect when sown after November

Seed Rate (kg/ha) : Early varieties : 120-130, Main season varieties : 75-100

Spacing (inter-row x intra-row) : Early varieties : 30cm × 5cm, Main season varieties : 45-60cm × 10cm

Seed inoculation: Inoculation of seed with *Rhizobium* culture can be practiced. The culture material is emulsified in 10% sugar or jaggery solution sufficient to moist the seed. Mix the emulsified culture thoroughly with seed and dry in shade before sowing. Seed inoculation helps in quick nodulation on the roots which in turn fix atmospheric nitrogen.

Seed treatment: The seeds may be treated with fungicides like Thiram or Captan (3g/kg of seed) or Bavistin (2.5-3 g/kg of seed) to save the crop against wilt disease. If both seed inoculation and fungicide treatments are to be given, then at first the seeds are treated with fungicide followed by inoculation with Rhizobium culture.

Manures and fertilizers: Full dose of farmyard manure @ 20 tonnes, 20-50 kg nitrogen, 30-60 kg phosphorus and 30-60 kg potassium per hectare should be applied at the time of sowing based on fertility status of the soil.

Interculture and weed control: First hoeing and earthing up is to be done after 2-3 weeks of sowing and second at flower initiation to get higher yield. Hoeing helps in removing the weeds and pulverizes the soil for proper aeration. Herbicides have also been found beneficial in controlling weeds. Pre-emergence application of Alachlor @ 3litres/ha or Pendimethalin @ 3litres/ha or Fluchloralin @ 2.5 litres/ha may take care of weeds in the initial growth stages.

There is another kind of pea which is consumed whole just like French bean, known as edible poded / snap / snow pea. Pods of these are very crisp, sweet and tender that can be eaten raw as well as cooked.

Irrigation: In general, pre-sown irrigation is essential for proper germination. It is important to apply irrigations before flowering, during flowering and at pod formation stage to obtain quality pods and good yield. It is possible to grow pea under rainfed conditions but sufficient moisture must be present in the field at the time of sowing.

Harvesting: The peas are harvested when the pods are fully green and well developed. The seeds should be fully developed but tender i.e. should not harden. Picking should be done as soon as green ovules are fully developed and pods still not over mature. Early varieties give 2-3 pickings while 3-4 pickings at 7-10 days interval are taken from main season varieties. Picking should be done either early in the morning or late in the afternoon. Picking during mid day deteriorates the quality of pea pod due to heat.

Yield: Early varieties: 60-85 q/ha

Main season varieties: 100-150 q/ha

Activity 7

Harvest a few pods of garden pea at different maturity stages. Shell the pods, taste them and observe the differences in sweetness. Discuss the importance of harvesting pea pods at proper maturity stage.

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DISEASE MANAGEMENT:

Powdery Mildew

1. **Powdery mildew *(Erysiphe pisi):*** First symptoms appear on the upper surface of the leaves as very small and discoloured spots which soon give rise to enlarge white powdery areas on the leaf, stem and pod. Multiple infection may cover the whole plant.

Powdery mildew

Management:

- Grow resistant varieties like Palam Priya.
- Spray Dinocap or Bitertanol or Hexaconzole @ 0.05% as the initial symptoms appear on the leaves.

2. **Fusarium wilt *(Fusarium oxysporum* f.sp. *pisi):*** Near wilt attacks young plants. The affected plants show yellow-orange internal discolouration in the lower internodes.

Fusarium wilt

3. **Root rot *(Fusarium solani):*** The vascular tissue shows red discolouration extending upward 1-3 nodes above soil surface. Diseased plants appear unthrifty, variously dwarfed depending upon the severity of infection, and may wilt and die.

The other soil borne organisms like *Rhizoctonia* and *Pythium* also cause seed decay, damping off and root rot.

Management: *Fusarium* wilt and root rot can be controlled by using following treatments:

- Seed treatment with Bavistin @ 3g/kg of seed
- Soil drenching with Bavistin @ 0.01% or Captan or Brassicol reduces the disease.
- Follow long crop rotation

4. **Bacterial blight:** Lesions appear on all above ground parts of the plant. They begin as small, water soaked, oval spots. Multiple lesions often appear together which may cover large portions of infected plants and give blighted appearance.

   Management: Slurry treatment of seed with streptomycine sulphate (2.5 g/kg of seed) or soaking seeds in streptomycine solution for 2 hours.

Bacterial blight

5. **Ascochyta blight:** Small purple spots develop on the surface of leaf, stem and pod.

   Management: Use 3-4 years crop rotation. Remove and dispose off diseased plants.

Insect-pest management:

1. **Pea aphid:** It attacks young vine sucking the juice from growing tip, later covering the whole plant. It causes curling of the leaves and pods.

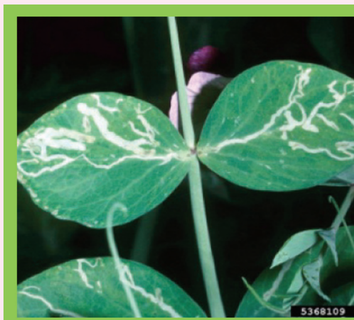
   Management: Spray Dimethoate @ 0.01% or spray of 0.06% nicotine sulphate

2. **Pod borer:** The young caterpillars first feed on the surface of the pods, bore into them and feed the seeds.

Management: Spray Malathion or Cypermitherin @ 0.01%

3. **Leaf minor:** The greenish larvae make serpentine tunnel in the leaves and feed on it. The infested leaves wither and dry. Flowering and pod formation is drastically affected.

   Management: Spray Cypermethrin or Fenitrothion or Fenthion @ 0.01%



Leaf minor
Source: www.forestryimages.org

4. **Pea Weevil:** The elongated, yellow eggs are laid on green pods and after hatching of eggs, the larvae burrow through the pod into the seed. They develop inside pea and come out by damaging the seed in storage.

   Management: Spray methiocarb @ 0.05% is effective. Fumigation of dry peas with methyl bromide.

Pea weevil

> ***Activity 8***
>
> *Plan a visit to a vegetable garden where pea pods are to be harvested. Try yourself to harvest the pea pods and then pack them for market.*
>
> ....
>
> ....

CHECK YOUR PROGRESS:

Fill in the blanks:

1. The processed products of garden pea are ________________, ____________________ and ________________ which are used for consumption in the off-season.
2. Being legume, ______________________ is recognized as soil building crop.
3. Pea requires frost-free weather particularly at ________________ and __________________stage.
4. Temperature above _____________ shorten the growing period of garden pea and adversely affects pollination.

5. Seed inoculation with ________________ helps in quick nodulation on the roots which in turn fix atmospheric nitrogen.
6. The critical stages of irrigation in pea are ______________________ and __________________.
7. The seed requirement for growing early pea is __________________________.
8. Hoeing helps in removing the ___________ and pulverizes the _________________ for proper aeration.

Short answers (write in reference to garden pea):

1. Seed rate
2. Spacing
3. Fertilizer recommendation
4. Weed management
5. Harvesting

Long answers:

1. Discuss in brief the soil and climatic requirements for the cultivation of garden pea.
2. Make a list of important diseases and insect-pests of garden pea. How can you control powdery mildew and leaf minor in pea?
3. What agronomic practices one should follow to raise a healthy crop of garden pea?

ONION

Botanical Name : *Allium cepa L.*

Family : Amaryllidaceae

Origin : Central and South Western Asia

Uses:

- The green leaves, and immature and mature bulbs are eaten raw.
- It is used in preparation of sauces, soups and seasoning of food on accounts of its special characteristic pungency.
- Also used in processed form e.g. flakes, powder and pickles.
- Onions are diuretic, applied on bruises, boils and wounds.
- It relieves heat sensation.

> ***Pungency in onion*** *is due to allyl-propyl-disulphide.*

- Bulb juice is used as smelling on hysterical fits in faintness.
- It is used to relive insect bites and sour throat.
- Onions play a part in preventing heart diseases and other ailments.
- Onions are given in jaundice, spleen enlargement and dyspeptic after cooping in vinegar.
- Roasted onions mixed with cumin, sugar candy and butter oil are a demulcent of great benefit in piles.
- The essential oil contains a heart stimulant, increases pulse volume and frequency of systolic pressure and coronary flow and stimulates the intestinal smooth musculature and the uterus.
- It reduces blood sugar & has lipid lowering effect.

Varieties: The onion varieties have been classified on the basis of size and skin colour. Further, onion has been classified as common and multiplier onion.

1. **Red Coloured:** Agrifound Dark Red, Agrifound Light Red, Arka Niketan, Arka Kalyan , Pusa Madhavi, Pusa Ratnar, Pusa Red, Pusa Riddhi ,Udaipur 101, Udaipur 103, Bhima Raj, Bhima Red
2. **Kharif Onion:** Arka Kalyan, Arka Pragati, N-53, Arka Niketan
3. **White skinned varieties:** Pusa White Flat, Pusa White Round, Punjab-48, Udaipur-102
4. **Yellow skinned varieties:** Brown Spanish (Long day variety, suitable for growing in hills), Early Grano (Good for salad, suitable for green onions).
5. **Multiplier Onion:** Agrifound Red, CO-1, C-2 (resistant to purple blotch), CO-3 (resistant to thrips), CO-4 (moderately resistant to thrips), MDU-1.
6. **Small Onion:** Agrifound Rose (pickling type, suitable for export), Arka Bindu

Soil: Soil should be friable, fertile, well drained and have an abundant supply of humus. A heavy soil is not desirable that bakes and crusts after irrigation. Sandy loam and silt loams are best suited to it. The soil pH should be in the range of 5.8-6.5. It is sensitive to high acidity and alkalinity.

Pickling onions or pearl onions *produces small bulbs which are pickled and used as condiments.*

Multiplier onion or potato onion *produce multiple tops, each of which produces small onion bulbs in clumps.*

Onion is normally regarded as long day plant i.e. bulb formation is promoted by long day conditions. Each cultivar needs a minimum day length for bulb formation, which is known as critical value. This critical value in combination with temperature influences bulb initiation. The short day cultivars when receive the critical day length limit, initiate bulb formation and development continues under long day conditions. Conversely, long day cultivars do not initiate bulb formation unless its critical value of long photoperiod is reached. If onion plants are kept under short day conditions, they continue to grow for over 3 years without bulbing.

Climate: It grows in mild climate without extremes of high and low temperature. The optimum temperature for seed germination should be 20-25°C. Low temperature and short photoperiods are required for vegetative growth, while relatively high temperature and long photoperiods are needed for bulb development. It requires 13-21°C temperature for vegetative growth before bulb initiation and 16-25°C for bulb development and 25-30°C for bulb maturation.

AGRONOMIC PRACTICES:

Sowing time

Season	Time of sowing	Time of transplanting	Harvesting time
Northern India			
Rainy *(Kharif)*	May- June (July)	July- Aug (Mid Aug)	Nov-Dec
Winter *(rabi)*	Oct-Nov (Nov)	Dec-Jan (Jan-early Feb)	May-June
Maharashtra and parts of Gujrat			
Rainy *(kharif)*	May-June	July Aug	Oct-Dec
Late rainy *(kharif)* or early winter *(rabi)*	Aug-Sept	Sept-Oct	Jan-March
Winter *(rabi)*	Nov-Dec	Dec-Jan	April-June
Tamilnadu, Karnataka & Andhra Pradesh			
Early rainy *(kharif)*	April-May	May-June	August
Rainy *(kharif)*	May-June	July-Aug	Oct-Nov
Winter *(rabi)*	Sept-Oct)	Nov-Dec	March-April

Seedlings become ready for transplanting in 8-10 weeks time. Seedlings must be about 15-20 cm in length at the time of transplanting.

Seed Rate: 8-10 kg/ha

Spacing: The onion seedlings are planted at a spacing of 15-20 cm between rows and 5-10 cm between plant-to-plant. Transplanting on ridges is ideal for kharif onion crop.

Soil preparation and transplanting: Onion should be planted in well-pulverized field by ploughing first with soil turning plough and afterwards with 4 to 5 ploughings with country plough. Leveling should follow ploughing. Onion is normally planted in flat beds however kharif onion is planted on ridges. Transplanting should be done during late afternoon

Manures and fertilizers: Apply well rotten farmyard manure @ 200-300 q/ha, nitrogen @ 60-150 kg, phosphorus @ 35-150 kg and potassium @ 25-120kg per hectare depending upon the soil test, cultivar and growing season. FYM is applied at the time of field preparation. Apply 50% nitrogen and entire quantity of phosphorus and potash at the time of transplanting or bulb sowing. Remaining half of the nitrogen is top dressed 5-6 weeks after transplanting.

Interculture and weed control: Onion is a closely planted and a shallow rooted crop and thus, hand weeding is difficult to be performed which may damage the crop. Therefore, use of chemical weedicides at initial growth stage followed by 1-2 hand weeding is beneficial. The critical period of crop-weed competition is between 4-8 weeks. Application of Alachlor (Lasso) @ 2 litres/ha or Pendimetalin (Stomp) @ 3 litres/ha in 750 liters of water before transplanting is beneficial for controlling weeds. Three hand weedings are sufficient to harvest economic crop if done at 30, 50 and 75 days after transplanting.

Irrigation: Onion needs very careful and frequent irrigation as it is a shallow rooted crop. Water requirement of the crop at the initial growth period is less and increases during later growth stages. Irrigation should be applied at an interval of 10-15 days in cool weather and at a weekly interval during hot weather. Bulb formation and bulb enlargement stages (70-100 days after transplanting) are critical for water requirement. Insufficient moisture tends to slow down bulb growth while over supply causes rotting. Generally, 10-12 irrigations are given in rabi season. Stop irrigation when the tops mature and start falling down.

Harvesting: Onions are ready for dry bulb harvesting when the tops get dried (or at neck fall stage) and bulbs are mature. Harvesting at this stage results in higher yield, longer storage life of bulbs and less neck rot. The green onions can be harvested when they reach pencil size until bulbing begins. It is desirable to leave 1.5-2.0 cm of the tops attached to the bulb as it helps to close neck and reduce storage losses.

Curing: Onion bulbs should be adequately cured because curing or drying of bulbs is an important process

Raising of kharif onion: *The salient points for raising this crop are as under:*

- *Onion sets are used as the propagating material for raising kharif crop. Onion sets are small bulbs (around 0.25-1.0 inch in diameter).*
- *Varieties recommended for this crop are N-53, Arka Kalyan, Arka Niketan etc.*
- *The seed requirement for raising sets is 5-7.5 kg/ha.*
- *Sowing of seed is done in nursery during end of January or beginning of February. Then, left the plants at same place till April.*
- *In April, small bulbs (sets) are formed due to closer spacing. The plants are uprooted and tops are removed.*
- *The sets having 1.5-2.0 cm in diameter and disease free are selected and stored till July.*
- *About 10 q sets are enough to plant one hectare area.*
- *Sets are planted 10 cm apart in rows on both sides of ridges spaced 35-45 cm.*
- *Sets are normally planted by July-August to get an early crop by early November.*

to remove the excess moisture from the outer skin and neck of onion bulb. Curing helps to reduce the chances of disease infection, minimizes shrinkage due to loss of moisture from the interiors and helps to develop good skin colour.

Bulbs are either cured in field or in open shades before storage. Onions are considered cured when neck is tight and the outer scales are dried until they rustle. Bulbs are cured in field for 3-5 days in wind row method. Then bulbs are placed in shade and cured for 7-10 days to remove field heat. This shade curing improves bulb colour and reduces losses during storage.

Yield: Rabi crop: 250-300 q/ha, Kharif crop: 200-250 q/ha

Storage: Onion bulbs have a rest period for about 2 months. Proper storage is important as higher temperature induces sprouting. Thorough ventilation, uniform comparatively low temperature, low humidity, proper maturity, optimum application of fertilizer(s), freedom from diseases and insect-pests is essential for successful storage.

Physiological disorders:

1. **Bolting:** It means emergence of seed stalk prior to time of bulb formation and adversely affects the formation and development of bulbs.

Bolting

Possible Reasons:

- Transplanting of aged seedlings
- Early sowing of seeds in the nursery beds, which result in the formation of small sets.
- Late transplanting of seedlings
- Low temperature (10-12°C) for prolonged period.

Management: Time of planting should be adjusted in such a way that the crop may expose to moderate temperature at bulbing. Sow nursery at proper time.

2. **Sprouting:** An important disorder in storage of onion and results in huge losses. It is associated with excessive moisture at maturity and supply of nitrogen.

Sprouting

Management: Adjust time of planting in such a way that harvesting can be done in dry period. Stop irrigation as soon as bulbs reach maturity. Spray iron sulphate or borax @ 500-1000 ppm 2-3 weeks prior to harvesting.

Disease Management

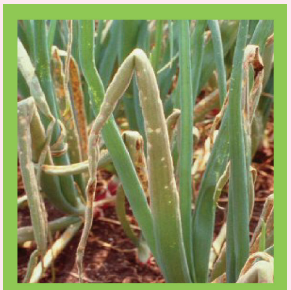
1. **Purple blotch *(Alternaria porri):*** Small white sunken spots develop on leaves. The lesions enlarge and turn purple under moist condition. The bulb tissue becomes papery.

Purple blotch

Management:

- Three summer ploughings reduce the disease severity.
- Spray Mancozeb or Blitox-50 (2g/liter) at 10 days interval, if required.

2. **Downy Mildew *(Peronospora destructor):*** There is violet growth of fungus on the surface of leaves and flower stalks which later become pale-green yellow and finally collapse.



Downy mildew

Management:

- Follow crop rotation with a 4 year break in onion cultivation.
- Maintain field hygiene and sanitation.
- Removal of primary infected onion plants.
- Spray Zineb @ 0.2%.

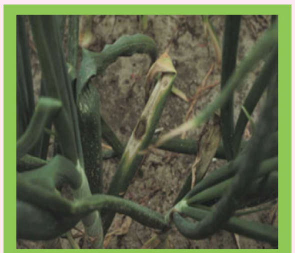
3. **Onion Smut *(Urocytis cepulae):*** It is a soil borne disease and infects cotyledon and seedlings which result in heavy mortality.

Onion smut

Management:

- Treat the seed with 55-85 g of Arsan per 4.5 kg of seed before sowing or with Thiram or Captan (3 g/kg of seed).
- Treat nursery soil with Thiram or Captan (0.2%) along with Methocal sticker.

4. **Stemphylium blight:** It appears on onion leaf as well as on leaf stalk. Infection appears as small yellow to pale orange spots or streaks in the middle of leaves/ flower stalks on one side.



Stemphylium blight

Management: Spray of Dithane-M-45 (0.25%) alongwith sticker triton can control the disease.

Insect- pests

1. **Onion thrips:** It is the major insect of onion and garlic. Onion infested with thrips develops spotted appearance on the leaves which turn into pale white blotches due to drainage of sap. The adults hibernate in soil, on grass and other plants in the onion field. Application of malathion or nuvacron has proved effective. Among synthetic pyrethroids, cypermethrin at 50 g ai/ha has also been found effective.

Thrips Maggots Mites

2 **Onion Maggots:** Maggots enter the bulbs through roots and attack the tender portion. Infested plants turn yellowish brown and finally dry. The affected bulbs rot in storage as infestation leads to secondary infection by

pathogenic organisms. Crop rotation should be followed. Application of thimet is beneficial.

3. **Mites:** They suck sap and turn plants yellow with sick appearance. Infested bulbs should be exposed to sun for 2 days. Dusting of S in the onion field @ 22 kg/ha.

Activity 9

Plan a visit to a vegetable garden where onion bulbs have been harvested. Discuss the curing process of onion bulbs and its importance in enhancing the shelf-life of bulbs. Make two small lots comprising one cured bulbs and other uncured one. Store them in cool and dry room. Observe the differences for storage life of bulbs.

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CHECK YOUR PROGRESS:

Objective type answers:

1. What causes pungency in onion
2. The most suitable soils for onion cultivation
3. Seed rate for onion cultivation
4. Spacing for planting onion
5. Stage indicating dry bulb harvesting
6. Important disorder in storage of onion
7. Major pest of onion
8. Important process that remove the excess moisture from onion bulbs
9. Type of onion that is pickled and used as condiment
10. The critical period of crop weed competition in onion

Fill in the blanks:

1. Low temperature and short photoperiods are required for _________ growth in onion.
2. Relatively _______ temperature and ___________ photoperiods are needed for bulb development of onion.
3. _______________ is normally regarded as a long day plant.

4. Onion is a ________________ rooted crop.
5. ________________ and _____________ stages are critical for onion production.
6. Onions are ready for dry bulb harvesting at ____________________stage when bulbs are mature.
7. ____________________ is an additional measure for the development of skin colour in onion.
8. Onion bulbs have a rest period for ____________ months.
9. ______________ means emergence of seed stalk prior to time of bulb formation.
10. It is desirable to leave __________ cm of the tops attached to the bulb as it helps to close neck and reduce storage loss.

Write in brief with respect to onion:

1. Effect of temperature and photoperiod
2. Weed management and irrigation
3. Harvesting
4. Importance of curing
5. Manures and fertilizer requirement and their application
6. Kharif onion

Long answers

1. Suggest agronomic practices to be followed for the cultivation of onion
2. Enlist the major diseases and insect-pests of onion crop. How would you manage purple blotch and thrips problem in onion?

ROOT CROPS

Root vegetables include carrot, radish, turnip, beet, parsnip, rutabaga, horse radish and Jerusalem artichoke. These crops are grown for their enlarged fleshy roots which actually consist of both root and stem tissues. These vegetables are of short duration and have high productivity. Hence, these can be grown in sequential cropping, intercropping and relay cropping which enables maximum use of arable land. Botanically they belong to different families but their cultural practices are almost similar.

Carrot

Botanical Name : *Daucus carota L.* **Family** : *Umbelliferae*

Origin : *South western Asia (Afghanistan)*

Uses:

- It is valued as a nutritive food mainly because of high carotene contents.
- It is used as a cooked vegetable, salad and soups.
- It increases the quality of urine and helps in the elimination of uric acid.
- Black carrots are used for the preparation of a soft beverage called Kanji, which is supposed to be a good appetizer.
- Red type is good for preparation of various types of sweets especially *Gajar Halwa* in northern India.
- Carrot seeds are aromatic, stimulant and carminative and its oil is used for flavouring different food items.

VARIETIES: The varieties of carrot are divided into two groups namely, Asiatic type and European type:

Asiatic or tropical type	European type or temperate type
1. It produces seed in plains 2. It does not require low temperature treatment for flowering 3. Roots are long and red in colour 4. Rich in lycopene	1. It produces seed in hills 2. It requires chilling (4.8-10°C) for flowering 3. Roots are medium in size and orange in colour 4. Rich in carotene

Varieties	
Pusa Kesar, Pusa Meghali (orange coloured), Pusa Vristi, Pusa Rudhira, Pusa Ashita (black coloured), Hisar Gairic	Pusa Yamdagini, Jeno, Imperator, Chantaney, Danvers, Early Nantes, Nantes, Nantes Half Long, Ooty l, Pusa Nayanjyoti (hybrid)

Soil: Carrots prefer deep, loose, well-drained, sandy loam to loam soil with a slightly acidic reaction. The edible roots become misshapen due to poor soil structure or obstructions such as stones, clods or trash.

Climate: It is predominantly a cool season crop. A temperature range of 7.2 to 23.9°C is suitable for seed germination and 18.3 to 23.9°C for better root growth. The optimum temperature for better colour development of roots is 15.6-21.1°C.

AGRONOMIC PRACTICES:

Sowing time: In north Indian plains, sowing can be taken up from middle of August to beginning of December.

Seed Rate: 6 kg/ha

Seeds are to be mixed with fine sand before sowing to facilitate even distribution. The seeds should be rubbed to remove fine hair before sowing.

Soil preparation: The soil should be thoroughly pulverized so as to obtain fine tilth for getting the best crop, otherwise roots get deformed in shape.

Spacing: 30 cm × 8-10 cm

The seed should be sown at a depth of 1-1.5 cm deep on the ridges and after germination maintain distance of *8-10cm* between the plants with in row by following thinning of plants.

Manures (q/ha) and fertilizers (kg/ha):

Farmyard manure 100 q/ha   50-90 N : 40-80 P_2O_5 : 40-80 K_2O

The nutrient dose depends upon the nutrient status of the soil. Full dose of farmyard manure, phosphorus, potassium and half dose of N should be applied at the time of transplanting. Remaining nitrogen should be top dressed in two equal installments at an interval of one month each.

Interculture and weed control: Carrots grow slowly at the seedling stage, therefore, the removal of weeds is quite essential especially at an early stage. For effective weed control, a pre-emergence application of Propazine @ 1.12 kg/ha has to be done. Earthing up is also essential for better growth and development of roots.

Irrigation: A pre-sowing irrigation is to be given to ensure better seed germination. Carrots require abundant and well-distributed water supply. Cracking of roots occur due to exposure to dry weather followed by wet weather. Carrots should be irrigated before any wilting of leaves takes place. It should not be irrigated heavily as it leads to excessive vegetative growth and thus the quality of roots gets deteriorated along with delay in maturity.

Harvesting: Carrots for fresh market are harvested before plants reach full maturity in order to assure quality, while those for processing are allowed to grow longer in the season to have high yield. For fresh market, small, uniform, tender and mild flavoured roots should be harvested.

Yield: **Asiatic types:** 250-300 q/ha.   **European types:** 100-150 q/ha

Post harvest handling: Roots should be washed thoroughly, graded and tied in bunches of 6 or 12 roots after harvesting. Fresh carrots can be stored for more than 3-4 days under ordinary conditions. At temperature 0-4.4 °C with 93-98% RH roots can be stored for 3-4 months. Mature topped carrots can be stored upto 7-9 months while immature ones can be not be stored for more than 2-3 weeks under cold storage at 32° F with high humidity (98-100%).

Physiological disorders:

1. **Root splitting:** Splitting or cracking of carrot roots is a major problem.

   Possible reasons:

   - Wider spacing as larger roots tend to split more.
   - Dry weather followed by wet weather is conducive to cracking of roots.
   - High nitrogen application
   - Early cultivars tend to split more readily than late ones.

Root splitting

2. **Cavity spot:** It appears as a cavity in the cortex. In most cases, the subtending epidermis collapses to form a pitted lesion.

   Possible reasons: Calcium deficiency associated with an increased accumulation of K and decreased accumulation of Ca.

Cavity spot

3. **Forking:** It is a common disorder in carrot and radish formed by the enlargement of secondary root growth.

   Possible reasons: Excess moisture during the root development. It occurs on heavy soils due to soil compactness.

Root forking

Diseases: The important disease are leaf blight, leaf spot or *Cercospora* blight, powdery mildew, watery soft rot, black rot, and bacterial soft rot.

Insect-pests: The serious pests are rust fly and turnip moth.

Activity 10

Take up harvesting of different root vegetable crops and observe for different physiological disorders.

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CHECK YOUR PROGRESS

Short answers

1. Which varieties of carrot set seed in hills?
2. Which group of varieties is a rich source of lycopene?
3. What is the result of growing carrots in soils with poor structure?

4. What is the time of sowing of carrot in northern Indian plains?
5. What is the seed rate of carrot for planting carrot in one hectare area?
6. What is the spacing to be followed for raising carrot crop?
7. At which stage of growth, it is essential to control weeds in carrot?
8. What is the major cause of root splitting in carrot?
9. Deficiency of which nutrient results in cavity spot?
10. Which disorder is resulting in enlargement of secondary root growth?

RADISH

Botanical Name : *Raphanus sativusL.*

Family : Brassicaceae

Origin : Western Asia

Uses: The leafy tops are very rich in vitamin A, B, C and minerals particularly Ca and Fe. The roots and leaves are consumed both as salad and as cooked vegetable. The roots are good appetizer, effective in curing liver, gall bladder and urinary disorders, piles and gastrodynia.

The characteristic pungent flavour is due to the presence of volatile isothiocynates.

Varieties

Asiatic/tropical/subtropical type	European/temperate Type
These produce seeds in plains	Seed production is limited to high hills.
Pusa Desi, Pusa Reshmi, Pusa Chetki, Japanese White, Pusa Mridula, Punjab Safed, Punjab Pasand, Arka Nishant, Chinese Pink, Hisar Mooli No. 1, Kalyanpur No. 1, Kalyani White, CO-I, Jaunpuri Mooli, Kashi Sweta, Kashi Hans	Pusa Himani, White Icicle, Rapid Red White Tipped, Scarlet Globe, Scarlet Long, Silver Queen, Kvarta, French breakfast, and Palam Hriday

Soil: Light, friable loamy soil containing high amount of humus are suitable for radish cultivation. Usually, the heavy soils produce rough ill shaped roots with small fibrous laterals. The optimum soil pH is 5.5-7.0.

Climate:

- It is predominantly a cool season crop and best adapted to cool or moderate climate.
- Indian types with greater temperature adaptation can resist heat better than the European types.

- The optimum temperature for best flavour, texture, root growth and development is 10-15°C. However, different varieties respond to varied range of temperature. This is the fact that radishes are available throughout the year by growing different varieties in different months.
- The Asiatic types are tolerant to high temperature than European types.
- During the hot weather, the roots become tough, pithy and pungent before reaching the edible type.
- Long days coupled with high temperature leads to premature bolting without adequate root formation.

Sowing time: In northern plains, time of sowing is as under:

1. European type: September-March
2. Asiatic type: August-January
3. Mild climate areas: Through out the year

Seed Rate: 9-12 kg/ha (1 g seed contains 80-125 seeds)

- Asiatic type: 10 kg European type: 12-14 kg

Soil preparation: The soil should be thoroughly pulverized so as to obtain fine tilth for getting the best crop, otherwise it results in deformed roots.

Spacing: European type – 30cm × 5-10cm

Asiatic types – 45 cm × 6-8 cm

The seed should be sown at a depth of 1.5- 3cm deep on the ridges for semi-long type and 1.25cm for round cultivar sand after germination maintain the distance of 5-10cm between the plants with in row by following thinning of plants.

Manures and fertilizers:

Farmyard manure

(q/ha)	N (Kg/ha)	P_2O_5 (Kg/ha)	K_2O (Kg/ha)
100	50-90	50-80	40-80

Full dose of farmyard manure, P, K and half of N should be applied at the time of transplanting. Remaining part of N should be top-dressed in two equal installments at an interval of one month.

Interculture and weed control: Weeding and hoeing are necessary after 20-35 days of sowing in mid maturity group of Asiatic type, while temperate and early Asiatic types require weeding after 15-20 days of sowing. Earthing up is also necessary to get well developed, quality and elongated roots as generally the growing roots tend to push out of the soil. Application of Pendimethalin 1.2 kg a.i./ha or Alachlor 1.5 kg a.i./

ha or Fluchloralin (Basalin)@ 0.9 kg a.i./ha or Isoproturan 1.0 kg a.i./ha or metalachlor @ 1.0 kg a.i./ha in 750 litres of water as pre-emergence is very useful for effective weed control.

Irrigation: A pre-sowing irrigation is to be given to ensure high seed germination. Irrigation frequency and amount of water required depend upon the planting season and available soil moisture. The soil should have sufficient moisture to obtain tender and attractive roots. During summer, frequent irrigation is necessary otherwise the growth will be checked and root will be pungent making them unfit for market.

Harvesting: The roots are harvested when they are of usable size and relatively young. The roots are washed and graded according to size and are tied into bunches alongwith tops for marketing. European types are ready to harvest in 25-30 days. Asiatic types require longer period i.e.Chetki type 30-40 days and mid maturity group 40-60 days.

Yield:

European type	50-80 q/ha
Asiatic type	200-500 q/ha

Post harvest handling: Immediately after harvesting, roots are hydrocooled which is effective in this regard. At 32° F temperature and 95-100% relative humidity, topped radishes can be stored for 3-4 weeks while bunched roots can be generally stored only for 1-2 weeks. Roots can be stored for 2 months at 0° C and 90-95% relative humidity.

Physiological disorders:

Pore extent or pithiness: It affects the marketable value of radish roots. Pores develop due to excessive root growth. Pores development is a sign of senescence. Delay in harvesting is the main reason for this disorder. Therefore, harvesting should be done at an appropriate time.

Elongated root or Forking: It is the secondary elongating growth in the root. It is due to excessive moisture during root development in heavy soils which leads to soil compactness. Use well decomposed organic manure to overcome this problem and ensure irrigation at proper time.

Diseases and insects:

Problem	Management
Damping off	Seed treatment with bavistin/thiram/captan
Alternaria blight	Seed treatment with bavistin/thiram/captan
White Rust	Arka Nishant is reported to be resistant
Aphids	Use systemic pesticides

CHECK YOUR PROGRESS

Fill in the blanks

1. ________________varieties of radish set seeds in plains.
2. The pungency in radish is due to __________________________.
3. ________________ weather makes roots tough, pithy and pungent before reaching the harvesting stage.
4. The radish is sown during _______________ in north Indian plains.
5. The seed rate of radish for sowing one hectare area is _______________.
6. The spacing to be followed for raising radish is___________________.
7. European type varieties of radish reach harvest maturity in _______________ days after sowing.
8. Delay in harvesting is the main reason for _________________ in radish.
9. Excessive moisture during the root development in heavy soils leads to ________________ disorder in radish.
10. Seed treatment with bavistin helps in managing _______________ disease.

TURNIP *(Brassica rapa* L.)

Origin: i. Mediterranean (European type varieties)

ii. Eastern Afganistan (Asiatic type varieties)

Uses: It is grown for elongated roots as well as for its foliage. Fresh roots are consumed as salad or cooked as a vegetable or used in pickles. The turnip greens are rich in vitamin A and C and contain appreciable amount of vitamin B, and are also good source of Ca, P and Fe.

Varieties

Asiatic/tropical/subtropical type	European/temperate Type
Early and more tolerant to heat. More pungent and better for pickles.	Sweeter and more palatable.
Pusa Kanchan, Pusa Sweti, Punjab Safed 4	Purple Top White Globe, Golden Ball, Snow Ball, Early Milan Red Top, Pusa Chandrima, Pusa Swarnima.

Turnip is best adapted to a cool or moderate climate. It is a hardy crop, can tolerate frost and mild freezing temperatures. Asiatic varieties require warmer conditions are sown earlier than european types. In India, Purple Top White Globe (PTWG) is the most common variety. It can be grown on all types of soil but good soil conditions and fertility favour uniform growth. Planting time under north plains is September-

December. Seed rate is 4-4.5 kg/ha. The plants are retained at a spacing 30-45 cm between the rows and at 7.5-15 cm with in rows. Proper moisture should be maintained during its growth. Pre-planting application of herbicides followed by hoeing and weeding in the later stages keep the crop free of weeds. Mix 200-250q/ha farmyard manure thoroughly at the time of field preparation. Application of nitrogen, phosphorus and potash @ 50-90: 50-80: 50-80 kg per hectare respectively is required to raise a healthy crop of turnip. Half quantity of nitrogen and full quantity each of phosphorus and potash is applied at the time of transplanting. Remaining quantity of nitrogen is applied after 30 days of transplanting. It should be harvested as soon as the roots attain appreciable size because quality of roots deteriorates at a faster pace. Large roots have poor texture and bitter taste. A light irrigation may be given before harvesting to facilitate lifting. After harvesting, roots are cleaned, tops are cut and roots are graded according to size and tenderness. Yield may vary from 25-30 t/ha under Indian conditions.

BEET ROOT

Botanical Name : *Beta vulgaris sp vulgaris.*

Origin : Europe, North Africa & West Asia

Variety : Detroit Dark Red, Crimson Globe

Roots are served as boiled, pickled or as a salad. Beet root is rich in protein, carbohydrates, Ca, P, Fe and vitamin C. Red colour of table beets is due to *beta cynin* and yellow pigmentation is due to *betaranthin*. It is a cool season crop that can tolerate mild frosts and light freezes. It grows best in the winters in the plains of India. Optimum seed germination occurs between 65 and 75° F. Beets are very sensitive to low temperature and if exposed to 4.5° C – 10° C for 15 days, bolting occurs even if the roots have not attained marketable size. It grows well in warm weather but the best colour, texture and quality are achieved in a cool weather condition. Excessive hot weather causes 'zoning' – the appearance of alternating light and dark red concentric circles in the rot. Sowing is taken up during September-November in north India and from July to November in South India. The seed balls are planted at a rate of 7-9 kg/ha in rows 45-60 cm apart and thinned later to an in-row spacing of 8-10 cm. Beet root has multigerm seeds in a fruit containing usually 2-6 seeds. Thinning is an essential operation in beet cultivation because the seed ball is actually a fruit containing 2-6 seeds each of which may germinate and produce a plant. Generally, the plants emerge in groups unless segmented seed or monogerm seed is used. Manures and fertilizers, interculture and weed management operations are more or less similar to that of radish and turnip. The soil should be kept sufficiently moist until emergence of seedlings. Three irrigations are sufficient when there are winter rains. The marketable maturity is just depending on the size ranging from 3-5 cm diameter. Usually, the top is removed for marketing the roots. Yield varies from 250-300 q/ha. Internal black spot, a physiological disorder is associated with boron deficiency. Plant usually remains dwarf or stunted. Apply 10-15 kg of Borax/ha.

CHECK YOUR PROGRESS:

1. The Asiatic type varieties of turnip are more __________________ in taste.
2. The most common variety of turnip in cultivation is ____________________.
3. __________________ weather causes zoning in beet root.
4. The beet root seed is called _______________ as fruit contain usually 2-6 seeds.
5. Black spot is associated with ___________________ deficiency.

OKRA

Botanical name : *Abelmoschus esculentus* (L.) Moench

Family : Malvaceae

Origin : Ethiopia

Importance and uses:

- Okra is rich in vitamins, Ca, K and other minerals.
- It is grown for its green, tender and nutritive fruits which are cooked in curry and are also used in soups besides being processed as canned and frozen.

Soil: Okra grows best in light soils ranging from sandy loam to loam though it gives good crop in heavy soil with efficient drainage facility during rainy season. The soil should be well drained as it is sensitive to water logging. The most ideal pH range for its cultivation is 6.0 to 6.8.

Climate: It is a warm season crop, sensitive to fluctuating environment and grows luxuriantly in warm and humid weather. The optimum temperature for better seed germination should be atleast 18° C, optimum being 25-30° C. Optimum temperature for its better growth is 24-27° C and temperature above 42° C causes flower drop. A temperature range of 30-35° C is desirable for improved pollination and subsequent seed setting.

Varieties:

Open pollinated varieties: Parbhani Kranti, Punjab Padmani, Arka Anamika, Arka Abhay, Pusa A-4, Varsha Uphar, Hisar Unnat, Hisar Naveen, Azad Kranti, Azad Bhindi1, Kashi Pragati, Kashi Vibhuti, Kashi Kranti,Phule Utkarsh, Gujarat Anand Okra-5

- Pusa Sawani, Parbhani Kranti, Varsha Uphar and Pusa A-4 varieties find favour for export.

Agronomic practices

Sowing times

Indo-Gangetic plains	✓ Spring-summer crop: February-March ✓ Autumn-winter crop: July- September
Eastern India	✓ January-February
Western & South India	✓ November to March-April
Hilly regions	✓ April-June
Most parts of India	✓ Rainy season crop: June-July.

Problems associated with okra cultivation

- The poor seed germination and erratic crop stand are the major problems in spring-summer crop due to low temperature in early spring, which can be overcome by selecting fresh and vigorous seed. Another problem is of shoot and fruit borer or spotted worm wall.
- Similarly, in rainy season crop, the major problems are incidence of yellow vein mosaic disease which can be overcome by growing resistant varieties. Crop stand may be affected if proper drainage is not provided. Problem of shoot and fruit borer is more serious during September.

Soil preparation: Okra should be planted in well pulverized field by ploughing first with soil turning plough and afterwards with 4 to 5 ploughings with country plough. Ploughing should be followed by levelling.

Seed Rate: 15-20 g/ha (Spring-summer crop) and 10-12 g/ha (Rainy season)

Seed germination can be enhanced by soaking the seed in water for 12-24 hours or GA 3 at 10 and 50 ppm or immersing the seeds for 5 minutes in pure acetone

Spacing: 30-45cm × 15 cm (Spring-summer) and 60 cm × 20-30 cm (Rainy season)

Manures and fertilizers: FYM @200-250 quintals per ha should be applied at the time of field preparation. In addition, apply 60-75 kg N, 50-60 kg phosphorus (P_2O_5) and 50-60 kg potassium (K_2O) K_2O per hectare depending upon the fertility status of the soil. Apply half of nitrogen and full dose of phosphorus and potassium at the time of sowing and remaining nitrogen can be top dressed after one month of sowing.

Interculture and weed control: Weeds cause more than 50% reduction in the marketable yield of okra. Frequent weedings are necessary to keep the crop weed free. First weeding may be done at 15-20 days and second at 40-45 days after sowing to keep the crop weed free at critical stages. Pre-emergence application of Pendimethalin @1 kg ai/ha or Alachlor @ 4 litres/ha or Fluchloralin @ 2.5 litres/ha + one hand weeding is effective to keep crop weed free.

Irrigation: Pre-sowing irrigation is necessary especially in spring-summer crop which ensures adequate germination and uniform crop stand. Then, next irrigation is to be provided after seed germination and the subsequent irrigations at 4-5 days interval during summer crop. Drainage of water is required as per frequency and intensity of rains during monsoon season.

Harvesting: The fruits attain marketable maturity in about 45-60 days after sowing. Only tender and small fruits (6-10 cm long) should be harvested preferably in the evening or morning. Frequent pickings are necessary for getting better quality fruits and handsome prices in the market. Delayed harvesting though increases yield but reduces the quality and profit margin, and even sometimes the entire produce is rendered unfit for marketing. For export purpose, dark green fruits about 6-8 cm long should be harvested.

Yield: 80-100q/ha (Spring-summer) and 120-150q/ha (Rainy season)

Activity 11

Plan a visit to a vegetable garden/market, observe okra fruits for tenderness and over maturity, pubescence (hair), deformity and fruit borer.

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Post-harvest management: For local markets, fruits are cooled and packed in jute bags or baskets, covered or stitched and then water is sprinkled over the bags, which helps in cooling as well as maintaining the turgidity of fruits thereby saving the produce from bruises, blemishes and blackening. For export, 5-8 kg size perforated paper cartons are ideal wherein pre-cooled fruits are packed and transported preferably in refrigerated vans.

Storage: Fresh okra fruits can be stored at 7-9° C at 70-75% relative humidity for a couple of days without much loss of colour, texture or weight. Fruit can be stored for 2 weeks at 8-10° C at 90% relative humidity.

Disease Management:

1. **Powdery Mildew:** White powdery growth on both sides of the leaf. The diseased leaves drop off from the plant.

   Management:

   - The disease can be controlled effectively by spray Sulfex (0.2%) or Karathane (0.05%) at 10 days interval.

Powdery mildew

2. **Leaf Spot:** There is appearance of spots in the leaf with grey centres and red borders. When the disease is severe, complete defoliation occurs.

Leaf Spot

Management:

- Seed treatment with organomercurials (0.2%) is effective to manage the disease.
- Spray Dithane M-45 (0.2%) or Captan (0.2%) or Bavistin (0.2%) at the appearance of the disease incidence to check the infection.

3. **Yellow Vein Mosaic Virus:** The veins of diseased leaves become yellow resulting in homogenous interwoven net work of yellow veins. In extreme cases, the infected leaves become totally yellow or cream colour. Infected plants remain stunted and bear very few deformed and small fruits. The disease causes heavy loss in yield if the plants get infected within 20 days after germination. It is transmitted by white fly.

Yellow vein mosaic virus

Management:

- Disease incidence can be reduced by checking the development of insect vector by the application of 4 to 5 foliar sprays of either Dimethoate (0.05%) or Metasystox (0.02%) followed by 1 or 2 sprays of mineral oil (2%).
- Soil application of Furadon @ 1.5 kg a.i./ha at the time of sowing
- Infected plants must be removed from the field
- Grow resistant varieties like P-8, Varsha Uphar, Arka Anamika, and Parbhani Kranti.

4. **Root rot *(Fusarium solani):*** Severely infected plants die as their roots turn dark brown. The fungus perpetuates in the soil or in the infected plants.

Root Rot

Management:

- Seed treatment with bavistin @ 3g/kg of seed
- Soil drenching with bavistin @ 0.01%,
- Follow long crop rotation

Insect-pests:

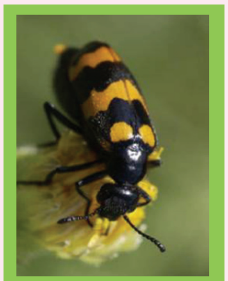
1. **Fruit borer:** The insect larvae are light yellow with black spots. They bore into the shoots during vegetative stage and feeds inside as a result of which the shoots droop down and dry-up. In the later stages, it infests the fruits which become disfigured and show holes.

Fruit borer

Management:

- Grow tolerant varieties.
- Remove and destroy damaged shoots and fruits.
- Application of carbaryl (0.1%) and malathion (0.05%) are effective.

2. **Flower feeding beetle/ Blister beetle:** Beetles feed on pollen, petals of flowers and flower buds thus, affecting fruit set adversely.



Blister Beetle

Management

- Hand collection & destruction of beetles. Application of 0.1% carbaryl or 0.05% malathion or 0.01% fenvalerate.

3. **White Fly:** It causes chlorotic spots on leaves. Nymphs secrete a sticky substance known as honeydew, which covers leaves and flowers. Plant growth is reduced.

White fly

Management:

- Plants affected by viral disease must be uprooted and destroyed.
- Monitoring the adult population with yellow sticky traps for early prediction and timely application of insecticide.
- Spray chemicals as prescribed in yellow vein mosaic

CHECK YOUR PROGRESS

Objective types (write with respect to okra cultivation):

1. Seed rate for rainy season crop
2. Spacing
3. Fertilizer dose
4. Major problems associated with spring-summer cultivation
5. Extent of yield losses caused by weeds
6. Critical stages of irrigation
7. Effect of delayed harvesting
8. Management of shoot and fruit borer.
9. Yellow vein mosaic resistant varieties (any two)
10. Insects which transmit yellow vein mosaic disease

BEANS

There are at least 18 types of cultivated beans. They are the members of family *leguminosae*. They have the ability to fix atmospheric N through root nodules. They are used as green vegetables or green shelled seeds or dry seeds as pulse, according to the stage at which they are harvested. Frenchbean, cowpea, cluster bean and dolichos bean are of economic importance. All beans except broad bean are susceptible to frost and are grown as a summer crop.

Importance and uses: The beans are valuable source of protein, Ca, Fe and vitamins. Some of the important beans are as under:

FRENCH BEAN

Origin: South and central America

Soil: A well drained, fertile and sandy loam soils are preferred with pH between 5.3 and 6.0

Climate: A warm season crop, sensitive to frost and very high temperature. The seeds do not germinate in cold soil. In very hot or rainy weather, plants drop their blossoms or pods. Mean monthly temperature of 10.0 to 23.9°C is the most ideal. The best pod setting is obtained at temperature range of 15-25°C for 4 hours after pollination.

Varieties recommended for cultivation in different parts of India

Dwarf varieties	Pole type varieties
Contender, VL Boni 1, Pusa Parvati, Arka Komal, Pant Anupama, Arka Suvidha, Arka Anoop, Phule Surekha, Kashi Param	Kentucky Wonder, SVM-1, Luxmi, KKL-1

Agronomic practices

Sowing time

Northern Indian plains	✓ Spring-summer crop: January-February ✓ Autumn-winter crop: July- September
South India	✓ September-October and crop is over by February

Soil preparation: Soil should be thoroughly prepared by employing 4 to 5 ploughings before sowing the seeds. Farmyard manure or compost should be applied and incorporated well into the soil. Sowing is done as follows:

- **Flat bed:** Generally, it is followed in spring-summer and autumn-winter crop.

- **Hill method:** Maintain row to row distance between the hills. Sow 5-6 seeds per hill and then retain only 3 plants per hill. This method facilitates proper drainage especially in heavy rainfall regions.

Seed rate (kg/ha): 80-90 (Bush type) and 30-40 (Pole type)

Seed inoculation: *Rhizobium* culture can be used to inoculate the seed before sowing. This seed inoculation helps in quick nodulation on the roots which in turn fix atmospheric nitrogen

Spacing (inter- row x intra-row) 45cm x 15cm (Bush type) and 90cm x 10-15cm (Pole type)

Manures and fertilizers: Farmyard manure @200-250 q/ha is applied at the time of field preparation. The full dose of recommended fertilizers i.e. 30-50 kg N, 60-100 kg P_2O_5 and 30-60 kg K_2O /ha should be applied at the time of sowing.

Interculture and weed control: Hoeing and earthing up are to be done after 2-3 weeks of sowing and second at flower initiation to get higher yield. Root injury should be avoided during the operation. Therefore, hoeing should be followed by earthing up to strengthen the plants and to encourage the root growth. Weeds can be controlled effectively with the pre-emergence application of Alachlor 3litres/ha or Pendimethalin @ 4 litres/ha or Thiobencarb @ 4 litres/ha or Fluchloralin @ 2.5 litres/ha.

Irrigation: Beans are shallow rooted and are sensitive to an oversupply of water. Therefore, avoid excessive watering and water logging conditions. Pre-sowing irrigation is essential for proper germination of the seeds. The critical stages of irrigation are flowering and pod setting. Additional irrigation is to be given when needed.

Harvesting: Pods are usually ready to harvest 2-3 weeks after the first blossom. The pods are picked when they are tender, immature and non-fibrous. Delay in harvesting increases the total yield but the quality falls rapidly. Bush varieties are ready for picking after 45 days of sowing where as pole types after 70 days and continue to give picking up to 6 months. Bush varieties give 2-3 pickings while pole types can be harvested in 4-6 pickings.

French bean pods

Yield (q/ha): 80-100 (Bush type) and 100-140 (Pole type)

Activity 12

Plan a visit to a vegetable garden and harvest bean pods. Check the pods for tenderness and stringyness.

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Disease Management:

1. **Anthracnose:** Small, pink lesions produce on cotyledon and stem which may spread to the leaves. The typical symptoms appear on pods having small, reddish brown to black blemishes and distinct circular, reddish brown lesions.

   Management: Seed treatment with bavistin/captan @ 2.5-3.0 g/kg of seed. Spray Bavistin @ 0.1% or Dithane-M-45@0.25% to control the disease. Grow resistant varieties.

Bean anthracnose
Source: www.cals.ncsu.edu

2. ***Cercospora* leaf spot:** Water soaked lesions develop on the leaf lamina which turn reddish brown to brown.

   Management: Spray Bavistin or Dithane-M-45

***Cercospora* leaf spot**
Source: agritech.tnau.ac.in

3. **Powdery mildew:** White powdery growth appears on the leaves, spreading to cover the stem and other plant parts.

   Management: Spray Karathane @ 0.05% or any sulphur fungicides.

4. **Ashy stem blight:** The infection starts from the stem just near the soil surface. The lesions on young plants are somewhat sunken and have a reddish brown colour which further enlarges and turn ashy grey at the centre.

   Management: Follow long crop rotation. Treat the seed with Bavistin @ 3 g/kg of seed.

5. **Rust:** Pustules are formed on all above ground plant parts but are more frequent on underside of leaves

   Management: Spray Bavistin @ 0.1%.

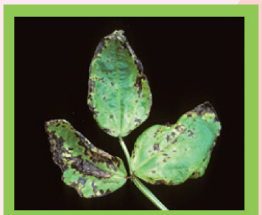
6. **Web blight *(Rhizoctonia solani)*:** The first symptoms appear as small, circular, water soaked spots on stems, pods and foliage which later become tan-brown with a dark border. Plants become seriously blighted.

   Management: Follow crop rotation. Spray Dithane-M-45 or Bavistin for effective management of this disease.

Web blight
Source:www.tropag-fieldtrip.comell.edu

7. **Bacterial blight:** Irregular, sunken, red to brown leaf spots surrounded by a somewhat narrow yellowish halo appears.

   Management: Use disease free seed. Soak the seed in a mixture of Streptocycline (1g) and Hexacap (25g) in 10 litre of water for 4 hrs before sowing.



Bacterial blight
Source: extension.umass.edu

8. **Common bean mosaic virus:** It is transmitted by an insect vector, aphid. It

produces chlorotic, crinkled and stiff young leaves as primary symptoms. This is followed by chlorosis and mottling and the compound leaves show downward curling and rolling.

Management: It is transmitted by vector aphids so, it is essential to control this pest. Spray dimetoate or 1% mineral oil for vector control.

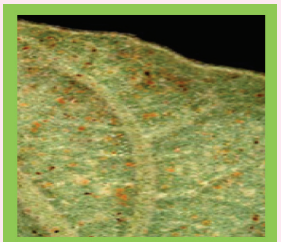
Insect- pests management:

Aphid

1. **Aphids:** They are tiny soft-bodied insects. Initially, damaged leaves show general yellowing. Young leaves become curled when aphids are numerous. They often transmit virus diseases.

   Management: Foliar application of dimethoate (0.03%), methyl demeton (0.025%) or malathion (0.05%) before flower initiation stage.

2. **Jassids:** In severely infested crop, it produces typical 'hopper burn' symptoms. Follow same control measures as in aphid.



Red Spider mite

3. **Red spider mite:** Feeding of mites result in large chlorotic patches on leaves. Often these damaged leaves curl when the infestation is concentrated on middle part of lower leaf surface. Severe infestation causes extensive yellowing and browning of entire leaves and eventually leaves drop.

   Management: Spray azadiractin (0.03%) or malathion (0.05%) or dicofol (0.04%). Repeat sprays at 10 day intervals.

Pod borer
Source: www.nbail.res.in

4. **Pod borer:** The larva feed on pods and also eats seed totally or partially. Spray carbaryl (0.1%) or cypermethrin (0.01%) at 15 days interval.

5. **Bean beetle:** Both larvae and adults feed on the leaves. Spray cypermethrin @ 0.01% to control the pest.

6. **Bean bug:** It is sucking pest and causes discolouration of leaves and pods. Spray cypermethrin @ 0.01% to control the pest.

7. **Hairy catterpillar:** The larvae cause damage by eating the leaves resulting in defoliation. In early stages, collect and destroy the larvae. Spray malathion @0.05% to control caterpillar.

8. **Bean weevil *(Bruchus spp.)*:** The eggs are laid on green pods and after hatching of eggs, the larvae burrow through the pod into the seed. They develop inside seed and come out by damaging the seed in storage. It is a storage pest. Put 1-2 tablets of Celphos/tonnes of material.

Cowpea *(Vigna unguiculata)*

Origin	Africa
Climate	A warm season crop, suitable to humid tropics and subtropical zones. Tolerates heat and dry conditions but intolerant to frost. Thrives best between 21 and 35°C. It can not withstand heavy rainfall and water logging.
Soil	It grows in all types of well drained soils with pH range of 5.5 to 6.5
Cultivars	Pusa Komal, Pusa Sukomal, Arka Samridhi, Arka Garima, Arka Suman, Bidhan Barbati-1, Bidhan Barbati-2, Kashi Kanchan, Kashi Gauri, Kashi Unnati. Photo insensitive varieties are Kashi Kanchan, Kashi Gauri, Kashi Unnati, Arka Garima and Arka Samridhi.
Sowing time	Spring-summer crop: February-March, Rainy season: June- July South India: December-January for spring-summer crop.
Seed rate:	12.5-20 kg / hectare.
Spacing	45-60 cm × 10-15 cm (bush type), 75 cm × 20-25 cm (indeterminate types)
Nutrition Requirement	50:80:80 kg NPK /ha, Band fertlizer 7-10 cm deep & 5-7 cm away from the seed is good practice.
Irrigation and inter culture	Same as that of bean
Harvesting	At three different stages of maturity: green snaps, green mature and dry.
Yield	50-80 q
Diseases	Anthracnose, Die back, Ashy stem blight, Powdery mildew, Bacterial blight, Mosaic
Insects	Aphids, Jassids, Pod Borer, Bean Weevil

Cluster bean or Guar *(Cyamopsis tetragonoloba)*

Importance	The mucillagenous seed flour is valued as a guar gum (glactomannan) and used in textile, paper, cosmetic and oil industries. It is a useful absorbent for explosives.
Origin	Africa
Climate	A typical tropical crop prefer warm climate though grown in subtropics in summer. Long day conditions are required for growth and short day conditions for induction of flowering. Average Temp 30-40°C is congenial for growth and development.

Soil	It can tolerate saline and moderately alkaline soils with pH 7.5 and 8 and prefers well-drained sandy loam soils.
Cultivars	Pusa Navbahar
Sowing time	North India: June- August , South India: Through out year
Seed rate:	15-40 kg / hectare.
Spacing	45-60 cm × 10-15 cm
Nutrition Requirement	10-20: 50-70:50-70 kg NPK/ha, respectively.
Irrigation and inter culture	Flowering is the most critical stage for watering. To keep field weed free, 2-3 weedings are enough. Herbicides 2,4-D and DSMA (disodium methane arsenate) each @ 2 kg/ha to control Parthenium weeds.
Harvesting	It is ready for picking after 40 days of sowing and duration is 120 days.
Yield	50-60 q/ha
Diseases & Insects	Same as other beans

CHECK YOUR PROGRESS

1. The seed rate required for raising dwarf varieties of French bean is ________________.
2. The recommended dose of fertilizers for French bean cultivation is ______________________.
3. French bean crop should be planted at a spacing of _____________ cm between rows and ____________ cm with in rows.
4. The most critical stages of irrigation application in French bean are ______________ and ____________________.
5. Herbicide recommended as pre-emergence application in French bean is ________________________.
6. Bush type varieties are ready for harvesting in ___________ days after harvesting.
7. ______________ can tolerate heat and dry conditions but intolerant to frost.
8. ¬¬¬¬¬¬¬_______________ tolerates saline and moderately alkaline soils.
9. ________________ is the most critical stage for watering in cluster bean.

LEAFY VEGETABLES

These vegetables include beet leaf, spinach, amaranth, and fenugreek etc. These crops are grown for their leaves. They are highly nutritious and rich sources of vitamin A and C and minerals like iron, calcium and phosphorus.

Beet leaf *(Beta vulgaris* var. *bengalensis* L.*)*

Variety: Pusa Bharti, All Green

The general tips which are to be followed for raising beet leaf crop

- It can be grown on any type of soil having sufficient fertility and proper drainage system but does not grow well in sandy loam soil.
- High yields of better quality greens are produced in neutral soils having a pH 7.0.
- It is highly tolerant to saline conditions and can be successfully grown in saline sodic soils.
- It is predominantly a cool season crop but can be grown throughout the year under mild temperature conditions.
- Sowing is done during September-November and also in February-March.
- The seed rate for raising crop in one hectare area is 25-30 kg/ha.
- The crop is planted at a spacing of 30 cm × 5-10 cm (thinning is done to maintain the spacing within the rows).
- Farmyard manure @ 100 q/ha can be added at the time of field preparation.
- The recommended dose of fertilizer is 40-70:30-50:30-50 kg NPK/ha, respectively depending upon the nutrient status of the soil.
- Full dose of phosphorus, potassium and half of N should be applied at the time of sowing. Remaining part of N should be top dressed in two equal installments at an interval of one month.
- To keep the fields weed free and to loosen the soil for proper aeration, 2-3 hoeings-cum-weedings are required.
- A pre-sowing irrigation is done to help the seeds to absorb moisture and germinate properly.
- The spring summer crop need frequent irrigation at 6-7 days interval whereas autumn winter crop requires irrigation at about 10-15 days interval.
- The crop is ready for harvesting in about 3-4 weeks after sowing. Subsequent cuttings are done at 15-20 days interval.

- Only well grown green succulent and tender leaves should be trimmed.
- Winter crop gives more cuttings than spring-summer crop.
- The average yield is 150-200 q/ha

FENUGREEK

There are two types of fenugreek which are of economic importance:

i) *Trigonella foenum-graecum,* common methi

ii) *Trigonella corniculata,* Kasuri or Champa methi or Marwari methi.

Kasuri Methi is slow growing and remains in rosette condition during most of the vegetative growth period. It bears dark green coloured leaves, yellow coloured flowers and sickle shaped pods. The seeds are very small in size. Their cultivation is mostly confined to North India.

Common Methi has light-green leaves, white or light violet coloured flowers and long slender pods with a prominent beak. It is quick growing upright crop. The pods are straight and seeds are bold.

The climate, soil and cultural practices for the cultivation of fenugreek are as under:

- The common cultivars are Lam Selection 1, Pusa Early Bunching, Kasuri Selection, CO-I Fenugreek, Rajendra Kranti, RMT-1, Methi No. 47, Methi No. 14, and Palam Soumya
- Clay loam soil is the ideal for its cultivation though can be grown in all types of soils.
- Being a cool season crop, it is fairly tolerant to frost and freezing weather. It can also be grown as a hot weather crop.
- Sowing time for common methi is mid September-mid March. When it is grown as a leafy vegetable, the duration of the crop is only 30-40 days and thus can be successfully adopted in the multiple cropping systems.
- Seed rate for common methi is 25 kg/ha and that for Kasuri type is 20 kg/ha
- Spacing is 20-30 cm × 5-7 cm.
- The field is ploughed to bring it to a fine tilth. Farmyard manure or compost is applied at the last ploughing.
- Manures and fertilizers requirement is FYM @ 10-25 t/ha, 30:40:45 kg $N:P_2O_5:K_2O$/ha, respectively.
- Frequent irrigation is necessary to obtain quick growth of the crop. Irrigation during early vegetative and grain formation stages is more critical than later stages.
- Excess irrigation is likely to make the crop susceptible to root rot disease.

- Weeding is necessary at the early stage of the crop. The crop growth is slow at the initial stage and becomes vigorous after 4-5 weeks which then does not allow weeds to compete with it.
- The young shoots are nipped off in about 3 weeks of sowing. More number of cuttings may be taken from the kasuri types.
- The first cutting is ready in about 25-30 days after sowing and the subsequent cuttings may be taken after an interval of 12-15 days.
- Yield of common methi is 80-100 q/ha while kasuri type produces 90-100 q/ha

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AMARANTHUS

It is a common leafy vegetable grown during summer and rainy season. The important characteristics are rapid growth, quick rejuvenation after each harvest, high yielding capacity and high nutritive value. There are 8 cultivated species of amaranthus, of which only two are most common belong to family Amaranthaceae

1. *Amaranthus blitum: chhoti chaulai*
2. *Amaranthus tricolor: Badi chaulai*

The general requirements and agronomic practices followed for its cultivation are as under:

- The varieties recommended for cultivation are Pusa Chhoti Chaulai, Pusa Badi Chaulai, Pusa Kirti (most suitable for summer), Pusa Kiran (for rainy season), Pusa Lal Chaulai (red pigmented variety), Arka Suguna, Arka Arunima

Amaranthus

- Warm humid climate is congenial. It responds well to full sunlight.
- Sandy loam soils with slight acidic pH are preferred. It is susceptible to water logging.
- Direct sowing is followed in north India for which 2.0-2.5 kg seed/ha is sufficient. Transplanting is done in Kerala and Tamil Nadu for which 1.0-1.5 kg seed is required to raise seedlings for one hectare area.
- It can be sown throughout the year except May-June in Northern plains.
- It should be planted at a spacing of 20 cm x 15 cm
- It requires plenty of water for its fast growth and high yield. Frequent irrigation may therefore be applied at 5-7 days interval depending on the soil, weather and season.

- Proper drainage must be provided during rainy season.
- Two to three weedings or hoeings are sufficient to keep the weeds under control and to ensure good aeration.
- First cutting can be taken about 25-30 days after sowing and subsequent harvestings can be done at 8-10 days.
- Normally 6-8 cuttings can be taken till the crop starts flowering or becomes unfit for consumption.
- Average yield is 60-80 q/ha.

CHECK YOUR PROGRESS

Write the following requirements for the cultivation of leafy vegetables namely, spinach beet, fenugreek and amaranthus:

1. Sowing time
2. Seed rate
3. Spacing
4. Manures and fertilizer requirement
5. Weed management and irrigation requirements
6. Harvesting

PERENNIAL VEGETABLES

Moringa (*Moringa oleifera* Lam)

Family: Moringaceae **Origin:** India

In India, it is grown for its tender pods and also for its leaves and flowers. The pods of moringa are used for preparation of many cuisines in south India and are valued for distinct flavour. It has a lot of medicinal value. It is fast growing and drought tolerant crop which can be grown under varied agro-climatic conditions.

The cultivation of moringa in India is done mainly in the southern states of Tamil Nadu, Karnataka, Kerala, and Andhra Pradesh.

Varieties: There are two types of moringa cultivated in India

1 **Perennial:** Jaffna (yazhpanam), Chavakacheri murungai, Chemmurungai, Palmurungai and Puna murungai

2. **Annual moringa:** PKM-1, PKM-2, GKVK-1, GKVK-2, GKVK-3, Dhanaraj

Moringa fruits

Climate: It can grow from sea level to 1800 above mean sea level. Dry, warm and semi-arid conditions are congenial for its growth. It performs best at 26-36°C. It is highly susceptible to frost and high temperature exceeding 40°C.

Soil: Sandy loam soils are most suitable for its cultivation with pH around 6.5 and good drainage. Water logging and heavy clay soils are not suitable.

Sowing: Perennial moringa is propagated by stem cuttings (limb cutting). Limb cuttings 100-150 cm in length with a diameter of 14-16 cm are planted in situ during the rainy season. Elite trees are cut down, leaving a stump with a 90 cm head from which 2 to 3 branches are allowed to grow. From these shoots, cuttings 100 cm long and 4 to 5 cm in diameter are selected and used as planting material. The limb cuttings are planted in pits of 60×60×60 cm at a spacing of 5x5 m, during the months of June to August.

Annual moringa is a transplanted crop. It is raised through seed. Seed rate of 600 g/ha is sown in nursery. Seedlings of 15-20 cm height are ready for planting in 6-8 weeks of sowing. The seedlings are transplanted in pits of 45×45×45cm at a spacing of 2.5×2.5 m, during the months of June to July, giving a plant population of 1600 plants/ha. The seeds of annual moringa may be directly dibbled in the pit to ensure accelerated and faster growth of the seedlings. The best suited season for sowing the seeds is September under southern Indian conditions.

Manures and fertilizers: Moringa trees are generally grown successfully without fertilizers.

FYM 12-15t/ha (8-10 kg/plant), crop requires 44 : 16 : 30 g NPK/ tree at the time of pinching (75 days after sowing). Nitrogen @ 44g / tree must be top dressed at first flowering (150-160 days after sowing) stage.

After care: Pinching the terminal bud on the central leader stem is necessary when it attains a height of 75cm (two months after sowing). This promotes the growth of many lateral branches and reduces the height of the tree. In addition, pinching reduces the damage due to heavy winds and makes harvesting much easier.

Irrigation: It is hardy and drought tolerant crop. Irrigation is required only in hot summers.

Ratooning/Pollarding: Cutting down the plant to a height of one meter from the ground level can be practised after one year to allow ratooning of the crop. Pollarding or pruning following harvesting is recommended to promote branching, increased pod production and easy harvesting. This is done during winters (November-

December) when no fruit production is seen and start bearing four or five months after ratooning. Crop can be retained for 3-4 years with regular pruning once in a year. During each ratooning operation, the plants are supplied with the recommended level of N, P and K nutrients along with 20-35 kg of FYM.

Perennial types are also pollarded back to a height of 0.3-0.45m from ground level during October-November, followed by manuring with organic matter (25kg) and the recommended input of fertilizers.

Harvesting and yield: The pods are harvested mainly between March and June. A second crop is normally harvested from September to October. Perennial types raised through cuttings take nearly a year to bear fruit. In general, the yield during the first two years of fruit-bearing is low (80-90fruit/year) and gradually increases to 500-600 fruit/tree/ year by fourth to fifth years. The annual moringa tree bears 250-400 fruit depending on the type.

CHECK YOUR PROGRESS:

1. What is the economic part for which moringa is cultivated?
2. What are the climatic conditions to which moringa is highly susceptible?
3. How is the perennial moringa propagated?
4. What are the effects of pinching on moringa cultivation?
5. Why pollarding is done in moringa?

IVY GOURD *(Coccinia grandis)*

- It is grown for its young and tender green fruits which are used as salad or cooked.
- It requires warm and humid climate with an ideal temperature of 20-30°C.
- It produces fruits through out the year in south India but plants remain dormant during winter in northern India.
- It can be grown on well drained light, medium (loam).
- Important varieties are Indira Kundru 5 and Indira Kundru 35
- It is propagated by stem cutting.
- Stem cutting should be 12-15 cm long with pencil thickness having 5-6 leaves.
- It is planted in basins which are 60 cm in diameter and are dug 3 m apart. Add 5 kg farmyard manure in each pit.
- Planting is done in June-July or February-March

Ivy gourd

- Plant population should have atleast 10% male plants.
- Vines are often trained on bower or bamboo structures.
- The recommended dose of fertilizer is 60:40:40 kg NPK/ha, respectively. Half dose of N plus full P and K are applied at planting time and rest of N in four equal splits.
- It requires good quantity of water but cannot withstand water logging conditions.
- Pruning of vines is most important. Repeated pruning of vines must be done when the plant seems to be weak and leaves turn yellow i.e. after every 3 to 4 months to maximise yield (newly developing vines produce more flowers and yield).
- Flowering starts after 50-60 days of planting and average yield is 10-15 t/ha.
- Harvesting of fruits is determined by change of colour from dark green to bright or light green.

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Chapter-5

Fertigation in Vegetable Crops

OBJECTIVE

Students will be able to learn about :-

- Importance of fertigation in vegetable production
- Principles and methods of fertigation
- Types of fertilizers to be used in fertigation
- Advantages and disadvantages of fertigation
- Constraints for successful adoption of fertigation

INTRODUCTION

Fertigation is a method of combined application of water and plant nutrients to save both water and fertilizers and simultaneously enhancing yield and quality of the crops. There may be certain questions arising in your mind. How does fertigation save water and fertilizers? Why should we follow fertigation? How can we install fertigation system? What are the principles and methods of fertigation? What are different equipments needed to install the system of fertigation? What kind of synthetic fertilizers we should use in fertigation? What are its advantages and disadvantages? What kind of precautions one must follow to have better function of fertigation system and equipments? You can face several questions of this category. This chapter will make you aware about the fertgation system and its functioning.

Fertigation technology has been well developed, tested, fine tuned and adapted both under protected and open conditions in Israel, USA, Australia, France, Greece and other developed countries. This was possible due to the development of water soluble fertilizers and liquid fertilizers of different grades, micro irrigation systems, micro sprinklers, micro jets and even sprinklers with e-jets. In India since last two decades, drip irrigation has received greater attention of the farmers and the government in view of its well proven advantages in both water scarce and sufficient areas. Studies conducted in India and elsewhere have indicated encouraging results of fertigation technology in potato, capsicum, maize, sunflower, banana and pomegranate. In India, the projected area to be covered under drip irrigation will be 10 million ha by 2025. Drip irrigation and fertigation go hand in hand in order to improve efficiency of water and nutrients in crop production. The traditional methods of application are not that effective and have resulted in reduced availability of nutrients to the plants because of limited root zone and reduced amount of mineralization in the restricted wetted zone. Fertigation overcomes these aspects and is currently recognized as the best means of supplying fertilizers and making use of the scare resources of water very economically, especially in greenhouses, orchards, vegetables, ornamental nurseries, high value plantations and even field crops. Fertigation technology has made rapid advances in commercial and export oriented floriculture with computerized programmes to fertigate the optimum quantities of fertilizers and water as per the physiological needs of the crops for better "blooms" with high quality. Drip irrigation permits application of fertilizers through irrigation water directly at the site of high concentration of root activity and result in improving the fertilizer use efficiency in crop production.

Importance of fertigation

In Israel, 80 % of the irrigated land is under fertigation.

The practice of fertigation started commercially in the middle of 20th century. The first reported example dates back to ancient Athens (400 B.C.), where city sewage was used for the irrigation of tree groves. Liquid ammonia was probably the first commercially produced liquid fertilizer but in modern fertigation the use of ammonia as the nitrogen source is negligible. Fertigation was first used in Israel in 1969 for tomato grown on sand dunes in a field experiment.

Fertigation is a method of fertilizer application in which fertilizer is incorporated with the irrigation water by the sprinklers or trickle irrigation systems. Nutrients in a solution are injected in the irrigation water using an appropriate injection device.

- Fertigation provides essential elements directly to the active root zone which results in minimizing losses of expensive nutrients
- It helps in improving productivity and quality of the farm produce.
- Fertilizer use efficiency is increased from 80 to 90 per cent.

1. Why fertigation?

Vegetable production in Indian agricultural scenario has wider scope for increasing the income of the marginal and small farmers. To be more competitive in today's market, the vegetable growers are looking for new ways to achieve superior quality produce with higher yields than the conventional methods. Presently, the vegetable crop production suffers mainly on the availability of water and nutrients. Therefore, water and fertilizer use efficiency through drip fertigation method can be maximized by the introduction of improved techniques. Nitrogen and potassium based fertilizers are the most commonly applied nutrients by fertigation for vegetable crops. Some formulations of phosphorus and micro-nutrients can also be used if compatible with the irrigation water (pH should be less than 6.5). The limited root zone and the reduced amount of mineralization in the restricted wetted zone are the main reasons for the reduced nutrient availability to the plant. These facts led to the installation of fertigation facilities with almost all applications of MIS (Micro irrigation system).

Micro-irrigation, an efficient method of providing irrigation water directly into soil at the root zone of plants, permits the water to consumptive use of plants and facilitates utilization of water soluble fertilizers and chemicals.

Why micro-irrigation is necessary?

- To improve the productivity of irrigated land
- To improve use-efficiencies of water, energy, nutrient and human efforts in agriculture
- To conserve scarce resources such as water and energy
- To extend the benefits of irrigated agriculture to more people with the available water
- To facilitate better crop management through fertigation and chemigation

Types of micro irrigation system

1. Sprinkler irrigation:

1) It conveys water from the source through pipes under pressure to the field and distributes over the field in the form of spray of "rain like" droplets.
2) It is more efficient than the surface Irrigation.
3) Evaporation losses may be only 2-8 per cent of the total sprinkler discharge.
4) Highly suitable for sandy, shallow and steep soils.

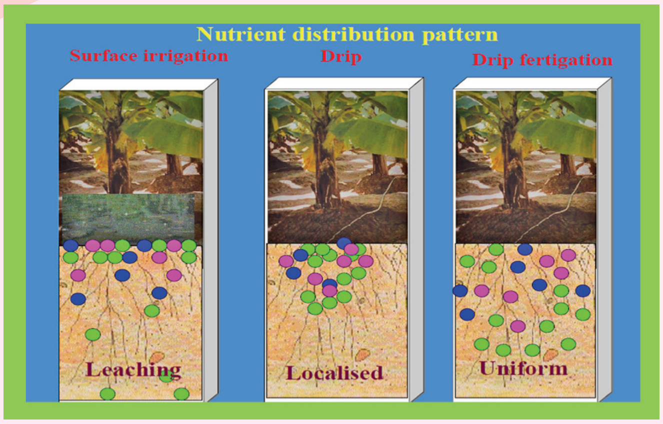
Irrigation is the application of water to a crop for assisting the production of a crop whereas the use of an irrigation system to apply the necessary application of nutrients or chemicals to the crop is called fertigation or chemigation.

2. Drip irrigation:

1) Water is delivered at near the plant, drop by drop.
2) Efficient method of providing irrigation water and fertilizers near the plants.
3) It permits the effective utilization of fertilizers, pesticides and other water soluble chemicals.

Slow application of water in the form of discrete or continuous miniature sprays is done through mechanical devices called emitters.

Fertilizer use efficiency: Surface irrigation is prone to leaching whereas in drip irrigation, nutrient distribution is localized near plant root zone and distribution pattern is uniform around root zone. From the Table 1, it

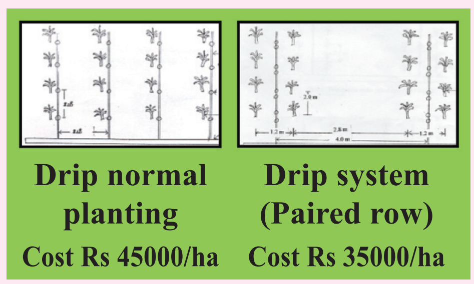


is very clear that the highest nitrogen, phosphorus and potassium fertilizer use efficiency is found with drip fertigation over drip irrigation and soil application.

Table1: Fertilizer use efficiency of NPK with different methods.

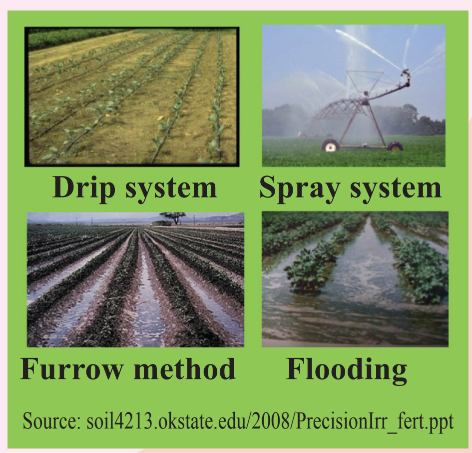
Nutrient	Fertilizer use efficiency (%)		
	Soil application	Drip	Drip fertigation
Nitrogen	30-50	65	95
Phosphorus	20	30	45
Potassium	50	60	80

Economics of drip irrigation system: The initial investment in drip irrigation system is mainly depends upon the spacing of crops. The initial cost is approximately Rs. 50-70 thousand per hectare for close spaced crops including vegetables whereas for widely spaced orchard and plantation crops, the cost is around Rs. 20-25 thousand per hectare. This high cost of drip system can be reduced by inducing paired row method and use of micro-tubes.



3. Spray irrigation:

1) Small sprinkler like devices called micro sprinkler sprays water over soil surface in the root zone.
2) Micro sprinklers can be located like emitters.
3) Discharge rates are usually 12-200 liters/hour.
4) Micro sprinkler normally require 35-300 K pa of pressure for proper operation.
5) Wetted diameter from 2-9 meters.



6) Primary advantage is its lower application rate.

7) Large orifices than drip emitters and cover large area in short time.

4. Pipe irrigation:

1) Use of clay pipes.

2) Clay pipes are buried beneath vegetable beds.

3) One end of pipe is blocked and other is tilted out of the soil to allow filling.

4) Water gradually escapes from the cracks between the pipe sections and through the pores in the clay to provide a continuous supply of water to the vegetables.

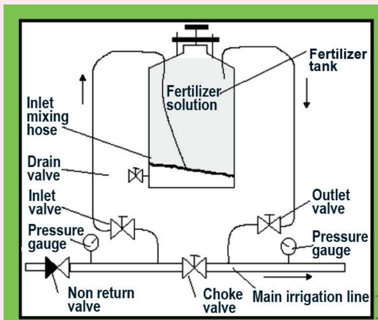
5) Optimum pipe size is 75 mm inside diameter and 300 mm long.

Fertigation equipments:

It is important to select an injection method that best suits the irrigation system and the crop to be grown. Incorrect selection of the equipment can damage parts of the irrigation equipment, affect the efficient operation of the irrigation system and reduce the efficiency of nutrients. Each fertilizer injector is designed for a specified pressure and flow range.

1. Fertilizer tank

- A tank containing fertilizer solution is connected to the irrigation pipe at the supply point.
- Part of the irrigation water is diverted through the tank diluting the nutrient solution and returning to the main supply pipe.
- The concentration of fertilizer in the tank thus becomes gradually reduced.
- Fertilizer tanks are available in 90, 120, 160 liters capacity.



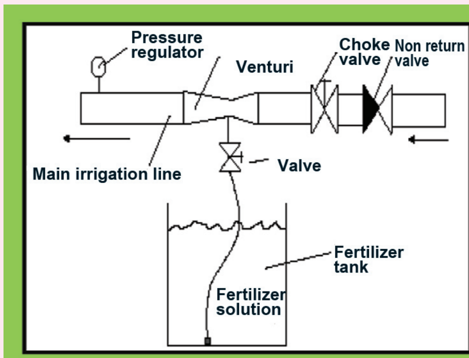
Fertilizer Tank

Source:earthfriendlylandscapes.blogspot.com

2. **Venturi injector:** This device causes a reduced pressure (vacuum) that sucks the fertilizer solution into the line.

Advantages:

- Very simple to operate and low cost device
- Easy to install and maintain
- Suitable for very low injection rates
- Injection can be controlled with a metering valve
- Suitable for both proportional and quantitative fertilization
- The suction rate of venturi is 30-120 litre per hour.



Venturi Injector

Source: earthfriendlylandscapes.blogspot.com

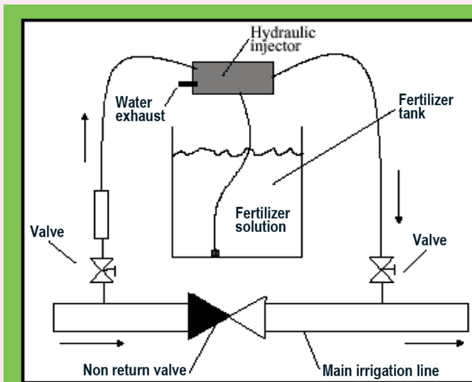
Disadvantages:

- Requires pressure loss in main irrigation line or booster pump
- Quantitative fertigation is difficult
- Automation is difficult
- Uneven water and fertilizer distribution in the field

3. **Fertigation pump:** Pumps are used to inject the fertilizer solution from a supply tank into the line. Injection energy is provided by electric motors, hydraulic motors.

Advantages:

- Very accurate for proportional fertigation
- No pressure loss in the line
- Easily adapted for automation
- Suction rates of pumps varies from 40 to160 liter per hour.



Fertigation Pump

Source: earthfriendlylandscapes.blogspot.com

Disadvantages:

- Expensive
- Complicated design

Maintenance of drip irrigation equipment

1. Sand filter back washing
2. Flushing of sub mains and laterals
3. Chlorination
4. Acidification

Objectives of fertigation:

- To maximize profit by applying the right amount of water and fertilizer.
- To minimize adverse environmental effects by reducing leaching of fertilizers and other chemicals below the root zone.

Principles of fertigation

Method of planting: Planting method is an important factor deciding the economic feasibility of drip/trickle or sprinkler irrigation method for fertigation. Drip/sprinkler irrigation methods are normally fit for feeding the fertilizers to root zone or zone of immediate utility. Depending on the crop root proliferation and canopy architecture the most appropriate method of planting needs to be worked out. The more convenient planting methods to reduce the cost on laterals are paired row and four row pairing systems e.g.in widely spaced crops like bell pepper, tomato and chilli, two paired row system would reduce the cost on lateral lines and yield advantage is similar to the normal row planting.

Scheduling of irrigation: In fertigation under drip/sprinkler, it is essential to irrigate with fertilizer solution at a optimum depth which is based on percentage replacement of daily evaporation based on the observations of open pan evaporimeter. Optimum depths vary depending on the crop, soil type, season and region.

Sources of fertilizers: Fertilizers supplying different primary, secondary and micronutrients are mixed with irrigation water and applied to zone of immediate utilization. It is important to mention that all the fertilizers are not suited for fertigation. Water soluble fertilizers are preferred because they do not leave suspended particles in the irrigation water. They are non corrosive and do not damage/block the components of fertigation unit.

Dose of fertilizers: The quantity of different nutrients required for fertigation is less than soil application.

Method of fertigation: The target of fertigation is to minimize the losses of nutrients and enhancing the efficiency of applied fertilizer solution. The options available are surface or subsurface fertigation. Under surface fertigation along with water, nutrients are also released on the soil surface near the root zone, while subsurface fertigation ensures application of fertilizer solution beneath the soil near the rhizosphere. The optimum depth of subsurface fertigation depends on the feeding zone of crops and nature of fertilizers. Since, phosphatic fertilizers move slowly from the point of placement and are subjected to fixation once they come in contact with soil, therefore subsurface fertigation would reduce these problems and improve the efficiency of added phosphorus.

Frequency of fertigation: The frequency of fertigation is governed by the nature of crop, duration, growth habit and yielding ability. Generally, fertigation is done daily or weekly or fortnightly depending upon the crop response.

Methods of fertigation

Continuous application: The total amount of fertilizer is injected at constant rate regardless of water discharge rate.

Three stage application:

- Irrigation starts without fertilizers.
- Injection begins when the ground is wet.
- Injection is stopped before the irrigation cycle is completed.
- Remainder of the irrigation cycle allows the fertilizer to be flushed out of the system for the system cleansing

Proportional application:

- The injection rate is proportional to the water discharge rate, e.g. one litre of fertilizer solution is mixed in to 1000 litres of irrigation water.
- This method is simple and allows increased fertigation during the periods of high water and nutrient demand.

Quantitative application:

- Nutrient solution is applied in a calculated amount to each irrigation block, e.g. 20 litre to block A, 40 litres to block B.
- This method is suited to automation and allows the placement of the nutrients by controlling precisely.

Advantages of fertigation

1. It improves fertilizer use efficiency, generally 60 to 80 per cent of the recommended dose of fertilizers through water soluble fertilizers. This is adequate to get yield equivalent to that obtained with the application of 100 per cent straight fertilizers.
2. Minimum loss of nutrients through leaching is there. It is only around 10 per cent as compared to 40-55 per cent in the traditional system.
3. Fertigation allows easy application of water soluble fertilizers of different grades and combinations within the rhizosphere.
4. High nutrient availability due to maintenance of soil moisture near field capacity under drip irrigation.
5. There is no damage to root system while top dressing of fertilizers unlike in traditional system.
6. Fertilizers could be applied as frequently as possible and at the growth stage where the demand is maximum.
7. There is considerable savings in the application cost of fertilizers.

8. Fertigation also help in maintaining or improving the physical, chemical and biological conditions of the soil.

9. There is 30-40 per cent economy in the use of irrigation water combined with higher water use efficiency due to ferti- drip in crop production.

For efficient and uniform distribution of plant nutrients, the irrigation system must fulfill certain requirements like:

1. It must be designed correctly to operate efficiently
2. It should ensure complete solubility of the fertilizers without leaving any residues
3. It should supply nutrient solution at constant rate and pressure from the main flow line

Disadvantages of fertigation

1. Uneven nutrient distribution system when the irrigation system is faulty. It leads to over fertilization or leaching of nutrients when excess water is applied to crops.
2. Chemical reactions of fertilizer with calcium and magnesium leads to chemical clogging.
3. Phosphatic fertilizers and some micronutrients may precipitate in micro-irrigation systems
4. Corrosion resistant fertigation equipments are needed
5. Potential chemical backflow into water supply source

Fertilizers suitable for fertigation

Sr. No.	Fertilizer	Formula	N-P-K	Solubility (mg / litre)
1	Urea	$CO(NH_2)_2$	46-0-0	84
2	Ammonium Nitrate	NH_4NO_3	34-0-0	151
3	Ammonium Sulphate	$(NH_2)SO_4$	21-0-0	73
4	Calcium Nitrate	$Ca(NO_3)_2$	16-0-0	
6	Urea Ammonium Nitrate	$CO(NH_2)_2NH_4NO_3$	32-0-0	Liquid
7	Potassium Nitrate	KNO_3	13-0-46	21
8	MAP	$NH_4H_2PO_4$	12-61-0	18
9	Potassium Chloride	KCl	0-0-60	31
10	Potassium Sulphate	K_2SO_4	0-0-50	9
11	Potassium thiosulphate	$K_2S_2O_3$	0-0-25	Liquid
12	MKP	KH_2PO_4	0-52-34	18
13	Phosphoric acid		0-52-0	
14	NPK		19-19-19, 20-20-20	

Source: National committee on Plasticulture Applications in Horticulture

Characteristics of fertilizers for fertigation

Any fertilizer applied through drip irrigation should have following characteristics:

- High nutrient content readily available to plants
- Soluble at field temperature conditions
- Fast dissolution in irrigation water
- Should not clog filters and emitters
- Low content of insolubles ($<0.02\%$)
- Minimum content of conditioning agents and compatible with other fertilizers
- Minimal interaction with irrigation water
- It should not result in drastic changes in water pH
- It should be low corrosive for control head system

Response of vegetable crops to fertigation

Micro-irrigation resulted in an increase in yield, increased water use efficiency (WUE) and saving of water in each crop (see Table 1).

Table 1: Water economy and yield enhancement in vegetable production through drip irrigation

Crop	Yield increase (%)	Water saving (%)
Tomato	50-60	40-60
Potato	20-30	40-60
Brinjal	20-30	40-60
Chilli	30-40	60-70
Cauliflower	60-80	30-40
Cabbage	30-40	50-60
Bottle gourd	30-40	40-50
French bean	55-65	30-40
Okra	25-40	20-30

Source: Soman (2009)

The drip- fertigation system resulted in water saving to the tune 30% in bulb crops to 70% in cucurbits (Table 2). Similar trend was found in fertilizer savings over traditional system of application.

Table 2: Water and fertilizer saving in vegetables under drip fertigation

Vegetable	Water saving over surface irrigation (%)	Fertilizer saving over traditional system of application (%)
Bulb crops	30-35	30-40
Cole crops	40-45	40-50
Solanaceous veg.	45-50	40-50
Cucurbits	60-70	60-70
Sweet corn	50-60	50-60

Source: Hasan et al. (2010)

Constraints for successful adoption of fertigation

1. ***The high cost of establishing fertigation systems:*** Majority of farmers are poor in India.
2. ***Clogging of lines:*** It is due to precipitation of bicarbonates and insoluble di-calcium phosphate, magnesium phosphate and calcium carbonate
3. ***Salt injury:*** In arid climate, mobile nutrient anions such as nitrate and chloride together with cations Na+ and Ca2+ may accumulate around the wet zone on the soil surface due to evaporation
4. ***Nutrient deficiency:*** On heavy clay soils, water ponding may be there and at high temperature due to anaerobic conditions, nitrate N loss by denitrification may be there.
5. ***Oxygen deficiency:*** Oxygen might be excluded from the saturation zone when there is continuous supply of water at higher regime in the wet soil volume
6. ***Lack of awareness:*** Efforts are needed to create awareness among people to create demand for micro-irrigation system and water soluble fertilizers.

Conclusion

- Fertigation offers an opportunity to optimize crop and vegetable production system with respect to both irrigation and fertilization.
- It provides variety of benefits to users like high crop productivity and quality, resource use efficiency, environmental safety, flexibility in operations, effective weed management and successful crop cultivation on fields with undulating topography.

- It is considered eco-friendly as it avoids leaching of nutrients especially $N\text{-}NO_3$.
- Vegetables have been found responsive to fertigation due to wide spacing nature, continuous need of water and nutrients at optimal rate to give high yield with good quality and high capital turnover to investments.
- Even though the initial cost of establishing the fertigation system is higher but in long term basis it is economical compared to conventional methods of fertilization as it brings down the cost of cultivation.
- It requires high management skills at operator level like selection of fertilizers, timing and rate of fertilizer injection, watering schedule as well as the maintenance of the system.

Suggested reading:

– Hasan M, Singh Balraj, Kaore SV, Tarunendu and Sabir Naved. 2012. Fertigation Scheduling for horticultural crops. Indian Farming 62(4): 41-46.

– Biswas BC. Fertigation in High Tech Agriculture: A Success Story of A Lady Farmer. Fertiliser Marketing News, Vol. 41 (10):4-8.

– Hasan M, Singh Balraj, Kaore SV, Tarunendu, Sabir Naved and Tomar B. 2010. B. S. Technical Bulletin No. TB- ICN: IARI, New Delhi-12 pp 44-80.

– Soman P. http://www.faidelhi.org/FAI%20Seminar%202009/FAI-Sem-09-pres-pdf/Dr%20P%20Soman.pdf.

Activity 1

Visit some vegetable farm having facility of fertigation. Compare the growth for different characters under fertigation with that of traditional irrigation system.

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CHECK YOUR PROGRESS

1. Define fertigation. What is the importance of fertigation?
2. Make a list of different irrigation methods and write the main characteristics of drip irrigation.
3. What are the criteria's for the selection of micro-irrigation system?
4. What are the principles of fertigation?
5. List the advantages and disadvantages of fertigation.
6. Prepare a list of different constraints for successful adoption of fertigation.

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Chapter-6

Role of Chemicals and Growth Regulators in Vegetable Production

OBJECTIVES

Students will be able to learn about :-

- Importance of chemicals and plant growth regulators in vegetable production
- Use of chemicals viz., fertilizers, herbicides and pesticides in vegetable production
- Effect of different growth regulators on growth and development of different vegetable crops

INTRODUCTION

We have studied about the nutrients, herbicides and pesticides in chapters 4 and 5 of XI^{th} class. In this chapter, you will learn about the applied aspect of different chemicals used in the life cycle of different vegetable crops to harness optimum yield of vegetable crops. In order to get maximum yield benefits from vegetable crops, chemical fertilizers are applied to meet the nutrient requirement of the crops particularly the macro nutrients viz., N, P and K. Many a times, deficiencies of secondary and micro-nutrients do appear under certain situations. The chemicals containing nutrients are used to manage these deficiencies. The other important aspect in vegetable production is weed management. Weeds cause heavy losses in the vegetable crops as they affect yield potential of the crop, add labor costs and may be the source of insect-pests or diseases. Herbicides are used to control different weeds. Vegetable crops are highly prone to diseases and insect-pests, chemical control is, in general, used to manage such pests. So, we can infer that chemicals are used in one or the other way to handle various production problems in vegetable crops. Now, certain questions may arise in your mind. Why fertilizer application is needed? What kinds of herbicides are used to control the weeds? Which are the chemicals used for insect-pest and disease management? This chapter will help you to resolve your all queries one by one.

Another aspect of this chapter is the use of growth regulators in vegetable production. Let's revise it. Different hormones regulate various functions of the human body. Similarly, growth hormones also play a vital role in regulating various growth processes in plants. Before, we discuss the effect of plant growth regulators on growth and development, it is essential to once again understand the basics of plant growth hormones. This chapter will provide information about the functions of different plant hormones and their effects in stimulating different growth stages of plants right from seed germination to maturity and senescence. To manipulate different growth processes in a plant, synthetic hormones known as growth regulators are applied. In this chapter, after briefing you the basics of plant hormones, review of research findings pertaining to the effect of plant growth regulators (PGRs) in vegetable production has been illustrated.

Use of chemicals for soil nutrient management

Vegetable requires nutrients for its growth and development which are absorbed from the soil. You have learnt about essential plant nutrients and their deficiency symptoms in chapter IV of class XI. Plant nutrients in fertilizers are classified as macronutrients and micronutrients. The most important macronutrients are nitrogen (N), phosphorus (P) and potassium (K) and soils are most likely to be deficient in these nutrients. Hence, these are required in relatively large amounts for plant growth. The other major nutrients, also called secondary nutrients, are calcium (Ca), magnesium (Mg) and sulfur (S). They are also required in relatively large amounts but are less likely to be deficient. Micronutrients are essential for plant growth, but plants require them relatively in small amounts. They include boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn). Manures and fertilizers are major nutrient supplying sources to plants. A deficiency of any of these nutrient elements can limit plant growth and development and ultimately affect the yield. Most soils contain sufficient amounts of the micronutrients needed to support plant growth. However, soils may be lacking in some of the macronutrients, particularly nitrogen, phosphorus and potassium. Therefore, it becomes important to ensure the presence of all the essential elements supplied by the soil in the right quantities and the right chemical forms for plant use. This is done by supplying organic matter and by the judicious use of fertilizers in order to supplement the nutrients required by the plants from soil to increase crop yield. The recommendations of primary nutrients in different vegetable crops are given in Table 1 which can be supplied through synthetic fertilizers (Table 2).

Fertilizers are the chemicals containing higher nutrient contents and are manufactured in the industries. Composition of different fertilizers commonly used in vegetable crop production is given in Table 2.

Table 1: Requirement of primary nutrients (NPK) for different vegetable crops

Crop	Recommended dose of primary nutrients (kg/ha)		
	N	P_2O_5	K_2O
Solanaceous vegetables	75-100	50-75	50-60
Potato	120	80	60
Onion	60-150	35-150	25-120
Pea	20-50	30-60	30-60

Cole crops	120-180	75-80	60-75
Cucurbits	60-100	50-75	50-85
French bean	30-50	60-100	30-60
Root vegetables	50-90	40-80	40-80
Leafy vegetables	40-70	30-50	30-50
Okra	60-75	50-60	50-60

Table 2: Synthetic fertilizers used to meet the requirement of primary nutrients

Fertilizer	**Composition (%)**		
	N	**P_2O_5**	**K_2O**
Nitrogenous fertilizer			
Calcium Ammonium Nitrate (CAN)	25	-	-
Urea	46	-	-
Anhydrous ammonia	82	-	-
Phosphatic fertilizers			
Single superphosphate	-	16	-
Potassic fertilizers			
Muriate of potash	-	-	60
Potassium sulphate	-	-	48
Complex fertilizers			
Di-Ammonium Phosphate (DAP)	18%	46%	-
Mixed fertilizers			
NPK (12:32:16)	12	32	16

Deficiency of secondary and micronutrients result in certain physiological disorders in vegetable crops. The blossom end rot in peppers and tomatoes, blackheart in celery, internal tip burn in cabbage and cavity spot in carrots are attributed to calcium deficiency. These disorders are usually related to the inability of the plant to translocate adequate calcium to the affected plant part rather than to insufficient soil calcium levels. The foliar application of calcium @ 6-12 kg/ha of calcium in 300-500 liters of water, using either calcium chloride or calcium nitrate. Agricultural lime should be used to correct calcium deficiency on acidic soils.

Deficiency of boron leads to brown/black heart in root crops, cracking in tomato and potato, brown rot in cauliflower etc. Deficiency of zinc is also observed in soils with high pH particularly for raising tomato, potato and onion. Acidic soils have a marked influence on the availability of molybdenum i.e. deficiency symptoms appear in high acidic soils which lead to whiptail in cauliflower. Iron deficiency is common in the soils rich in sodium and calcium. Copper deficiency show poor pigmentation in carrot roots and onion bulbs. Nutrients can be absorbed through plant leaves. In some situations, foliar-applied micronutrients are more readily available to the plant than soil-applied micronutrients, but foliar applications do not provide continuous nutrition like that of soil applications. Foliar spray may be used to supplement soil applications of fertilizer or to correct deficiencies that develop on the growing crop. The application rate of secondary and micronutrient on foliage are given in Table 3. It is essential to use lower doses on the young plants and higher doses on plants with dense foliage.

Table 3: Application rates and sources of secondary and micronutrients for foliar application

Nutrient	Rate (kg/ha)	Suggested source
Calcium (Ca)	1-2	Calcium chloride or calcium nitrate
Magnesium (Mg)	1-2	Magnesium sulfate (Epsom salts)
Manganese (Mn)	1-2	Soluble manganese sulfate or finely ground manganese oxide
Copper (Cu)	0.6-1.2	Basic copper sulfate or copper oxide
Zinc (Zn)	0.14-0.3	Zinc sulfate
Boron (B)	0.1-0.3	Soluble borate
Molybdenum (Mo)	0.07	Sodium molybdate
Iron (Fe)	1-2	Ferrous sulfate
Use a minimum of 300-500 litres of water per ha.		

Vegetables are exhaustive crops with an exceedingly high uptake of nutrients from the soil. It is, therefore, necessary to replenish these plant nutrients either through chemical fertilizers or through organic sources to restore soil fertility. The use of chemical fertilizers to enhance soil fertility and crop productivity has often negative effect on the complex system of biogeochemical cycles e.g. fertilizer use has caused leaching and run-off of nutrients, especially nitrogen (N) and phosphorus (P), leading to environmental degradation. The main negative effect of traditional chemical nutrition on soil fertility is the gradual decrease in soil organic matter. This phenomenon affects mainly microbial activity in the soil. The consequences of such unsustainable practices have dramatically changed the soil fertility scenario which is evident from the emergence of multi-nutrient deficiencies. Therefore, interest has grown in environmentally sustainable agricultural practices. The potential way to decrease negative environmental impacts resulting from inefficient use of chemical fertilizers is to follow integrated nutrient management (INM) practices by combining the use of organic manures, mineral fertilizers and inoculation with plant growth promoting rhizobacteria (PGPR). This balanced use of plant nutrients corrects nutrient deficiency, improves soil fertility, increase nutrient and water use efficiency, improves crop and environmental quality and above all enhances crop yields and farmers' income.

CHECK YOUR PROGRESS

Fill in the blanks

1. The soils are most likely deficient for ____, ______ and ______________ nutrients.
2. Urea contain _____________ per cent nitrogen.
3. ________________ fertilizer is a source of phosphorus application.
4. ____________________ is an example of compound fertilizer.
5. Ca deficiency causes ________________ disorder in carrot.
6. Brown heart in root crops is caused due to the deficiency of _______________.
7. Copper deficiency shows poor ______________ in carrot roots and onion bulbs.
8. Calcium can be supplied through _________________ chemical.
9. Application of sodium molybdate supplies ______________ nutrient.
10. _____________ spray may be used to supplement soil application of fertilizers.

Short answers

1. Why chemical fertilizers are necessary to be applied in soil?
2. Name the sources of fertilizers which can supply NPK. Also mention their composition.
3. Deficiencies of secondary and micronutrients result in certain physiological disorders. Justify the statement.
4. Why integrated nutrient management (INM) is important in vegetable production than using chemical fertilizers alone?

USE OF CHEMICALS FOR WEED CONTROL

Soil fumigants: Carbon dioxide, methyl bromide, chloropicrin, cynamide etc. and soil sterilants like, simazine, atrazine, formaldehyde etc. are applied to soil to kill weeds. Soil fumigation with methyl bromide and allyl alcohol for 2-3 weeks before sowing a crop is a popular practice for pest control including weeds in vegetable nursery. High cost of chemicals and application techniques restrict its usage by small farmers. They are extremely toxic chemicals and need proper handling.

Herbicides: The chemical compounds which are used to control the weeds are called weedicides or herbicides. They are grouped into two categories namely, selective and non selective herbicides.

1. **Non-selective:** Herbicides are toxic to all plants. They are used (i) to clean uncropped areas, (ii) inter-row or directed spraying between a developing crop, (iii) close proximity to a growing crop, (iv) areas which are shortly to be cropped but must not have residue effect. Paraquat, glyphosate, and glufosinate ammonium are non-selective herbicides. They provide residual control of weed seedlings and can persist for many months, and in some cases, over a year.
2. **Selective herbicides:** These herbicides kill the weed but not the crop. These are generally used by the vegetable growers to manage the weeds.

The herbicides are further classified according to their mode of action, time of application and method of application.

Based on mode of action

1. Contact: They kill those plant parts which come in direct contact with the weedicide e.g. Paraquat
2. Translocated: They kill the whole plant as on application, the herbicide move from treated part to different plant parts through xylem and phloem e.g. Glyphosate.

Based on method of application

1. Soil applied: Herbicides act through root and other underground parts of weeds and are usually applied in soil as pre-plant or pre-emergence e.g. Alachlor, Pendimethalin, Fluchloralin etc.
2. Foliage applied: The herbicides primarily active on the plant foliage and are usually applied as foliar spray on to the weeds e.g. Glyphosate, Paraquat, 2,4-D etc.

Based on time of application:

1. Pre-planting herbicides: The herbicides are applied before the crop is planted or sown. They can be applied on the soil as well as on the foliage of the plant e.g. Fluchloralin or Alachlor can be applied to soil and incorporated before transplanting of solanaceous vegetables. Glyphosate or Paraquat can be applied on the foliage of perennial weeds like Cyperus rotundus before planting of any vegetable crop.

2. Pre-emergence herbicides: They are applied before crop or weeds emerge. They are applied after the sowing of the crop but before the emergence of weeds e.g. Alachlor or Pendimethalin in pea crop.

3. Post-emergence herbicides: They are applied after the crop or weeds have emerged e.g. Simazine in potato

The herbicides recommended for use in vegetable crops are illustrated in Table 4

Table 4: Herbicides used for control of weeds in vegetable crop

Crop	Herbicide	Rate (kg/ha)	Time of application
Solanaceous crops	Fluchloralin (Basalin)	1.25	Pre plant incorporation
	Metribuzin (Sencor)	0.25	Pre-emergence
	Alachlor (Lasso)	1-3	Pre-plant incorporation and 8 days after transplanting
	Pendimethalin (Stomp)	1-1.5	4-5 days after transplanting
Potato	Simazine (Princep)	0.25	Post-emergence
	Nitrofen	2-2.5	Pre-emergence
	Alachlor (Lasso)	2.5	10 days after sowing
	Metribuzin (Sencor)	0.5	Pre-emergence
	Oxadiazon (Ronstar)	1.5	Pre-emergence
Peas	Linuron (Afalon)	0.5	Pre-emergence
	Alachlor (Lasso)/ Nitrofen	2.0	Pre-emergence
	Pendimethalin (Stomp)	1.5	Pre-emergence
	Fluchloralin (Basalin)	1.5	Pre emergence and pre plant incorporation
Root vegetables	Nitrofen (TOKE-25)	2.0	Pre-emergence
	Linuron (Afalon)	0.5	Pre-emergence
	Oxadiazon (Ronstar)	1.5	Pre-emergence
	Alachlor (Lasso)	1.5-2.0	Pre-sowing incorporation
Okra	Trifluralin (Treflan)	1.0-1.5	Pre-sowing incorporation
	Alachlor (Lasso)	1.25	Pre-emergence
	Fluchloralin (Basalin)	1-1.5	Pre-sowing

Cauliflower	Fluchloralin (Basalin)	1.25	Pre-plant incorporation
	Alachlor (Lasso)	1.5-2.5	Pre-plant incorporation
	Pendimethalin (Stomp	0.75-1.0	Pre-plant incorporation
Cabbage	Trifluralin (Treflan)	1-1.5	Pre-plant incorporation
Onion	Trifluralin (Treflan)	1-1.5	Pre-plant incorporation
	Fluchloralin (Basalin)	0.75	Pre-plant incorporation

Chemical weed control in vegetables shows peculiar environmental and health concerns due to the relatively short growth cycle, fresh edible parts consumed as vegetable. Further, a repeated use of herbicides with similar mode of action may lead to resistance and deterioration of soil texture. Therefore, an Integrated Weed Management System (IWMS) in vegetables should be followed by using preventive cultural weed control methods or an integration of non-chemical and chemical weed control methods. Pre-emergence application of herbicides in vegetables must be followed in combination with atleast one hand weeding.

CHECK YOUR PROGRESS

Give one example of the herbicide used to control weeds

1. Soil fumigant
2. Non-selective herbicide
3. Selective herbicide
4. Pre-planting herbicide
5. Post-emergence herbicide

DEFINE THE FOLLOWING TERMS:

a) Herbicide
b) Non-selective herbicide
c) Contact herbicide
d) Pre-emergence herbicide
e) Foliage applied herbicide

Long answers

1. Why integrated weed management strategy is essential to control weeds in vegetable crops?
2. Suggest pre-emergence/pre-plant herbicides to control weeds in tomato, potato and pea.

USE OF CHEMICALS FOR DISEASE CONTROL

Fungicides: There are two different types of fungicides used to manage diseases namely, protectants and eradicants.

1. **Protectants** deposit on the surface of plants and their mode of action depend upon contact of the chemical with the pathogen. As new growth needs to be protected, growing plants need on-going protectant spray applications. These chemicals generally control a wide range of fungal pathogens.

2. **Eradicants** or curatives are systemic fungicides and are absorbed by the plants. Their mode of action controls pathogens at sites some distance away from where the chemical applied on the plant. These chemicals may move into new growth and therefore do not need to be applied as often as protectants. Unfortunately, because systemic pesticides are specific to the type of fungi they control, their continued use can lead to resistance development in the fungal population e.g. resistance has been developed for downy mildew, powdery mildew and gray mould.

Chemical disease control begins with:

1. **Soil sterilization:** Soil should be sterilized to kill fungi, bacteria spores, insect larvae and pupae and weed seeds. This can be done by using a formaldehyde drench, treating with chloropicrin (a tear gas)

2. **Seed treatment:** The seed is usually treated with captan or thiram or bavistin.

3. Continued application of fungicides or antibiotics on the growing crop plants.

Antibiotics: *Streptomycin is used primarily on bacterial diseases in pepper and tomato. It has been recommended for use on seedlings beds and on potato seed pieces.*

The control measures of diseases of different vegetable crops have been discussed in chapter III.

Table 5: Common fungicides recommended

Common name	Trade name	Dose (%)	Purpose
Captan	Captaf	0.2-0.25	Seed treatment, drenching to control soil borne diseases
Thiram	Hexathir, thiride	0.2-0.25	Seed treatment
Carbendazim	Bavistine, Derosol, JK stein	0.05-0.1	Broad spectrum i.e. seed treatment, control *Sclerotinia, Fusarium, Anthracnose* etc.
Dinocap	Karathane	0.1-0.15	Powdery mildew

Mancozeb	Dithane-M-45, Indofil-M-45	0.2-0.25	Broad spectrum contact fungicides, control late blight of solanaceous vegetables, fruit rot of tomato, Downy mildew, *Rhizoctonia* etc.
Zineb	Dithane-Z-78	0.2-0.25	
Copper oxychloride	Blitox 50, Fytolon, Blue copper	0.3	Broad spectrum fungicide, a substitute to Mancozeb/Zineb, also control bacterial diseases
Bitertanol	Bayleton	0.05	Very effective to control powdery mildew
Hexaconzole	Contaf	0.025-0.05	Powdery mildew, rust, *Stemphylium* etc.
Difenconazole	Score	0.025-0.05	Rust, Alternaria

It is essential to follow integrated disease management (IDM) approach. IDM uses all available management strategies to maintain pest pressure below an economic injury threshold. The principles of pest management should always be based on the integration of basic concepts such as avoidance, exclusion, eradication, protection, resistance and therapy. The adoption of integrated pest management in vegetable crops is of paramount importance as most of the vegetables are not harvested at the end of the crop season rather they are harvested in several pickings e.g. tomato, brinjal, cucumber, pea, beans, okra etc. Furthermore, many of the vegetables are eaten raw, therefore, dependence on chemicals for the control of various pests is a great health hazard to the consumers. The growing awareness regarding pesticide residues, pollution to the environment and sub-soil water and increased problem of pathogen resistance towards the pesticides have forced to shift from the total dependence up on the pesticides and to adopt IPM strategies that would involve one or more than one approach of pest management.

Exclusion: *Preventing pathogens from establishing in the field e.g. use of disease free planting material.*

Eradication: *Plant pathogens can be eliminated through steam pasteurization of field beds or fumigation with formalin to eliminate soil-borne diseases and nematodes.*

Avoidance: *It involves using common sense practices to avoid situations that promote disease development e.g. avoid overhead watering late in the day as it leads to the development of Botrytis.*

Protection/Prevention: *Fungicides can be applied before the appearance of any disease e.g. seed treatment, application of fungicides before the appearance of disease.*

Therapy: *To teat infected plants to prevent further spread of disease e.g. mercuric chloride treatment to control damping off.*

USE OF CHEMICALS FOR INSECT-PEST MANAGEMENT

The chemicals used to control insects are called insecticides. The insecticides are curative in action and are one of the important tools to check the flaring pest populations. Insecticides have been classified into different groups namely, botanicals pesticides, microbial pesticides, insect growth regulators (IGR), synthetic chemical pesticides etc. are in use.

The inorganic insecticides which include cryolite and various types of sulphur are generally not commonly used rather the organic insecticides are preferred these days in vegetable crops. They consist of botanical compound derived from plants and plant parts e.g. pyrethrum and rotenone and various synthetic organic chemicals including chlorinated hydrocarbons, organic phosphates, carbamates and pyrethroids. These last two groups are widely used commercially. Since they kill broad spectrum of insects but have relatively low mammalian toxicity.

Some of the serious limitations of the insecticides have been highlighted in recent years. Out of these, problem of insecticide residues is a major health concern which has cropped up due to indiscriminate use of pesticides. It is essential to adopt need based judicious and safe use of insecticides. In order to avoid contamination of the produce from pesticide residues, use of pesticides having less persistence and the suggested waiting period between last insecticidal application and harvesting should be followed. Among the chemical insecticides, vegetables with less picking interval should be sprayed with insecticides having less waiting period.

Other challenge with pest managers is to minimize the development of resistance in pest species to the pesticides. This can be checked or delayed by avoiding repeated application of same insecticide from the same group. Incorporating botanicals and microbials in management schedule shall prove better in Insecticide Resistance Management Programme (IRM) (Table 6). The control measures of insect-pests of different vegetable crops have been discussed in chapter IV. One should apply the pesticides by taking all safety measures including the protective kit to avoid the direct effect of pesticides to the applicator.

Table 6: Insecticides and miticides for use on vegetable crops

Insecticides	Application rate (per liter of spray solution)*	Target pests	Waiting Period**
Abamectin	0.5ml	Whitefly, thrips, aphid	
Acetamiprid	0.4g	Whitefly, thrips, aphid, leafminer	1
Bifenthrin	0.5ml	Whitefly, aphid, thrips, leafminer	1
Buprofezin	0.8ml	Whitefly, yellow mite	1

Chlorfenapyr	0.5ml	Mite	
Cypermethrin	0.5 ml/ 1 ml	Aphid, thrips, mealybug, borer	2
Dicofol	1ml	Mite	2
Flufenoxuron	1-1.5ml	Thrips, mite	
Fluvalinate	2-3ml	Mite	
Imidacloprid	0.2ml	Aphid, thrips, whitefly, leaf miner	
Lambda cyhalothrin	1ml	Caterpillars, aphid, whitefly	
Malathion	2ml	Bugs & other sucking pests	7
Novaluron	1ml	Catrepillars	
Profenofos	1ml	Whitefly, thrips, caterpillars	3
Propargite	2-3ml	Mites	1
Spinosad	1ml	Whitefly, leafminer, aphid, caterpillars	1
Spiromesifen	1 ml	Mite and whitefly	
Thiamethoxam	0.3 g	aphid, whitefly, thrips	1
Triazophos	2ml	Mite, thrips, aphid, leaafminer	10

** based on the effective dose worked out on the basis of research findings of various researchers*

*** Waiting period after last application of pesticide to harvesting as recorded on different vegetable crops under field conditions*

As discussed earlier, integrated pest management (IPM) is also a sustainable strategy to manage insect-pests. IPM is a systematic approach to manage pests that combines a variety of techniques and strategies to either reduce pest populations or lessen their economic impact. It is a site-specific strategy for managing pests that relies on correct pest identification and understanding the pest biology. With a long-term perspective, it is easier to see that an investment in IPM can pay for itself in a higher-quality crop and a cleaner environment.

CHECK YOUR PROGRESS

1. Which group of insecticides kill broad spectrum of insects and has relatively low mammalian toxicity?
2. What is the serious limitation of insecticide use in vegetable crops?
3. What care one has to take to avoid contamination of produce from pesticide residue?
4. Name any two insecticides which can control white fly.

5. Which insect (any one) can be controlled by spraying cypermethrin?
6. Name the chemical which is used for soil sterilization?
7. Which fungicide is used for seed treatment?
8. Mention two fungicides with broad spectrum behaviour.
9. Which fungicide is used to control powdery mildew disease?
10. Name the antibiotic which is used to control bacterial diseases?

GROWTH REGULATORS

What are plant hormones?

Plant hormones are the organic substances which are produced naturally in the plants, controlling growth and other physiological functions at a site remote from its place of production and active in minute amounts. They are termed as phytohormones. These plant hormones control cellular processes in targeted cells. Plant hormones regulate the upward and downward growth of tissues, leaf formation, stem growth, fruit development and ripening, plant longevity and even plant death. Therefore, hormones are vital to plant growth and are also called as growth factors or growth hormones. These hormones usually move within plant from a site of production to the site of action.

Plant hormones may be defined as organic compounds other than nutrients, which in small amount promotes/ inhibits or otherwise modify any physiological response in plants. Plant hormones are naturally produced within plants. Similar chemicals are also produced by fungi and bacteria which can affect plant growth. A large number of related chemical compounds are artificially synthesized to regulate the growth of different plants both under open field conditions and artificial or laboratory conditions. These man made compounds are called Plant Growth Regulators or PGRs. The external application of these substances on plants can bring about modification by improved seed germination, rooting, better plant growth, better fruit set, increased rate of ripening and increased yield.

Classes of plant hormones

In general, there are five main classes of plant hormones. Each class has stimulatory as well as inhibitory action. These five major classes of plant hormones are:

1. Auxins
2. Gibberellins
3. Cytokinins

4. Absciscic acid
5. Ethylene

1. **Auxins:** Auxins positively influence root initiation, stem elongation, bud formation, fruit development and apical dominance. Auxins promote the production of other hormones and in combination with cytokinins, control the growth of stems, roots, and fruits, and convert stems into flowers. They also promote lateral and adventitious root development and growth. e.g. Indolacetic acid (IAA), Indol butyric acid (IBA), Napthalene acetic acid (NAA), 2,4-dichloro phenoxy acetic acid (2,4-D) etc.

2. **Gibberellins:** They are active in regulating dormancy, flowering, fruit setting and stimulating seed germination and extending growth of shoots after seed germination. They stimulate cell division or cell elongation or both especially in genetically dwarf species, beans, peas etc. Gibberellins also reverse the inhibition of shoot growth and dormancy induced by ABA. e.g. Gibberellic acid (GA).

3. **Cytokinins:** They have similar effects as those of gibberlins in breaking the dormancy of a wide range of seeds and in increased fruit set. They mainly stimulate cell division, and prevent chlorophyll degradation. They also help in delaying senescence or the aging of tissues. They are responsible for mediating auxin transport throughout the plant and affect internodal length and leaf growth. Cytokinins counter the apical dominance induced by auxins. They in conjunction with ethylene promote abscission of leaves, flower parts, and fruits. e.g. Kinetin, Zeatin.

***Inhibitors:** These are the diverse group of plant growth substances that inhibit or retard the physiological processes in plants. ABA is the most common naturally occurring inhibitor. It has been reported to act as anti auxin, anti gibberlin or anti cytokinin.*

4. **Ethylene:** It plays an important role in the ripening of fruits, inhibition of root growth, and abscission or the shedding of plant parts etc. Ethylene is also known to play a role in seed and bud dormancy, induction of roots, flowering, and stem elongation. e.g. ethylene.

5. **Abscisic acid (also called ABA):** It is involved in the abscission of plant organs, retardation of vegetative buds, regulation of fruit ripening and generally in reduction of growth. It accumulates within seeds during fruit maturation and prevents seed germination within the fruit. In plants, ABA plays important role in closing the stomata under water stress. e.g. abscisic acid.

Table 7: List of hormones and their physiological responses

Effects	Auxin	Gibberlins	Cytokinin	Abscisic acid	Ethylene
Cell elongation	+	+	+	_	_
Cell division	+		+		_
Apical dominance	+		_		
Leaf length		+			
Leaf breadth			+		
Chlorophyll formation			+		
Vein elongation	+				
Leaflet movement	+				
Root formation	+				
Abscission	_	_		+	+
Inducing maleness	_	+		_	
Inducing femaleness	+		+		+
Fruit growth and division	+	+	+	+	+
Xylem formation	+	+			
Flower	+	+	+	_	+
Breaking seed dormancy		+	+	+	+
Breaking bud dormancy		+	+	+	+
Senescence		_	_	+	+
Tropism	+	+		+	

Where, *'+ sign' represents promote and '- sign' represents inhibition*

Table 8: Practical utility of plant growth hormones

Class	Practical utility
Auxins	Promote lateral and adventitious root growth, stimulate stem elongation, flower formation and fruit development
Gibberellins	Increase seed germination, shoot length, flowering, fruit setting and fruit size

Cytokinins	Delay aging of tissues i.e. prolonged storage life of vegetables, stimulate bud initiation and root growth
Ethylene	Induce uniform ripening in fruit and vegetables
Abscisic acid (ABA)	Promote flower production by shortening internodes and regulate fruit ripening

Non-traditional plant hormones: These are present in some plant species, not universally available in all plant species. These are

1. **Aromatic compounds:** They include phenols and benzoic acid to the polymeric tannins, the cinnamic acid, the commarins and the flavanoids. They affect flowering and such other physiological characteristics. The commarins are strong inhibitors of seed germination.
2. **Nitrogen containing compounds** *e.g.* colchicines
3. **Terpenoid compounds** *e.g.* monoterpene essential oil (growth inhibitor), α-methylene lactones (both growth inhibitor and root stimulator)
4. **Aliphatic alcohols** *e.g.* Tricontanol
5. **Triazoles:** It is a new type of plant growth retardant and has a great broad spectrum retarding ability e.g. Paclobutrazol, uniconazol, triapentanol etc.
6. **Polyamines:** They are essential for cell division, normal morphology and hence plant development.

Mechanism of hormone action: The responses to plant hormones have bearing on the mechanism of hormone action

1. Increased plasticity of the shoot and elasticity of the root wall
2. Increased permeability to water
3. Enhanced capacity to retain water
4. Decrease in protoplastic viscosity.
5. An accelerated rate of respiration and cyclosis.
6. More rapid synthesis of protein, with lowered levels of free amino acid.
7. Increase in monosaccharides at the expense of reserve polysaccharides

Growth retardants: They are new type of organic chemicals which in general check the rate of growth without any adverse effect. They may retard cell division and cell elongation, and thus plant height is affected without causing mal formation of leaves and stems e.g. CCC (Chlorocholine chloride). The main advantages of growth retardants are

1. Control of lodging
2. Reduction in vegetative growth
3. Increase in chlorophyll biosynthesis and photosynthesis
4. Delay in leaf senescence
5. Improving the quality of seedlings used for transplanting
6. Resistance against low temperature stress
7. Resistance against fungal infection *e.g. Fusarium* wilt in watermelon

Role of Plant Growth Hormones in Vegetable Production:

The chief purpose of using plant growth regulators is to optimize plant production by modifying growth, development, stress behavior, and yield of vegetable crops. The synthetic plant growth regulators cause their effects through changing the endogenous level of naturally occurring hormones and hence modifying growth and development of plants in the intended direction and to a desired extent. Their role in hardening of seedlings raised through biotechnology before transferring to the open field conditions deserves special mention. The plant regulators carry following benefits:

Benefits of Using PGRs

- Better seed germination
- Improved plant establishment
- Increased root development
- Efficient nutrient uptake
- Healthy and vigorous crop
- Better fruit set
- Increased retention of flowers and fruits
- Bigger and shining produce
- Breaking seed dormancy
- Helps in modifying sex expression
- Induction of dormancy (CIPC treatment in Potato)
- Enhanced keeping quality
- Enhanced tolerance to stress conditions
- Significant increase in yield

During recent years, the interest in vegetable production has increased rapidly because of good price realization and its role in nutritional security. The increase in the production of vegetable crops has been achieved by adopting improved varieties, efficient use of chemical fertilizers and better agronomic practices. Besides, growth regulating chemicals are also becoming important as they modify crop growth, flowering, fruiting and vegetable production.

The reports of various research workers on the effects of synthetic growth regulators on different growth parameters of some of the important vegetable crops are discussed hereunder:

1. **Tomato:** Under normal growing conditions, fruit set in tomato is not a problem. However, during off-season cultivation in hot summer months and winter season result in considerable reduction in yield. Tomato varieties namely, HS-102 and TAMU Saladatta can set fruits at high temperature conditions. On the other hand, varieties like Pusa Sheetal and Cold Set can give fruits during winter. Foliar application of PCPA 50 ppm (50 mg in one litre of water) in combination with covering of tomato plants under polythene bags during cooler months has resulted in early and high yield during early spring summer season. Similarly, spray of cycocel (500 ppm) before onset of frost induce regeneration in frost damaged tomato plants and also results in maximum fruit set and yield. In another study, application of Parafen (sodium salt of p-chlorophenoxy acetic acid 4-PCPA) at 30 ppm in winter and early spring under poor natural light conditions, improved fruit formation, ripening and fruit yield.

   During summer season, foliar application of PCPA (50 ppm) or Ethrel (250 ppm) at turning stage of fruits accelerated ripening, produced early fruit yield, and also improved the fruit quality (vitamin C, T. S.S. and lycopene content). In the green house under high temperature (with day/night temperature of 30/18°C) conditions, applications of benzyl adenine (BA) at 10 ppm alone or in combination with gibberlin (GA_4+7) at 25 ppm increased fruit set and yield. Thus, growth regulators help in promoting off- season tomato cultivation which is more remunerative.

2. **Chilli:** High temperature in early flowering stage of chilli causes heavy flower and fruit drop. Spray of Planofix (α-NAA formulation) @ 100 ml/ 450 litres of water per hectare or NAA (50 ppm) or Paclobutrazol (300 ppm) or 2,4-D (2 ppm) at flowering stage followed by second spray three weeks after the first spray reduces flower drop and thus, improve fruit set and yield. Similarly, spray of NAA @ 50 ppm or planofix @ 10-20 ppm or tricontanol @ 2 ppm at full flowering stage enhance fruit set at higher temperature in chilli. Application of 400 ppm etherel enhanced the fruit setting and fruit quality in both winter and summer crops.

3. **Bell Pepper:** Two foliar sprays of NAA (10 ppm) at flower initiation followed by another spray after 15 days reduced the flower drop and improved fruit set and fruit size. The treatment with 2,4-D (2 ppm) at

fortnightly interval during the flowering season of winter grown sweet pepper (transplanting in December) increased flowering in the winter crop. The application of Mixtalol (containing tricontanol) at 3.0 ml/liter to young plants (3 fully expanded leaves) and to flowering plants gave the highest increase in plant growth and yield.

4. **Brinjal:** There is a problem of reduced fruit set in brinjal as it bears four type of flowers namely, true short style, pseudo short style, medium style and long style. Of these, true and pseudo short style flowers do not bear fruits while there is only 30-60 % fruit set in medium and long style flowers. The beneficial effects of growth substances on fruit set in brinjal has been observed by using PCPA (20 ppm), 2,4-D (2.5 ppm) and NAA (60 ppm). Also, application of cytozyme crop plus thrice at 3, 6 and 9 weeks after transplanting have proved beneficial.

5. **Potato:** The freshly harvested tubers have a rest period for 8 weeks and as a result fail to sprout if sown immediately. This dormancy can be broken by dipping tubers in 5ppm solution of GA_3 for 10 seconds or in acquous solution of thiourea for one hour followed by dipping in 2 ppm solution of GA for 10 seconds or in thiourea (sodium potassium thiocynate) @ 1-2% solution for one to one and half hours. In other studies, spray of ascorbic acid (100 ppm), borax (25 ppm) and cytozyme crop plus (0.2%) on the standing crop have also improved tuber yield significantly.

6. **Onion:** Onion bulbs are harvested during the late April-May and at that time there is a glut of onion bulbs in the market. Many a time, the prices slash to the extent that farmers are even unable to get the input costs. Therefore, it is important to enhance the shelf-life of onion bulbs in the storage. Sprouting is the major problem in storage which spoils the bulb quality. Spray of maleic hydrazide (MH) @ 1500-2000 ppm (first mix in boiling water and later add normal water) or borax (1000-1500 ppm) or iron sulphate (1000-1500 ppm) about 15 days before harvesting is recommended for checking the sprouting of bulbs during storage. It is important that at the time of spray, the leaves of the crop have not dried up. Onion seed germination has been improved by soaking seed in NAA or IBA at 10 mg/litre of water.

7. **Garlic:** Foliar spray of Gibberellic acid (50 ppm) after one month of planting garlic cloves increase the bulb diameter and also bulb yield. Similar to onion, sprouting in storage is a serious problem in garlic which can be reduced by spraying MH (1500-3000 ppm) or borax (1000-1500 ppm) or iron sulphate (1000-1500 ppm) about 2-3 weeks prior to harvesting. NAA (50-80 ppm) also inhibited sprouting in storage. Application of paclobutrazol (5 ppm) and cycocel (1000 ppm) has been effective in accelerating crop development and increased bulb yield.

8 **Cole crops:** Foliar spray of Cytozyme (0.2%) after 15 and 30 days of transplanting of seedlings has improved curd, head and knobs yield significantly. It also hastened early curd and head formation in cauliflower and cabbage, respectively. Application of GA4+7 (80 mg/liter of water) has resulted in curd

initiation at high temperature besides early harvest and larger crud diameter. Treatment of cauliflower seedlings with NAA (10 ppm) as starter solution has been found effective in enhancing plant stand in the field along with vegetative growth.

9. **Cucurbits:** Cucurbits, in general, bears monoecious flowers i.e. male and female flowers are present separately on the same plant. Though sex expression and sex ratio are varietal characteristics but they are influenced by environmental conditions. Low fertility, high temperature, and long light periods induce maleness. Exogenous application of plant regulators can modify the sex ratio and sequence in the desired direction, if applied at 2 or 4 leaf stages (critical stage at which either sex can be suppressed or promoted). Application of different growth regulators and other chemicals at 2 and 4 leaf stages have been found effective to enhance number of female flowers, early harvest, more number of fruits/plant and high fruit yield of the following cucurbits:

   a) Cucumber: GA_3 (5-10 ppm), ethereal (CEPA- 2chloroethylphosphonic acid) @ 50-250 ppm and NAA (100 ppm)

   b) Watermelon: Tri-iodo benzoic acid (TIBA) @ 25-50 ppm and GA_3 (25 ppm)

   c) Muskmelon: Ethrel (500 ppm)

   d) Bottle gourd: NAA (25 ppm), ethrel (250 PPM), boron (3 ppm) and calcium (5 ppm)

   e) Bitter gourd: GA_3 (5-10 ppm) and BA (25 ppm)

   f) Pumpkin: Etheral (250 ppm)

   g) Ridge and sponge gourd: Etheral (100 ppm)

   h) Round melon: MH (50 ppm)

   Under green house conditions, application of NAA (30-100 ppm) or ethereal (250-500 ppm) first at 4-5 leaf stage and second just before bud initiation in cucumber has resulted in production of female flowers on lower nodes and early flowering.

   The use of plant growth regulators in increasing the fruit yield is successful only in those cucurbitaceous vegetable crop in which the immature edible fruits are harvested from a vine very frequently than those cucurbitaceous crops in which the fruits are retained on the vine for longer duration till repening as in muskmelon, watermelon and pumpkin.

10. **Summer squash:** As discussed above, under natural conditions, male flowers appear early while female flowers appear late and in less numbers. Therefore, in order to improve fruit set during early February and March foliar application of Ethrel (250 ppm) at 2 and 4 true leaf stage of plants have resulted in early harvest, increased number of fruits and total fruit yield.

11. **Garden pea:** Improvement in the yield of pea cv. Bonneville has been observed by seed treatment along with foliar application of cytozyme crop plus (0.2%). Application of GA_3 (50 ppm) twice at 30 days after sowing and again 15 days later has been found effective in increasing early and total yield. Drought resistance along with yield was increased by using chlormequat (Chlorocholine ccloride, CCC) either as soil application at 6 kg/ha or as seed treatment with 1% solution or as foliar spray at 3-6 kg/ha (at flower bud development). Seed soaking for 24 hours in Planofix (50 ppm) has also resulted in good plant growth and high green pod yield.

12. **Sweet potato:** Application of ethephon (250 ppm), CCC (50-150 ppm), Kinetin (50-100 ppm) and GA_3 has resulted in higher tuber yield.

13. **Okra:** Seed treatment with cycocel (100 ppm) for 24 hours followed by foliar application on 20th and 40th days after sowing has resulted in highest fruit set and yield. Seed treatment with GA_3 (45 ppm) has increased the plant height, flowering and fruit yield. Soaking the seeds for 24 hours in GA_3 at 10 mg/litre or IAA at 100 mg/litre or NAA at 100 mg/litre of water has enhanced the seed germination.

14. **French bean:** Spray of PCPA @ 2ppm or NAA 5-25 ppm induces pod formation when pods do not set normally at prevailing temperatures.

Table 9: List of growth regulators along with their important uses in vegetable crops.

S. No.	Growth Regulators	Conc. (mg/l)	Method of application	Crops	Attributes affected
1	Cycocel (CCC)	250-500	Foliar sprays	Cucurbits, tomato, okra	Flowering, sex-expression, fruit yield
		250	Seed treatment	Okra	Resistance to salt, high fruit yield
		250	Seedling treatment	Tomato	Resistance to virus, and high yield
2	Isopropyl-N(3-chlorophenyl)	5000	Dust or tuber	Potato	Storage at room temperature
3	p-chlorophenoxy acetic acid (PCPA)	50	Foliar spray	Tomato	Fruit set, and high yield
4	2,4-diuorophenoxy acetic acid	0.5	Foliar spray	Tomato	Fruit set, and high yield

5	Ethephon (CEPA)	100-500	Foliar spray	Cucurbits, okra, tomato	Flowering, fruiting, sex-expression and yield
		1000	Pre-harvest	Tomato, chillies	Fruit ripening, earliness and yield
		2000	Post-harvest	Tomato, chillies	Fruit ripening
6	Ethylene chlorophydrin	(1l/20g)	Vapour treatment	Potato	Breaking dormancy
7	Gibberellic acid (GA)	1	Tuber dip	Potato	Breaking dormancy
		10	Foliar sprays	Watermelon, tomato	Sex expression, fruiting yield
		40-100	Seed or foliar	Okra, tomato, brinjal	Seed germination, fruit set and yield
8	Indole acetic acid (IAA)	10-15	Seed or foliar	Spinach, fenugreek, okra, tomato, brinjal, cowpea, onion	Seed germination, fruit set and yield
9	Indole butyric acid (IBA)	0.2	Seedling roots	Cabbage, cauliflower	Seedling set, growth and yield
		25-100	Foliar sprays	Lettuce, Chinese cabbage	Growth and yield
		250	Foliar sprays	Cowpea	Fruit set and yield
10	Maleic hydrazide (MH)	25	Foliar spray	Peas	Growth and yield
		50-150	Foliar spray	Cucurbits	Flowering, sex-expression and yield
		2500-3000	Foliar sprays	Onion and garlic	Reducing storage losses
11	Mixtallol	2	Foliar sprays	Tomato, chilli, brinjal, potato	Flowering, fruit set and yield

12	Methyl ester of NAA	5000	Cluster tuber dip	Potato	Improving shelf life
13	Naphthalene acetic acid (NAA)	0.2	Seedling roots	Cauliflower, cabbage, tomato, brinjal, onion	Seedling set, growth and yield
		10-20	Foliar sprays	Chillies, tomato	Flower drop, fruit set and yield
		25-30	Seed/ foliar	Okra, tomato, brinjal, onion, cucurbits	Seed germination, growth and yield
		100	Foliar sprays	Cabbage, cauliflower	Plant growth and yield
14	Naphthoxy acetic acid (NOA)	25-100	Seed/foliar	Tomato, okra	Germination, growth and yield
15	2,4,5-tri chloro phenoxy-acetic acid (2,4,5-T)	75-125	Foliar sprays	Potato	Improving shelf life
16	Silver nitrate	500	Foliar sprays	Cucumber	Induction of male flowers in gynaecious lines
17	Silver thiosulphate	400	Foliar sprays	Muskmelon	Induction of male flower in gynoecious lines
18	2,3,5- Triiodobenzoic acid (TIBA)	25-50	Foliar sprays	Cucurbits	flowering, sex expression and yield
		700	Foliar sprays	Soybean	Fruit set and yield
19	Triacontanol	2	Foliar sprays	Chilli, peas	Fruit set and yield
20	Thiourea	1000	Tuber dip	Potato	Breaking dormancy

Use of Plant growth Regulators in abiotic stress management: Seedling dip treatment in Cycocel (0.5-1.0 %) for 10-12 hours before transplanting in saline soils has raised the capacity of plants to tolerate salinity and increased the yield of vegetable crops. Similarly in dry conditons, foliar spray of Cycocel (250 ppm) at vegetative growth stages of plants in vegetable crops has made the plants to sustain drought conditions and has increased the yield.

Use of growth regulators in hybrid seed production: Growth regulators can be used as an aid in hybrid seed production. Use of ethephon has been used for producing temporary female lines in some cucurbits. Successful F_1 hybrid in squash has been made by using female line produced with ten weekly sprays of ethephon. Plant growth regulators have also been used for maintenance of gynoecious lines. In cucumber, GA_3 sprays have been made to induce female flowers in gynoecious lines. Silver nitrate at 500 mg/litre has been reported to be as effective as GA_3 in inducing male flowers on gynoecious lines of cucumber. However, in muskmelon, foliar sprays of Silver thiosulphate at 400 mg/litre has been found the best for induction of male flowers on gynoecious lines.

CHECK YOUR PROGRESS

Fill in the blanks:

1. Artificially synthesized chemicals used to regulate the growth of different plants are called_______________.
2. The most common auxin found in plants is ______________________.
3. Seed dormancy is regulated by ______________________.
4. _____________________ prevent chlorophyll degradation.
5. Seed dormancy is a problem in _____________ crop and can be broken by using ___________________.
6. Fruit set in tomato under sub-optimal temperature conditions can be enhanced by using _______________________.
7. Sex expression in cucumber by inducing more female flowers can be achieved by spraying ___________________ .
8. Fruit set in chilli can be improved by the application of _________________.
9. In order to improve fruit set during early February and March in summer squash, application of _____________ is effective.
10. Sprouting is a major problem in storage of onion which can be suppressed by spraying __________________ atleast 15 days before harvesting.

Name the growth regulator which has its role in following physiological process of plants:

1. Increasing average fruit weight and number of fruits/plant in tomato.
2. Enhance fruit set in bell pepper
3. Promote flowering in brinjal
4. Prevents seed germination within fruit
5. Enhancel capacity of vegetables to tolerate salinity
6. Produce temporary female lines in some cucurbits
7. Curd initiation at high temperature in cauliflower

Long answers

1. Define plant hormones and plant growth regulators. Enlist different classes of plant hormones along with their functions.
2. Explain the mechanism of hormone action.
3. What are growth retardants? What are their advantages?
4. What are the benefits of using PGRs? Enlist them.
5. Explain the role of PGRs in fruit set of solanaceous vegetable crops under sub-optimal temperature conditions.
6. PGRs modify sex expression in cucurbits. Justify your statement by giving few examples.
7. Suggest some PGRs with their application rate and stage of application in enhancing yield and other attributes in garden pea and okra.
8. What precautions should be taken into account while applying plant growth regulators?

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★★★

Chapter-7

Seed Production of Techniques Vegetable Crops

OBJECTIVES

Students will be able to learn about :-

- Basic principles of seed production of vegetable
- Techniques of vegetable seed production
- Post harvest processing of vegetable seeds

INTRODUCTION

Seed is the most vital input for vegetable crop production. Most of the vegetable crops have to be started from seed. The production of vegetable seeds requires skill, knowledge and specialization. The efficacy of other inputs like fertilizer, irrigation, weedicide, pesticides, harvesting and processing revolves around the use of good quality seed. A good quality vegetable seed must confirm the following:

1. Genetically pure
2. Physiologically pure
3. Physiologically viable
4. Free from weed & other crop seed
5. Free from pest & disease

Successful & quality seed production of a crop depends on thorough knowledge of the reproduction process of a particular crop. The technique of seed production must take into account several features of reproduction whether sexual (by seed) or asexual (vegetative method). Production technology for seed varies from location to location and from crop to crop. It also depends on pollination behavior. Vegetable crops can be classified as follows based on pollination behaviour:

1. **Self pollinated vegetable crops:** Pollen from an anther may fall on stigma of the same flower leading to self pollination. Examples of self pollinated vegetable crops are tomato, lettuce, peas, beans. Some of the essential conditions for self-pollination are :

    a. ***Bisexuality:*** In this both male and female reproductive organs are present in the same flower. Without this condition self-pollination is never possible.

b. ***Homogamy:*** This is the condition in which anthers and stigmas of a bisexual flower mature at the same time resulting in self-pollination.

c. ***Cleistogamy:*** In this condition the bisexual flowers never open and therefore, self-pollination is only the way of pollination, e. g. lettuce.

2. **Cross pollinated vegetable crops:** The majority of cultivated vegetable crops are cross pollinated. Pollen from flower of one plant is transferred to stigma of another plant which is called cross pollination. Examples of cross pollinated vegetable crops are cole crops, cucurbits radish, carrot, beet, amaranthus etc. Nature favours cross-pollination and the agencies which help in bringing cross-pollination in flowers are:

- Air (Anaemophily), e.g. Amaranthus, spinach, beet
- Insects (Entomophily): All cucurbits, all brassica, onion, carrot

There are many reasons which favour cross-pollination in the crops, some of which are listed below:

a. ***Dicliny:*** Dicliny or unisexuality is a condition in which either staminate (male) or pistillate (female) flowers occur on the same plant or on different plants, e. g. cucumber, watermelon, pumpkin, squash, asparagus etc.

b. ***Dichogamy:*** The stamens and pistils of hermaphrodite flowers may mature at different times facilitating cross-pollination, e.g. sweet corn, sugar beet etc.

c. ***Self-incompatibility:*** It refers to the failure of pollen from a flower to fertilize the same flower or other flowers on the same plant, e.g. cabbage, cauliflower, mustard, cole crops, root crops etc.

d. ***Male sterility*****:** Male sterility refers to the absence of functional pollen grains in otherwise hermaphrodite flowers. Male sterility is not very common in natural populations but is of great value in production of hybrid seed.

3. **Often cross pollinated vegetable crops:** In some vegetables crops, cross pollination often exceeds 5 % and may reach upto 50%. Example of cross pollinated vegetable crops are brinjal, okra, chilli, capsicum

Principles of vegetable seed production

Production of genetically pure and quality vegetable seed requires high technical skill and specialization. The producer should be familiar with genetic and agronomic principles of seed production.

During the course of seed production, it is necessary to ensure that the product is true-to type. Genetic purity of a variety can deteriorate due to several factors during production cycle. The important factors of apparent and real deterioration of varieties are as follows:

a. Developmental variations

b. Mechanical mixtures

c. Mutations

d. Natural crossing

e. Minor genetic variation

f. Selective influence of diseases

g. Technique of the plant breeder

Of these, mechanical mixture, natural crossing and selective influence of diseases are perhaps the most important reasons of genetic deterioration of varieties during seed production followed by raising the seed crops in areas outside their adoption which may cause developmental variations and genetic shifts in varieties.

It is very important to maintain genetic purity. For the maintenance of varietal purity various methods have been suggested. The important safeguards for maintaining genetic purity during seed production are:

i) **Control of seed source:** The use of seed of an appropriate class and from an approved source is necessary for raising the seed crop. Four classes of seeds, namely, breeder's, foundation, registered and certified seeds have been defined by the Association of Official Seed Certification Agencies (AOSCA) :

   Breeder's seed: Breeder's seed is the genetically pure seed produced by the concerned breeder or by the institution which is used for the production of foundation seed.

   Foundation seed: Foundation seed is also genetically pure seed produced from breeder's seed under strict supervision. Foundation seed is the source of registered and/or certified seed.

   Registered seeds: The progeny of foundation seed that is handled to maintain satisfactory genetic identity and purity and that has been certified by the certifying agency. This class of seed is suitable for production of certified seed.

   Certified seed: Certified seed is the progeny of foundation seed. Certified seed is so handled as to maintain satisfactory genetic identity and purity and that has been approved and certified by the certifying agency.

ii) **Crop rotation:** Satisfactory intervals between related or similar crops is required to minimize the risk of plant material or dormant seeds remaining from the previous crops, which are likely to cross-pollinate or make admixture with the planned seed crop. In addition to these, the reasons for crop rotation include plant nutrition, maintenance of soil physical condition and minimizing the risk of soil-borne pests and diseases. In practice, therefore, attention must be paid to the numbers of years since a related crop was grown in the same soil.

iii) **Isolation:** One major factor during the course of seed production is to ensure that the possibility of cross-pollination between different plots or fields is minimized. Adequate isolation also assists in avoiding admixture during harvesting and the transmission of pests and pathogens from alternative host crops. Vegetable seed crops can be isolated by time and by distance. In isolation by time system seed production is arranged in such a manner that the cross-compatible varieties are grown in successive years or seasons provided the rules regarding rotation are applied. When isolation by time is not possible, then isolation by distance is to be followed. Isolation distance primarily depends on the nature of pollination of the crop. In general, highly cross-pollinated (by insects) vegetable crops like onion, radish, cabbage, cauliflower and cucurbits require isolation distance of 800-1000 meter while wind pollinated vegetables like spinach, beet require isolation distance of about 2000 meters. Isolation distance also varies according to category of seeds like foundation and certified seeds.

iv) **Rouging of seed crop:** The existence of off-type plants in the seed crop is a potential source of genetic contamination. The removal of such plants is termed as rouging. Not only the off-types but the diseased and abnormal plants are also to be removed. The number of rouging required for the seed crop will vary with the kind of vegetables, purity of the seeds sown, nature of the previous crop etc. Rouging may be done at the three stages as soon as the off-types are recognizable: Vegetative stage, flowering stage and maturity stage.

v) **Seed certification:** The genetic purity in the commercial seed production is maintained through a system of seed certification. Seed certification implies that the crop and seed lot have been duly inspected and that they meet requirement of good quality pedigree seeds. To achieve this purpose, qualified and well-trained personnel of seed certification agencies carry out field inspection at appropriate stages of crop growth. The field standards include land requirements, isolation requirements, maximum permissible off-types etc are taken into consideration while certification is done.

vi) **Grow-out tests:** Varieties being grown for seed production should periodically be tested for genetic purity by grow-out tests to make sure that they are being maintained in their true form.

ACTIVITY:

1. Collect flowers having bisexuality, homogamy, cleistogamy from the vegetable garden / field nearby.
2. Visit seed production plot of any vegetable crop and identify offtype, disease and pest infected plants in the field and suggest rouging practice.

CHECK YOUR PROGRESS

Match the followings

	A		B
1.	Self-incompatibility	a.	Onion
2.	Anaemophily	b.	Lettuce

3.	Cleistogamy	c.	Amaranthus
4.	Entomophily	d.	sugar beet
5.	Dichogamy	e.	cole crops

Seed production methods of vegetable crops

Vegetable seed growing is a highly specialized job. It needs specific knowledge and skill to be conversant with various aspects of seed production. Most of the vegetable crops produce seed satisfactorily in dry climate. But some crops like cabbage, late varieties of cauliflower and European varieties of root crops require cool climate for their seed production. After harvesting, threshing and drying, seed is subjected to processing. The objective of processing is to maintain and improve various quality factors such as physical purity, germination, vigour and storability. This is done by removing various impurities and undesirable material such as inert matter, broken, immature, rotten, diseased and insect damaged seeds, weed seeds and seeds of other crops. Processing includes cleaning, grading, treating and packaging.

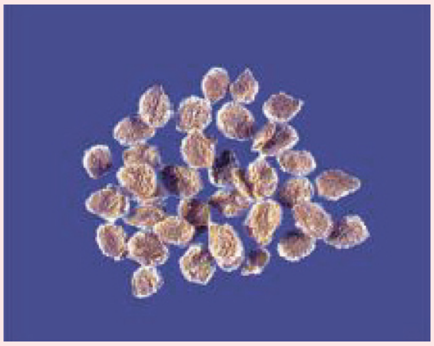
Solanaceous vegetables

Tomato, brinjal, chilli and capsicum are grouped under solanaceous vegetables and out of this tomato is self pollinated and brinjal, chilli and capsicum fall under category of often cross pollinated vegetables. The method of cultivation for seed production is nearly the same as that of cultivation for fruit production. Individual plants with good fruiting are marked and ripe fruit are collected for seed purpose. Rouging of seed crop throughout the crop period is a must to maintain the true-to-type plants.

In tomato, the extraction of seed from ripe fruit is done by fermenting the crushed fruits for 1–2 days and then putting it in water, so that the seeds settle down and pulp and skin float which are easily separated. Seed separation can also be done using commercial HCl. It takes only about half an hour's time, after which the seeds are cleaned up and dried. Sometimes alkali method is also used to separate out the seeds from pulp. In this method, the pulp containing seeds is mixed with 10% washing soda in equal quantities and kept in an earthen vessel for about 12 hours. Thereafter, seeds are washed with water and dried. The quantity of fruit required to produce 1 kg tomato seed varies from 160–210 kg, depending on the variety. On an average 100–150 kg/ha tomato seed can be obtained.

In brinjal, the ripe and yellow fruits are crushed and stored for overnight and the seeds thereafter are washed, sieved and dried. About 200–300 kg seeds can be obtained from a hectare of brinjal crop. Acid method can also be used for seed extraction in brinjal.

In chilli and capsicum, the ripe fruits are harvested and dried. Drying can be done by spreading the fruits under the sun which may take 10–15 days time, depending on the light intensity or the fruits can be dried in hot-air oven at about 54.4°C in 2–3 days. The seeds are extracted by breaking open the dried fruits by hand. On an average about 200–300 kg/ha of seeds in chilli and about 100–150 kg/ha of seeds in capsicum can be obtained.

		
Tomato seeds	**Brinjal seeds**	**Chilli seeds**

Do you know?

- *One gram of tomato seed contain 250 - 300 seeds,*
- *One gram of brinjal seed contain 200 - 250 seeds*
- *One gram of Chilli and capsicum seed contain 150 - 200 seeds*

Cole crops

Cauliflower, cabbage, knol-khol are major vegetables of cole crop group and these vegetables are highly cross pollination in nature. The method of cultivation of seed crop of cole crops is nearly the same as that of cultivation for head/curd production. Rouging of seed crop throughout the crop period is essential to maintain true-to-the type plants. The specified isolation distance must be adhered to strictly for maintaining the purity of seed.

Since cole crops are basically cool season crops, they require low temperatures for flowering and seed setting. Hence their seed production is restricted mainly to hilly areas. Early and mid season varieties of cauliflower, however, can flower and produce the seeds in different parts of the plains. The methods of seed production in cole crops are:

Seed-to-seed method: The plants with good curd are left in the field, where they flower and produce seeds. But this method occupies a lot of area because selected plants for seed production are left scattered in the field. However, in early cauliflower, this method yields relatively better quantity and quality of seeds. The seeds ripen from March to May.

In cabbage, the transplanting is done in last week of September and seeds are ready by May–June next year. Cabbage is biennial in nature. In the first year, the heads are formed and the next year seeds are produced. It requires chilling temperature (4.5-10°C) for about 30-60 days for seed production. Because of it, the cabbage seed cannot be produced in plains.

Head-to-seed method: The selected heads of cabbage or curds of cauliflower are uprooted carefully and replanted in a compact block for seed production. While transplanting, a spacing of *75cm × 75cm* may be maintained. In cauliflower, at the time of transplanting, a scooping or incision in the middle of the curd is given to facilitate the growth of side stalks which permit better quality seed production.

Stump method: The heads are cut just below the base by a sharp knife, keeping the stem with the outer leaves intact. The beheaded portion is called stump. In the following season when the dormancy is broken, the buds sprout from the axis of all the leaves and leaf scars. In this method though the seed yield is more, the flower shoots require heavy staking otherwise they breakdown easily during intercultural operations.

Stump with central core intact method: The heads are chopped on all sides with downward perpendicular cuts in such a way that the central core is not damaged. During the last week of February and till 15th March when the heads start busting, two vertical cross cuts are given to the head taking care that the central growing point is not injured.

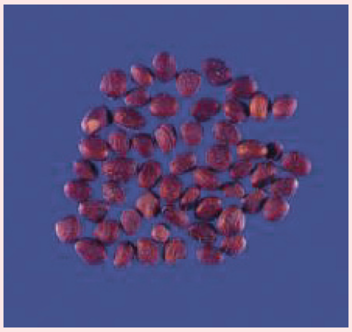
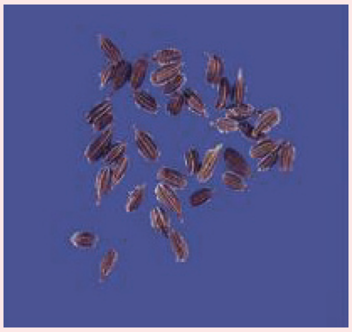
Head intact method: If crop matures in the first season, the heads are examined for trueness to the type. The plants with off type heads are removed. The head is kept intact and only a cross cut is given to facilitate the emergence of a stalk. On an average, 300-400 kg/ha seed yield from cauliflower and 400–500 kg/ha seed yield from cabbage can be obtained.

Root Crops

Radish, carrot, turnip, beet are grouped in root crop and these vegetable are also cross pollinated in nature. The method of cultivation is nearly the same as for fresh roots. However, the seed is produced by seed-to-seed method or transplanting root-to-seed method. Transplanted root-to-seed method is better since it gives an opportunity to rogue out off-type roots at the time of transplanting, maintaining only true-to-type roots for seed production. In plains, radish is sown from September to January and in hilly areas from March–August. Seed crop should be harvested when most of the pods turn yellow. After that it is dried and seeds are threshed out from the pods. A hectare of radish seed crop yields 600–1,000 kg seed.

Carrot is sown from August–November in plains and from March–July in hilly areas. In carrot, the seeds are formed in umbels. The first and largest umbel is formed on main flowering stalk and is known as primary or king umbel. Secondary umbels are formed at the terminus of branches from the main flowering stem and flower in a sequence from the top to the bottom of the inflorescence. Tertiary umbels originate on secondary umbel stem. The seeds from primary umbels are heavier, more mature and of high quality. Since in carrot all the umbels do not mature together, harvesting is done 2–3 times. However, the seed crop can be harvested when all the secondary umbels mature and tertiary umbels turn yellow. A hectare of carrot seed crop yields 450–500 kg seeds.

In turnip, the asiatic types are sown from July–September and European types from October–December in the plains and from March–May in hilly area. The harvesting is done during summer when pods mature and becoming brownish-red. After threshing, the seeds are separated out. About 500–600 kg seeds/ha can be obtained from turnip.

	
Radish seeds	**Carrot seeds**

Cucurbits

Bottle gourd, bitter gourd, sponge gourd, ridge gourd, pumpkin, cucumber, muskmelon, watermelon are important cucurbitaceous vegetables. Cucurbits are cross pollinated vegetable crop. The method of cultivation for seed crop is the same as that of fresh fruits. However, the harvesting is done when fruits are fully mature and become dry. Rouging of seed crop throughout the crop period is a must to maintain true-to-type plants. Generally, seeds are extracted by cutting open the fruits longitudinally. In watermelon, pumpkin etc. seeds are embedded in the pulp. Therefore, different methods are applied for extraction of seeds.

In mechanical methods, axial flow vegetable seed extractor is used to separate out the pulp from seeds, whereas in chemical methods commercial grade HCl is used to separate the pulp from seeds within 15–20 minutes. Thereafter, the seeds are washed in water and dried to prescribed moisture levels. From a hectare of seed crop, 300-500 kg bottlegourd seeds, 100-300 kg bitter gourd seeds, 300-400 kg luffa, pumpkin, cucumber and round melon seeds, 200-300 kg muskmelon seeds and 400-500 kg watermelon seeds can be obtained.

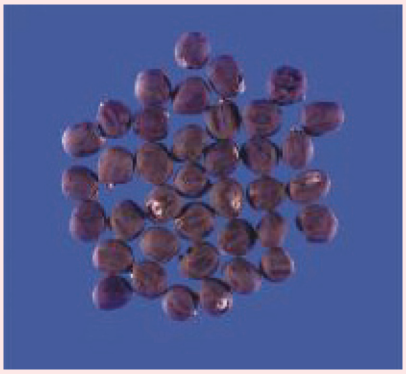
Cucumber seeds

Peas and beans

Peas and beans (French bean, cowpea, dolichos bean, cluster bean) are highly self pollinated vegetable crops. The cultivation practices for seed crop of peas and beans are more or less the same as for green pods. Although a self-pollinated crop, pea, is well-known for producing off-type plants. Hence, rigorous rouging must be undertaken at flowering and fruiting stage. When almost 90% pods on the plants mature and turn dry, the whole plants are uprooted and collected. After about a week, the seeds are separated out from the pods by threshing and winnowing. The ripe and dry pods can also be picked up by hand and threshed. Usually the moisture content of seeds at this time is higher. On an average, from a hectare of seed crop about 1,500 kg pea, 1,000 kg french bean, 1,000 kg cowpea, 700 kg dolichos bean and 700 kg cluster bean seeds can be obtained.

Okra

There are no specific practices to be followed for the crop raised for seed production. Since it is an often cross-pollinated crop, maintaining the proper isolation distance is a must. The YVMV-affected plants should be rouged out in addition to rouging off-type plants.

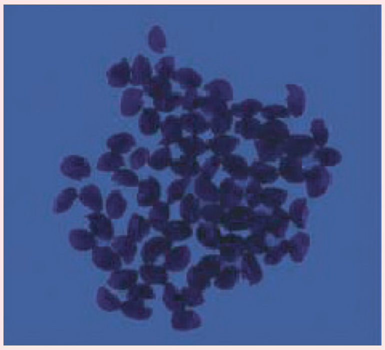


Okra seeds

Its fruits are harvested when they become dry on plants. Seeds are taken out from the pods and are dried to specified moisture level, cleaned, treated and stored. A hectare of okra crop gives about 1,000–1,200 kg seeds.

Onion

Onion seeds are largely produced in Gujarat, Maharashtra, Madhya Pradesh and Rajasthan. In Uttar Pradesh, Haryana, Punjab and Bihar it suffers from purple blotch resulting in a low seed yield which is uneconomical. Onion is a biennial crop taking 2 full seasons to produce seeds. In the first year, bulbs are produced and in second year seed stalks are produced. Onion is a long day plant but seed production is day neutral. It requires cool condition during early development of the bulb crop and again prior to and during early growth of seed stalk. Varieties bolt readily between 10 and 15°C. During harvesting and curing of the seed, fairly high temperature and low humidity are desirable. Onion is largely cross-pollinated crop with up to 93% natural cross-pollination, but some self-pollination does occur. It is chiefly pollinated by honeybees. For seed production, the field should be isolated from fields of other varieties of onion or fields of the same variety.

	
Onion seed crop	**Onion seeds**

Mostly bulb-to-seed method is used for seed production. Seed-to-seed method is used if bulbs have lower keeping quality. Well-matured bulbs should be harvested, and topped, leaving a 1.27 cm mark. Before storage, a thorough selection and curing of bulbs should be done. The time required for curing depends on weather conditions and may take 3-4 weeks. The mature bulbs should be stored in well ventilated, cool stores (0-4.5°C) until 3-4 weeks prior to planting.

The best time for planting of bulbs is the second fortnight of October. The rouging carried out in the field when bulbs are not harvested. After harvesting, true-to-type bulbs are selected. Seed is ready for harvesting when first formed seed in the heads get blackened. A total of 2-3 pickings may be necessary to harvest the heads. Seed heads are cut, snapped off, keeping a small portion of the stalk attached. Seed heads after harvesting should be thoroughly dried. Seeds from heads are removed. After that seeds are cleaned by putting them in water and dried under the sun or by drier and stored. The moisture content should not be more than 6-8%. Seed yield is 850-1,000 kg/ha.

ACTIVITY:

1. Collect 1 g of tomato, brinjal and chilli seed. Note down the differentiating characteristics and count the number of seeds per gram.
2. Try to extract tomato and brinjal seed from ripened fruit.

Post-harvest processing of vegetable seeds

Harvesting, drying, storage and processing operations markedly influence the seed quality, especially its viability or germination capacity as well as the yield.

Harvesting

In general, the later the crop is harvested, the greater will be the seed yield. The optimum time of harvest for a given seed crop is the point beyond which losses will be greater than the potential seed yield which requires further ripening. Vegetable seed crops are classified into three broad groups, depending on the state of seed at harvest time.

Dry seed: The seed is usually dried on the plant before harvesting; e.g. *Brassicas,* lettuce, peas, beans, beet and onion.

Fleshy fruits: The ripened fruits are picked from the plants and dried first. The dried fruits are then opened later to remove the dried seeds, e.g. chillies, okra, gourds, pumpkins and eggplant.

Wet fleshy fruits: In fruits containing a high level of moisture, the seed has a gelatinous or mucilaginous coating adhering to it. This has to be removed after seed extraction by a fermentation process or treatment with dilute acids. Such fruits are harvested when they mature and ripen e. g. tomato and cucumbers.

Threshing, winnowing, cleaning and grading

Threshing involves beating or rubbing the plant material to detach the seed from its pod or fruit. The detached seed is then winnowed to remove chaff, straw and other light material from the seed. The seed may be cleaned by removing heavier material like soil, stones, etc. and graded into different sizes by sieving.

Traditional threshing methods: Seed has to be extracted from dry seed heads (e.g. onion, lettuce, *Brassicas),* dried fruits (chilli, pepper and gourds) or from fleshy fruits like tomato, cucumbers and melons in which the seeds are wet at the time of extraction. Threshing may be carried out by beating or rolling the seed containing material to separate it from other plant debris or 'straw'. It may be performed manually, with animals or mechanically. Head threshing is simplest and can be a cheaper method if sufficient labour is available. Seeds may be hand-rubbed (legumes), beaten against a solid wall (lettuce) or on the ground with *stick* (dried fruits). Thickness or depth of the plant material being threshed should be sufficient to avoid damage to the seeds.

Mechanical threshing: Various types of threshing machines with adjustable cylinder speeds are available for extraction of vegetable seeds. The cylinder clearance, concave mesh size, air flow rate and screen size greatly influence the efficiency of these machines.

Wet seed extraction: Wet seed extraction is followed in certain vegetable crops which bear ripe seeds in fleshy fruits, e.g. tomato and cucumber. Such seeds have a gelatinous layer around them. The seeds along with this gelatinous materials and the pulp are squeezed or spooned from the cut fruits into containers. The fruit skin and other cell debris are discarded. The pulp containing the seed is allowed to ferment for 1 to 5 days depending up on the stage of fruit-ripening and fermenting temperature. Completion of the fermentation process leading to break down of gelatinous coating can be determined by daily inspection. The mixture must be stirred daily to allow uniform fermentation and avoid seed discoloration. An attack by insects such as fruit flies can be avoided by covering the container with muslin cloth. Use of iron vessels for fermentation can also lead to seed discoloration. After the completion of the fermentation process, the seed is washed repeatedly by directing a jet of water into the vessel. The light seed and other debris floating on the surface should be discarded. The remaining good seed is finally poured into a retaining sieve, and subsequently spread out to dry on suitable matting. Dilute inorganic acids such as hydrochloric acid may also be used to separate gelatinous material from the seed. About 5 to 8 litres of commercial grade HCl are required for 100 kg of tomato pulp. The mixture is stirred for about one-half hour and seed is washed out as described above. Seed of some fleshy fruits like melons, sweet peppers, etc, which are also extracted wet, do not require fermentation. They are simply macerated and rubbed in water.

Seed drying

Seeds contain natural moisture, which at harvest time is often higher than the optimum required for the maximum potential life and best germination. The amount of moisture in the seed is probably the most important factor influencing the longevity and germination capacity of the seed.

After the seed is detached from the mother plant, its moisture content is a function of relative humidity (RH), and it is at equilibrium with that of the surrounding air. Seeds of fleshy fruits such as tomato, cucumber and melons, have much higher moisture content at harvest, and may absorb more water during their wet extraction process. On the contrary, seeds formed in fruits which become desiccated during the ripening process are relatively dry at the time of harvest, e.g. onion, amaranthus, *Brassicas,* etc. Different kinds of seeds vary greatly in their moisture content at a given relative humidity.

Seed storage

Seed is required to be conserved through proper storage for a short or long period of several months due to many reasons which include:

- It may be uneconomic to multiply each seed stock annually.
- It is not always possible to estimate seed yields.
- Demands for seed may fluctuate and good seed stocks are valuable and can be difficult or costly to produce.

A small quantity of seed may be stored on the farm using traditional methods, but conservation of large quantities of certified seed requiring storage periods of 18 months or more need appropriate storage methods to overcome the deterioration effects of temperature and relative humidity of the storage environment.

Seed processing

Seed processing aims at cleaning of seeds to remove plant debris (chaff, straw, flower heads, stem, leaf etc.), non-seed materials (soil, sand or stone particles), seeds of other crops, seeds of common and noxious weeds, and seed appendages (which may interfere with free running of the seed in future operations, including sowing). Seed processing upgrades or concentrates seed by removal of seed of undesirable quality such as damaged, diseased, insect affected, partly germinated, discolored, lighter, larger or smaller than the optimum. Processing of seeds thus reduces the total weight of a seed lot and increases its value per unit weight or volume. Processing, however, does not normally increase genetical quality of seed. It also does not separate the seeds of different varieties of the same crop or improve seed germination, with the possible exception of a process which breaks dormancy.

Seed cleaning operations have following four processes:

A. Winnowing

B. Pre-cleaning or conditioning ('Scalping')

C. Basic cleaning, and

A. Winnowing

Dry seed which has been extracted by hand or with a thresher can be further separated from the lower density plant debris by winnowing. This operation is performed by hand, using the natural breeze or by blowing to remove plant debris.

B. Pre-cleaning or conditioning

Pre-cleaning, also called 'scalping' is usually practiced to pre-clean or condition the seed material before further processing. This operation normally removes the bulk of the plant debris and other undesirable material. The most commonly used machine for pre-cleaning is the 'scalper'. Seed clusters may be required to be broken during the pre-cleaning process. The 'scalper' scalps off the larger pieces of plant debris (stem, haulm, pod, dried flower and other foreign materials, such as stone, clod, etc.). Smaller seeds fall through a vibration or rotating sieve. Some scalper machines have an air flow to remove dust, chaff and other lighter materials from the seed.

C. Basic cleaning

This is the generalized cleaning operation used to remove all but the contaminants requiring special processes to separate them. 'Screening' and 'air separation' are the two main basic cleaning operations performed with the help of various machines.

Packaging

The processed seed is required to be packaged properly in uniformly sized bags and closed. Seed is usually supplied to the farmers in bags. During its transfer from the processing plant to the field, seed is subjected to rough handling. A package must ensure:

- A convenient unit for handling transport and storage,
- Protection against contamination, mechanical damage and seed loss,
- A suitable environment for storage, and
- A barrier against loss of seed and escape of pesticides

Bags manufactured from cloth, paper or plastic film are normally used to package seed. Cloth bags woven from jute or cotton or from synthetic fibers such as nylon or other polymers may be used. These bags, however, are not suitable for seed treated with a highly poisonous pesticide. Paper bags built up of several thick layers are more suitable for humid conditions. Polyethylene plastic bags are being increasingly used for packaging, owing to their strength and impermeability to moisture. Denser and thicker grade plastic bags provide good protection against rough handling and are resistant to rodent damage.

CHECK YOUR PROGRESS

Subjective Questions

1. What are various criterias for good quality vegetable seeds? Classify vegetables on the basis of pollination behaviour with examples.
2. What are principles of vegetable seed production? Discuss in detail.
3. Discuss seed production of solanaceous vegetables.
4. Discuss different methods of seed production in cole crops.
5. Post-harvest processing of vegetable seeds

Write short note on the following

1. Crop rotation
2. Isolation and rouging of seed crop
3. Seed production of root crops
4. Seed processing

Fill in the blanks

1. Condition where both male and female reproductive organs are present in the same flower is called …………..
2. …………. is the condition in which the anthers and the stigmas of a bisexual flower mature at the same time resulting in self-pollination.
3. …………..is the condition where bisexual flowers never open and therefore, the self-pollination is only the way of pollination.
4. ……………is a condition in which the flowers either staminate (male) or pistillate (female) occur on the same plant or on different plants.
5. …………………refers to the absence of functional pollen grains in hermaphrodite flowers.

Further readings and references

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★★★

Chapter-8

Hybrid Seed Production of Vegetable Crops: An Entrepreneurship Opportunity

OBJECTIVES

Students will be able to learn about:-

- Basic principles of hybridization
- Mechanism of hybrid seed production
- Techniques of hybrid seed production of important vegetable crops
- Entrepreneurship opportunity

INTRODUCTION

Seed replacement rate in vegetable crops is more than 80% as compared to nearly 10% in other food crops. It is expected to touch 100% in another two to three year. This has happened because the farmers grow them for immediate marketing and their produce is subjected to competition to decide the prices. Hence the vegetable growers can not compromise with the quality of seeds for the fear of rejection of their produce. They buy the best seeds and frequently try the new products to remain a successful grower. The seed companies in turn get instant response and success if they develop new promising hybrids. The impact of vegetable hybrid technology can be seen by the variety and quality of vegetables in the market. It has attracted a large number of marginal farmers around the cities to grow hybrid vegetables. The share of hybrid seed is increasing at a fast pace of 8-10% annually in most of the vegetable crops. In this chapter our focus will be to learn the techniques of hybrid seed production to get employment opportunity in seed industry or starting own enterprises in vegetable seed business.

Hybrid breeding:

The mating or crossing of two plants of dissimilar genotype is known as hybridization. In plants crossing is done by placing pollen grain from one genotype (male parent) on to the stigma of flower of another genotype (female parents). The seed as well as the progeny resulting from the hybridization are known as hybrid. In other words, the progeny of a cross between genetically different plants is called hybrid or F_1 hybrid. In self pollinated crops, it is difficult to cross but in cross pollinated crops it is easier. For production of a hybrid, crossing between two parents with different economically important traits is important. Heterosis is superiority of F_1 (offspring from cross) in one or more characters over its better parental or mid parental value. Desirable heterosis can be

- **Positive –** like in case of yield, quality, disease resistance
- **Negative –** like in case of plant height, maturity duration

Hybrid varieties have been evolved in those high valued vegetable crops which exhibit marked heterosis such as solanaceous vegetables (tomato, eggplant, sweet pepper), cucurbits (melons, watermelon, cucumber, squash, pumpkin and gourds), cole crops (cabbage and cauliflower), root and bulb crops (onion, radish, carrot) and fruit vegetable like okra. The popularity of F_1 hybrid cultivars is due to their vigour, uniformity, disease resistance, stress tolerance and good horticultural traits including earliness and long shelf-life expressed and therefore giving consistent stable high yield.

Mechanism for facilitating hybrid seed production in vegetable crops:

Commercial hybrid seed production demands crossing technique which is easy and also economical to maintain parental lines. These techniques are specific to crop floral biology and flowering behaviour. Different mechanisms adopted for commercial hybrid seed production of vegetable crops are discussed below:

1. Hand emasculation and pollination
2. Self-incompatibility
3. Male sterility
4. Manipulation of sex expression

1. Hand emasculation and pollination:

Most of the seeds of F_1 hybrid vegetables are produced by hand-pollination. The method in principle is simple as it involves the manual emasculation of the pollen-producing organ, the anthers, followed by hand pollination with pollen of the male parent and then preventing other pollen from contaminating the pollinated flowers. Although, it is labor intensive method, this system is being practiced in all the solanaceous crops and cucurbits, wherein a single pollination of a female flower produces many seeds and remains cost effective.

2. Self incompatibility:

Self-incompatibility (SI) refers to inability of a plant to set seed upon self pollination despite male and female gametes are viable. Self incompatibility is very common in Brassica, Petunia and Lilium. Self-incompatibility prevents self pollination (in breeding) and promotes cross pollination (out breeding) and creates genetic variability. SI is seen in hermaphrodite and homomorphic flowers. The self-incompatibility response is genetically controlled by one or more multi-allelic loci, and relies on a series of complex cellular interactions between the self-incompatible pollen and pistil. Self incompatibility (SI) can be classified as:

I. **Heteromorphic self incompatibility:**

In this system flowers are of different morphology of the reproductive parts. The morphological differences can be seen visibly in flowers. The characters affecting this type of SI are style length, filament length and pollen size etc.

II. **Homomorphic self incompatability**

Flowers morphology is same, so mating types cannot be recognized by morphological features. This types of self-incompatibility is controlled by 'S' alleles. For crossing parental 'S' alleles should be different, then only fertilization takes places and seed sets. Two types of self-incompatibility:

a. *Sporophytic self-incompatibility (SSI):* In SSI, the incompatibility of pollen is due to genotype of the anther (the sporophyte) in which it was created. SSI is less common as compared to GSI. This form of SI was identified in the Brassicaceae and Convolvulaceae families.

b. *Gametophytic self-incompatibility (GSI):* In GSI, the incompatibility of the pollen is determined by its own gametophytic haploid genotype. This is the more common type of SI, existing in the families: Solanaceae, Rosaceae, and Papaveraceae families.

3. Male sterility

Male sterility is defined as the absence or non-function of pollen grain in plant or incapability of plants to produce or release functional pollen grains. The use of male sterility in hybrid seed production of vegetables has a great importance as it eliminate the process of mechanical emasculation.

Types of male sterility:

The different types of male sterility are as follows:

i) **Genetic male sterility:** The pollen sterility, which is caused by nuclear genes, is termed as genic or genetic male sterility. It is usually governed by a single recessive gene 'ms'. A male sterile line may be maintained by crossing it with heterozygous male fertile plant and such a mating produces 1:1 male sterile and male fertile plants. This system has been reported in tomato, pepper, chilli, muskmelon, watermelon and okra and commercially exploited for chilli and muskmelon in India.

ii) **Cytoplasmic male sterility:** This male sterility is conditioned by the interaction of nuclear gene (Chromogene) and sterile cytoplasm but neither the genetic factor nor the cytoplasmic factor alone can regulate sterility. This male sterility has been utilized in carrot, sweet pepper, chilli, radish, turnip, cauliflower, cabbage, broccoli and Chinese cabbage and onion. This male sterility is sensitive to temperature and is unstable under fluctuating environments which hinders its utilization in hybrid seed production. Indian Institute of Horticultural Research (IIHR), Bangalore has released two F_1 hybrids of onion Arka Kirtiman and Arka Lalima using cytoplasmic male sterility and Indian Agricultural Research Institute, New Delhi has developed a tropical carrot hybrid Pusa Vasuda.

iii) **Chemical induced male sterility:** A method of producing male sterile lines which circumvents the difficulties of genetic induction is the use of chemical sterilization agents. The principle involved here is that the chemical acts as a gametocide selectively altering the male gamete, i.e., pollen, by inducing physiological abnormalities, which in turn prevent pollen development, pollen shed, or pollen viability. A number of chemical compounds have been shown to have at least a partial effect in producing male sterility in plants. Among these are: Ethephon, FW 450 and Ethidium bromide.

iv) **Transgenic male sterility:** From the beginning of 1990's, new genetic approaches have been proposed and implemented to develop male sterility systems through genetic transformation. The ability to design new molecular strategies and their successful execution has been possible because of the isolation, cloning and characterization of anther or pollen specific genes and promoter sequences. These genes are expressed in pollen themselves (gametophytic expression) or cells and tissues (sporophytic expression) that directly or indirectly support pollen development, such as tapetum, filament, anther wall.

4. Manipulation of sex expression:

Production of hybrid seeds in cucurbitaceous vegetables is possible through manipulation of sex expression. Gynoecious lines are available in cucumber and muskmelon and have been exploited for hybrid seed production commercially. Monoecious cultivars produce male and female flowers on same plants. Gynoecious lines produce only female flowers and can be easily used as female parent to produce hybrid seeds in large scale. Multiplication of gynoecious cucumber line is made possible by induction of male flowers through spraying of GA_3 (2000 ppm) or silver nitrate at seedling stage. IARI has developed a cucumber hybrid Pusa Sanyog with the use of this mechanism but it is suitable mostly for temperate zones. Recently gynoecious lines of bittergourd have also been developed.

CHECK YOUR PROGRESS

Fill in the blanks

1. The mating or crossing of two plants of dissimilar genotype is known as ……………
2. ………… is superiority of F_1 (offspring from cross) in one or more characters over its better parental or mid parental value
3. In case of yield, quality, disease resistance, desirable heterosis is ………whereas it should be ………… in case of plant height, maturity duration

4. Inability of a plant to set seed upon self pollination despite male and female gametes are viable is called……………. and it is common in …………..

5. Absence or non-function of pollen grain in plant or incapability of plants to produce or release functional pollen grains is termed as…………….

6. F_1 hybrids of onion ………… and ……………. are developed by using cytoplasmic male sterility.

Methods of hybrid seed production in some important vegetable crops:

1. Solanaceous Vegetables:

Tomato:

Heterosis in tomato is manifested in the form of earliness, total yield, uniformity of produce, greater plant vigour and better adaptability to unfavourable environment.

Tips for hybrid seed production

- Transplanting should be done in recommended isolation distances in the proper plant ratio 5:1 (female : male).
- Rouging should be done at different recommended stages and before hybridization, it must be checked for trueness to type.
- Sowing of male parent should be done up to 3 weeks earlier than female parent.
- Emasculation should be done in their late bud stage. For commercial hybrid seed production the emasculation of female flowers and pollination by hand is still considered economical and efficient. Indeterminate tomato varieties are staked and trained with either single stem or double stem, whereas, the determinate tomato varieties are trained with 3 stems. Usually 1st to 4th cluster on each branch are selected for emasculation. Buds where the corolla have just opened and form an angle up to 45° in respect to the flower axis (a day prior to anthesis) are selected for emasculation. The emasculation operation involves holding the corolla at the base and with a single upward pull pick off the corolla along with all the stamens.
- Usually the anthers are picked off a day before anthesis with the help of forceps leaving the petals intact. Such petals turn yellow on the day of anthesis. Fresh pollen collection on the day of anthesis by a vibrator has the highest viability, because only ripe pollens are shed by vibrating the flowers. Pollens are collected in a glass tube or on a glass plate from the male line.
- Pollination may be done immediately or one day after emasculation.

- Pollens are transferred to the stigma by finger or by inserting the stigma into a glass tube containing the pollen grains. Left over pollen grains in the glass tube are not used on the next day because its viability is reduced considerably.
- Each pollinated flower is marked with coloured tag or remove some parts of the calyx from flowers immediately after pollination which provides confirmation that fruit containing hybrid seed at the time of harvest.
- Pollen grains can be stored for a longer period (2 months) of time when its moisture content is reduced using a desiccator and the temperature is kept around 0°C.
- Tomato seeds are extracted mainly by fermentation method. Under warm conditions, the fermentation process is complete in 24 hours. At 25ºC, it requires 2 days for the completion of fermentation process. The pulp is stirred several times in a day to maintain a uniform rate of fermentation and to avoid discolouration of the seed. Seeds are than washed with clean water. Tomato seed is also extracted using acid (HCl) or alkali (NaOH), 10 cc or 36 percent HCI or 30 percent NaOH is added in 4 kg of tomato pulp. The treatment is given for a period of 15 minutes, which separates the jelly from tomato seeds. The seeds are than washed thoroughly and then dried.
- One kg of tomato fruit will produce 3-4 g of seed yield (1000-1200 seed). Av. seed yield: 60-70 kg/ha depending upon the performance of parental lines.
- Nearly 40 percent of the total labour expenditure is on flower emasculation during the course of hybrid seed production, which can be reduced by using male sterile lines.

Selection of flower bud for hybridization

Emasculation

Collection of male flower for pollen

Pollen collection

Pollination

Fig: Hybridization in tomato

Brinjal and sweet pepper

Heterosis in eggplant is manifested in earliness, fruit number per plant and fruit weight. In case of sweet pepper, heterosis is manifested for plant height, days to flower, fruit weight, number of fruits per plant, and total yield.

Tips for hybrid seed production

- Emasculation and hand pollination is the useful production techniques. Stigma is receptive a day prior to anthesis in eggplant. Hence bud pollination is possible giving good fruit set and seed yield.
- In sweet pepper, emasculation is done a day prior to anthesis, whereas, pollination is done in the morning on the day of anthesis.
- Natural cross pollination ranged from 0.2-46.8% in eggplant flowers. Emasculated flowers are never visited by pollinators.
- Pepper flowers are visited by honey bees occasionally. Fresh pollen grains are collected on the day of anthesis by a vibrator and can be stored for a period of 1 to 2 months at 0ºC, using silica gel for proper drying of the pollen grains.
- In order to obtain optimum yield and good quality seed, it is essential to train the eggplant as well as sweet pepper plants. The first and 2nd flowers are harvested at the initial stages. This will boost plant growth as well as the number of seeds formed in subsequent fruits.
- The training of eggplant involves allowing two lateral branches below the first flower and the remaining lateral branches are removed. This technique is aimed to attain sound growth of plant.
- Eggplant fruits are harvested 50-55 days after anthesis and are stored for a period of 10 days for post harvest ripening. Sweet pepper fruits are harvested 60-65 days after anthesis. The ripe fruits are crushed and seeds are separated by washing with excess of water without fermentation. The seeds are dried using dry air at 28-30°C.

- A satisfactory seed yield in eggplant is 150-200 kg/ha with a thousand seed weight ranging from 4-5 g. In peppers the seed yield varies from 100 to 200 kg/ha.

2. Cucurbitaceous vegetables:

Cucurbitaceous plants produce three types of flowers depending on species and variety. One plant may contain more than one type of flowers, and more than one sex forms may be available in a species. According to the sex forms, cucurbitaceous plants can be grouped as follows:

– **Hermaphrodite:** All flowers of a plant are bisexual (available in some varieties of Luffa, Satputia)

– **Monoecious:** Male and female sexes are in different flowers of the same plant (the most common sex form). e.g. cucumber, bottle gourd.

– **Andromonoecious:** Male and hermaphrodite flowers are in the same plant. eg. muskmelon

– **Gynomonoecious:** Female and hermaphrodite flowers are in the same plant.

– **Trimonoecious or Androgynomonoecious:** Male, female and hermaphrodite flowers are in the same plant.

– **Dioecious:** Male and female flowers are in different plants. eg. Pointed gourd

– **Gynodioecious:** In dioecious species some plants of a variety bear only female flowers and others bear hermaphrodite flowers.

– **Sub-gynoecious:** When gynoecious plants of dioecious species produce some male or hermaphrodite flowers.

Monoecious sex form is the most common one in this family. Hermaphroditism is the original sex form from which monoecious and dioecious sex forms have been evolved. Depending upon the sex expression of the cucurbits following are the methods used for hybrid seed production:

Hybrid seed production techniques

i) Bagging of female flower and hand pollination:

It is followed in the most of the cucurbits except muskmelon

- Sowing or transplanting should be done in recommended isolation distances in the proper plant ratio 4:1 (female : male)
- Cover both male and female flower with butter paper or tied with rubber band, one day prior to pollination
- Next morning pollinate the stigma of the protected female flower in the female line and again bag it

	
Bagging of female flower	**Hand pollination**

ii) Emasculation and hand pollination

- Emasculation should be done one day prior to anthesis in the hermaphrodite / andromonoceous flowers and cover it
- It is practiced in muskmelon
- Pollination is done in the early morning of next day of emasculation
- F_1 seed collected from the pollinated fruit

iii) Pinching of male flowers from female line and open pollination

- It may be economical in bottle gourd
- Sowing or transplanting should be done in recommended isolation distances in the proper plant ratio 3:1 (female : male)
- Male flowers are removed completely from the female line one day prior to anthesis
- Keep one medium sized bee colony/acre for maximum fruit set

iv) Use of gynoecious flowering habit: gynoecious line bears only female flowers

- Temperate gynoecious line are unstable under high temperature (>30°C) and long day conditions
- Maintenance of gynoecious line: spray GA_3 @1500-200 ppm or silver nitrate @200-300ppm or silver thiosulphate @400ppm at 2-4 leaf stage
- Pusa Sanyog (Japanese gynoecious line x Green Long Naples), hybrid of cucumber developed using gynoecious line and suitable for temperate region

v) Use of male sterility

- Punjab Hybrid-1(ms-1 x Hara Madhu) variety of muskmelon developed using male sterile line

vi) Use of monoecious line in muskmelon:

- At Indian Agricultural Research Institute (IARI), New Delhi four Monoecious lines (M1, M2, M3, M4) were developed
- Pusa Rasraj (M3 x Durgapura Madhu) variety of muskmelon was developed using monoecious line but could not be popularized due to oblong fruit shape which was not liked by consumers.

vii) Chemical suppression of male flower and open pollination

- Two true leaf stage is most responsive stage for chemical suppression
- In gourds, pumpkin and squashes, etheral @ 200-300 ppm suppress male and initiated female flower in first few nodes on female parent
- For complete suppression of male flower in squash spray ehteral @ 400-500 ppm (twice)
- Other method is same as pinching of male flower from female line and open pollination (discussed above)

3. Onion:

Heterosis is manifested in uniform bulb size and bulb weight. Development of an F_1 hybrid in onion requires the development of A line (Smsms)- male sterile line; B line (Nmsms)- an inbred maintainer for A line and C line (NMsMs)- pollinator male parent.

Hybrid seed production techniques

- Hybrid seed is produced in the open in an isolated field
- Bulb of A line x C line (ratio-4:1/8:2) planted in a way that flowering of both must synchronize and rouging must also be practiced before dehiscence in the morning
- Keep 3-4 bee hives/0.4ha for maximum seed set
- F_1 hybrid seed is harvested from A line
- Arka Kirtiman and Arka Lalima are developed using this technology in onion
- Hybrid seed yield in onion ranges from 300-350 kg per hectare.

4. Cole crops:

Heterosis in cabbage, cauliflower and broccoli is manifested in head/curd size, early maturity, head/curd weight. In cole crops it is the sporophytic incompatibility system, which is most prevalent.

Hybrid seed production techniques

- The commercial F_1 hybrid seeds are produced by the inter planting of 2 self-incompatible but cross compatible inbred lines used in the development of that particular hybrid

  S_1 S_1 (inbred line) x S_2 S_2 (inbred line) ------- S_1 S_2 (F_1 hybrid seed)

- Use of CMS: Use of CMS in cole crops is effective because edible portion is other than seed.
  - o A line (male sterile with Ogura gene)
  - o B line (maintainer line)
  - o C line (pollinator line): best combiner
  - o A line x C line ------- F_1 hybrid seed
- Seed yield varies from 500 - 800 kg/ha.

Entrepreneurship opportunity

The hybrid vegetable seed industry in India is estimated to be of Rs.891 crores. The highest value of hybrid seed sales is estimated to be through tomato (185 crore) followed by okra (150 crore), Chilli (140 crore) and cauliflower (90 crore). The acreage under domestic hybrid seed is 23,802 ha and the production of hybrid seed is 1410 tonnes. India is the second largest producer of hand pollinated hybrid seeds in vegetables among the Asian countries, next only to China. The contract hybrid seed production is mainly done in solanaceous crops, okra and cucurbits for local market and export. It is being done in the open fields by hand pollination in south Indian states of Kamataka and Andhra Pradesh which are having ideal climatic conditions, trained manpower and cost effective skilled labourers. The contract seed production is organized for 300-400 acres in a seed village through local organizers under the technical supervision of the trained person. Now there is a shift towards the production of quality hybrid seeds in protected structures such as (1) net houses and low cost net cum poly tunnels for the production of hybrid seeds of cucurbits and solanaceous vegetables by the progressive farmers and (2) fan and pad cooled green houses for the production of hybrid seed of high value vegetables like capsicum, chilli, indeterminate tomato, muskmelon and cucumbers through out the year by corporate seed sector for export. One study conducted in 2005 indicated that about 994 tonnes of hybrid seed was being produced in tropical vegetables from an estimated area of 7,957 acres leading to employment generation of 2.71 million man-days per year, generating a net income of Rs. 372.94 million by involving a total of 10,394 farm families. Further, about 3.28 million man days of skilled laboures were also involved in the hybrid seed production of temperate vegetables generating an additional income of Rs. 130.28 million. Solanaceous crops contribute 56.46% towards employment generation, followed by cucurbits (28.08%) and okra (15.46%).

The vegetable seed industry is expected to be active and dynamic with hybrid varieties developed indigenously for domestic markets and commercial farming and superior open pollinated varieties produced for the benefit of marginal farmers and homestead gardens. With improved hybrid seed production practices, it is hoped to bring down the price of hybrid seed to make it accessible to the majority of farmers. Finally, there is a great scope for development and expansion of the vegetable seed industry and hybrids in India. The market is immense and the farmers are eagerly looking for improved seeds. There is a need for strong public private partnership to further strengthen the seed sector for healthful green India. The public sector research started ground work in most developing countries in order to uplift the technical and managerial level of the farmers, by developing and disseminating (slowly) improved agricultural practices. The private sector has also contributed considerably to the overall growth of the vegetable industry, by developing and making available superior hybrids and quality seeds to the farmers, the demand for quality seed and hybrids is steadily increasing with the improving technological skills of the vegetable farmers.

In India, commercial seed production for export on a commercial scale was organized during the 70^{s} by two private companies. A number of medium and small sized companies have begun to operate now in this venture covering seed production in most of the solanaceous and cucurbitaceous crops for internal market and exports. They include Namdhari Seeds, Mahyco, Indo-American Hybrid Seeds, Golden Seeds, Tropica, Exim, Oriental Biotech, Unicorn Biotech, etc. Custom production for export is mainly for companies in USA, Europe and Japan. Vegetable seed export constitutes nearly 70% of total seed exports. Today there are about 500 small, medium and large companies engaged in vegetable seed business. This suggests further expansion of domestic seed production capabilities through public, private and farmers' participation creating enabling environment for entrepreneurship opportunity for educated rural youth.

India is endowed with several advantages making it competitive for production of open pollinated varieties and hybrid vegetable seeds for domestic and export market and meeting international quality standards. The state of Karnataka produces nearly 90% of the total hybrid vegetable seeds, the major areas being located around Ranebennur in the northern part of the state. Availability of trained labour and guaranteed returns and incentives for quality has helped in setting up of several seed villages. The returns can be as high as three times as that of crops for market purpose from the same area. This has also helped in improving the socio-economic scenario of these regions, including overall prosperity, narrowing down of rural/urban divide and employment generation especially for village women and youth. It is estimated that the total employment generation is over 7,00,000 in this sector. This is one of the most significant achievements of this agricultural activity leading to improved per capita income and quality of life. Hard work and diligence of the farm workers involved have helped in meeting the international seed quality standards, which in turn has led to continued growth of the business. New areas for production are also being added, extending this benefit to rural areas. India has a major advantage in having a choice of latitudes and altitudes to select appropriate seed production areas. Greenhouses have also been set up for successful production of difficult to produce crops like capsicum. Availability of quality technical expertise, increased production and productivity of hybrid seeds of international standards, reduced risks and maintaining low costs have helped to make custom seed production a viable opportunity for foreign companies in India. New untapped areas should be explored indigenously for production of seeds of tropical as well as temperate vegetable crops. Rural folk should be encouraged and trained in seed production of vegetable varieties and hybrids. With low cost labour availability and environment suitability for quality, vigorous and bold seed production, all kinds of vegetable seeds can be produced in India for domestic and export markets which will not only save foreign exchange instead earn it besides empowering rural poor with skill, generate employment and income.

ACTIVITY

1. Visit vegetable garden and practice hand emasculation in tomato and brinjal.
2. Visit vegetable garden and note down the differentiating characteristics of male and female flowers in cucurbits
3. Practice hand emasculation, pollination and bagging in any vegetable crops available nearby.
4. Arrange a visit of vegetable seed market and get an idea about demand of hybrid seeds of different vegetable crops of your locality.
5. A visit of any hybrid seed production farm/ seed processing plant may be organized.

CHECK YOUR PROGRESS

Subjective Questions

1. Discuss about mechanism of hybrid seed production in vegetable crops.
2. Methods of hybrid seed production in solanaceous vegetable.
3. Discuss techniques of hybrid seed production of onion.

Write short note on the following

1. Male sterility
2. Self incompatibility
3. Sex forms of cucurbitaceous vegetables

Further readings and references

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