– PRODUCTION GUIDELINE –

Cauliflower

(*Brassica oleracea* var. Botrytis)

agriculture,
forestry & fisheries

Department:
Agriculture, Forestry and Fisheries
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Content

Cauliflower is one of several vegetables in the species Brassica oleracea, in the family Brassicaceae. It is an annual plant that reproduces by seed. Typically, only the head (the white curd) of aborted floral meristems is eaten, while the stalk and surrounding thick, green leaves are used in vegetable broth or discarded.

Its name is from Latin caulis (cabbage) and flower, an acknowledgment of its unusual place among a family of food plants which normally produces only leafy greens for eating. *Brassica oleracea* also includes cabbage, Brussels sprouts, kale, broccoli, and collard greens, though they are of different cultivar groups.

Classification

Scientific name: *Brassica oleracea* var. botrytis L.

Common names: Cauliflower

Family name: Brassicaceae (Cruciferae)

Origin and distribution

Cauliflower traces its ancestry back to the wild cabbage, a plant thought to have originated in ancient Asia Minor, which resembled kale or collards more than the vegetable that we now know it to be.

The cauliflower went through many transformations and reappeared in the Mediterranean region, where it has been an important vegetable in Turkey and Italy since at least 600 BC.

It gained popularity in France in the mid-16th century and was subsequently cultivated in Northern Europe and the British Isles. The United States, France, Italy, India and China are countries that produce significant quantities of cauliflower.

Major production areas in South Africa

Cauliflower performs and grows well in most parts of the country, ranging from Brits and Marble Hall, the central Free State, cool Lowveld areas, Eastern Free State, Gauteng, Mpumalanga Highveld, KwaZulu-Natal coastal area, KwaZulu-Natal interior, Eastern Cape, Limpopo (Marble Hall and Groblersdal), North West, Northern Cape, Western Cape, warm Lowveld areas, Southern Cape, Polokwane and Dendron.

Description of the plant

Cauliflower, a cruciferous vegetable, is in the same plant family as broccoli, kale, cabbage and collards.

Leaves

Surrounding the curd are ribbed, coarse green leaves that protect it from sunlight, impeding the development of chlorophyll.

Flowers

The flowers are attached to a central stalk.

Seeds

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.

Cultivars

Cauliflower cultivars are discussed in the following table.

Variety	Season	Days to maturity	Plant type	Head mass (kg)	Colour	Shape	Remarks
Synergy	Summer	85–110	Medium to large	0,8–1,5 kg	White	Deep round	Reasonable heat and cold tolerance, processing (freezing) and fresh market
Sabadel	Early summer	70–80	Large	Big	White	Dome	Fresh market and industry
TSX C40	Summer	75–80	Medium	1–1,2	White	Dome	Holds well in field, tolerant to blackrot
Lagardo	Autumn, Winter, Spring	90–120	Medium	0,8–1,5	Cream white	Ball to dome	Fresh market, freezing and prepack
Arano	Winter	90– 20	Medium to large	0,8–1,5	White	Deep round	Ideal for prepack and freezing
Huntsmen	Year round	90–120	Medium	1–1,7	Cream white	Ball to dome	Standard for mild summers and winters
Juneau	Year round	90–120	Medium to large	0,8–1,5	White	Deep round	Reasonable heat and cold tolerance, processing (freezing) and fresh market
TSX C22	Year round	70–75	Medium to large	0,6–1,2	White	Dome	Ideal for prepack and freezing, Blackrot tolerant
White Gold	Year round	75–80	Medium	0,5–8	Fresh green	Triangular	Good standing ability, strong against riceyness and red discolouration

Climatic requirements

Temperature

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. Young, hardened cauliflower plants can withstand temperatures of 0 °C for less than 36 hours. The minimum and maximum growing temperatures for cauliflower are 0 and 30 °C, with the optimum growing temperature for this crop between 15 and 22 °C. The minimum, optimum and maximum germination temperatures for cauliflower are 7, 27 and 29 °C respectively.

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.

Soil requirements

Soil fertility

Recommendations for supplemental organic matter, fertiliser, lime or manure should be based on a soil test and a nutrient management plan. Nutrient management plans balance the crop requirements and nutrient availability, with the aim to optimise crop yield and minimie groundwater contamination, while improving soil productivity.

Manure

Cauliflower does well when manure is applied. However, it is best not to use manure from animals that have been fed turnips or rutabagas. Excessive use of manure may contribute to tip burn, hollow stem, internal browning, head rot and other problems. Uncomposted manure may not be applied directly to the crop prior to planting.

Lime

Lime should be applied to maintain the soil pH in the range of 6,5 to 7,0, unless club root control is required (pH of 7,2). If the soil pH is below 6,2, apply lime either in autumn of previous year or six weeks before planting.

Site and soil

Cauliflower is grown on many different types of soil, but does best in a rich, well-drained soil with a high moisture-holding capacity. High humus content in the soil will provide better aeration and water penetration. If a soil is low in organic matter, stable or green manures can be supplied. Cauliflower grows best on a neutral or slightly acid soil (pH 6,0 to 6,5).

Well-drained, sandy loam soils are suited to early varieties, whereas loamy and clay loam soils are suited to late ones because they are to some extent tolerant of poor drainage.

CULTIVATION PRACTICES

Propagation and crop establishment

Seed treatment

Today seed companies are pelletising 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.

Soil preparation

Good soil preparation is important when planting cauliflower. The best way to determine soil conditions is to have a soil test performed.

Planting

Planting period

For early markets, transplants must be raised in greenhouses. About four to five weeks are required to produce transplants, therefore for early production, seeding in the middle of March is recommended.

Spacing

Spacing between rows should be 91 or 102 cm.

Transplanting

Plants may be grown in plastic plug trays/plant cells, or in peat blocks (e.g. Jiffy pots). Normally 300 g of seed will produce enough plants for one hec-

tare. Old or large cauliflower plants and those grown at low temperatures (10 to 15 °C) are likely to button (form heads prematurely) and bolt if exposed to a period of cool weather after field setting. Seedlings are ready to be planted outside when they are about 15 cm high with 6 to 8 true leaves. Slight hardening off is beneficial, but severe hardening off may stunt growth. Hardening off is the process whereby, 2 weeks before planting, transplants are gradually acclimatised to the outdoor environment.

Seeding rate

For late markets, transplants may be raised in plastic plug trays/plant cells, a greenhouse seedbed, or direct seeded. When direct seeding, 1 kg of seed is required per hectare, because seed is generally planted at twice the final spacing. Direct seed two to three weeks earlier than transplanting for the same harvest date. Place seeds 12 mm deep and 35 to 50 cm apart, in rows that are 60 to 90 cm apart. Plant spacings that are more square (i.e. 50 cm x 60 cm) will aid in providing a more uniform crop.

Fertilisation

Field fertilisation

Nitrogen

For successful cauliflower production 130 to170 kg/ha of actual nitrogen is required. If manure is applied then there is a need for a reduction in the quantity of total nitrogen applied to the field. Broadcast between 65 and 85 kg/ha of nitrogen before planting and work it into the soil. Apply the remainder in two sidedress applications. The first application should be 7 to10 days after planting and the second 4 to 6 weeks later. If the season is very moist, a third sidedress application may be used three weeks after the second application. Adequate nitrogen produces a dark green colour in cauliflower leaves. Nitrogen deficient plant leaves are light green, eventually turning yellow and may be shed.

Phosphorous

A soil test will determine the level of phosphorus requirements. Broadcast or bandplace any needed phosphate before planting and work in. Phosphorus is important for root development and cool, wet soil conditions hamper its uptake. Deficiency symptoms include slow growth and delayed maturity.

Potassium

A soil test will determine the level of potassium requirements. Apply potassium in autumn by broadcasting and working into the soil. Excessive potassium may lead to increased tip burn (internal and/or external).

Sulphur

Cauliflower crops have a high need for sulphur and on sandy soils low in organic matter; soil sulphate levels may be low. Early deficiency symptoms appear as interveinal chlorosis on the youngest leaves and the leaves may become reflexed. Application of gypsum should be considered on these soils.

Magnesium

Magnesium deficiency symptoms appear on the older leaves first and include interveinal chlorosis. As the chlorosis intensifies, purple blotches may be seen near the leaf margins. Deficiency is fairly frequent, especially on light acid soils to which dolomitic lime has not been applied. Refer to the table below for fertiliser sources and rates of magnesium.

Magnesium application rates

		Foliar applied		Soil applied	
Source	Composition Mg (%)	Nutrient (kg/1 000 ℓ)	Product (kg/1 000 ℓ)	Product (kg/ha)	Product
Sulphate of potash magnesia	11	–	–	30	270 kg/ha
Epsom salts	10,5	1,9	18	30	285 kg/ha
Dolomitic lime	6–13	–	–	120–260	2 t/ha

Micronutrients

Boron: Boron deficiency may cause hollow stem, stem discolouration, cracking, leaf rolling, deformed buds as well as browning of cauliflower curds. If the soil test indicates low levels of boron, apply some boron to the soil or leaves. Refer to the micronutrient application table below for a list of fertiliser sources and application rates.

Manganese: Manganese deficiencies may occur on sandy, overlimed soils. Manganese deficiency causes yellowing between the veins of young leaves. Leaves gradually turn pale green with darker green next to the

veins, petioles and stems. Foliar sprays of manganese sulphate may be necessary to correct a deficiency. Refer to the micronutrient application table below for a list of fertiliser sources and application rates.

Molybdenum: Molybdenum deficiency causes whiptail in cauliflower. Whiptail results in a deformed growing point, causing no head to develop, as well as leaf blades consisting mostly of midribs. If soil tests indicated low levels, foliar application of molybdenum is necessary. Refer to the micronutrient application table below for a list of fertiliser sources and application rates. Excessive molybdenum is toxic to plants and animals—use it with care. It will carry over in the soil.

Micronutrient application rates

			Foliar applied		Soil applied	
Nutrient	Source	Composition	Nutrient (kg/1 000 ℓ)	Product (kg/1 000 ℓ)	Nutrient (kg/ha)	Product (kg/ha)
Boron (B)	Sodium borate	12–21% B	0,1–0,3	–	1,0–3,0	–
Manganese (Mn)	Manganese chelates	5–12% Mn	0,5–1,0	–	–	–
	Manganese sulphate	28% Mn	0,5–1,0	1,8– 36	–	–
Molybdenum (Mo)	Sodium molybdate	39% Mo	0,1–0,25	0,25–0,6	–	–

Irrigation

The availability of water can be critical to successful production. In the case of direct seeding, plan to irrigate every three days until the seedlings are established.Steady, even growth of cauliflower plants is necessary for high quality and yields. Irrigation may also be used to cool plants during periods of high temperature. Fertiliser could be applied through an irrigation system. Cauliflower requires a regular water supply of 25 mm every 5 to 7 days. 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.

Weed control

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. 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. 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. Crop rotation is discussed in great detail in the section below. However, it essentially involves growing different groups of crops on the same piece of land in successive years. Stale seedbed is a technique whereby the planting bed is made early, under dry conditions, water may be applied and weeds are allowed to germinate and grow. After the first flush of weeds, they are controlled with a total herbicide (glyphosate) or by a flame weeder. For weeds that escape and grow close to the crop, hoeing can be used as a control option. Between-row cultivation is an important method of cultivation. This can be done on a regular basis. Care must be taken to avoid fields where herbicide residue from previous years persists in the soil as crop injury may occur.

Cultural control practices

No-till methods of planting cauliflower have been successful. Cauliflower is transplanted on existing beds from a previous lettuce crop and weeds are controlled through mechanical cultivation.

Weeds are a threat to the cultivation of any crop. They compete with the crop for sunlight, water and nutrients. Control of weeds, especially cruciferous weeds, is fundamental for pest management. Weeds can host a variety of diseases and pests that can be transmitted to cauliflower. Weed control is the most important during the first 30 days of plant establishment, after this period cauliflower is better able to compete with weeds. The canopy created by the cauliflower stand also shades the underlying soil

and inhibits the germination of weed seeds. The planting date can also give cauliflower an advantage. Fields planted when summer weeds are dying back, but before winter weeds have started to germinate, have decreased weed competition. It is essential that weeds are destroyed before they flower and produce seed. One plant can produce hundreds or thousands of seeds, depending on the species of weed.

The summer broadleaf weeds most frequently found between the months of August and October are pigweed (*Amaranthus* spp.), purslane (*Portulaca oleracea*), lambsquarters (*Chenopodium album*) and groundcherry (*Physalis wrightii*).

Common summer grasses include barnyard grass (*Echinochloa crusgalli*), junglerice (*Echinochloa colonum*) and sprangletop (*Leptochloa* sp.). The winter broadleaf weeds most commonly found between the months of November and March are black mustard (*Brassica nigra*), wild radish (*Raphanus sativus*), shepherd's-purse (*Capsella bursa-pastoris*), London rocket (*Sisymbrium irio*), cheeseweed (*Malva parviflora*), sowthistle (*Sonchus oleraceus*), knotweed (*Polygonum* sp.), annual yellow sweet clover (*Melilotus indicus*), prickly lettuce (*Lactuca serriola*), and nettle-leaf goosefoot (*Chenopodium murale*).

Common winter grasses include canary grass (*Phalaris minor*), annual blue grass (*Poa annua*), wild oats (*Avena fatua*) and wild barley (*Hordeum* sp.).

Cultural control: Cauliflower should be encouraged to grow quickly and establish the stand, which will increase the ability of cauliflower to out compete any weeds present in the field. Precise planting, a regular water supply and appropriate fertilisation will help increase the ability of cauliflower to compete.

It is important to maintain field sanitation by always cleaning equipment used in one field before it is used in another and ensuring that any manure that is used is weed seed free. Contaminated irrigation water from canals, reservoirs and sumps can also spread weed seed. Irrigation ditches, field borders and any other uncropped area should be maintained weed free. A properly levelled field is important to prevent the buildup of water in isolated areas, especially when utilising furrow irrigation. This water buildup will promote the germination of weeds that are favoured by wet conditions.

The planting date can also give an advantage to cauliflower over weeds. Fields have decreased weed competition when they are planted when the summer weeds are declining and before the winter weeds begin to germinate.

Another method used to control weeds is to till the field, form beds and irrigate prior to planting. This will encourage the germination of the weed seeds. The field can then be sprayed with a nonselective herbicide or a rotary hoe used to eliminate the weeds. After the weeds have been destroyed, the cauliflower is planted. Disking will eliminate germinated weeds but will also expose new weed seeds that may germinate and cause a second flush of weeds.

Cultivation and hoeing can be used to control weeds but should be done with care because of the shallow root system of cauliflower.

Rows and beds must be planted carefully and the cultivation equipment must be carefully aligned. Fields should be disked after harvest to eliminate any weeds present and to prevent the weeds from flowering and spreading seed.

Rotating to a non-cruciferous crop will allow the use of herbicides that are more effective for the control of crucifer weeds. Crop rotation also promotes different cultural practices and planting times that will aid in weed control.

Pests and pest management

Effective management of any pest requires the use of multiple pest control techniques. Integrated Pest Management (IPM) is a system that integrates managerial, cultural, physical, biological and chemical control techniques to manage pests. A key to IPM is to understand what pests are in your crop, through scouting and adjusting production practices to discourage pests from becoming problems. IPM is a proactive approach to pest management, rather than just a reaction to pests as they occur.

Cabbage maggot

The cabbage maggot or cabbage fly (*Delia redicum*) adults fly close to the ground near brassica plants and lay elliptical, white eggs on the stems of crops or in nearby crevices in the soil. The adult is a two-winged, ash-grey fly, with black stripes on the mid-section. It is half the size of a housefly, but has longer legs. Eggs hatch in three to seven days. Larvae are white, legless maggots that enter the roots and feed by rasping the plant tissue with a pair of hook-like mouthparts and tunnelling into the roots. Feeding damage by the cabbage maggot results in misshapen roots and the entry of decay organisms and other species of maggots is allowed, resulting in stunted plants or young plants dying off. Maggots mature in three to four weeks and pupate. The pupae are 6 mm long, oval, hard shelled and dark

brown. Pupae overwinter in the soil near the roots of the host plant. Adult flies emerge in two to three weeks; the first generation usually emerges in late May to early June. The presence of adult flies can be determined by looking for eggs which are laid at the base of plants. Generally, there are two to three generations a year.

Control: Biological control options include maintaining high numbers of the following natural predators which are frequently found in the field: ground beetle, rove beetle, spiders, harvestmen or daddy-long-legs and ants.

Cultural controls include covering young plants with a floating row cover to prevent the flies from depositing eggs after plant emergence, and inter-cropping clovers or other legumes to prevent the flies from finding open ground near a brassica stem.

If using pesticide controls, scout plants frequently and treat when damage is first observed.

Caterpillar pests

The imported cabbage worm (*Pieris rapae*), cabbage looper (*Trichoplusia orichalcea*), diamondback moth (*Plutella xylostella*) and purple-backed cabbageworm (*Evergestis pallidata*) are all pests of cauliflower. High levels of feeding damage will cause severe defoliation, resulting in stunted plants. Cauliflower can also become unmarketable if the heads are stained with frass (insect excrement) or if frass is visible.

The adult of the imported cabbageworm is a white moth, easily seen going from plant to plant laying eggs during the summer. The eggs hatch into velvety-green larvae with one thin yellow stripe down the centre of their backs. The cabbageworm larvae do not loop when they walk. They are generally the most prevalent of the caterpillars found on cole crops.

The cabbage looper gets its name from the way it forms a loop as it walks. It is a smooth, green larva with two white stripes along the back and two along the sides. The cabbage looper is capable of causing the most damage to cole crops. Cabbage loopers do not overwinter in this region. Adult moths migrate into the region during the summer. Cabbage looper tends to be more problematic during the late summer.

The diamondback moth is much smaller than the previous insects. Three to six generations of 1,1 cm yellow-green larvae may develop each year. The larvae squirm actively when disturbed and produce many small holes on the host plant. This pest can bore into the heads of cabbage. Diamondback moths do not survive the winter in this region. Adult moths

migrate in throughout the growing season. Consequently there is often an overlap in generations and all stages may be present at one time.

The purple-backed cabbageworm is not as frequently seen as the others but will cause serious damage in high numbers. The larvae are purple on the back and pale yellow along the sides. There are one to two generations a year.

Control: Biological control options include maintaining high numbers of the following natural predators which are frequently found in the field: ground beetles, spiders, damsel bugs, minute pirate bugs, assassin bugs, big-eyed bugs, and lacewing larvae will all attack the caterpillars. There are also some commercially available parasitic wasps that sting and parasitise the eggs and larvae of caterpillars; these include *Trichogramma* spp., *Copidosoma* spp., *Apanteles* spp., *Diadegma* spp., and *Hyposoter* spp.

Cultural controls include pheromone emitters to disrupt mating, evening overhead sprinkler irrigation, and placement of floating row covers over young crops to exclude egg-laying females.

If using pesticide controls, scout plants frequently and treat when the threshold level has been reached. To determine the threshold level, count the number of plants out of 25 randomly selected plants that have 1 or more caterpillars, than multiply by 4. This will give the percentage of plants infested. For cauliflower, the threshold guidelines are 20 to 30% before heading and 5 to10% after heading.

Cutworms

Cutworms (*Agrotis ipsilon*) are greyish, fleshy caterpillars up to 5 cm long, which curl up when disturbed. Plants may be chewed off above or below ground level and may be damaged higher up by climbing cutworms. Most of the cutworm damage is to newly set plants in the field, but they are often found attacking seedlings in plant bed and greenhouses. Late infestation of variegated cutworm occasionally occurs.

Control: Prepare the soil two weeks before planting to cultivate in cover crops and destroy weeds. Check the plants frequently and treat when damage is first observed.

Aphids

The cabbage aphid, *Brevicoryne brassicae*, is a major pest of cole crops worldwide. Aphids are small, soft-bodied, slow-moving insects. A colony consists of winged and wingless adults and various sizes of nymphs.

Aphids may be black, yellow or pink, but mostly are various shades of green. They are often found in large colonies on the under surface of leaves; however, aphids will feed on heads, flower stalks as well as leaves, resulting in unmarketable produce. Aphids feed by piercing plants and sucking out plant sap, resulting in distorted plant parts and a slowing of plant growth. The plants may be covered by a sticky substance, called honeydew, which is excreted by the aphids.

Control: Biological control options include maintaining high numbers of the following natural predators which are frequently found in the field: syrphid flies, lacewings and predaceous midges produce larvae which will feed on aphids and the adults and larvae of minute pirate bugs, big-eyed bugs, lady beetles, soldier beetles and parasitic wasps like *Diaeretiella rapae* will also consume aphids.

Cultural controls include using high-pressure sprinkler irrigation to knock the insects off of plants, as well as using living mulch such as clover interplanted with the crop.

If using pesticide controls check the plants frequently and treat when damage is first observed.

Green peach aphid, *Myzus persicae*

Green peach and turnip aphids also infest fields sporadically. Heavy populations are particularly injurious to seedlings. Green peach aphid can stunt seedlings if populations are particularly heavy, but pose little threat to more mature plants because it feeds on older leaves and rarely attacks the cauliflower heads or “curds”. Turnip aphids on the roots of cauliflower plants can stunt or even kill them.

Many natural enemies feed on these two aphid species, but populations of beneficial insects are generally eliminated by the application of pesticides targeting other pest species. Chemical treatments for cabbage aphid generally control these two species as well. Mature plants can tolerate low to moderate infestation of green peach and turnip aphid.

Chemical control: The peak period for pesticide applications for aphid control is in the early stages of head formation. If the insect becomes established inside the cauliflower, foliar insecticidal applications, which rely on contact poisoning, become ineffective.

Chemical control of aphids on cauliflower, as with other cole crops, is based primarily on the use of organophosphate (OP) compounds.

Thrips

Thrips (*Thrips tabaci*) are slender, yellow-brown insects about 1 mm long. They feed by puncturing the leaves and sucking up the exuding sap. This leads to the appearance of dark warts or blisters on the leaves. They also feed on curds, damaging them and making them unmarketable. They overwinter on refuse, weeds, and legume forage crops. Populations increase quickly when the air temperature is above 21 °C.

Control: Destroy refuse and control weeds. Heavy migrations of thrips can occur following the cutting of forage, particularly alfalfa or clover. It is critical to control them at early head formation.

If using pesticide controls, check the plants frequently and treat when damage is first observed.

Flea beetles

Flea beetles (*Phyllotreta* spp.) are small, shiny black beetles, about 2 mm in length. They are very active early in the growing season, especially during periods of dry, sunny weather. Flea beetles can seriously damage seedlings and transplants, and to a lesser extent larger plants, by chewing small pinholes through the leaves. There is one generation a year. The larvae live in the soil and feed on the roots.

Control: Biological control options for flea beetles include using a braconid wasp that will parasitise and kill off adult flea beetles, and using nematodes that attack the larvae.

There are several cultural controls which can be used to combat flea beetles. Trap crops such as Chinese type cabbages, radishes or collards can be used, living mulches or polycultures are further possibilities. Covering young seedlings with a floating row cover to prevent the insects from attacking the plants is another option. Using white or yellow sticky traps every 4,5 to 9 m and making sure to destroy plant debris are also good cultural control practices.

If using pesticide controls, scout the plants frequently and treat when the threshold has been reached. One flea beetle per plant (up to the sixth leaf stage) is the threshold number. After the six leaf stage, feeding will not interfere with plant growth.

Tarnished plant bugs

Adult tarnished plant bugs are light brown to reddish brown in colour and about 5 to 6 mm in length. They occur throughout the season and are very

active and quick moving. They feed on cauliflower curds, causing brown blemishes or streaks which reduce the marketability of the head.

Control: Keep plantings and adjacent areas weed free. Avoid planting next to legumes. Check the plants frequently and treat when damage is first observed.

Slugs

Slugs exist in various sizes up to 10 cm. They eat holes in the leaves and leave a trail of mucus, which makes the plants unsightly. The control of slug populations has been a continuing problem in the cole crop industry.

Control: Slugs prefer areas which are cool, moist and high in organic matter. Sod crops, weedy fence lines and hedgerows fulfil these conditions. Because slugs can overwinter fairly easily, cultural practices aimed at controlling them should begin at least one year before the susceptible crop is put in. If possible, sod crops should not be followed by cole crops. A cultivated strip around the crop has been shown to reduce the number of slugs migrating from weedy field borders. If urea (4 kg/ha) is sprayed on this cultivated strip, slug movement may be further impeded. The salt irritates the slugs as they move over it. Repeated applications are necessary as rainfall washes it into the soil. Slugs are usually more numerous in heavy, moist soils; sandy soils usually have smaller slug problems.

Nematodes

Sugarbeet cyst nematode, *Heterodera schachtii* Cabbage cyst nematode, *H. cruciferae*, rootknot nematodes, *Meloidogyne incognita*, *M. javanica*, *M. arenaria*, *M. hapla*.

Nematodes are parasitic, microscopic roundworms less than 4 mm in length and live on the roots and surrounding soil of all vegetable crops. Overall, nematodes may infest as much as 75% of the cole crop area.

The cyst nematode (*Heterodera* spp.) is the most harmful genus to cole crops, and can be found throughout California. Cole crops are the only host for cabbage cyst nematode (*H. cruciferae*), which can cause more plant injury and stunting than the rootknot nematode when abundant. In the case of the sugarbeet cyst nematode (*H. schachtii*), cole crops, beets, spinach and related weeds have all been shown to harbour large populations (UC IPM, 1997). The cyst nematode can be found on all soil types, but its limited host range allows management by crop rotation with non-host plants.

Rootknot nematode (Meloidogyne) can also be a problem in cole crops, but to a lesser extent than cyst nematode.

Rootknot nematodes produce small, distinct galls from the size of a pin-head to one inch in diameter.

Nematodes, usually in the egg stage, overwinter in the soil in decaying vegetable matter, where they may persist for long periods of time. Symptoms from nematodes can mimic other problems in the field, particularly clubroot. Nematodes primarily cause an overall stunting of the plant, wilting, small head formation and lower yields. When cyst nematodes attack seedlings, the entire cauliflower planting may be ruined economically (F. Laemmlen, 1999).

Chemical control: Soil fumigation can be used to control nematodes in cases where rotation or other non-chemical practices are not feasible.

When fumigants are used, many have the added benefit of weed control and suppression of soil-borne diseases.

Disease control

Clubroot

Clubroot (*Plasmodiophora brassicae* Wor.) 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: There are seven steps that can be taken to reduce the occurrence of this disease;

- 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.

Grey leaf spot and black leaf spot

Alternaria brassicae (grey leaf spot) causes small and light brown or grey lesions and *A. brassicola* (black leaf spot) causes larger and darker lesions. These diseases are seed and soil borne. Small black spots (1 to 2 mm in diameter) appear on the leaves, later turning into a tan colour with target-like, concentric rings. When the spots dry out, the tissue falls from the leaves, resulting in a ‘‘shot-hole’’ appearance. Cool temperatures, rain and high humidity favour the development of this disease. Spots usually are most conspicuous on the outer, older leaves. The disease causes small, brown, sunken lesions and decay of cauliflower curds, under very wet conditions. The spots enlarge in storage to sunken, black areas. Alternaria is a secondary fungus; it usually invades the plant after it has been damaged by other pests or management practices.

Control: Use clean, certified seed or a hot water seed treatment if certified seed is not available. Practise long rotations between cole crops, avoid overhead irrigation and make sure that plant debris is incorporated. Good air circulation is needed in the field, as well as in storage. Keep the storage temperature at 0 °C and relative humidity at 92% to 95%.

Downey mildew

This disease is caused by the fungus *Peronospora parasitica*. 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 leg

Black leg is caused by the fungus *Phoma lingam*. This disease can be seed borne. Early signs of black leg appear as small spots on the leaves of young plants. On the stems the spots are more linear and often surrounded by purplish borders. Stem lesions at the soil line usually extend to the root system, causing dark cankers. The fibrous root system may be destroyed although new roots sent out above the lesion may keep the plant alive. Many plants wilt abruptly and die off.

Control: Use clean, certified seed, or seed which has been hot-water treated. This organism is capable of surviving in the soil for three years without another cole crop present. Practise a 4-year crop rotation, destroy brassica weeds and thoroughly incorporate plant debris. Good air and water drainage is critical in controlling this disease, along with avoiding water on the crop in the afternoons and evenings.

Black rot

Black rot is caused by the bacterium *Xanthomonas campestris* and can live in the soil for one year without another cole crop being present. Humid, rainy conditions favour the disease, which is usually spread by splashing rain or irrigation water. Black rot lesions first appear at the leaf margins.

The tissue turns yellow and the lesion progresses toward the centre of the leaf, usually in a v-shaped area with the base of the v toward the midrib. The veins become dark and discolouration frequently extends to the main stem and proceeds upward and downward.

Control: Refer to the black leg control measures, as they are useful in control of black rot as well.

Fungal diseases

DAMPING-OFF (*PYTHIUM* SP., *RHIZOCTONIA SOLANI*)

Damping off is occasionally observed in cauliflower fields. Damping off is a soil-borne fungus that attacks germinated seedlings that have not emerged yet or have just emerged. Cool, wet weather promotes infection by most *Pythium* species, whereas cool to moderate weather promotes *Rhizoctonia* infection. Fields that have poor drainage, compacted soil and/or high green organic matter are the most susceptible to damping off.

The damping-off fungi will not affect plants that have reached the three to four-leaf stage.

Damage usually occurs at soil level, leaving lesions in the stem tissue. The tissue becomes dark and withered; the weak support causes the seedling to collapse and die off. Pythium can also attack the seedlings' roots, causing them to turn brown and rot. Seedlings that are attacked by Rhizoctonia but continue to grow will develop wirestem.

Cultural control: All residue from the previous crop should be plowed under and completely decomposed before planting cauliflower. It is best to plant when the soil is warm, as this will speed up germination and allow the crop to quickly reach a resistant stage of growth. Overhead or sprinkler irrigations are the best methods for promoting rapid germination. It is important to manage water and avoid oversaturating the field. Fields should be properly drained and low areas should be eliminated to avoid water accumulation. Transplants should be inspected for healthy, white roots. It is important to avoid stressing the crop, as this will make it more susceptible to damping off.

Post-harvest control: There are no methods for the post-harvest control of damping off.

Alternative control: Some growers spread compost on the soil to control pathogens.

Bacterial diseases

Black rot (*Xanthomonas campestris*)

Black rot is occasionally observed in cauliflower fields. This bacterium normally only occurs when the weather is warm and humid. The disease spreads rapidly when there is unusually high rainfall or if overhead irrigation is used. Animals and humans can also spread *Xanthomonas*. The bacterium enters the plant through the leaf stomata (breathing pores), leaf margins or insect wounds. *X. campestris* survives in crop debris, infected weeds and infected seed.

The initial symptoms of black rot are yellow-orange v-shaped lesions that occur along the cotyledon and leaf margins. As the disease progresses, these lesions dry out and the leaves are shed from the plant. Black rot damages the plant's vascular system, giving it characteristic black veins. This disease can become systemic, in which case these black veins are also be observed in the main stem.

Black rot is sometimes deceiving with no observable symptoms at cool temperatures, rather only resulting in small, brown spots that resemble symptoms of other bacterial diseases. Prolonged infection can cause plant stunting, wilting and even the dying off of plants. When black rot is severe, it can also affect the taste of the cauliflower curd.

Biological control: There are no available methods for the biological control of *Xanthomonas*.

Cultural control: Planting only seed and transplants that are certified to be disease free will help control black rot. If the seed is infected, it can be treated with hot water, which will reduce infection but will also reduce the germination percentage of the seed. Cole crops should not be planted in the same field more than once every four years; this reduces the risk of spreading the disease between crops. It is also important to control weeds, especially cruciferous weeds, and volunteer plants that can act as hosts for black rot.

One should be careful when clipping or mowing transplants before planting as this will spread *Xanthomonas campestris*. Irrigation should be performed with care, to avoid overwatering the crop. Fields should be deeply plowed after harvest to kill off bacteria and speed up the decay of plant debris.

Bacterial soft rot (*Erwinia* sp.)

Bacterial soft rot is occasionally reported to occur on cauliflower. Bacterial soft rot does occur in the field, but is more frequent during post-harvest

storage. Infection often occurs on cauliflower that is stored at warm temperatures, or if heat is allowed to accumulate in the storage containers. This disease is capable of destroying an entire lot of cauliflower.

Open injuries on the plant provide an entry for the bacterium. A plant that was infected with downy mildew or black rot or that has been damaged by freezing or insects is particularly susceptible to bacterial soft rot. The structure of the cauliflower head also contributes to bacterial infection. The crevices formed by the immature flower buds are capable of holding water, creating an ideal environment for bacterial growth. The initial sign of infection is water-soaked spots on the plant. Once inside the cauliflower the bacterium spreads rapidly. It dissolves the middle lamella that holds cells together and causes the inner contents of the cell to shrink. The infected portions of the plant can develop a brown colour and the wet rot is often accompanied by a foul odour.

Erwinia is spread by: machinery, insects, rain, irrigation and humans.

Biological control: There are no available methods for the biological control of *Erwinia*.

Chemical control: There are no methods for the direct chemical control of *Erwinia*; however, insecticides can help control the insects that damage cauliflower leaving it susceptible to bacterial infection.

Cultural control: Crops should be cultivated carefully, to prevent damage to the plant that could provide an entryway for bacterial infection. It is important to control weeds in and around the field that could act as a host to *Erwinia*.

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.

Other cultivations practices

Cauliflower blanching

The commercial cauliflower varieties grown in most areas are self-blanching, meaning they have inner wrapper leaves that are large enough to cover the curd and protect it from discolouration caused by the sun. Most varieties produced today have some self-blanching capabilities, however,

the older varieties do not and will have to be put through a process called blanching, which is defined as tying the outer leaves of cauliflower to protect the curd. 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.

Crop rotation

A general guideline to follow concerning crop rotation is that a crop should never follow itself. Continuous cropping of any crop will result in an increase of disease and insect pressure and possibly a reduction in yields. A proper rotation will include growing different botanical families on the same piece of land, in sequential seasons. The table below outlines some of the common botanical families vegetables belong to.

Botanical family	**Vegetable crops**
Asteraceae	Lettuce, endive, artichoke, radicchio
Alliaceae	Leeks, garlic, onion
Chenopodiaceae	Spinach, Swiss chard, beetroot
Brassicaceae	Broccoli, cauliflower, Brussels sprouts, cabbage, kale, turnip, kohlrabi, radish
Cucurbitaceae	Winter squash, summer squash, watermelons, muskmelons, cucumbers, pumpkins
Poaceae	Sweet corn
Fabaceae	Beans, peas, groundnuts
Solanaceae	Tomato, eggplant, peppers, potatoes
Apiaceae	Carrots, parsley, parsnip, fennel

By rotating crops that leave a high volume of residue in the soil, soil fertility can be enhanced naturally. Crop rotation can also improve soil structure by alternating deep-rooted and shallow-rooted plants.

Crop rotation plays a key role in an IPM programme by aiding in the suppression of diseases, insects and weeds. Crops within the same plant family tend to be susceptible to the same pests, therefore rotation of non-susceptible crops for several years allows all plant material to decompose and pest cycles to become disrupted. Without the presence of susceptible plant

material, the number of disease and insect organisms will begin to diminish.

Crop rotation aids in weed control because the growth habit of each crop differs, which causes a decrease in a weed's' ability to compete for space. Tillage practices and timings are different for each crop group, resulting in a decrease in a weed's ability to establish permanently.

Because of disease and insect pressures it is best not to plant cauliflower more often than once every four years. Brassica crops use a lot of nitrogen so it may be beneficial to plant a legume crop before cauliflower. Cauliflower has an intermediate root depth that will aid in improving soil structure and aeration. This crop has small seeds which will require a finely manicured seedbed; therefore previous crop residue will not be tolerated. If transplants are used, the roots can tolerate some plant residue, but too much will negatively affect root growth.

Tying

Cauliflower for processing is not normally tied. When this is done to keep heads white, leaves are usually gathered around the head at about the time that they are 2 cm in diameter. Leaves are held together with rubber bands or string. When several tyings are needed, use different coloured rubber bands. This facilitates harvesting by allowing all plants with the same colour band to be harvested at the same time.

Thinning

After the first true leaves have formed, the plants must be thinned so as to leave 1 plant at each location (about 3 weeks after seeding). Avoid delay in thinning as thinning large plants results in too much disruption of the remaining plants, contributing to an uneven harvest.

Cauliflower curd defects and physiological 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.

Lack of heads in cauliflower

During periods of extremely warm weather (days above 30 and nights of 25 °C) cauliflower can remain vegetative (does not head) because the

plants do not receive enough cold for head formation. This can cause a problem in scheduling the marketing of even volumes of the crop.

Buttons: Buttoning is the formation of miniature heads of poor quality because of premature shift to the generative stage. This is caused by using plants that are quite large (with thick stems) at the time of transplanting to the field. Such plants go quickly into the generative phase, producing a smaller than normal head. The condition may also be aggravated by stressful environmental conditions that cause the shift from vegetal to generative growth, resulting in buttoning of a percentage of the plants. Severe N deficiency and crowding of plants in the transplant bed have been reported to be contributing factors.

Cauliflower buttoning

Buttoning is the premature formation of a head 2,5 to 10 cm in diameter. Buttoning can occur anytime between seeding and an almost mature plant, but usually occurs shortly after transplanting into the field. Generally foliar growth slows down after buttoning, resulting in too few nutrients to nourish the curd to marketable size. Losses are usually most severe in the early planted crop during cold, wet seasons, when vegetal growth is affected by:

1. too much hardening off of greenhouse plants
2. too little hardening off of greenhouse plants
3. low soil nitrogen
4. low soil moisture
5. continued cold weather (4 to 10 °C for a day or more)
6. Other—diseases, insects, micronutrient deficiency, etc.

Some cultivars, particularly early ones, are more susceptible to buttoning than others.

Tip burn of cauliflower

This problem can cause severe economic losses. Internal leaves turn brown and fold over, developing curds. Eventually secondary rots cause the leaves to become mushy and smear over the curds, making them unmarketable. It is a physiological disorder which is associated with an inadequate supply of calcium to the young, actively growing inner leaves. High humidity, low soil moisture, high potash, high nitrogen, or low soil calcium all influence calcium availability. Some cultivars are relatively free of tipburn problems.

Hollow stem in cauliflower

This condition starts with gaps that develop in the tissue, and gradually they enlarge to create a hollow stem, sometimes from the base of the stalk into the head. Ordinarily, there is no discolouration of the surface of these openings at harvest, but both discolouration and tissue breakdown may develop soon after harvest. Avoid excessive nitrogen after head initiation. Dense plantings will maintain even growth rates and decrease the occurrence of hollow stem.

Hollow stem is related to rapid growth. High temperatures combined with high levels of nitrogen, large stem diameters, wide plant spacing and boron deficiencies cause cauliflower to grow quickly. This disease causes the inner tissue of the stem, the pith, to crack or collapse, often leaving the inner stem hollow. When hollow stem is caused by a boron deficiency, the cracked tissue is also darkened in colour. The best way to avoid hollow stem is to maintain an adequate nutrient availability and prevent rapid stem growth.

Riceyness

This disorder causes the curds to become uneven and fuzzy, reducing marketability. Riceyness is caused by low temperatures just after planting, warm temperatures during curd development or a late supply of nitrogen to plants.

Ricey curds acquire a velvety appearance somewhat like a pot of boiled rice. This is caused by the development of small, white flower buds. This defect is attributed to high temperatures during curd development and is aggravated by overmaturity and with rapid growth and heavy N side-dressing. Some varieties are more prone to riceyness than others.

Riceyness of cauliflower causes the head to develop an uneven, velvety appearance and the flowering structures emerge through the head. This disease is caused by warm weather. Unfortunately, there are no preventative measures other than avoiding plant exposure to warm temperatures. There are cultivars available that are more resistant to riceyness.

Leafy curd

Small leaves develop and protrude through the head during high temperatures, drastic fluctuations in day and night temperatures or improper nitrogen balance.

Leaves in curd: Small leaves in the curd occur when the plant responds to warm temperature after the curd forms. The cause is the result of reversion to vegetal growth.

Yellow and green curds: Yellowing and greening are the result of excessive exposure to sunlight and resultant chlorophyll formation. The occurrence of whiptail, a molybdenum deficiency disorder, may contribute to this problem by making it difficult to tie plants, or provide adequate leaf cover, to shield the heads from sunlight. Yellowing may also be associated with overmature heads. (See also item on “purpling” below.)

Browning of curds: Brown discoloration and breakdown of curds is associated with boron and calcium deficiency and certain diseases.

Pink curds: Pinking generally occurs in the interior branches of the head. It is reported to be the result of excessively cool temperatures at harvest for the variety being grown. Some varieties are more prone to pinking than others. Snowball types are resistant to this defect.

Purple curd discolouration: Purpling occurs on the surface of the head. Varieties differ in their sensitivity to purpling. In sensitive varieties (Snowball types), purpling may be aggravated by overmaturity or poor leaf cover that causes heads, or portions of them, to be exposed to light. Poor plant growth and leaf cover may be caused by compacted soils or nutrient, temperature, water, or other stress conditions that limit growth. Also, premature head initiation may be triggered by cool temperatures (10-15 °C). This stops leaf formation and may cause heads to be formed on plants that have inadequate leaf growth for good head protection. When these conditions occur, heads may have to be harvested when they are smaller than desirable, before they become exposed or overmature.

Head shape: Low temperatures promote flat heads while high temperatures promote conically shaped heads.

Internal cavitation and discolouration: Recent research at Oregon State University indicates that these disorders increase with rising rates of nitrogen and water. Furthermore that boron deficiency may aggravate discolouration, and that high boron applications may not effectively reduce discoloured cavities caused by high nitrogen and water rates.

Blind heads: A percentage of the plants in the field form no heads at all as a result of some damage. The damage can be the result of cold temperatures slightly above 32 °F for spring-planted cauliflower as the cauliflower just passes the seven-leaf stage, or from freezing damage during initial stages of curd formation. For summer-planted, fall-harvested cauliflower,

other causes for blind heads reported are: Growth point damage from insects (larvae of the diamond-back moth, thrips, lygus bug, diabrotica, and certain cutworms), and rodents. Also moisture stress and damage from certain insecticide solvents during periods of high temperature (over 90 °F if these occur just at the beginning stages of curd initiation) have also been implicated. Molybdenum deficiency is not believed to be involved, but speculation has centred on calcium and/or boron deficiency during the very early stages of seedling growth or transplant production. It is also thought that the latter conditions may be aggravated by factors that limit root growth (herbicide, moisture, compaction, etc.)

Frost damage: In general, varieties with good curd protection and dense heads would be less sensitive to early fall radiation frosts (where temperature of plant tissue falls below the temperature of ambient air because of radiant heat loss to the clear night sky) that results in discolouration of the curd surface. Leaves tend to protect the curd and greater density would mean greater storage of heat during daylight hours.

Witches broom: A proliferation of axillary shoots occurs as a result of damage to the growth point. This may, or may not be associated with blind heads and buttoning, and may be induced by boron deficiency. Sometimes one or more of these side-shoots will form a small curd.

Blind heads is a description of plants that fail to produce a curd. It may be caused by poor fertility, insect damage, disease, genetic defects and low temperature.

Although cauliflower is relatively tolerant of cold temperatures, cold temperatures can damage the curds of the cauliflower. The damage that occurs also renders the plant susceptible to secondary infections.

Winds that are strong and carry sand can cause abrasion of the leaves and render them susceptible to secondary infections. When the leaves heal themselves, it results in thickened, discoloured areas that can be misidentified as pathogen infection. Wind can also severely damage seedlings, pinching the stem and collapsing them.

High salt concentrations in the soil can be damaging to cauliflower. Symptoms include stunted plants, thick, dark leaves, yellowing or burning at the leaf margin and roots that are orange in colour and rough in appearance. Salt may also inhibit seed germination.

Nutrient deficiencies can cause stunted plants, chlorosis and leaf spotting. Nitrogen, phosphorus and molybdenum are the most frequent element deficiencies to cause damage. Inadequate molybdenum will cause whip-

tail, a disease that results in a deformed growth point and wrinkled, strap-like leaves. Inadequate nitrogen can cause buttoning, that is characterised by the development of small curds. Soil and plant tissue should be sampled regularly to determine if deficiencies are present. However, it is usually not possible to replenish an element after the stand has been established.

Harvesting and handling

Harvest the curds when they are fully developed, compact and before they grow loose or separate and become ricey, generally some days after they have become visible. A good curd must be regular in shape, globular, firm and white, orange or purple in colour, depending on the cultivar.

The size of the curds varies widely, depending on the cultivar and growing conditions, the largest curds attaining a diameter of 30 cm or more. Early cauliflower is generally smaller than late cauliflower. Frequently market preference is given to medium-sized curds between 15 and 25 cm in diameter, while those under 10 cm are unacceptable.

Curds are sometimes marketed without foliage, but it is better to harvest them with a whorl of leaves still attached for protection. When the cauliflower heads are to be transported in flat crates, the upper part of the foliage is generally removed. As a rule, the heads are packed in a single layer to reduce the risk of damage. When the heads are to be transported loose or in high crates, as little foliage as possible should be cut away. Field wrapping trimmed heads in perforated cellophane or plastic bags prior to cooling and storing minimises dehydration and protects the curds from being soiled. Care must be taken to minimise handling because any physical damage may result in later development of speckling or browning of curds during storage and marketing.

Harvest season/period

The cauliflower harvest season begins in late July and ends in late October, depending on the weather.

Harvesting methods

Cauliflower is generally hand harvested, using a knife. To aid in the harvesting processes, mechanical conveyor belts may be used to transport cartons to and from workers in the field.

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 hydrocooling. 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, prepackaged 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

Cauliflower for processing is not normally stored. When storing cauliflower keep it at 2 °C and a relative humidity of at least 95%. If in good condition, cauliflower can be held satisfactorily for 3 to 4 weeks at 0 °C. The storage life is about 2 weeks at 3 °C, 7 to 10 days at 4 °C, 5 days at 10 °C, and 3 days at 15 °C. Slightly immature, compact heads keep better than more mature ones. Successful cold storage depends not only on preventing decay, spotting and water-soaking but also on retarding aging (browning) of the head, or curd, and in preventing the leaves from wilting, yellowing and dropping off. A high relative humidity of at least 95% is desirable to

prevent wilting. Canadian researchers found that a humidity of 98 to 100% was satisfactory for cauliflower, mainly because it allowed even less weight loss to occur than that at 90 to 95%.

Containers should be handled carefully to avoid bruising of the heads; they should be stacked with the flower heads down to protect the curds from bruising and from getting dirty. Slatted crates or bins should be used so that moderate air circulation can remove the heat of respiration. When it is desirable to hold cauliflower temporarily out of cold storage, packing in crushed ice will aid in keeping it fresh. Freezing causes a greyish-brown discolouration and softening of the curd accompanied by a water-soaked condition. After freezing, affected tissue may be rapidly invaded by soft-rot bacteria.

In general, use of various controlled atmospheres has not been promising. The storage life of cauliflower was not extended by either low oxygen or high carbon dioxide at 2,4 or 7 °C, and cauliflower curds were damaged by low oxygen (2% or less) or by high carbon dioxide (5% or more). Injury as a result of controlled atmospheres is mainly apparent only when the stored product is cooked.

Cauliflower keeps for 2 to 6 weeks at 0 °C and 95% relative humidity. Heads should be cooled to 5 °C or below soon after harvest. Both hydro-cooling and vacuum cooling are effective methods to remove field heat. In addition, forced-air cooling can be used. Never use ice on cauliflower. Cauliflower that is destined for storage is preferably cut slightly immature, otherwise the curds may separate. Controlled atmospheres do not extend the storage life of cauliflower and may cause off-odours, softening or discolouration.

Market preparation

With tunnel-house production early cauliflower cultivars may produce in late June. Early field production does not start until early July. Availability of cauliflower on the market could be stretched to late November with the use of refrigerated storage.

Preparation for the market

The heads are hauled to the packshed where the foliage is trimmed so that it extends about 5 cm above the curd for protection. Sort and pack heads of a uniform size in each crate. Wirebound and cardboard crates usually hold 6, 12 or 24 heads. Heads are trimmed closely, wrapped in perforated film, and packed in cartons. The film must be perforated to prevent off-

colors and off-flavours after the cauliflower is cooled. Cauliflower should be moved to market rapidly or placed in 0 to 2 °C storage. Keep it refrigerated during shipping and marketing. Many growers are trimming in the field, placing it in perforated plastic bags and packing in the field to reduce costs.

PRODUCTION SCHEDULE

Activities	January	February	March	April	May	June	July	August	September	October	November	December
Soil sampling		X	X	X	X							
Soil preparation			X	X	X	X	X					
Planting			X	X	X	X	X					
Fertilisation			X	X	X	X	X					
Irrigation			X	X	X	X	X					
Pest control			X	X	X	X	X					
Disease control			X	X	X	X	X					
Weed control			X	X	X	X	X					
Thinning			X	X	X	X	X					
Leaf sampling			X	X	X	X	X					
Harvesting					X	X	X	X	X			
Marketing				X	X	X	X	X	X			

UTILISATION AND NUTRITIONAL VALUE

Preparation

Cauliflower should not be washed until it is going to be cut up and used. After the cauliflower has been cut up as shown below, soak it in salt water or vinegar water to help force any insects out that are lodged within the florets.

Culinary/cooking

Cauliflower can be roasted, boiled, fried, steamed or eaten raw. Steaming or microwaving better preserves anticancer compounds than boiling. When cooking, the outer leaves and thick stalks are removed, leaving only the florets. The leaves are also edible, but are most often discarded. The florets should be broken into similar-sized pieces so they are cooked evenly. After eight minutes of steaming, or five minutes of boiling, the florets should be soft, but not mushy (depending on size). Stirring the cauliflower while cooking can break the florets into smaller, uneven pieces. Cauliflower is often served with a cheese sauce, as in the dish cauliflower cheese.

Low carbohydrate dieters can use cauliflower as a reasonable substitute for potatoes; while they can produce a similar texture, or mouth feel, they lack the starch of potatoes.

Nutritional value

Cauliflower is low in fat, but high in dietary fibre, folate, water, and vitamin C, possessing a high nutritional density.

Cauliflower contains several phytochemicals, usually occurring in the cabbage family that may be beneficial to human health.

Boiling reduces the levels of these compounds, with losses of 20 to 30% after five minutes, 40 to 50% after ten minutes, and 75% after 30 minutes. However, other preparation methods, such as steaming, microwaving and stir-frying, had no significant effect on the compounds.

A high intake of cauliflower has been associated with reduced risk of aggressive prostate cancer.

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