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Chapter

10

Scientific Cultivation of Cauliflower (*Brassica oleracea* L. var. *botrytis*)

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Cauliflower is one of the most important winter vegetable grown throughout the country. According to an estimate of NHB hectares area was covered in India under cauliflower cultivation in 2012-13.important hills in south. In India two separate groups of cauliflower are commonly grown i.e. Indian or Tropical type and European or Temperate type known as snowball type. The typical Indian or Tropical type cauliflower has been developed by the inter-crossing of Cornish type (Biennial) with European strains.

Table 1. Main difference between Indian and European cauliflower

S.No.	Characteristics	Indian type	European type
1	Heat tolerance	Yes	No
2	Curd formation at	20-27°C	5-20°C
3	Maturity	Early	Late
4	Variability	More	Less
5	Self incompatibility	Strong	Less or no
6	Curd colour and flavour	Yellow and strong	White and mild
7	Juvenility	Short	Long
8	Requirement of vernalization	No need but requires cold treatment at 10-13R°C for 6 weeks	Require vernalization at 7R°C for 8-10 weeks

History and Origin

Cauliflower was introduced in India in 1822 from England by Dr. Jemson, Incharge , Company Bagh, Saharanpur (Uttar Pradesh). The name of cauliflower has originated from the Latin words 'Caulis' and 'Floris' which means stem and flower, respectively. Cauliflower is thought to be domesticated in the Mediterranean region. According to Boswell (1949), it originated in the island of Cyprus from where it moved to other areas like Syria, Turkey, Egypt, Italy, Spain and north western Europe. In the middle of the 16th century, the first illustration and description of cauliflower was presented by the herbalist Dodoens (1544).

Area and Production

India is the largest producer of cauliflower in the world. The major cauliflower producing states are West Bengal (26%), Bihar (17%), Madhya Pradesh (10%), Orissa (10%), Gujarat (8%), Haryana (7%), Assam (6%) and Maharashtra (3%). According to FAO and Indian Horticulture Database 2013, total area 1226455 ha, production

22153522 MT and productivity 18.1 MT/ha of cauliflower in the world. The total area of cauliflower in India is 402,000 ha, production 7887,000 MT and productivity 19.6MT/ha. In Uttarakhand total area of cauliflower 2.76 '000 ha and production is 36.72 '000MT.

Table 2. Area, Production and Productivity of cauliflower in different states of India

State	Area	Production	Productivity
West Bengal	73.00	1863.00	25.5
Bihar	63.11	1193.73	18.9
M.P.	24.56	690.00	28.1
Orissa	44.70	675.47	15.1
Gujarat	28.62	532.28	18.6
Haryana	30.44	492.26	16.2
Assam	21.71	449.25	20.7

Area in '000 ha, Production in '000 MT and Productivity = MT/ha

Importance and Uses

There is hardly any house where it is not regularly used as vegetable. With the development of tropical types in cauliflower in addition to temperate types, it has now become possible to grow this vegetable almost throughout the year particularly in the Northern and central part of India. Cauliflower growers may be benefited by growing this crop to a great extent near large cities or by sending the produce to distant places where they can fetch better price.

It is generally used as cooked vegetable either singly or mixed with potato as fried or in curry form. Small pieces of cauliflower can be fried with besan for the preparation of pakoras. Grated cauliflower is used to prepare stuffed parathas.cit is also used in preparation of pickle with other vegetables.

Nutritional Value

The nutritive value of cauliflower is given below:

Moisture (%)	Protein (%)	Fat (%)	Mineral matter (%)	Fibre (%) (%)	Carbohydrate (K Cal)	Calories
90.8	2.6	0.4	1	1.2	4	30
Minerals						
Phosphorus (mg/100g)	Potassium (mg/100g)	Calcium (mg/100g)	Magnesium (mg/100g)	Iron (mg/100g)	Sodium (mg/100g)	Copper (mg/100g)
57	138	33	18	1.23	53	0.13
Manganese (mg/100g)	Zinc (mg/100g)	Sulphur (mg/100g)	Chlorine (mg/100g)	Molybdium (mg/100g)	Cromium (mg/100g)	
0.1	0.4	231	34	0	0.003	
Vitamins						
Carotene (mg/100g)	Thiamine (mg/100g)	Riboflavin (mg/100g)	Niacin (mg/100g)	Vitamin C (mg/100g)	Choline (mg/100g)	Folic acid-Free (mg/100g)
30	0.04	0.1	1	56	127	0

Botany

Cauliflower, a cruciferous vegetable, is in the same plant family as broccoli, kale, cabbage and collards. Surrounding the curd are ribbed, coarse green leaves that protect it from sunlight, impeding the development of chlorophyll. The flowers are attached to a central stalk. Seeds are head shaped. The head of a cauliflower, also called a "curd," is a group of tightly packed flower buds that have not fully developed. The buds are attached to fleshy stalks where most of the nutrients for their growth are stored. The taxonomical position of cauliflower is as follows:

Order: Crucuferae; Tribe: Brassicae ; Sub-tribe: Brassica

The family cruciferae is characterized by 4 petals, standing opposite to each other in square cross, 6 stamens of which 2 are short and 4 long and a special kind of pod called siliqua. Cauliflower is a monogenomic species whose genomic constitution is C and chromosome number is 2n=18.

Major Varieties

Cauliflower is a thermo-sensitive crop. Varieties differ in their temperature requirement for curd initiation and development. They have been classified into different maturity groups according to their temperature requirement.

Table 3. Maturity groups in cauliflower

Maturity	Sowing time	Transplanting time	Temperature requirement for curd initiation and development
Early			
September maturity (mid September-mid october)	Mid May	July beginning	20-27°C
October maturity (mid October-mid november)	May end-mid June	Mid July	20-25°C
Mid early			
November maturity (mid November-mid december)	July end	September beginning	16-20°C
Mid late			
December maturity (mid December-mid january)	August end	September end	12-16°C
Late			
Snowball	September end-mid October	October end-mid November	10-16°C

Early varieties

Early Kunwari

Recommended for Haryana, Punjab, and Delhi. Very early variety. Curds hemispherical with even surface, ready for harvesting from mid September to mid October. Average yield is 8 t/ha.

Pusa early Synthetic

Main season variety. Curds somewhat creamy white to white and compact. Ready for harvest from mid December to mid January. Average yield is 11 t/ha.

Pant Gobhi-3

Early maturing variety. Curds medium sized and solid white. Curds ready for harvest from October. Average yield is 10 t/ha.

Pusa Deepali

Developed at IARI, New Delhi. Recommended for Northern India particularly Delhi and Punjab. Early maturing variety, curds compact, self-blanching, white, medium sized and almost free from riceyness. Curds ready for harvest in late October. Average yield is 12 t/ha.

Pant Gobhi-2

Early maturing variety. Curds compact, composite and creamy white. Curds ready for harvesting from November to December. Average yield is 12 t/ha.

Mid-early varieties

Improved Japanese

An introduction from Israel. Plants erect, leaves bluish green, curds compact and white. Yield potential is 20t/ha.

Pusa Hybrid 2

First F1 hybrid released by public sector organization. Plants semi-erect with bluish green leaves, resistant to downy mildew. Curds are creamy white, very compact, yielding 23 t/ha.

Pusa Sharad

A variety released by IARI. Foliage bluish green, leaf with narrow apex and prominent mid-rib. Semi-dome shaped white and very compact curd. Average yield 24t/ha.

Pant Gobhi-4

A variety for November maturity. It has medium long stem, semi-erect leaves, hemispherical creamy white, medium compact, non-ricey curds. Average yield 14t/ha.

Mid-late varieties

Pusa Synthetic

A synthetic variety, plants erect, frame narrow to medium, curds creamy white and compact. The yield potential is 27t/ha.

Pant Shubhra

Recommended for cultivation in Northern India. Early growing variety. Curds are compact, slightly conical and creamish white. Ready for harvest in November. Average yield is 20 t/ha.

Pusa Shubhra

Plants tall, long stalk, leaves light bluish green twisting backwards from the middle. Curds medium, flat, compact and white. Field resistant to black rot and curd blight.

Pusa Himjyoti

Erect bluish green leaves with waxy coating, curds retentive white, self blanched, solid and 500-600gm in weight.this is only the variety which can be grown from April-July in the hills.

Punjab Jiant 35

Main season variety. Curds white, compact medium sized. Ready for harvesting from mid November to December. Average yield is 17 t/ha.

Late varieties

Pusa Snowball

Ideal for cooler climates of North Indian states. Late maturing variety. Curds medium sized, solid, having attractive white colour. Ready for harvesting from January to March. Average yield is 25-30 t/ha.

Pusa Snowball K 1

Late maturing variety. Curds very compact, medium in size and snow white in colour. Ready for harvesting from January to April. Average yield is 25-30 t/ha. Susceptible to black rot.

Ooty 1

Suitable for growing in hilly regions of Tamil Nadu above 1,800MSL. It has a potential yield of 46t/ha in 110-120 days.

Soil

Cultivation of cauliflower is done mainly on sandy to heavy soils rich in organic matter. Early crops prefer light soil while late crops thrive better on heavier soils due to retention of moisture. On heavy soils, plants grow more slowly and the keeping quality is improved. A pH range of 5.5-6.5 is considered as optimum for growing cauliflower. Plants growing in saline soils are prone to diseases.

Climate

Cauliflower is a thermo-sensitive crop. In India, cauliflower is grown in large areas having a cool and moist climate. The cauliflower varieties are very sensitive to temperature. High temperature during maturity will result in yellowish leafy curds. It is therefore essential to choose proper variety to be sown at proper time. The Brassica family is quite cold resistant, making them well adapted to cool season production. With most Cole crops, a cold period is necessary for flowering. However, each crop has its own temperature tolerance. For good seed germination, a temperature of 10-21°C is required. A temperature range of 15-21°C is considered as optimum for growth and curd formation of the crop. Temperature below 10°C during growth delays maturity and undersized small unmarketable buttons are formed.

High temperatures during cauliflower production delay maturity and increase vegetal growth and cool temperatures hasten maturity and may induce 'bolting'. Bolting is the premature formation of seed stalks. Fluctuating temperatures may induce some cauliflower cultivars which have started heading, to revert to the vegetative phase, which results in poor-quality curds.

Seed Treatment

Today seed companies are pelletizing cauliflower seeds. Pelleted coatings broaden the temperature range in which the seeds will germinate. Pelleted seed is a mix of powders placed around the seed to form a ball. This makes the seed more uniform in size, weight and shape, allowing for easier handling at planting time.

Preparation of Field

The soil should be well prepared and brought to a fine tilth. The manure and fertilizer should be applied as a basal dose while preparing the field. Drainage is a problem for early and mid-early crop in north India and sometimes in the mid season crop when the monsoon prolongs, beds should be prepared after the last ploughing and following fertilizer application as basal dose. The beds should be so prepared that the excessive water drains out rapidly without causing soil erosion.

Seed Rate and Sowing

The cauliflower crop is grown from seedlings raised in nursery beds. For early crop 500-600gm seeds are required to plant one hectare area while for mid and late crops, about 350-400gm seeds are sufficient. Seeds are sown on raised nursery beds. The conditions for nursery raising of early crop are not very optimum since the period has high temperature, low humidity with dry hot winds. For such situations it has been suggested that the beds should be made cool by providing sufficient moisture in the beds and by covering them during hotter period of the day. The nursery beds should be narrow and about 30cm wide so that through the channels, the water can go to the whole bed through percolation.

Sowing Time

The time of seed sowing will depend on the variety, season and location. The early varieties are sown in may-June, and first fortnight of July, mid-season in July-august, mid-late in September and late varieties in October.

Transplanting

The seedlings are transplanted in the field after 30-40 days of sowing. The distance of planting is 60 × 30 cm for early varieties and 60 × 45 cm for mid season and late maturing varieties. The seedlings are transplanted in flat beds or on ridges. During rainy season planting on ridges is preferred.

In a field experiment at Experimental Farm of Indian Agricultural Research Institute (IARI), New Delhi during *Rabi* 2012-13, it is revealed that application of 125% RDF + FYM @ 5 t/ha over 100% RDF + FYM @ 5 t/ha and 75% RDF + FYM @ 5 t/ha exhibited higher curd yield in cauliflower (Table 4; Fig. 1). Similarly, planting geometry of 60 × 30 cm in late season cauliflower (28.76 t ha^{-1}) resulted in higher cauliflower yield and profitability over other respective planting geometries (Choudhary, 2013).

Table 4. Effect of planting geometry on productivity of cauliflower

Treatments	Curd (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Cauliflower (60 × 45 cm)	22.64	48.32	46.95	1,81,102	1,35,245	3.95
Cauliflower (60 × 30 cm)	28.76	61.56	46.80	2,30,098	1,83,341	4.92
Cauliflower (45 × 45 cm)	27.50	58.99	46.74	2,20,036	1,73,579	4.73

[Source: Choudhary, 2013]

Fig. 1. A view of different planting geometries in late season cauliflower (Pusa Snowball K 1) at IARI, New Delhi.

Manures and fertilizers

About 25-30 tonnes of FYM is applied to the soil at the time of field preparation. The application of fertilizers, 100-150kg N, 60-80kg P and 80kg K per hectare is done at ploughing and field preparation. Only half quantity of N is used for basal application. The other half quantity of n is top dressed after 30-35days of transplanting. Later urea (1-2 percent) is sprayed on the young plants at 7-10 days interval to enhance the plant growth.

Irrigation

The availability of water can be critical to successful production. The seedlings are irrigated immediately after transplanting. Later the frequency of watering will depend on soil type and season. Irrigations during rainy season may be fewer than in summer and cool season. During winter or cool season irrigations are at 10-12days interval and in summer more frequently at weekly intervals. Overwatering and water logging should be avoided. The most critical moisture period is during head development. Irrigation at the wrong time can cause problems such as head rot of cauliflower. Sprinkler, big gun, furrow and drip irrigation are used in cauliflower production.

Intercultural Practices

Weed management is a major field problem for commercial cauliflower production. Weeds compete with the intended crop for nutrients, which can lead to a reduction in harvest as well as a delay in plant maturation. Regular weeding during initial stages of plant growth is essential. Light hoeing is also required along with weeding. In addition, weeds provide a habitat for insects, nematodes and diseases and can reduce the efficacy of spray-applied pest control materials by interfering with pesticide deposition. Herbicides are available to use on a cauliflower crop. Rates and methods of application can be found on the product label. A number of shallow cultivations are an essential part of a weed control programme. Normally, the crop is kept free of weeds by 2-3 hand weedings and 1-2 hoeings. One day before transplanting of seedlings, the application of Pendimethalin (0.56 kg a.i./ha in 600-750 litres of water) followed by a hand weeding 40-60 days after transplanting effectively checks the weed population. If necessary, earthing up is done 30 days after transplanting. At the time of earthing up the plants are supported with soil to avoid toppling of the plant during head formation. Good weed control requires integration of cultural and chemical methods. Cauliflower should be planted to land free of perennial weeds, where the annual weed seed population has been reduced by cultural practices such as crop rotation, stale seedbed or hoeing. The plants grown on ridges will require earthing up which can be done at the time of topdressing of nitrogen.

Blanching

The developing curd of the spreading plant type is often covered with the leaves of cauliflower removed from the plant or by tyeing the upper leaves for blanching the curd so that it does not become yellowish when exposed to the sunlight. The ultraviolet rays of the sunlight affect the curd colour. In the erect or semi-erect plant types of late varieties the small terminal leaves cover the developing curd and protect it from sunlight.

The market demands cauliflower which is pure white or pale cream in colour. Heads exposed to sunlight develop a yellow and/or red pigment. The usual method to exclude light is to tie the outer leaves when the curd is 8 cm in diameter. Leaves may also be broken over the curd to prevent yellowing. In hot weather blanching may take 3 to 4 days, but in cool weather, 8 to 12 days or more may be required. The new orange and purple-coloured cauliflower curds generally do not require blanching.

Yield

The average yield of an early variety is about 10-12 tonnes per hectare which is lower than the main season and late maturing varieties. The curds of early varieties are smaller sized than later maturing varieties. The yield of mid-season and late varieties is around 20-30tonnes per hectare.

Sorting and Grading

Harvesting of cauliflower, which is performed manually, begins in December and is usually completed by 7 March. Cauliflower should be harvested when the head is approximately 15 cm in diameter, the curds are still compact and white and the leaves are still healthy and green. Harvested cauliflower for the fresh market is cut at the base of the head. The spreading leaves are removed; leaves that wrap around the head are trimmed 5 cm above the head for protection of the curd. The heads are then cleaned, packed into cartons and then shipped to the cooler. Sometimes the heads are wrapped in perforated plastic. If the heads are wrapped in plastic, the carton is cooled by hydrovac. If the heads are not wrapped in plastic, the carton is cooled by hydro-cooling. Cauliflower is packed with 6, 8, 9, 12, 15, 18 or 22 heads per cardboard box. Nine or 12 heads per carton are the most desirable size. Cauliflower that is to be processed is packed into bulk bins and shipped to the packinghouse. In the packinghouse cauliflower is inspected for defects, trimmed, washed with mildly chlorinated water and then packaged. Most cauliflower is freshly processed and cut into florets for bagging, some cauliflower is processed for pickling.

Packaging

Cauliflower is packaged after being closely trimmed into 1 or 2 layer cartons of 12 to 24 heads, with 12s the most frequent. Much of the cauliflower now marketed is closely trimmed of leaves, pre-packaged in perforated film

overwraps, and packed in fibreboard containers. The overwraps should provide four to six ¼ cm holes per head to allow adequate ventilation.

Storage

After harvesting the curds can be stored for 3-4days at room temperature. In cold storage, the curds at 0R"C and 85-90 per cent relative humidity keep well for about 30 days.

Important disorders: Cauliflower crops show various non-parasitic disorders which cause tissue to die off. In some cases, these deviations have been shown to depend mainly on heritable characters; whereas in other cases external factors had a least marked effect.

Riceyness: When the surface of the curd is loose and has velvety appearance due to elongation of pedicel and formation of small white flower buds at the curding stage, such curds are called ricey. Apart from fluctuating and unfavourable temperature, heavy application of N and high humidity may cause riceyness.

Control

- Selection of proper varieties for a particular time of cultivation
- Optimum application of nitrogenous fertilizer
- Planting of resistant and tolerant varieties help minimize this condition.

Fuzziness: Fuzziness appears as flower pedicels of velvety curds elongate. It may be hereditary or non-hereditary. Cultivation in abnormal time encourages fuzziness.

Leafy curds: Development of small green leaves (bracts) inside the segments of the curd makes them leafy. Prevalence of high temperature especially after curd initiation or fluctuation in temperature at curding stage aggravates leafy curds.

***Control*:** Selection of proper varieties may help reduce it.

Blindness: During the early stage of plant growth, damage to growing point by insects, low temperature or frost causes blindness. Plants grow without terminal bud and fail to form any curd. The leaves of blind plant become thicker and leathery owing to accumulation of carbohydrates.

***Control*:** Damage of growing point by insects may be avoided by proper spraying of insecticides.

Bottoning: Development of small curds in young plants and fewer, less developed leaves is known as bottoning. Deficency of nitrogen, water stagnation in field, transplanting of old seeding, planting early type cauliflowers under lower temperature are causes for it. Identifying exact cause helps overcome this malady. This crop is very sensitive and any check during its early vegetative growth also results in bottoning.

Chlorosis: Chlorosis shows an interveinal, yellow mottling of lower older leaves. Since Cauliflower has a high magnesium requirement, its deficiency cause chlorosis When grown on high acidic soil.

Control

- This can be corrected by applying magnesium oxide@300kg/ha.
- Liming soil and use of chemical fertilizer containing soluble magnesium also keeps this in control.

Hollow stem: In heavy fertilized soils, particular with nitrogen, rapidly growing plants of Cauliflower develop hollow stem and curd. It may be corrected by close spacing and optimum use of nitrogenous fertilizers.

Browning: Browning is caused due to boron deficiency. Generally, the deficiency symptoms of boron are externally visible on plants after the curd formation. In early stage, the water soaked areas appear on the stem and curd surface. As the plant grows, the stem becomes hollow with water soaked tissue covering the internal walls of the cavity. In advanced stage of deficiency, brown or pink coloured areas are seen on curd surface and therefore, it is also called brown rot or red rot or browning of the curd. Sometimes the stem may become hollow even without brown areas on the curd. The affected curds are bitter in taste. The foliage colour first changes to dull green and then greenish yellow at the apical margin of the older leaves. When there is severe deficiency of boron, then leaves are under developed and smaller. The growing point may die in young stage of plant itself.

Control:

- The deficiency of boron may be corrected by applying borax.
- The quantity of borax depends on soil type, soil pH and the extent of deficiency.
- In acid soil, 10- 15 kg borax/ha is sufficient while larger quantity may be required as natural and alkaline soils.

Whiptail: Whiptail disorder is caused due to deficiency of molybdenum. In young plants the deficiency symptoms are chlorosis of leaf margins and the whole leaves may turn white. The leaf blades do not develop properly. When the deficiency is severe, only the midribs develop. This condition is commonly known as 'Whiptail'. The growing point of the plant is also deformed which prevents the curd development. The deficiency of molybdenum generally occurs in acid soils when the soil pH is below 5.5.

Control

- Lime application in acidic soils is done to increase the availability of molybdenum. The quantity of lime is determined by initially measuring the pH of the soil.
- Alternately, soil application of Sodium Molybdate (10-15 kg/ha) effectively controls the deficiency symptoms.

Important Diseases

Damping off (*Pythium spp.*)

Symptoms: It is more common disease of cauliflower. Both pre and post emergence damping off occur in cauliflower. The invasion of the host plant by the fungus before the emergence of the seedling from soil causes pre emergence damping-off. It is primarily due to conditions which inhibit or slow down seed germination and allow the pathogen to grow. Post emergence damping off occurs above the ground on young seedlings in which the stem tissue becomes soft and water soaked and the plant collapses at or near the soil level. The roots may also get affected resulting in the death of the seedling. Excess soil moisture and high temperature are favourable for the disease development and it spreads from the un-decomposed infected plant debris present in the soil.

Control

- Soil solarisation or soil treatment with formaldehyde in nursery beds.
- Drenching the soil in nursery bed with Thiram and Dithane M-45 (0.2%) or bavistin (0.1%).
- Seed treatment with fungicides like Thiram, Captan, Ceresan or Bavistin 3gm per kg of seeds before sowing.
- Crop rotation with cereals.
- Keep the plants actively growing with fertilizers.
- Overcrowding of seedlings to be avoided.
- Regulate watering/irrigation carefully to avoid excess soil moisture.
- ♦ Provide good drainage.
- ♦ Destroy the infected plant debris after harvesting.
- ♦ Rotate the nursery bed site.

Leaf spot and Blight or Black spot (*Alternaria brassicae*)

Symptoms: The fungus causes brown rot of cauliflower curd. Small, circular lesions appearing on leaves enlarge and coalesce in concentric rings with yellow halos. The tan coloured dead centres of the lesions any drop out making a hole or these may be covered with sooty black spores. In the affected curds of cauliflower become brown and later the entire curd is discoloured and unmarketable. The fungus also causes damage to pods and seeds with brown to black spots at seed production stage and the harvested seeds are contaminated resulting in poor germination. It is a serious problem in cauliflower seed production.

Clubroot (*Plasmodiophora brassicae*)

Symptoms: It is a soil-borne disease which affects cauliflower. Early infections are difficult to detect as symptoms begin underground. Symptoms include small to large swellings and other malformations of the roots. As a result of these swellings, water and nutrient flow are restricted within the plant, which causes the above-ground parts to wilt, turn colour and look stunted. Wilting is most common on warm, sunny days; plants may show little wilting early in the morning or late at night. The clubroot fungus enters the plant through the many fine hairs on the roots. The extent of the disease is affected by many factors. Moist, cool soils usually produce more diseased plants than dry, warm soil. The disease also thrives best in acid soils; that is when the pH is below 7. Once land becomes infested with this disease, it will remain so for several years. When the affected plants rot and break down in the fall, the fungus spores are released into the soil, where they may live for 10 to 20 years, ready to infect any Cole crop subsequently planted. Because the fungus spores are in the soil, movement of the soil by any means (boots, tools, wheels or wind and water, etc.) also spreads the disease.

Control

- Isolate (if possible) or avoid the use of infested fields for brassica crops for about seven years. The disease affects only the brassica crops so any other crop may be planted as long as brassica type weeds are not present.
- Do not apply clubroot infested manure on land to be used to grow brassicas. Cattle fed infected plant material can pass the fungus spores in manure; therefore it is best to put contaminated manure back on the field that contained the infected roots, thereby preventing the spread of the disease to other fields.
- Another possibility would be to place contaminated manure on permanent pasture lands that will not be used for any susceptible crop and where runoff will not spread the disease to clean fields.
- Rotate crops and fields as a preventative measure before clubroot occurs. Allow at least three years between growing susceptible crops.
- Clean and disinfect all equipment used on infested land before using on a non-contaminated field. Washing or steam cleaning will prevent carrying the disease to clean fields. Live steam delivered at 690 kPa pressure for five minutes is the best method to disinfect equipment.
- Control susceptible weeds whenever possible. Weeds of the mustard family will maintain or increase the level of infestation of clubroot in a field. Examples of susceptible weeds are as follows: wild radish, wild mustard, stinkweed, pepper grass, shepherd's purse, false flax, hare's ear mustard, worm seed mustard and yellow rocket.
- Apply lime to raise the pH of the soil to at least 7,2. Clubroot seems to thrive best in moist, acid soils, therefore wet, poorly drained land should be avoided or the drainage improved.
- Use clubroot-free transplants. The only way to ensure clean transplants is to use sterile soil. Clean boxes and equipment with steam. In the early stages of infection, plants may not show any signs of disease, so it is essential to purchase plants from a reliable source or to follow the procedures for producing healthy plants. Make sure you have enough clean plants for the area to be planted. Diseased plants next to healthy ones will result in all plants becoming infected. When growing transplants in the field, it is important to select a well-drained area where it is known that clubroot has never occurred. Certain soil fumigants will control the clubroot organism.

Stalk Rot (*Sclerotinia sclerotiorum*)

This fungus can cause serious losses in the field, in storage, and under transit and market conditions. Generally, damp weather favours the occurrence of the disease. Infections may occur on the stem at the ground level, on the leaves at their bases, or where the foliage comes in contact with the soil. The infections begin as water-soaked, circular areas, which soon become covered by white, cottony fungal growth. The affected tissue becomes soft and watery as the disease progresses. The fungus eventually colonizes the entire cabbage head and produces large, black, seed like structures called sclerotia on the diseased tissue.

Control: The disease can be managed most successfully by combining cultural practices that discourage disease development. Planting cabbage in fields that are surrounded by dense woods will restrict air circulation and subsequently delay drying. Rows should be planted in the direction of the prevailing winds to promote free flow of air movement within the plants. Fields with a history of white mold should be planted with non-susceptible crops such as grains (corn, rye, wheat, etc.). Cabbage and other susceptible crops (cauliflower, beans, peas, etc.) should not be planted in fields where white mold has become a problem because continuous cropping of susceptible crops will result in a buildup of the fungus in the soil and increased disease incidence. Mechanical injuries to cabbage heads during harvesting operations should be avoided.

Downey mildew (*Peronospora parasitica*)

This disease is caused by the fungus. Once infected, the plant shows white, fuzzy masses in patches on the underside of leaves, stems and heads. The top of the leaves turn purple, then later turn yellow or brown. It may cause browning and black streaking on stems below the curd and black, brown or grey spotting on the curds of cauliflower. Infection is favoured by wet, cool weather, especially during prolonged periods of leaf wetness, such as during dew or fog. This fungus overwinters in seed and can survive for at least two years. It also overwinters on infected plants and can survive in the soil for at least one year.

Control: Good air and water drainage is critical in controlling this disease, along with avoiding water on the crop in the afternoon and evenings. Crop rotation with non-brassica plants and incorporating plant debris will also aid in controlling this disease.

Rhizoctonia

The soil-borne fungi *Rhizoctonia* and *Pythium* cause two diseases of cauliflower, namely damping off and wirestem. Pre-emergence dampingoff occurs when seeds are attacked and decay, as well as when plants germinate, but fail to emerge. Post-emergence damping off occurs when the stems of 2 to 5 cm tall plants are attacked. A water soaked area completely encircles the stem near the soil line and the seedling wilts and topples over. Wirestem results from an extension of the damping-off process, but new infections may occur on plants 10 to15 cm tall. The stem above and below the soil line darkens, and the outer cortex tissue decays and sloughs off in a sharply defined area encircling the stem. The stem is thin and wiry at the lesion but remains erect. The plant may survive, but will perform poorly.

Control: For the prevention of damping off and wirestem in seedbeds, only sterilised soil or soil that has not previously been used for brassicas for several years should be used. Seeds should be hot-water treated and treated with a suitable fungicide. Plant density should permit adequate light and air penetration. Factors such as deep planting, reduced seed vigour and excessively cold, hot, moist or saline soils that delay seed emergence should be avoided. Deficiencies of calcium, potassium and nitrogen or excessive nitrogen may promote disease. A field rotation with non-brassica crops should be practised for at least three years. Avoid soil mounds onto the lower leaves when cultivating.

Black Rot (*Xanthomonas campestris* pv. *campestris*)

This bacterial disease is common in areas having a warm and wet climate. Plants can be infected during any growth stage and the symptoms resemble nutritional deficiencies. Infected seedlings become yellow, drop lower leaves, and may die. Leaves may be affected on only one side of a seedling. Plants infected because of contaminated seed may not develop symptoms for many weeks. The classic symptom of black rot is caused by local infection that results when bacteria enter leaves through natural openings of leaf margins. The infected tissue turns pale green-yellow and then turns brown and dies. Affected areas are usually wedge- or V shaped. These areas enlarge as the disease progresses, and severely affected leaves may drop off. The veins in infected leaves, stems, and roots sometimes become black. The heads of the infected plants remains small and its quality is reduced making it unfit for marketing.

Control: An integrated approach is needed to manage black rot successfully. Use of black rot tolerant varieties is the best method to control the disease. Considerable reduction in disease has been observed when seeds are treated with Agrimycin-100 (100ppm) or Streptocycline (100 ppm). Planting should be done on raised beds to

facilitate drainage. Cultivation in the fields where crucifers have been continuously grown during last 2 years should be avoided. Plants should be thoroughly inspected for black rot symptoms and the affected plants should be removed and destroyed.

Post-harvest control: Cauliflower should be handled carefully to avoid bruising and damage that will leave the plant susceptible to infection. Plants must be thoroughly cleaned and stored at a low temperature, typically 4 °C. It is important to keep the storage facility free of soft rot bacteria by immediately destroying any infected plants and maintaining a clean facility.

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